future wise

816 Second Ave, Suite 200, Seattle, WA 98104
p. (206) 343-0681
futurewise.org

June 15, 2020

Mr. Rick White, Director
City of Pasco Community & Economic Development Department
525 N. Third Ave.
Pasco, Washington 99301

Dear Director White:

Subject: **Comments on the City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement (May 2020).**
Send via email to: whiter@pasco-wa.gov

Thank you for the opportunity to comment on the City of Pasco Comprehensive Plan Draft Environmental Impact Statement (Draft EIS). Futurewise works throughout Washington State on the implementation of the Growth Management Act (GMA). We work with local communities to support land-use policies that encourage healthy, equitable and opportunity-rich communities, and that protect our most valuable farmlands, forests, and water resources. We have members across Washington State including in the City of Pasco.

Futurewise strongly supports the City of Pasco's decision to prepare an EIS on the comprehensive plan update including urban growth area alternatives. Preparing an EIS makes information on the impacts of the proposed alternatives available to decision makers and the public. This results in better decisions. Preparing an EIS can also speed project level environmental review after the comprehensive plan is adopted because information and analysis from the EIS can be incorporated into the environmental review documents for those actions.

However, the Draft EIS as written is not adequate and violates the Washington State Environmental Policy Act (SEPA). We have comments to improve the Draft EIS so that it complies with the minimum requirements of SEPA.

In addition, WAC 197-11-070(1) provides that:

> (1) Until the responsible official issues a final determination of nonsignificance or final environmental impact statement, no action concerning the proposal shall be taken by a governmental agency that would:
> (a) Have an adverse environmental impact; or
> (b) Limit the choice of reasonable alternatives.

WAC 197-11-070(1) "applies to any (1) 'governmental agency' (2) capable of taking 'action' (3) '[l]imit[ing] the choice of reasonable alternatives.'"[1] Choosing an urban growth area (UGA) expansion alternative will limit the choice of a reasonable alternative. So until the final EIS is issued, the City cannot choose an UGA expansion to request from Franklin County.

Factsheet (Page b)

Page b of the factsheet includes information on the availability of the Draft EIS. Hispanic or Latinx persons make up 55.1 percent of the City of Pasco's population.[2] Of the population over five years of age, 50.4 percent speak a language other than English at home.[3] So we appreciate and support that the Public Participation Plan for the City of Pasco 2018 Comprehensive Plan provides on page 5 that "[e]fforts will be made to provide notices in English and Spanish."

Also, given the high percentage of the population in the City of Pasco speaking a language other than English at home, we recommend that versions of the draft comprehensive plan and the final EIS be made available in Spanish and the public participation efforts should reach out to the Hispanic and Latinx population in addition to the population as a whole.

1.5. Background information on GMA (page 2)

Please correct the last sentence on page 2. The City of Pasco and Franklin County are required to do periodic updates of their comprehensive plans and development regulations every eight years.[4]

Table 2 Existing Residential Capacity (page 5)

It would helpful to include a reference to a more detailed description of how the existing residential capacity in Table 2 was determined. The City of Pasco is also considering the adoption of legislation to allow more "Missing Middle" housing in the city which Futurewise strongly supports. We recommend that the EIS include an estimate of the increased housing capacity this legislation will create.

3.2. Comparison of Alternatives to GMA Goals (pages 13 – 16)

The GMA transportation goal discussion on page 14 does not disclose that Alternatives 2 and 3 do not have densities sufficient to support transit citywide, an important element of a multimodal transportation system. While transit is especially important to the three percent of Pasco's occupied housing units that do not have access to a vehicle and residents of other households that are too young or otherwise do not drive, all Pasco residents and businesses benefit from increased

---

[1] *Columbia Riverkeeper v. Port of Vancouver USA*, 188 Wn.2d 80, 96–97, 392 P.3d 1025, 1032 (2017).
[2] United States Census Bureau, *QuickFacts Pasco city, Washington* p. *1 accessed on June 3, 2020 at: https://www.census.gov/quickfacts/pascocitywashington and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "U.S. Census Bureau QuickFacts_ Pasco city, Washington.pdf."
[3] *Id.*
[4] RCW 36.70A.130(5)(d).

transportation choices.[5] Parts of the City of Pasco have a very high proportion of households that lack access to private vehicles compared to Washington State as a whole.[6] Public transit is particularly important in those parts of the city.

The GMA housing goal discussion on page 14 does not disclose the impacts of allowing residential uses so close to the Tri-Cities Airport and the adverse impacts this will have on the planned housing.[7]

"Since before statehood, fertile soils, available irrigation water, sunny skies and long summer daylight hours have made agriculture a cornerstone for economic development" in Franklin County.[8] The GMA economic development goal discussion on page 14 does not disclose that Franklin County has designated most of the land in the proposed UGA expansions as agricultural lands of long-term commercial significance.[9] The discussion does not disclose that much of this land is also irrigated.[10] The Draft EIS does not disclose the economic impacts of the loss of this agricultural land of long-term commercial significance. The economic development goal discussion on page 14 does not disclose the impacts of allowing residential uses so close to the Tri-Cities Airport and the impacts of the limited expansion opportunities created by the UGA expansion and residential zoning in the vicinity of the airport.[11] These impacts are inconsistent with RCW 36.70A.020(5).

There is no analysis as to the consistency of the proposed comprehensive plan with RCW 36.70A.020(8), the GMA natural resource industries goal. RCW 36.70A.020(8) requires the City of Pasco to "[m]aintain and enhance natural resource-based industries, including productive timber, agricultural, and fisheries industries. Encourage the conservation of productive forestlands and productive agricultural lands, and discourage incompatible uses." Since most of the land proposed for the UGA expansions is designated as agricultural resource lands of long-term commercial

---

[5] United States Census Bureau, Selected Housing Characteristics American Community Survey Table: DP04 p. *5 (2018) accessed on June 3, 2020 at: https://data.census.gov/cedsci/table?q=Rent%20by%20monthly%20housing%20costs&g=0400000US53&tid=ACSDP1Y2018.DP04&t=Housing&hidePreview=true&moe=false and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "DP04 Selected Housing Characteristics Franklin Co & Pasco searchable.pdf."
[6] Washington State Department of Health, Information by Location (IBL) - Washington Tracking Network (WTN) Social Vulnerability to Hazards No Access to a Private Vehicle (%) map accessed on June 8, 2020 at: https://fortress.wa.gov/doh/wtn/WTNIBL/ and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2020-06-08 Pasco No Access to Private Vehicle map.pdf."
[7] Proposed LU-1 Future Land Use Map.
[8] *Economic Development Plan Franklin County, Washington* Res. 2016-211 p. 5 lasted accessed on June 11, 2020 at: http://www.co.franklin.wa.us/planning/documents/2016EconDevPlan_May_2019.pdf and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2016EconDevPlan_May_2019.pdf."
[9] *Franklin County Growth Management Comprehensive Plan* p. 96 (Agricultural Lands map) (Adopted Feb. 27, 2008 Resolution Number 2008-089) accessed on June 4, 2020 at: http://www.co.franklin.wa.us/planning/documents/2008ComprehensivePlan-Entirepdfwebsite_000.pdf and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2008ComprehensivePlan-Entirepdfwebsite Franklin Cty.pdf."
[10] Soil Map—Franklin County, Washington (Pasco UGA Expansion NW Part) p. 1 (6/4/2020) enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "Pasco NW UGA Expansion Soil_Map.pdf;" Soil Map—Franklin County, Washington (Pasco UGA Expansion NE Part) p. 1 (6/4/2020) enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "Pasco NE UGA Expansion Soil_Map.pdf."
[11] Proposed LU-1 Future Land Use Map.

significance the comprehensive plan update is inconsistent with RCW 36.70A.020(8).[12] The failure to disclose this inconsistency anywhere in the Draft EIS is a serious SEPA violation.

The GMA open space and recreation goal discussion on page 15 does not disclose the impacts of converting agricultural and rural land to relatively low-density residential uses. The GMA environment goal discussion on page 15 also does not disclose the environmental impacts of converting agricultural and rural land to relatively low-density residential uses. These impacts include a loss of farmland, reduced storm water recharge to ground water, increased storm water runoff, increased greenhouse pollution, and loss of wildlife habitat on rural and agricultural land. These impacts are inconsistent with RCW 36.70A.020(9) and (10).

The GMA historic preservation goal discussion on page 16 does not disclose that the city's planning and regulations focus on known archaeological and cultural sites. The Washington State Department of Archaeology and Historic Preservation has developed an archaeological predictive model that can predict where archaeological resources, a type of cultural resource, are likely to be located and where the department recommends archaeological surveys should be completed before earth disturbing activities and other uses and activities that can damage archaeological sites are undertaken.[13] The predictive model shows that Pasco and the UGA expansion areas have a "high risk" and "very high risk" of cultural resources in these areas.[14] Land development can adversely impact these resources and this adverse impact on actual but currently unidentified cultural resources is not disclosed. This impact is inconsistent with RCW 36.70A.020(13).

The adequacy of an EIS "is assessed under the 'rule of reason' … which requires a reasonably thorough discussion of the significant aspects of the probable environmental consequences of the agency's decision."[15] The failure to even mention the significant adverse impacts identified above and inconsistencies with the GMA goals means that the Draft EIS is not adequate.

4.1. Earth (pages 17 to 20) and Summary of Impacts by Alternative 4.2.1. Earth (page 58)

Two letters commenting on the scope of the EIS requested that the EIS examine impacts on agricultural land.[16] However, the Draft EIS does not disclose that the land proposed for the UGA expansions includes 694.7 acres of prime farmland.[17] This is 20 percent of the UGA expansions.[18] The Draft EIS also does not disclose that UGA expansions also include 2,203.9 acres of farmland of

---

[12] *Franklin County Growth Management Comprehensive Plan* p. 96 (Agricultural Lands map) (Adopted Feb. 27, 2008 Resolution Number 2008-089).
[13] Washington State Department of Archaeology and Historic Preservation, Find a Historic Place webpage accessed on June 5, 2020 at: https://dahp.wa.gov/historic-preservation/find-a-historic-place.
[14] *Id.*
[15] *Weyerhaeuser v. Pierce Cty.*, 124 Wn.2d 26, 38, 873 P.2d 498, 504 (1994) internal quotation marks and citations omitted.
[16] *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* pp. 86 – 87 (May 2020).
[17] Soils Pasco Proposed Urban Growth Area (UGA) Expansion June 2020 enclosed with this letter on beginning on page 17; Soil Map—Franklin County, Washington (Pasco UGA Expansion NW Part) pp. 1 – 23 (6/4/2020); Soil Map—Franklin County, Washington (Pasco UGA Expansion NE Part) pp. 1 – 28 (6/4/2020).
[18] *Id.*

statewide importance.[19] This is another 63.5 percent of the UGA expansion.[20] Together the prime farmland and farmland of statewide importance cover 2,898.6 acres and 83.5 percent of the proposed UGA expansions.[21]

Prime farmland is generally described as "land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is also available for these uses (the land could be cropland, pastureland, rangeland, forest land, or other land, but not urban built-up land or water). It has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when treated and managed, including water management, according to acceptable farming methods."[22] Farmland of statewide importance "is land, in addition to prime and unique farmlands, that is of statewide importance for the production of food, feed, fiber, forage, and oil seed crops. Criteria for defining and delineating this land are to be determined by the appropriate State agency or agencies. Generally, additional farmlands of statewide importance include those that are nearly prime farmland and that economically produce high yields of crops when treated and managed according to acceptable farming methods. Some may produce as high a yield as prime farmlands if conditions are favorable."[23]

Franklin County designates prime farmland and farmland of statewide importance as agricultural lands of long-term commercial significance.[24] This was also not disclosed in the Draft EIS. The Draft EIS also does not disclose that the prime farmland and farmland of statewide importance will be converted to urban uses by Alternatives 2 and 3. No mitigation is proposed for these undisclosed adverse impacts.[25]

The adequacy of an EIS "is assessed under the 'rule of reason' … which requires a reasonably thorough discussion of the significant aspects of the probable environmental consequences of the agency's decision."[26] The failure to even mention these significant adverse impacts on agricultural soils means that the Draft EIS is <u>not</u> adequate.

4.2 Surface Water: 4.2.2. Impacts, Alternative 1: No Action Alternative (page 23)

The Draft EIS claims on page 23, without any citation to evidence or analysis, that "[s]ince the additional and projected future growth won't be occurring within the City limits, sprawled development will take place in the areas surrounding the City." While there are some rural lands near Pasco, most of the land adjacent to Pasco and the existing UGA is designated as agricultural lands of

---

[19] *Id.*
[20] *Id.*
[21] *Id.*
[22] 7 Code of Federal Regulations (CFR) § 657.5(a)(1).
[23] 7 CFR § 657.5(c).
[24] *Franklin County Growth Management Comprehensive Plan* p. 93 p. 96 (Agricultural Lands map) (Adopted Feb. 27, 2008 Resolution Number 2008-089).
[25] RCW 36.70A.130(5)(d).
[25] *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* pp. 19 – 20 (May 2020).
[26] *Weyerhaeuser v. Pierce Cty.*, 124 Wn.2d 26, 38, 873 P.2d 498, 504 (1994) internal quotation marks and citations omitted.

long-term commercial significance and are protected from sprawling development.[27] Most of the land in the western UGA expansion is also agricultural lands of long-term commercial significance.[28] The proposed western UGA expansion avoids the Rural lands north of Pasco between North Road 36 and Road 52.[29] It also does not include the Rural land north of the existing UGA along the Columbia River.[30] Given this evidence and the relatively low densities proposed for most of the UGA expansions, it is incorrect to assume, as the Draft EIS apparently does, that Alternative 1 will lead to more sprawl and greater impacts on surface and ground water quality. This sentence must be deleted to comply with SEPA.

4.2 Surface Water: 4.2.3. Mitigation Measures (page 24) and Summary of Impacts by Alternative 4.2.2. Surface Water (page 59)

Compact UGAs also help conserve water long-term. Large lots and low densities increase water demand, increase leakage from water systems, and increase costs to water system customers.[31] So accommodating the same population in a right-sized UGA can reduce future water demands and costs.[32] One of the mitigation measures for water quantity should be a smaller UGA expansion that conserves agricultural lands of long-term commercial significance.
Additional mitigation measures that should be included in the EIS include:

- Requiring street trees between streets and sidewalks. This will both reduce storm water runoff and making walking more inviting by helping to shade sidewalks and give a sense of protection from cars to pedestrians. Street trees can also help moderate temperatures.

- Assessing storm water fees based in part on impervious surfaces. The current storm water fees only consider impervious surfaces for uses other than single-family dwellings. This tends to encourage single-family homes to have large areas of impervious surfaces, increasing storm water runoff and water pollution.

Mitigation measures that reduce temperatures, such as planting street trees, will likely become increasingly valuable. The University of Washington Climate Impacts Group projects that in the Tri-cities the mean daily maximum heat index from May to September will increase from 82.6 degrees in 1970-2006 to 83.7 degrees in a low summer warming scenario, 84.9 degrees in a moderate warming scenario, and 87.1 degrees in a high warming scenario by 2025, just five summers from now.[33] By

---

[27] *Franklin County Growth Management Comprehensive Plan* p. 96 (Agricultural Lands map) (Adopted Feb. 27, 2008 Resolution Number 2008-089).
[28] *Id.*
[29] *Id.*
[30] *Id.*
[31] United States Environmental Protection Agency, *Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies* pp. 3 – 5 (EPA 230-R-06-001: Jan. 2006) accessed on June 5, 2020 at: https://www.epa.gov/smartgrowth/growing-toward-more-efficient-water-use and on the data CD enclosed with Futurewise's June 11, 2020, letter with the filename: "growing_water_use_efficiency.pdf."
[32] *Id.* at p. 8.
[33] J. Elizabeth Jackson, MA; Michael G. Yost, PhD; Catherine Karr, MD, PhD, MS; Cole Fitzpatrick, MA; Brian K. Lamb, PhD; Serena H. Chung, PhD; Jack Chen, PhD; Jeremy Avise, PhD; Roger A. Rosenblatt, MD; Richard A.

2045, the mean daily maximum heat index, May through September, is projected to increase to 84.2 degrees in the low warming scenario, 86.4 degrees for the moderate warming scenario, and 90.0 degrees in the high warming scenario.[34]

4.3. Plants and Animals: 4.3.1. Affected Environment (pages 25 – 27) and Summary of Impacts by Alternative 4.2.3. Plants and Animals (page 60)

Futurewise appreciates that the Draft EIS includes information on priority habitats and species identified the Washington State Department of Fish and Wildlife (WDFW). This is helpful to decision makers and the public.

Page 25 includes the following statement "WDFW designation of priority habitat types is advisory only and carries no legal protection; although, such designation may increase the significance of impacts as evaluated through the National Environmental Policy Act (NEPA) and the SEPA process." While the Washington State Department of Fish and Wildlife does not have the authority to regulate most of the upland habitats identified by the priority habitats and species program, counties and cities are required to designate and conserve priority species and habitats through their GMA critical areas regulations.[35] WDFW does have regulatory authority over projects within the wetted perimeter of rivers, streams, and lakes.[36] We recommend that sentences to that effect be included in the Final EIS.

We appreciate the discussion of salmon and other aquatic species on page 27. In addition, the Upper Columbia & Snake Fall Upriver Brights have been identified as a priority Chinook salmon species for the recovery of the Southern Resident Orcas.[37] These salmon use the Columbia River and Snake River at Pasco and large parts of Franklin County.[38] To protect the Chinook salmon and help recover the Southern Resident Orcas, the Southern Resident Orca Task Force recommends

---

Fenske, PhD, Public Health Impacts of Climate Change in Washington State: Projected Mortality Risks Due to Heat Events and Air Pollution p. 355 & 359 in M. McGuire Elsner, J. Littell, and L Whitely Binder (eds), *The Washington Climate Change Impacts Assessment* (Climate Impacts Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington: 2009) accessed on June 8, 2020 at: http://cses.washington.edu/db/pdf/wacciach10health653.pdf and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "wacciach10health653.pdf."

[34] *Id.* p. 359.

[35] E. Larsen, J. M. Azerrad, N. Nordstrom, editors, *Management recommendations for Washington's priority species, Volume IV: Birds* p. vi (Washington Department of Fish and Wildlife, Olympia, Washington, USA: 2004) last accessed on June 11, 2020 at: https://wdfw.wa.gov/publications/00026/ and enclosed on the data CD enclosed with Futurewise's June 11, 2020, letter with the filename: "wdfw00026.pdf;" *Ferry Cty. v. Concerned Friends of Ferry Cty.*, 155 Wn.2d 824, 832 – 33, 123 P.3d 102, 106 (2005).

[36] Chapter 77.55 RCW.

[37] National Oceanic and Atmospheric Administration and the State of Washington Department of Fish and Wildlife, Southern Resident Killer Whale Priority Chinook Stocks p. 6 (June 22, 2018) last accessed on June 5, 2020 at: https://www.documentcloud.org/documents/4615304-SRKW-Priority-Chinook-Stocks.html and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "SRKW-Priority-Chinook-Stocks.pdf."

[38] WDFW Mapping SalmonScape Ocean chinook-ESU enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "Chinook & Steelhead ESUs Franklin County.pdf."

increasing affordable housing and reducing urban sprawl by growing "up instead of out."[39] The proposed UGA expansions are inconsistent with the Southern Resident Orca Task Force recommendations and the EIS needs to disclose this impact. Further, a potential mitigating measure should be reducing or eliminating the UGA expansions.

The EIS should also analyze excluding Priority Habitats and Species including Washington State Department of Fish and Wildlife identified sandy shrub steppe habitats and potential breeding sites for burrowing owls from the UGA expansions. This will better conserve wildlife habitats as the GMA requires.

The Draft EIS on page 27 lists Townsend's Ground Squirrel as one of the species listed as threatened or candidate species associated with shrub steppe habitat. While this is true generally, Townsend's Ground Squirrel is not known to be found in Franklin County. We recommend instead that the Washington Ground Squirrel, which is found in Franklin County, be substituted.[40]

4.3. Plants and Animals: 4.3.3. Mitigation Measures (pages 29 – 30)

Futurewise supports adopting and implementing low-impact development (LID) requirements and retaining native plants and native soils which the Draft EIS identifies as mitigating measures the City may implement. LID and retaining native plants and native soils can protect fish and wildlife habitat and water quality.[41] We also support including the Broadmoor area as a wildlife area and corridor because this area includes significant areas of shrub-steppe habitat.

In addition to the proposed mitigation measures which Futurewise supports, we recommend that the city consider requiring landscaping with native plants to provide vegetation of habitat significance in streetscapes, buffers for stormwater swales, rain gardens, and other habitat features.

4.4. Land Use (pages 30 – 34) and Summary of Impacts by Alternative 4.2.4. Land Use (page 61)

Two letters commenting on the scope of the EIS recommended that the EIS examine impacts on agricultural land.[42] Franklin County designates most of the land in the proposed UGA expansion as

---

[39] Southern Resident Orca Task Force, *Final Report and Recommendations* p. 107 (Nov. 2019) accessed on June 5, 2020 at: https://www.governor.wa.gov/issues/issues/energy-environment/southern-resident-orca-recovery/task-force and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "OrcaTaskForce_FinalReportandRecommendations_11.07.19.pdf"

[40] Washington State Department of Fish and Wildlife, Species and Habitats Identified for Franklin County in the Franklin County tab of the file "2020_distribution_by_county.xlsx" enclosed in a separate email and accessed on June 15, 2020 at: https://wdfw.wa.gov/species-habitats/at-risk/phs/list.

[41] AHBL & HDR, *Eastern Washington Low Impact Development Guidance Manual* p. i, pp. 7 – 11 (State of Washington Department of Ecology Publication # 13-10-036: June 2013) accessed on June 15, 2020 at: https://fortress.wa.gov/ecy/publications/SummaryPages/1310036.html.

[42] *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* pp. 86 – 87 (May 2020).

agricultural lands of long-term commercial significance.[43] This was not disclosed in the Draft EIS. The Draft EIS also does not disclose that the agricultural lands of long-term commercial significance will be converted to urban uses by Alternatives 2 and 3. No mitigation is proposed for these undisclosed adverse impacts.[44]

The GMA prohibits including agricultural lands of long-term commercial significance within an UGA unless there is a purchase or transfer or development rights program adopted and implemented for those lands and they are protected as agricultural lands of long-term commercial significance.[45] This inconsistency with the GMA was not disclosed in the Draft EIS. The Draft EIS does not document that the agricultural lands of long-term commercial significance no longer meet the Franklin County or GMA criteria for such designations.

In addition to these undisclosed impacts, the Draft EIS does not disclose the impacts of allowing residential uses so close to the TriCities Airport on airport operations, the impacts of the limited airport expansion opportunities created by the UGA expansion, and the impacts of airport operations on residential uses in the vicinity of the airport.

The adequacy of an EIS "is assessed under the 'rule of reason' … which requires a reasonably thorough discussion of the significant aspects of the probable environmental consequences of the agency's decision."[46] The failure to even mention these significant adverse impacts on agricultural lands of long-term commercial significance means that the Draft EIS is <u>not</u> adequate. It is the same with the impacts on the airport and the impacts of locating housing so close to the airport.

4.5. Environmental Health: 4.5.1: Affected Environment (page 35)

The U.S. Environmental Protection Agency's Environmental Justice Screening and Mapping Tool documents that many areas of Pasco are in proximity to Risk Management Plan (RMP) facilities.[47] These are facilities that have potential chemical accident management plans and are within five kilometers (km) (or nearest one beyond 5 km) each divided by distance in km.[48] This map is calculated from the U.S. Environmental Protection Agency's RMP database. The UGA expansion

---

43 *Franklin County Growth Management Comprehensive Plan* p. 96 (Agricultural Lands map) (Adopted Feb. 27, 2008 Resolution Number 2008-089).
44 RCW 36.70A.130(5)(d).
44 *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* p. 34 (May 2020).
45 RCW 36.70A.060; *Futurewise v. Benton County and the City of Kennewick and the Kennewick Industrial District, LLC*, Eastern Washington Region Growth Management Hearings Board Case No. 14-1-0003, Final Decision and Order (Oct. 15, 2014), at 30 – 36 of 38.
46 *Weyerhaeuser v. Pierce Cty.*, 124 Wn.2d 26, 38, 873 P.2d 498, 504 (1994) internal quotation marks and citations omitted.
47 U.S. Environmental Protection Agency's Environmental Justice Screening and Mapping Tool Traffic Proximity Screen shot accessed on June 8, 2020 at: https://ejscreen.epa.gov/mapper/index.html?wherestr=Pasco%2C+Washington and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2020-06-08 EPA EJScreen Pasco RMP Proximity.pdf"
48 U.S. Environmental Protection Agency's EJSCREEN: Environmental Justice Screening and Mapping Tool Glossary of EJSCREEN Terms (part) accessed on June 8, 2020 at: https://www.epa.gov/ejscreen/glossary-ejscreen-terms and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: 2020-06-08 EPA EJScreen Glossary Part.pdf.

areas are within the 90 to 95 percentiles for Washington State. Parts of Pasco and all of the UGA expansion areas also have a higher proximity to hazardous waste than other parts of Washington State.[49] We recommend that the EIS disclose these potential adverse impacts and identify potential mitigating measures. Given this and other issues with the UGA expansions planned for residential and commercial uses, one mitigating measure should be not including the area proposed for residential and commercial development within the UGA.

4.7. Population, Housing, and Employment: 4.7.2. Impacts (page 39) and Summary of Impacts by Alternative 4.2.6. Population, Housing and Employment (page 63)

Futurewise's scoping comment letter recommended that the EIS should analyze impacts on affordable housing.[50] Housing is an element of the environment.[51] There is a significant need for more affordable housing in Pasco. A quarter of the homeowners with mortgages are paying 30 percent or more of their incomes for housing, the standard for cost overburdened housing.[52] For renter-occupied housing units, 41.2 percent are paying 30 percent or more of their incomes for housing.[53]

Overcrowding is related to housing affordability. Of the occupied housing units, 8.4 percent have 1.01 to 1.50 occupants per room.[54] Nearly four percent of the occupied housing units (3.9 percent) have 1.51 or more occupants per room.[55] There are early indications that overcrowding increases the risk of acquiring infectious diseases including Covid-19. Providing more opportunities for affordable housing by zoning for more affordable densities can reduce overcrowding.

Different alternatives may have different impacts on the affordable housing. However the Draft EIS does not analyze displacement impacts or whether each of the alternatives allow densities that would allow the construction of housing affordable to all income groups. This analysis is still needed.

The City of Pasco is considering the adoption of legislation to allow more "Missing Middle" housing in the City which Futurewise strongly supports. We recommend that the EIS include an estimate of the increased housing capacity this legislation will create and an analysis of the potential impacts of the legislation.

---

[49] U.S. Environmental Protection Agency's Environmental Justice Screening and Mapping Tool Hazardous Waste Proximity screen shot accessed on June 8, 2020 at: https://ejscreen.epa.gov/mapper/index.html?wherestr=Pasco%2C+Washington and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2020-06-08 EPA EJScreen Hazardous Waste Proximity.pdf"
[50] *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* p. 100 (May 2020).
[51] WAC 197-11-444(2)(b)(ii).
[52] United States Census Bureau, Selected Housing Characteristics American Community Survey Table: DP04 p. *10 (2018).
[53] *Id.* p. *11.
[54] *Id.* p. *7.
[55] *Id.*

4.8. Parks and Recreation: 4.8.3. Mitigation Measures (pages 42 – 43)

Figure 4-5, Proposed and Existing Parks, Schools and Open Space on page 43, includes the note "Urban Growth Area: Park/Open Space Area build as area develops." It is unclear if this is a mitigation measure or something else. We recommend that the mitigation measures include a requirement that developers dedicate and construct neighborhood serving parks as development occurs. Where a park will serve more than one development, latecomer agreements could be used to share the costs with the other developments.

In addition, Figure 4-4 shows significant areas of the City that lack a neighborhood serving park or a school that can also function as a neighborhood park within a 15-minute walk of all homes. Figure 4-5 shows that this need will not be met in all areas of the City. We recommend as a mitigating measure that the parks and recreation plan should identify neighborhood park opportunities and funding to provide neighborhood parks within a 15-minute walk in all neighborhoods.

4.9. Transportation (pages 44 – 48) and Summary of Impacts by Alternative 4.2.8. Transportation (page 64)

We appreciate that the EIS, Volume 2 of the comprehensive plan, and the map folio have analyzed traffic impacts including traffic impacts on state highways. We appreciate the planned transportation projects. We also applaud and support the City's complete streets policy.

However, the comprehensive plan and the UGA expansions have the potential to increase vehicle miles traveled and to increase traffic hazards. It does not appear that vehicle miles traveled and increased traffic hazards were analyzed and measures to reduce them were considered.

The UGA expansions and planned residential uses close to the airport will adversely impact the operations and expansion potential of the Tri-Cities Airport, an important regional transportation and economic development asset.[56] While the Draft EIS points to policy LU-2-E which discourages the siting of incompatible uses adjacent to the Pasco airport, the location of Low Density Residential and Medium Density Residential comprehensive plan designations adjacent to and at the northwest end of the runway is inconsistent with this policy.[57] The EIS does not analyze the adverse impacts of these designations on the airport, particularly the residential designations at the north end of the runaway that preclude future expansion opportunities.[58] Nor does it analyze the impacts of the airport on the housing to be built in these areas.[59]

---

[56] Proposed LU-1 Future Land Use Map. "The Tri-Cities Airport (PSC) is the largest airport in the Southeastern Washington and Northeastern Oregon region and the fourth largest air carrier airport in the state of Washington with connections to eight major hubs." Port of Pasco, Tri-Cities Airport ● PSC webpage accessed on June 5, 2020 at: https://www.flytricities.com/.

[57] Proposed LU-1 Future Land Use Map.

[58] *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* pp. 32 – 34, p. 45, p. 64 (May 2020).

[59] *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* pp. 32 – 34 (May 2020).

The draft EIS mentions recreational and commute bicycling and walking, but not walking and bicycling to access stores and services or the relevance of the placement of commercial zoning to allow for more convenient access by pedestrians and bicyclists.

There also does not appear to be plans to address the need for transit, walking, and bicycling within the city and within the urban growth area. Parts of the City of Pasco have a high proportion of households that lack access to private vehicles compared to Washington State as a whole.[60] Public transit is particularly important in those parts of the city but is also beneficial citywide. Walking and bicycling are important citywide. We were unable to find a long-range citywide plan for bicycle facilities, trails, sidewalks, and safe pedestrian crossings of major arterials. The levels of fatal and serious crashes involving pedestrians and bicyclists in parts of the City of Pasco underline the need for such a plan.[61] The Draft EIS also did not analyze the need for these facilities. This analysis should be added to the EIS.

The U.S. Environmental Protection Agency's Environmental Justice Screening and Mapping Tool documents that many areas of Pasco suffer traffic proximity compared to other areas of Washington State.[62] Many of these areas are proposed to be designated for residential uses.[63] We recommend that the EIS analyze whether noise walls, tree plantings, or other mitigation measures should be implemented to protect existing and proposed neighborhoods.

4.10. Public Services and Utilities (pages 48 – 54 and 4.2.9. Public Services and Utilities (page 65)

Residential growth in the City of Pasco has increased the exposure of residences on the Wildland Urban Interface to wildfires.[64] Expanding the city onto agricultural and rural lands will increase this exposure. Fire services are an element of the environment.[65] The impacts of the alternatives and UGA expansions on community fire safety must be analyzed in the EIS and mitigation measures identified such as: directing growth away from areas with a moderate to high wildfire threat levels.[66] Another potential mitigating measure would be to require new developments to meet Firewise

---

[60] Washington State Department of Health, Information by Location (IBL) - Washington Tracking Network (WTN) Social Vulnerability to Hazards No Access to a Private Vehicle (%) map.
[61] Washington State Department of Health, Washington Tracking Network (WTN) Fatal and Serious Crashes involving a Pedestrian or Bicyclist- Rate per 100,000 accessed on June 8, 2020 at: https://fortress.wa.gov/doh/wtn/WTNPortal/home/#!q0=849 and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2020-06-08 WRN Fatal & Serious Crashes Ped & Bike.pdf."
[62] U.S. Environmental Protection Agency's Environmental Justice Screening and Mapping Tool Traffic Proximity Screen shot accessed on June 8, 2020 at: https://ejscreen.epa.gov/mapper/index.html?wherestr=Pasco%2C+Washington and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2020-06-08 EPA EJScreen Pasco Traffic Proximity.pdf."
[63] Proposed LU-1 Future Land Use Map.
[64] *Franklin County, Washington Community Wildfire Protection Plan* pp. 48 – 51 (Approved by the Franklin County Commissioners 2014) last accessed on June 11, 2020 at: https://www.dnr.wa.gov/publications/rp_burn_cwpp_franklin_co.pdf and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "rp_burn_cwpp_franklin_co.pdf."
[65] WAC 197-11-444(2)(d)(i).
[66] See the *Franklin County, Washington Community Wildfire Protection Plan* pp. 45 – 46 (Approved by the Franklin County Commissioners 2014) for the threat level map.

Communities Program standards or the equivalent. Unfortunately, the Draft EIS did not include this analysis and mitigating measures despite the fact that Futurewise's scoping letter included this information.[67]

The changing climate will also increase wildfires in the West including the City of Pasco. A recent peer-reviewed study showed that human caused global warming has made wildfire fuels drier and caused an increase in the area burnt by wildfires between 1984 and 2015.[68] Global warming's drying of wildfire fuels is projected to increasingly promote wildfire potential across the western US.[69] The area of this increase in drying fuels includes the City of Pasco.[70]

The Draft EIS noted that "[i]rrigation exists surrounding the City, and this significantly reduces wildfire risk."[71] But this ignores the *Franklin County, Washington Community Wildfire Protection Plan* which states three times that "[m]any irrigation systems and wells rely on above ground power lines for electricity. These power poles pass through areas of dense wildland fuels that could be destroyed or compromised in the event of a wildfire."[72] One of the purposes of an EIS is to provide accurate information to the public and decisions makers not to shoot from the hip. This statement in the Draft EIS also ignores the fact that the comprehensive plan update proposes to pave over thousands of acres of irrigated farmland and replace them with flammable homes.

The Draft EIS states that "the City conducted an Expanded UGA Infrastructure Evaluation, which evaluated the impact of the anticipated growth, UGA expansion, and land use changes. As a result, in order to accommodate future growth, the City will need to make additional improvements to the West Pasco WTP, Zone 3 Reservoir, and acquire additional water rights to meet the 2038 demands."[73] But the Draft EIS does not indicate whether it is possible to acquire the water rights or whether the water rights will be acquired at the expense irrigated farms. This requires further analysis and disclosure.

4.11. Heritage Conservation (pages 54 – 57) and Summary of Impacts by Alternative 4.2.10. Heritage Conservation (page 66)

We appreciate this section of the Draft EIS and particularly appreciate the disclosure that construction allowed under the alternatives could potentially impact cultural resources including recorded and unrecorded archaeological sites.

The Washington State Department of Archaeology and Historic Preservation has developed an archaeological predictive model that can predict where archaeological resources, a type of cultural

---

[67] City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement pp. 100 – 101 (May 2020).
[68] John T. Abatzogloua and A. Park Williams, *Impact of anthropogenic climate change on wildfire across western US forests* 113 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA (PNAS) 11770 p. 11773 (Oct. 18, 2016) last accessed on June 5, 2020 at: http://www.pnas.org/content/113/42/11770.
[69] *Id.*
[70] *Id.* at p. 11771.
[71] City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement p. 52 (May 2020).
[72] *Franklin County, Washington Community Wildfire Protection Plan* p. 68, p. 70, p. 72 (Approved by the Franklin County Commissioners 2014).
[73] City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement p. 100 (May 2020).

resource, are likely to be located and where the department recommends archaeological surveys should be completed before earth disturbing activities and other uses and activities that can damage archaeological sites are undertaken.[74] The predictive model shows that the City of Pasco and the UGA expansion areas have a "high risk" and "very high risk" of cultural resources.[75] The Draft EIS should include as a mitigating measure adopting regulations that require consultation with Native American Tribes and Nations and site investigations by archaeological professionals before allowing ground disturbing activities in the city and UGA.

The EIS should analyze the impacts on air quality and greenhouse gas emissions

Futurewise's scoping comment letter requested that the EIS analyze impacts on air quality and greenhouse gas pollution.[76] Air quality is an element of the environment.[77] Elevated ozone level averages in the Tri-Cities for 2015 through 2017 exceeded the federal regulatory limit which could trigger sanctions from the Environmental Protection Agency. As a result, a joint study was conducted with the Department of Ecology, Washington State University, and Benton Clean Air Agency, the Tri-Cities Ozone Precursor Study (T-COPS). The study found that elevated ozone levels are not caused by one source and that traffic emissions are a major source of air pollutants in the Tri-Cities.[78] Particulate matter from vehicle emissions, fires, and blowing dust contribute to unhealthy air quality that increase symptoms of asthma and heart disease. Weather, topography and wind directions contribute to high-levels of ozone in the Tri-Cities. Expanding the UGA will increase vehicle miles travelled and emissions. These are all probable adverse impacts on elements of the environment and should have been but were not analyzed in the EIS.

Climate is also an element of the environment.[79] Washington State enacted limits on greenhouse gas emissions and a statewide goal to reduce annual per capita vehicle miles traveled for light-duty vehicles. Comprehensive planning is one way to reduce greenhouse gas pollution and vehicle miles traveled. Almost half of all greenhouse gas emissions in our state result from the transportation sector.[80] Land use and transportation strategies that promote compact and mixed-use development and infill reduce the need to drive and greenhouse gas emissions.[81] Expanding the UGA will increase

---

[74] Washington State Department of Archaeology and Historic Preservation, Find a Historic Place webpage accessed on June 5, 2020 at: https://dahp.wa.gov/historic-preservation/find-a-historic-place.

[75] *Id.*

[76] *City of Pasco Comprehensive Plan: Non-project Draft Environmental Impact Statement* pp. 102 – 103 (May 2020).

[77] WAC 197-11-444(1)(b)(i).

[78] Department of Ecology website, Air Quality Studies, "Tri-Cities Ozone Precursor Study (T-COPS)" https://ecology.wa.gov/Asset-Collections/Doc-Assets/Air-quality/Research-Data/20171212TriCitiesOzonePrecursorStudy, last visited June 8, 2020.

[79] WAC 197-11-444(1)(b)(iii).

[80] Evan Bush, *Washington's greenhouse-gas emissions continue to trend higher in latest inventory* Seattle Times p. *5 (Nov. 19, 2019) accessed on June 8, 2020 at: https://www.seattletimes.com/seattle-news/environment/washingtons-greenhouse-gas-emissions-continue-to-trend-higher-in-latest-inventory/ and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "WA GHG emissions trend higher Seattle Times Nov 2019.docx."

[81] Caroline Rodier, *A Review of the International Modeling Literature: Transit, Land Use, and Auto Pricing Strategies to Reduce Vehicle Miles Traveled and Greenhouse Gas Emissions* p. 21 (2009-10-01) accessed on June 8, 2020 at: https://escholarship.org/content/qt2jh2m3ps/qt2jh2m3ps.pdf and enclosed on the data CD accompanying

vehicle miles travelled and emissions. These are all probable adverse impacts on climate, an element of the environment, and should have been analyzed in the Draft EIS, but were not.

In addition, Washington is already not on track to meet the 2020 greenhouse gas reduction requirement of 90.0 million metric tons (MMT).[82] The 2017 emissions were 97.5 MMT.[83] Trips generated by residents of the UGA expansion will increase global warming and its adverse impacts on Franklin County including increased wildfires, increased demands for water, and reduced water availability in the summer and fall due to a reduction in water stored as snow in the spring and summer.[84] Recent scientific reports document that "the required cuts in emissions are now 2.7 per cent per year from 2020 for the 2°C [temperature increase] goal and 7.6 per cent per year on average for the 1.5°C goal."[85] "Further delaying the reductions needed to meet the goals would imply future emission reductions and removal of CO_2 from the atmosphere at such a magnitude that it would result in a serious deviation from current available pathways. This, together with necessary adaptation actions, risks seriously damaging the global economy and undermining food security and biodiversity."[86] We cannot afford to take actions that increase global warming pollution, we must decrease it. Actions that increase global warming pollution also violate RCW 36.70A.020(10) which directs the City of Pasco to "[p]rotect the environment and enhance the state's high quality of life, including air and water quality, and the availability of water."

SEPA EISs are required to analyze greenhouse gas pollution. As the Shorelines Hearings Board concluded, "because it failed to fully analyze the impacts of greenhouse gas emissions from the Project and to consider whether additional mitigation is required, the Final EIS is remanded to Cowlitz County and the Port for further SEPA analysis consistent with this opinion."[87]

Thank you for considering our comments. If you require additional information, please contact Alison Cable at telephone 206-343-0681 x114 and email: alison@futurewise.org or Tim Trohimovich at telephone (206) 343-0681 Ext. 101 and email: tim@futurewise.org.

Futurewise's June 11, 2020, letter with the filename: "A Review of the International Modeling Literature Transit, Land Use, and Auto Pricing.pdf."

[82] State of Washington Department of Ecology, *Washington State Greenhouse Gas Emissions Inventory: 1990-2015: Report to the Legislature* p. vii & p. 1 (Publication 18-02-043: Dec. 2018) accessed on June 8, 2020 at: https://fortress.wa.gov/ecy/publications/documents/1802043.pdf and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "1802043.pdf;" Evan Bush, *Washington's greenhouse-gas emissions continue to trend higher in latest inventory* Seattle Times (Nov. 19, 2019.

[83] State of Washington Department of Ecology, *2017 greenhouse gas data* webpage accessed on June 8, 2020 at: https://ecology.wa.gov/Air-Climate/Climate-change/Greenhouse-gases/2017-greenhouse-gas-data and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2019-11-25 2017 Greenhouse Gas Data.pdf."

[84] State of Washington Department of Ecology, *Climate change and the environment* webpage accessed on June 8, 2020 at: https://ecology.wa.gov/Air-Climate/Climate-change/Climate-change-the-environment and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "2019-11-25 Climate Change and the Environment.pdf."

[85] United Nations Environment Programme, *Emissions Gap Report 2019* p. xx (UNEP, Nairobi: 2019) accessed on June 8, 2020 at: http://www.unenvironment.org/emissionsgap and enclosed on the data CD accompanying Futurewise's June 11, 2020, letter with the filename: "EGR2019 for emailing.pdf."

[86]

[87] *Columbia Riverkeeper, Sierra Club, and Center For Biological Diversity v. Cowlitz County, Port of Kalama, Northwest Innovation Works-Kalama, LLC, and State of Washington, Department of Ecology*, Shorelines Hearings Board (SHB) No. 17-010c, Order on Motions for Partial Summary Judgment (Sept. 15, 2017), at 18, 2017 WL 10573749, at *9.

Very Truly Yours,

Alison Cable
Tri-Cities Program Manager

Tim Trohimovich, AICP
Director of Planning & Law

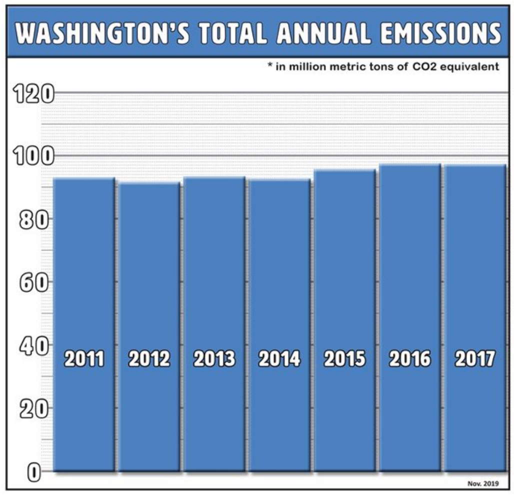
Enclosure

Soils Pasco Proposed Urban Growth Area (UGA) Expansion June 2020				
Soils NW Part of Pasco UGA Expansion				
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**	**Farmland Classification**
10	Chedehap fine sandy loam, 0 to 2 percent slopes	297.1	10.4%	Prime farmland if irrigated
11	Chedehap fine sandy loam, 2 to 5 percent slopes	45.5	1.6%	Prime farmland if irrigated
89	Quincy loamy fine sand, 0 to 15 percent slopes	1,509.6	52.8%	Farmland of statewide importance
90	Quincy loamy fine sand, 15 to 30 percent slopes	126.1	4.4%	
96	Quincy-Dune land complex, 5 to 40 percent slopes	23.7	0.8%	
102	Quincy-Timmerman complex, 0 to 15 percent slopes	318.0	11.1%	Farmland of statewide importance
128	Royal fine sandy loam, 0 to 2 percent slopes	49.6	1.7%	Prime farmland if irrigated
129	Royal fine sandy loam, 2 to 5 percent slopes	145.4	5.1%	Prime farmland if irrigated
184	Timmerman fine sandy loam, 2 to 5 percent slopes	40.0	1.4%	Prime farmland if irrigated
217	Winchester loamy coarse sand, 2 to 5 percent slopes	305.2	10.7%	
Totals for Area of Interest		2,860.3	100.0%	
Prime Farmland Total		577.6	20.2%	
Farmland of Statewide Importance Total		1,827.6	63.9%	
Soils NE Part of Pasco UGA Expansion				
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**	**Farmland Classification**
4	Burbank loamy fine sand, 0 to 5 percent slopes	24.6	4.0%	
5	Burbank loamy fine sand, 5 to 10 percent slopes	2.9	0.5%	
29	Hezel loamy fine sand, 0 to 15 percent slopes	6.0	1.0%	Farmland of statewide importance
44	Kennewick silt loam, 2 to 5 percent slopes	3.4	0.6%	Prime farmland if irrigated
76	Pits	91.5	14.9%	

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI	Farmland Classification
89	Quincy loamy fine sand, 0 to 15 percent slopes	356.4	58.2%	Farmland of statewide importance
92	Quincy loamy fine sand, loamy substratum, 0 to 10 percent slopes	13.5	2.2%	Farmland of statewide importance
126	Royal loamy fine sand, 0 to 10 percent slopes	0.4	0.1%	Farmland of statewide importance
128	Royal fine sandy loam, 0 to 2 percent slopes	60.6	9.9%	Prime farmland if irrigated
129	Royal fine sandy loam, 2 to 5 percent slopes	36.3	5.9%	Prime farmland if irrigated
144	Sagemoor very fine sandy loam, 0 to 2 percent slopes	0.3	0.0%	Prime farmland if irrigated
183	Timmerman fine sandy loam, 0 to 2 percent slopes	6.5	1.1%	Prime farmland if irrigated
184	Timmerman fine sandy loam, 2 to 5 percent slopes	10.0	1.6%	Prime farmland if irrigated
Totals for Area of Interest		612.2	100.0%	
Prime Farmland Total		117.1	19.1%	
Farmland of Statewide Importance Total		376.3	61.5%	
Total for Both UGA Expansions Areas				
Prime Farmland		694.7	20.0%	
Farmland of Statewide Importance		2,203.9	63.5%	
Total		2,898.6	83.5%	
AOI means Area of Interest, the UGA expansion areas				
Source: United States Department of Agriculture Natural Resources Conservation Service Web Soil Survey accessed on June 4, 2020 at: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm; Soil Map—Franklin County, Washington (Pasco UGA Expansion NW Part) p. 1 (6/4/2020) enclosed in a separate email with the filename: "Pasco NW UGA Expansion Soil_Map.pdf;" Soil Map—Franklin County, Washington (Pasco UGA Expansion NE Part) p. 1 (6/4/2020) enclosed in a separate email with the filename: "Pasco NE UGA Expansion Soil_Map.pdf."				

2017 greenhouse gas data

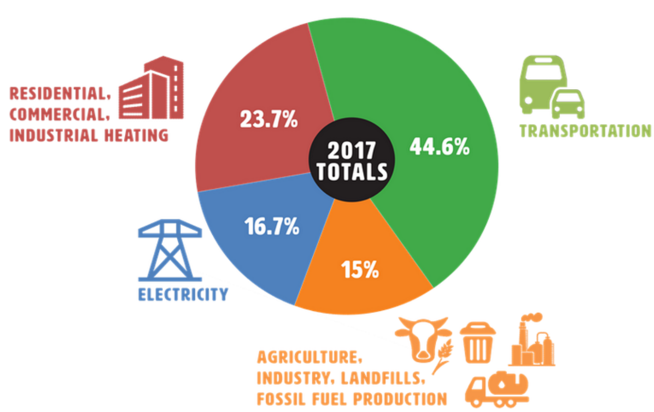
We compile an annual greenhouse gas emissions inventory that estimates the combined emissions from all sources in Washington state. This estimate is based on data from the Washington Department of Commerce, the U.S. Environmental Protection Agency, and the U.S. Energy Information Administration.



Greenhouse gas emissions in Washington were nearly flat from 2016 to 2017, falling by 116,700 metric tons of carbon dioxide, equivalent to to 97.5 million tons.

Below, you can learn more about where these emissions came from.

Sources of Washington greenhouse gases in 2017



Transportation — 43.5067 million metric tons −

Transportation was the largest category of greenhouse gas emissions in Washington during 2017. This category includes emissions from on-road gasoline and diesel vehicles, marine vessels, jet fuel and aviation gasoline, railroads, and natural gas used in transportation. Emissions from on-road gasoline — personal cars and trucks — contributes over half of total emissions in this category.

- 44.6% of total Washington emissions
- 43.5067 million metric tons of emissions

Learn more about how we're helping reduce greenhouse gases from transportation.

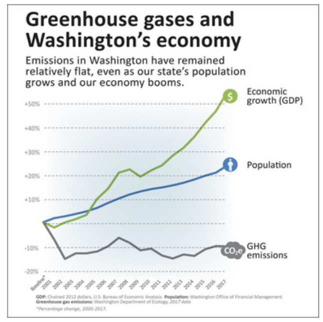
Residential, commercial, industrial heating — 23.106 million metric tons +

Electricity generation — 16.2376 million metric tons +

Other — 14.9639 million metric tons +

Is Washington making progress in reducing greenhouse gas emissions?

Washington's greenhouse gas emissions fell sharply following the 2008 recession, then began growing slowly again in 2012, albeit with dips in emissions in 2014 and 2017. The good news is that the growth in emissions has significantly lagged economic and population growth in Washington, showing that the state's economy is much more efficient, in greenhouse gas terms, than it was in the past. In 2017, for instance, Washington had the strongest economic growth in the nation, but emissions declined slightly.



View the text version of this image.

Signs of progress

Emissions from electricity production were down in both 2016 and 2017, with sharp increases in the amount of renewable energy driving that trend. Some of this switch to renewables is attributable to Washington's Energy Independence Act, which requires state utilities to get 15 percent of their electricity from renewable sources by 2020. Future reductions in emissions will be driven by the 2019 Clean Energy Transformation Act, which requires utilities to stop using coal power by 2025, be greenhouse gas neutral by 2030, and use only non-emitting sources of electricity by 2045.

Reasons for concern

Emissions from shipping and transportation are up, due to increases in aviation, marine shipping, and diesel truck traffic. Emissions from home, business, and industrial heating are also up. With Washington's growing population and strong economy, reducing emissions in these areas will require new approaches.

- Learn more about how Washington is working to reduce greenhouse gas emissions.

Related links

- Washington clean car standards
- Transportation implementation plans
- Gov. Jay Inslee's energy and environment priorities
- University of Washington Climate Impacts Group
- EPA greenhouse gas emissions

Contact information

Andrew Wineke
Air Quality Program
andrew.wineke@ecy.wa.gov
360-407-6932

Climate change and the environment

Climate change
- Greenhouse gases
- Climate change & the environment
  - Science
  - Ocean acidification
  - Sea level rise
  - Water supply impacts
  - Wildfire risks

Tackling climate change is a priority for us. We're working to protect fish, farms, and Washington's rivers, lakes, and coastline from the damage that rising temperatures and shifting precipitation patterns will cause.

I want to...

- Read the climate change response strategy

Extreme weather

When people think of climate change, they often only consider extreme weather and rising temperatures. Extreme weather events, like frequent droughts and stronger storms, are examples of what will increasingly occur. All of these changes are emerging as humans continue to add heat-trapping greenhouse gases to the atmosphere.

Extreme weather events can drastically alter biodiversity, increase the frequency of heat waves, wildfires, dust storms, erosion, and floods. Extreme weather also harms the agricultural industry and the economy.

Learn more about extreme weather.

Ocean acidification

When carbon pollution from human activities is absorbed by seawater, the ocean becomes more acidic. These chemical changes can threaten marine life, especially shellfish, corals, and plankton, on which larger marine life depend.

We are working with other agencies to better understand climate change impacts on marine life and the economy.

Learn more about ocean acidification in Washington and our work on orca recovery.

Sea level rise

Rising sea levels are a serious consequence of climate change. On average, sea levels have swelled over eight inches since 1880, with about three of those inches gained in the past 25 years. The oceans continue to absorb heat from greenhouse gases, resulting in thermal expansion, melting glaciers, and loss of polar ice sheets. Rising waters can lead to coastal hazards such as flooding and habitat changes. Inland, saltwater can contaminate wetlands, aquifers, and agricultural soils.

We are partnering with other agencies to prepare for sea level rise along Washington's 3,300 miles of coastline.

Learn more about sea level rise on Washington's coast.

Water supply

Rising temperatures due to climate change means more precipitation falls as rain rather than snow, reducing snowpack levels, and threatening water supplies for many parts of Washington. In many areas, climate change is likely to increase water demand while water supplies are shrinking. In other areas, an increase in precipitation can lead to flooding, degrading water quality and damaging communities and infrastructure.

Washington relies on snowpack to feed the streams and rivers as it melts in the spring and summer. We monitor the amount of snow received to replenish that supply.

Learn more about Washington's water

Learn more about Washington's water supply .

Wildfires

Higher spring and summer temperatures due to climate change cause earlier spring snowmelt. These weather changes cause soils to be drier for longer, increasing the likelihood of drought, and turning forests into kindling, particularly in the Western United States. Wildfires threaten air quality, your health, the economy, and the environment.

Climate scientists project that the number of acres burned by wildfires each year in the Northwest may reach 1.1 million acres by the 2040s. This puts both Washington's air quality and forests at risk.

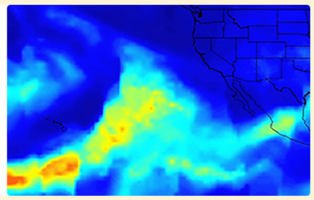
Learn more about wildfires in Washington.

Scientific reports

Because Earth's climate is changing faster than at any point in recorded history, it is important to understand and prepare for these changes. We are tracking carbon pollution in Washington, studying its effects on the state's environment, and helping communities prepare for the impacts of climate change.

To help protect Washington's natural resources, we write and share reports, conduct studies, and collaborate with other agencies.

See our collection of reports and studies.



Related links

- Gov. Jay Inslee's energy and environment priorities
- University of Washington Climate Impacts Group
- NOAA climate
- NASA Global climate change
- U.S. Global Change Research Program

							Terrestrial Habitats
Species/ Habitat	Aspen Stands	Biodiversity Areas & Corridors	Herbaceous Balds	Inland Dunes	Juniper Savannah	Old-Growth/Mature Forest	Oregon White Oak Woodlands
Scientific Name or Family	na	na	na	na	na	na	na

Priority Area	na	na	na	na	na	na	na
Priority Species Criterion #1	na	na	na	na	na	na	na
Priority Species Criterion #2	na	na	na	na	na	na	na
Priority Species Criterion #3	na	na	na	na	na	na	na
State Status	na	na	na	na	na	na	na
FedStatus	na	na	na	na	na	na	na
SGCN	na	na	na	na	na	na	na
Adams	x	x		x			
Asotin	x	x			x	x	
Benton	x	x		x			
Chelan	x	x				x	
Clallam		x	x			x	x
Clark	x	x	x			x	x
Columbia	x	x			x	x	
Cowlitz	x	x	x			x	x
Douglas	x	x		x			
Ferry	x	x		x		x	
Franklin	x	x		x			

Garfield	x	x		x	x	x	
Grant	x	x		x			
Grays Harbor		x	x			x	x
Island		x	x			x	x
Jefferson		x	x			x	x
King		x	x			x	x
Kitsap		x	x			x	x
Kittitas	x	x		x		x	x
Klickitat	x	x		x		x	x
Lewis	x	x	x			x	x
Lincoln	x	x		x		x	
Mason		x	x			x	x
Okanogan	x	x		x		x	
Pacific		x	x			x	x
Pend Oreille	x	x				x	
Pierce	x	x	x			x	x
San Juan	x	x	x			x	x
Skagit		x	x			x	x
Skamania		x	x			x	x
Snohomish		x	x			x	x
Spokane	x	x				x	
Stevens	x	x		x		x	
Thurston	x	x	x			x	x
Wahkiakum		x				x	x
Walla Walla	x	x		x	x		
Whatcom	x	x	x			x	x
Whitman	x	x					
Yakima	x	x		x		x	x

PRIORITY HABITATS

				Aquatic Habitats					
West Side Prairie	Eastside Steppe	Shrub-Steppe	Riparian	Freshwater Wetlands & Fresh Deepwater	Instream	Open Coast Nearshore	Coastal Nearshore	Puget Sound Nearshore	Caves
na	na	na	na	na	na	na	na	na	na

na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na
	x	x	x	x	x				x
		x	x	x	x				x
		x	x	x	x				x
		x	x	x	x				x
x			x	x	x	x	x	x	x
x			x	x	x				x
	x		x	x	x				x
x			x	x	x				x
		x	x	x	x				x
	x	x	x	x	x				x
	x	x	x	x	x				x

	x	x	x	x	x				x
		x	x	x	x				x
x			x	x	x	x	x		x
x			x	x	x			x	x
x			x	x	x	x	x	x	x
x			x	x	x			x	x
			x	x	x			x	x
		x	x	x	x				x
	x	x	x	x	x				x
x			x	x	x				x
		x	x	x	x				x
x			x	x	x			x	x
		x	x	x	x				x
			x	x	x	x	x		x
			x	x	x				x
x			x	x	x			x	x
x			x	x	x			x	x
			x	x	x			x	x
			x	x	x				x
			x	x	x			x	x
	x	x	x	x	x				x
			x	x	x				x
x			x	x	x			x	x
			x	x	x				x
	x	x	x	x	x				x
			x	x	x			x	x
	x	x	x	x	x				x
		x	x	x	x				x

Habitat Features			Lamprey		Sturgeon		Mud-minnow	Herring	
Cliffs	Snags and Logs	Talus	Pacific Lamprey	River Lamprey	Green Sturgeon	White Sturgeon	Olympic Mudminnow	Pacific Herring	Lake Chub
na	na	na	*Lampetra tridentata*	*Lampetra ayresi*	*Acipenser medirostris*	*Acipenser transmontanus*	*Novumbra hubbsi*	*Clupea pallasi*	*Couesius plumbeus*

na	na	na	Any Occurrence	Any Occurrence	Any Occurrence	Any Occurrence	Any Occurrence	Breeding Areas, RC	Any Occurrence
na	na	na		x	x		x	x	x
na	na	na			x	x		x	
na	na	na	x		x	x		x	
na	na	na	None	SC	None	None	SS	SC	SC
na	na	na	None	None	FT	None	None	None	None
na	na	na	x	x	x	x	x	x	x
x	x	x							
x	x	x	x	x		x			
x	x	x	x	x		x			
x	x	x	x			x			
x	x	x	x	x	x	x	x	x	
x	x	x	x	x	x	x			
x	x	x	x	x		x			
x	x	x	x	x	x	x			
x	x	x	x			x			
x	x	x				x			
x	x	x	x	x		x			

x	x	x	x	x		x			
x	x	x	x			x			
x	x	x	x	x	x	x	x	x	
x	x	x				x		x	
x	x	x	x	x	x	x	x	x	
x	x	x	x	x		x	x	x	
x	x	x	x	x		x		x	
x	x	x	x	x		x			
x	x	x	x	x		x			
x	x	x	x	x		x	x		
x	x	x				x			
x	x	x	x	x		x	x	x	
x	x	x	x			x			x
x	x	x	x	x	x	x		x	
x	x	x							
x	x	x	x	x		x		x	
x	x	x				x		x	
x	x	x	x	x		x		x	
x	x	x	x	x	x	x			
x	x	x	x	x		x	x	x	
x	x	x							
x	x	x				x			x
x	x	x	x	x		x	x	x	
x	x	x	x	x	x	x			
x	x	x	x			x			
x	x	x	x	x		x		x	
x	x	x	x	x		x			
x	x	x	x	x		x			

Minnow		Sucker	Smelt						
Leopard Dace	Umatilla Dace	Mountain Sucker	Eulachon	Longfin Smelt	Surfsmelt	Bull Trout/ Dolly Varden	Chinook Salmon	Chum Salmon	Coastal Res./ Searun Cutthroat
Rhinichthys falcatus	*Rhinichthys umatilla*	*Catostomus platyrhynchus*	*Thaleichthys pacificus*	*Spirinchus thaleichthys*	*Hypomesus pretiosus*	*Salvelinus confluentus/S. malma*	*Oncorhynchus tshawytscha*	*Oncorhynchus keta*	*Oncorhynchus clarki clarki*

Any Occurrence	Any Occurrence	Any Occurrence	RC	Breeding Areas, RC	Breeding Areas, RC	Any Occurrence	Any Occurrence	Any Occurrence	Any Occurrence
x	x	x	x			x	x	x	
			x	x	x	x	x	x	
			x	x	x	x	x	x	x
SC	SC	SC	SC	None	None	SC	SC	SC	None
None	None	None	FT	None	None	FT	FT	FT	None
x	x	x	x		x	x	x	x	
x		x				x	x		
x	x	x				x	x	x	
x	x	x				x	x		
			x	x	x	x	x	x	x
x		x	x			x	x	x	x
x		x				x	x		
x		x	x			x	x	x	x
x	x	x				x	x		
	x					x			
x		x				x	x		

x		x				x	x		
x		x				x	x		
			x	x	x	x	x	x	x
				x	x		x	x	x
			x	x	x	x	x	x	x
				x	x	x	x	x	x
				x	x	x	x	x	x
x	x	x				x	x		
x		x				x	x	x	x
x		x	x			x	x	x	x
						x			
				x	x	x	x	x	x
x	x					x	x		
			x	x	x	x	x	x	x
						x			
				x	x	x	x	x	x
				x	x	x	x	x	x
				x	x	x	x	x	x
x		x				x	x	x	x
				x	x	x	x	x	x
	x					x			
				x	x	x	x	x	x
			x			x	x	x	x
x	x	x				x	x		
				x	x	x	x	x	x
x		x				x	x		
x	x	x				x	x		

FISH									
Trout, Salmon, Whitefish							Cod		
Coho Salmon	Kokanee	Pink Salmon	Pygmy Whitefish	Rainbow Trout/ Steelhead/ Inland Redband Trout	Sockeye Salmon	Westslope Cutthroat	Pacific Cod	Pacific Hake	Walleye Pollock
Oncorhynchus kisutch	*Oncorhynchus nerka*	*Oncorhynchus gorbuscha*	*Prosopium coulteri*	*Oncorhynchus mykiss*	*Oncorhynchus nerka*	*Oncorhynchus clarki lewisi*	*Gadus macrocephalus*	*Merluccius productus*	*Gadus chalcogrammus*

Any Occurrence	Any Occurrence	Any Occurrence	Any Occurrence	Any Occurrence	Any Occurrence	Any Occurrence	Breeding Areas, RC	Breeding Areas, RC	Breeding Areas, RC
x			x	x	x		x	x	x
x		x	x		x		x	x	x
x	x	x		x	x	x	x	x	x
SC	None	None	SS		SC	None	SC	SC	SC
FT	None	None	None		FT/FE	None	Fco	Fco	None
x			x	x	x	x	x	x	x
				x		x			
				x	x	x			
x		x		x	x				
x	x		x	x	x	x			
x	x	x	x	x	x		x	x	x
x	x	x		x	x				
	x			x	x	x			
x	x	x		x	x				
x	x			x	x	x			
	x			x		x			
x				x	x	x			

				x	x	x			
x	x			x	x	x			
x	x	x		x	x		x	x	x
x		x			x		x	x	x
x	x	x		x	x		x	x	x
x	x	x	x	x	x		x	x	x
x		x		x			x	x	x
x	x		x	x	x	x			
x		x		x	x				
x				x					
	x			x		x			
x	x	x		x	x		x	x	x
x	x		x	x	x	x			
x		x		x	x		x	x	x
	x		x	x		x			
x	x	x		x	x		x	x	x
x	x	x		x	x		x	x	x
x	x	x		x	x		x	x	x
x	x	x		x	x				
x	x	x		x	x		x	x	x
	x			x		x			
	x			x		x			
x		x		x	x		x	x	x
x		x		x	x				
x	x			x	x	x			
x	x	x		x	x		x	x	x
				x	x	x			
x	x			x	x	x			

Rockfish	Tiger Rockfish	*Sebastes nigrocinctus*
	Redstripe Rockfish	*Sebastes proriger*
	Quillback Rockfish	*Sebastes maliger*
	Greenstriped Rockfish	*Sebastes elongatus*
	Copper Rockfish	*Sebastes caurinus*
	China Rockfish	*Sebastes nebulosus*
	Canary Rockfish	*Sebastes pinniger*
	Brown Rockfish	*Sebastes auriculatus*
	Bocaccio Rockfish	*Sebastes paucispinis*
	Black Rockfish	*Sebastes melanops*

RC	RC	RC	RC	Any Occurrence	RC	RC	RC	RC	Any Occurrence
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
SC	SC	SC	SC	SC	SC	SC	SC	SC	SC
None	FE	None	FT	None	None	None	None	None	None
	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x

x	x	x	x	x	x	x	x	x	x
x	x	x	x		x	x	x	x	
x	x	x	x	x	x	x	x	x	x
x	x	x	x		x	x	x	x	
x	x	x			x	x	x	x	x
x		x	x		x	x	x	x	
x	x	x	x	x	x	x	x	x	x
x	x	x	x		x		x	x	
x		x	x	x	x	x	x	x	x
x		x	x	x	x	x	x	x	x
x	x	x	x		x	x	x	x	
		x			x		x		
x		x	x		x	x	x	x	

			Greenling	Sculpin	Sand Lance	Right-eye Flounder		Salama	
Widow Rockfish	Yelloweye Rockfish	Yellowtail Rockfish	Lingcod	Margined Sculpin	Pacific Sand Lance	English Sole	Rock Sole	Cascade Torrent Salamander	Dunn's Salamander
Sebastes entomelas	*Sebastes ruberrimus*	*Sebastes flavidus*	*Ophiodon elongatus*	*Cottus marginatus*	*Ammodytes hexapterus*	*Pleuronectes vetulus*	*Pleuronectes bilineatus*	*Rhyacotriton cascadae*	*Plethodon dunni*

RC	Any Occurrence	RC	Any Occurrence	Any Occurrence	Breeding Areas, RC	Breeding Site	Breeding Areas, RC	Any occurrence	Any occurrence
x	x	x		x				x	x
x	x	x	x		x				
x	x	x	x		x	x	x		
SC	SC	SC	None	SS	None	None	None	SC	SC
None	FT	None	None	None	None	None	None	None	None
	x			x	x			x	x
x	x	x	x		x	x	x		
								x	
				x					
								x	x

x	x	x	x		x	x	x		x
	x	x	x		x	x	x		
x	x	x	x		x	x	x		
	x	x	x		x	x	x		
		x	x		x	x	x		
								x	x
	x	x	x		x	x	x		
x	x	x	x		x	x	x		x
	x	x	x		x	x	x	x	
x	x	x	x		x	x	x		
		x	x		x	x	x		
								x	
	x		x		x	x	x		
			x		x	x	x	x	
									x
				x					
	x	x	x		x	x	x		
								x	

AMPHIBIANS							REPTILE		
anders		Frogs and Toads					Turtles	Snakes	
Larch Mountain Salamander	Van Dyke's Salamander	Columbia Spotted Frog	Northern Leopard Frog	Oregon Spotted Frog	Rocky Mountain Tailed Frog	Western Toad	Western Pond Turtle (also known as Pacific Pond Turtle)	California Mountain Kingsnake	Sharp-tailed Snake (formerly Common Sharptail Snake)
Plethodon larselli	*Plethodon vandykei*	*Rana luteiventris*	*Rana pipiens*	*Rana pretiosa*	*Ascaphus montanus*	*Bufo boreas*	*Actinemys marmorata*	*Lampropeltis zonata*	*Contia tenuis*

Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence
x	x	x	x	x	x	x	x	x	x
SS	SC	SC	SE	SE	SC	SC	SE	SC	SC
None	None	None	None	FT	None	None	None	None	None
x	x	x	x	x	x	x	x	x	x
		x							
		x			x	x			
		x				x			x
	x					x	x		
x				x		x	x		
		x			x	x			
x	x					x	x		
		x				x			
		x				x			

		x			x	x			
		x	x						
	x					x	x		
						x	x		
	x					x	x		
x				x		x	x		
						x	x		
x		x				x			x
x				x		x	x	x	x
x	x					x	x		
		x				x			
	x					x	x		
		x				x			
	x					x			
		x				x			
x	x			x		x	x		
						x			x
		x		x		x			
x	x			x		x	x	x	x
				x		x	x		
		x				x			
		x				x			
	x			x		x	x		
	x					x			
		x			x	x			
		x		x		x			
		x				x			
x	x	x				x			x

ES

	Lizards	Marine Birds							
Striped Whipsnake	Sagebrush Lizard	American White Pelican	Brown Pelican	Cassin's Auklet	Clark's Grebe	Common Loon	Marbled Murrelet	Short-tailed Albatross	Tufted Puffin
Masticophis taeniatus	*Sceloporus graciosus*	*Pelecanus erythrorhynchos*	*Pelecanus occidentalis*	*Ptychoramphus aleuticus*	*Aechmophorus clarkii*	*Gavia immer*	*Brachyramphus marmoratus*	*Phoebastria albatrus*	*Fratercula cirrhata*

RC, Breeding areas	x	x	x	SE	None	x					x						
Any occurrence	x			SC	FE	x					x						
Any occurrence in suitable habitat	x	x		ST	FT	x					x			x			
Breeding sites, Migratory Stopovers, RC	x	x		SS	None	x				x	x				x	x	
RC, Breeding areas	x	x		SC	None	x	x								x		
Breeding areas	x	x		SC	None						x						
RC in foraging & resting areas		x		None	None	x					x						
Breeding areas, RC	x	x		SE	None	x	x		x	x					x		x
Any occurrence	x			SC	None	x	x	x	x	x			x		x	x	x
Any occurrence	x			SC	None	x			x								x

	x								
x	x	x			x				
			x			x	x	x	x
						x	x	x	x
			x	x		x	x	x	x
						x	x		
						x	x		
x	x	x							
x	x								
							x		
x	x	x							
						x	x		
	x					x			
			x			x	x	x	
		x				x			
						x	x		
				x			x	x	x
						x	x	x	
						x	x		
		x							
						x			
						x	x		
							x		
x	x	x							
		x				x	x	x	
	x	x							
x	x								

	Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead	Bucephala islandica, Bucephala clangula, Bucephala albeola
	Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser	Aix sponsa, Bucephala islandica, Bucephala clangula, Bucephala albeola, Lophodytes cucullatus
	Western High Arctic Brant (formerly called Brant)	*Branta bernicla*
Herons	Great Blue Heron	*Ardea herodias*
	Black-crowned Night-heron	*Nycticorax nycticorax*
	E WA breeding: Terns	Laridae
	E WA breeding concentrations of: Grebes, Cormorants	Podicipedidae, Phalacrocoracidae
	W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids	Phalacrocoracidae, Hydrobatidae, Laridae, Alcidae
	W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids	Gaviidae, Podicipedidae, Phalacrocoracidae, Procellariidae, Hydrobatidae, Alcidae
	Western grebe	*Aechmophorus occidentalis*

RC		x	x	NA	NA							x		x			
Breeding areas			x	NA	NA				x	x	x	x		x	x	x	
RC in foraging and resting areas, migratory stopovers		x	x	None	None	x					x						
Breeding areas		x		None	None		x	x	x	x	x	x	x	x	x	x	x
Breeding areas		x		None	None		x		x	x					x		x
Breeding areas		x		NA	NA		x		x						x	x	x
Breeding areas		x		NA	NA		x		x	x					x	x	x
Breeding areas		x		NA	NA						x						
RC		x		NA	NA						x						
RC, Breeding areas, Migratory stopovers, Regular occurrences in winter	x	x		SC	None	x	x	x	x	x	x	x		x	x	x	x

						x			
x			x	x	x	x		x	
x	x	x				x	x	x	x
x	x	x				x	x	x	x
x	x	x				x	x	x	x
x	x	x				x	x	x	x
x	x	x				x	x	x	x
x			x	x	x	x		x	
x			x	x	x	x		x	
						x		x	x
x			x	x	x	x		x	
x	x	x				x	x	x	x
x			x	x	x	x		x	
x	x	x				x	x	x	x
x			x	x		x		x	
x	x	x				x	x	x	x
x	x	x				x	x	x	x
x	x	x				x	x	x	x
x						x		x	x
x	x	x				x	x	x	x
x			x	x		x		x	
x			x	x		x		x	
x	x	x				x	x	x	x
x						x		x	x
x			x	x	x	x		x	
x	x	x				x	x	x	x
			x	x		x			
x			x	x	x	x		x	

BIRDS

Waterfowl					Hawks, Falcons, Eagles				
Harlequin Duck	Snow Goose	Trumpeter Swan	Tundra Swan	Waterfowl Concentrations	Ferruginous Hawk	Golden Eagle	Northern Goshawk	Prairie Falcon	Chukar
Histrionicus histrionicus	*Chen caerulescens*	*Cygnus buccinator*	*Cygnus columbianus*	(Anatidae excluding Canada geese in urban areas)	*Buteo regalis*	*Aquila chrysaetos*	*Accipiter gentilis*	*Falco mexicanus*	*Alectoris chukar*

RC in WDFW primary management zones for chukar			x	None	None			x	x	x			x		x		
Breeding areas			x	None	None		x	x	x	x			x		x		x
Breeding areas, including alternate nest sites, post-fledging foraging areas	x			SC	None			x		x	x	x	x	x		x	
Breeding and Foraging areas	x			SC	None	x	x	x	x	x	x	x	x	x	x	x	x
Breeding areas, including alternate nest sites. If breeding area is not known, approximate with a 7.0 km2 (4.35 mi2) area around known nest sites, foraging areas	x			ST	None	x	x		x				x		x		x
Significant breeding areas, RC in winter		x	x	NA	NA		x	x	x	x	x	x	x	x	x	x	x
RC		x	x	None	None				x			x		x	x		x
RC		x	x	None	None							x		x			
RC		x	x	None	None												
Breeding areas, RC saltwater		x	x	None	None	x				x	x			x		x	

				x	x	x	x	x	x
			x	x	x	x		x	x
x		x		x		x	x		
x	x	x	x	x					
x		x		x		x	x		
x		x	x	x		x	x		
x		x		x					
x			x	x	x	x	x	x	x
x				x	x	x	x	x	x
x				x		x	x		
			x	x	x	x		x	
x		x		x		x	x		
x				x		x	x	x	x
		x	x	x		x	x		
x				x		x	x		
x				x		x	x		
x		x		x		x			
x	x	x	x	x		x	x		
x			x	x		x	x		
x	x	x	x	x		x	x		
			x	x	x	x	x	x	
				x		x	x		
x				x		x			
		x	x	x		x	x		
			x	x	x	x	x	x	
x	x	x	x	x		x	x		
				x	x	x		x	x
x			x	x	x	x	x	x	x

Upland Game Birds							Cranes	Shore	
Dusky Grouse	Mountain Quail	Ring-necked Pheasant	Greater Sage Grouse	Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)	Sooty Grouse	Wild Turkey	Sandhill Crane	Western Snowy Plover (formerly called Snowy Plover)	Upland Sandpiper
Dendragapus obscurus	*Oreortyx pictus*	*Phasianus colchicus*	*Centrocercus urophasianus*	*Tympanuchus phasianellus*	*Dendragapus fuliginosus*	*Meleagris gallopavo*	*Antigone canadensis*	*Charadrius nivosus*	*Bartramia longicauda*

Any occurrence	x			SE	None	x	x	x					x			
Breeding areas	x			SE	FT	x										
Breeding areas, RC, migration staging areas	x			SE	None	x	x					x		x		
RC and roosts in WDFW's Primary Management Zones for wild turkeys			x	None	None			x					x	x		
Breeding areas, RC			x	None	None					x	x	x		x		
Breeding areas, leks, RC, critical wintering habitat (riparian zones)	x		x	SE	None	x	x			x					x	x
Breeding areas, leks, RC	x		x	ST	Fco	x	x		x						x	
Self-sustaining birds observed in RC in WDFW's eastern Washington Primary Management Zone for pheasant			x	None	None		x	x	x				x		x		x
Any occurrence			x	None	None	x		x		x		x	x			
Breeding areas, RC			x	None	None			x		x			x		x	x

x	x	x				x			x
		x	x	x			x		
	x				x	x		x	
	x				x				
					x				
	x				x				
x			x		x	x			
	x	x	x		x	x	x		
	x				x	x			
x		x	x	x			x		x
	x				x	x			
x			x	x	x				
	x				x	x		x	
x									
	x				x				
					x				
					x				
	x				x				
					x				
x							x		x
x				x					
	x				x	x			
					x	x	x		
x	x	x				x			x
					x				
		x				x			x
		x	x		x	x	x		

ebirds		Pigeons	Cuckoos	Owls			Swifts	Woodpecker	
E WA breeding occurrences of: Phalaropes, Stilts and Avocets	W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae	Band-tailed Pigeon	Yellow-billed Cuckoo	Burrowing Owl	Flammulated Owl	Northern Spotted Owl (formerly called Spotted Owl)	Vaux's Swift	Black-backed Woodpecker	Pileated Woodpecker
Scolopacidae, Recurvirostridae	Charadriidae, Scolopacidae, Phalaropodidae	*Columba fasciata*	*Coccyzus americanus*	*Athene cunicularia*	*Otus flammeolus*	*Strix occidentalis*	*Chaetura vauxi*	*Picoides arcticus*	*Dryocopus pileatus*

Breeding areas	x			SC	None			x		x	x	x	x	x	x	x	
Breeding areas, Regular occurrences	x			SC	None			x		x			x			x	
Breeding areas, Communal roosts	x			SC	None			x	x	x	x	x	x	x	x	x	
Any occurrence	x			SE	FT	x				x	x	x		x			
Breeding sites, Regular occurrences	x			SC	None	x		x		x			x			x	
Breeding areas, foraging areas, RC	x			SC	None	x	x	x	x	x			x		x	x	x
Any occurrence	x			SE	FT	x	x		x								x
RC, Occupied mineral sites			x	None	None	x					x	x		x			
RC		x		NA	NA						x	x		x			
Breeding areas		x		NA	NA		x	x	x	x			x		x	x	x

x				x	x		x	x	x
x			x	x					
	x	x	x			x	x		x
	x	x					x		x
	x	x				x	x		x
	x	x	x			x	x	x	x
	x	x	x				x		x
x				x	x	x	x	x	x
x		x		x	x	x	x	x	x
	x	x				x	x	x	x
x				x	x		x	x	x
	x	x	x			x	x		x
x			x	x	x	x	x	x	x
	x	x				x	x		x
x					x		x	x	x
	x	x	x			x	x	x	x
	x	x					x		x
	x	x				x	x	x	x
	x	x			x	x	x	x	x
	x	x	x			x	x	x	x
x				x	x		x	x	x
x			x		x		x	x	x
	x	x	x			x	x		x
	x	x				x	x		x
x				x	x		x	x	x
	x	x				x	x	x	x
x				x			x		x
x		x	x	x	x	x	x	x	x

		Humpback Whale *	*Megaptera novaeangliae*
		Blue Whale *	*Balaenoptera musculus*
		Dall's Porpoise	*Phocoenoides dalli*
	Perching Birds	Streaked Horned Lark	*Eremophila alpestris strigata*
		Slender-billed White-breasted Nuthatch	*Sitta carolinensis aculeata*
		Sage Thrasher	*Oreoscoptes montanus*
		Sagebrush Sparrow (formerly Sage Sparrow)	*Amphispiza nevadensis (formerly Amphispiza belli)*
		Oregon Vesper Sparrow	*Pooecetes gramineus affinis*
		Loggerhead Shrike	*Lanius ludovicianus*
	...rs	White-headed Woodpecker	*Picoides albolarvatus*

Breeding sites, Regular occurrences	Regular occurrences in breeding areas, RC	Any occurrence	Breeding areas. Regular occurrences in suitable habitat during the breeding season	Breeding areas. Regular occurrences in suitable habitat during the breeding season	Any occurrence	Any occurrence	RC in foraging areas and in migration routes	RC in foraging areas and in migration routes	RC in foraging areas and in migration routes
x	x	x	x	x	x	x		x	x
							x	x	x
SC	SC	SC	SC	SC	SC	SE	None	SE	SE
None	None	None	None	None	None	FT	None	FE	FE
x	x	x	x	x	x	x		x	x
	x		x	x					
x				x					
	x		x	x					
x	x		x	x					
		x					x	x	x
		x			x				
		x			x	x			
	x		x	x					
x	x								
	x		x	x					

x				x					
	x		x	x					
		x				x	x	x	x
		x					x		
							x	x	x
		x					x		
							x		x
x	x		x	x					
x	x		x	x					
		x			x				
x	x		x	x					
		x				x	x		x
x	x		x	x					
		x				x	x	x	x
		x			x	x	x		
		x					x		
		x					x		
x					x				
		x					x		
x				x					
x									
		x			x	x	x		
		x				x			
	x			x					
		x					x		
	x		x	x					
x	x		x	x					

Group	Common Name	Scientific Name
Bats	Townsend's Big-eared Bat	*Corynorhinus townsendii*
Bats	Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat	Eptesicus fuscus, Myotis spp., Antrozous pallidus
Marine Mammals	Northern Sea Otter (formerly called Sea Otter)	*Enhydra lutris*
Marine Mammals	Steller (Northern) Sea Lion	*Eumetopias jubatus*
Marine Mammals	California Sea Lion	*Zalophus californianus*
Marine Mammals	Harbor Porpoise (formerly called Pacific Harbor Porpoise)	*Phocoena phocoena*
Marine Mammals	Orca (Killer Whale)	*Orcinus orca*
Marine Mammals	Harbor Seal	*Phoca vitulina*
Marine Mammals	Sperm Whale *	*Physeter macrocephalus*
Marine Mammals	Gray Whale	*Eschrichtius robustus*

Any occurrence	x	x		SC	None	x	x	x	x	x	x	x	x	x	x	x	x
RC in naturally occurring breeding areas and other communal roosts		x		NA	NA		x	x	x	x	x	x	x	x	x	x	x
RC	x	x		ST	Fco	x					x						
Haulout areas		x		None	None						x						
Haulout areas		x		None	None						x						
RC in foraging areas and in migration routes	x	x		SC	None	x					x						
RC in foraging areas and in migration routes	x	x		SE	FE	x					x						
Haulout areas		x		None	None						x			x			
RC in foraging areas and in migration routes	x	x		SE	FE	x					x						
Any occurrence	x	x		SS	FE	x					x						

								x	x
								x	x
x	x	x	x	x	x	x	x	x	x
x		x	x	x				x	x
x	x	x	x	x	x	x	x	x	x
x		x	x	x	x	x		x	x
x	x	x	x	x	x	x		x	x
								x	x
								x	x
								x	x
								x	x
x		x	x	x	x	x		x	x
								x	x
x	x	x	x	x	x	x		x	x
								x	x
x		x	x	x	x	x		x	x
x		x	x	x		x		x	x
x		x	x	x				x	x
					x	x		x	x
x		x	x	x	x			x	x
								x	x
								x	x
		x	x	x	x			x	x
		x						x	x
								x	x
x		x	x	x				x	x
								x	x
								x	x

MAMMALS

	Rabbits			Rodents					
Keen's Myotis (formerly Keen's Long-eared Bat)	Black-tailed Jackrabbit	Pygmy Rabbit	White-tailed Jackrabbit	Olympic Marmot	Washington Ground Squirrel	Western Gray Squirrel	Mazama (Western) Pocket Gopher	Townsend's Ground Squirrel	Cascade Red Fox
Myotis keenii *(formerly Myotis evotis keenii)*	*Lepus californicus*	*Brachylagus idahoensis*	*Lepus townsendii*	*Marmota olympus*	*Spermophilus washingtoni*	*Sciurus griseus*	*Thonomys mazama*	*Spermophilus townsendii*	*Vulpes vulpes cascadensis*

Any occurrence	x			SC	None	x				x							
Breeding Area, Occurrence, RC	x			SC	None	x			x								
Any occurrence	x			ST	FT	x											
Any occurrence	x			ST	None	x				x							
RC	x			SC	FC	x	x						x		x		x
Any occurrence	x			SC	None	x					x						
RC	x		x	SC	None	x	x		x	x			x		x	x	x
Any occurrence	x			SE	FE	x									x		
RC	x		x	SC	None	x	x		x	x			x		x		x
Any occurrence	x	x		SC	None	x					x						

	x		x						
	x	x	x		x				
x				x		x	x		
x									
x				x			x		
									x
x									
	x		x			x		x	x
	x		x			x		x	x
						x	x		x
	x		x		x				
x				x			x		
			x			x			x
x						x	x		x
x									
x									x
						x			x
x									x
			x						
						x	x		
	x		x		x				
x									x
	x		x		x				
	x		x			x		x	x

Terrestrial Carnivores						Lar			
Fisher	Gray Wolf	Grizzly Bear	Lynx	Marten	Wolverine	Bighorn Sheep	Columbian Black-tailed Deer	Columbian White-tailed Deer	Moose
Pekania pennanti	*Canis lupus*	*Ursus arctos*	*Lynx canadensis*	*Martes caurina*	*Gulo gulo*	*Ovis canadensis*	*Odocoileus hemionus columbianus*	*Odocoileus virginianus leucurus*	*Alces alces*

Any occurrence	Regular occurrence	Any occurrence	Any occurrence	Regular occurrence	Any occurrence	Breeding areas, RC	RC, Migration corridors	RC	RC
x	x	x	x		x			x	
				x		x	x		x
SE	SE	SE	ST	None	SC	None	None	SE	None
FC	FE	FT	FT	None	Fco	None	None	FE	None
x	x	x	x	x	x	x		x	
	x			x	x	x			
x	x	x	x	x	x	x			
x				x			x		
x				x			x	x	
	x			x	x	x			
x				x			x	x	
	x	x	x	x	x	x			x

	x			x	x	x			
x				x			x		
							x		
x				x			x		
x				x	x		x		
							x		
x	x			x	x	x			
x				x	x		x		
x				x	x		x		
						x			
x				x			x		
x	x	x	x	x	x	x			x
				x			x		
x	x	x	x	x	x	x			x
x				x	x		x		
							x		
x	x	x	x	x	x		x		
x				x	x		x		
x		x	x	x	x		x		
			x	x	x				x
x	x	x	x	x	x				x
x				x			x		
				x			x	x	
	x			x		x			
x	x	x	x	x	x		x		
									x
x				x	x	x	x		

ge Ungulates					Gastropods				
Mountain Goat	Northwest White-tailed Deer	Elk	Mule Deer (formerly called Rocky Mountain Mule Deer)	Woodland Caribou	Blue-gray Taildropper	Columbia Oregonian	Dalles Sideband	Shortface Lanx (formerly Giant Columbia River Limpet)	Columbia Pebblesnail
Oreamnos americanus	*Odocoileus virginianus ochrourus*	*Cervus elaphus*	*Odocoileus hemionus hemionus*	*Rangifer tarandus*	*Prophysaon coeruleum*	*Cryptomastix hendersoni*	*Monadenia fidelis minor*	*Fisherola nuttalli*	*Fluminicola columbiana*

Any occurrence	x	x		SC	None			x									x
Any occurrence	x	x		SC	None	x		x									x
Any occurrence	x			SC	None	x											
Any occurrence	x			SC	None	x											
Any occurrence	x			SC	None	x								x			
Any occurrence	x			SE	FE	x											
Breeding areas, Migration corridors, RC in winter			x	None	None		x	x	x	x			x		x	x	x
Calving Areas, Migration Corridors, RC in Winter and in foraging areas along coastal waters			x	None	None			x	x	x	x	x	x	x	x	x	
Migration corridors, RC in winter			x	None	None			x		x			x		x	x	
Breeding areas, RC			x	None	None					x	x						

	x	x	x						
		x	x						
x		x							
x		x							
x		x							
x	x	x	x						
		x	x			x	x		
x		x			x				
	x	x	x						
x		x							
x	x	x	x					x	x
		x							
x	x	x	x	x					
x		x							
x		x							
		x	x			x			
x		x							
	x	x	x					x	x
x	x	x	x						
		x							
		x							
	x	x	x						
x		x							
	x	x	x						
x	x	x	x						

Bivalves	Pacific Razor Clam	*Siliqua patula*
	Pacific Oyster	*Crassostrea gigas*
	Olympia Oyster	*Ostrea lurida*
	Manila (Japanese) Littleneck Clam (formerly called Manila Clam)	*Venerupis philippinarum*
	Native Littleneck Clam	*Leukoma staminea*
	Butter Clam	*Saxidomus giganteus*
	Pacific Geoduck	*Panopea generosa*
	California Floater	*Anodonta californiensis*
	Poplar Oregonian	*Cryptomastix populi*
	Pinto (Northern) Abalone	*Haliotis kamtschatkana*

Any occurrence	Any occurrence	Any occurrence	RC	RC	RC	Regular occurrences	Any occurrence	RC	RC
x	x	x					x		
x		x	x	x	x	x	x	x	x
x			x	x	x	x	x	x	x
SE	SC	SC	None	None	None	None	SC	None	None
Fco	None	None	None	None	None	None	None	None	None
x	x	x					x		
	x								
		x							
x			x	x	x	x	x	x	x
		x							
		x							
		x							

		x							
		x							
				x	x	x	x	x	x
x			x	x	x	x	x	x	
x			x	x	x	x	x	x	x
			x	x	x	x	x	x	
x			x	x	x	x	x	x	
		x							
			x	x	x	x	x	x	
		x							
				x	x	x	x	x	x
			x	x	x	x	x	x	
x			x	x	x	x	x	x	
x			x	x	x	x	x	x	
			x	x	x	x	x	x	
		x							
		x							
			x	x	x	x	x	x	
		x							
x			x	x	x	x	x	x	

Invertebrates

Crustaceans		Beetles				Dragonfly		Worms
Dungeness Crab	Pandalid shrimp (Pandalidae)	Beller's Ground Beetle	Columbia River Tiger Beetle	Hatch's Click Beetle	Mann's mollusk-eating Ground Beetle	Columbia Clubtail	Pacific Clubtail	Giant Palouse Earthworm
Metacarcinus magister	*Pandalus spp.*	*Agonum belleri*	*Cicindela columbica*	*Eanus hatchi*	*Scaphinotus mannii*	*Gomphus lynnae*	*Gomphu kurilis*	*Driloeirus americanus*

Breeding Areas, RC	RC	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence
		x	x	x	x	x	x	x
x	x							
x	x							
None	None	SC	SC	SC	SC	SC	SC	SC
None	None	None	None	None	None	None	None	None
		x	x	x	x	x	x	x
			x		x			
						x		
								x
x	x	x						
					x			
			x					

						x		
x	x							
x	x							
x	x							
x	x	x		x			x	
x	x							
								x
x	x	x						
x	x							
x	x						x	
x	x							
x	x							
			x				x	
x	x							
x	x	x					x	
x	x							
			x		x			x

Millepedes	Butterflies							
Leschi's Millipede	Chinquapin Hairstreak	Great Arctic	Island Marble **	Johnson's Hairstreak	Juniper Hairstreak	Mardon Skipper	Makah Copper	Oregon Silverspot
Leschius mcallisteri	*Habrodais grunus herri*	*Oeneis nevadensis gigas*	*Euchloe ausonides insulanus*	*Callophrys johnsoni.*	*Callophrys gryneus*	*Polites mardon*	*Lycaena mariposa makah*	*Speyeria zerene hippolyta*

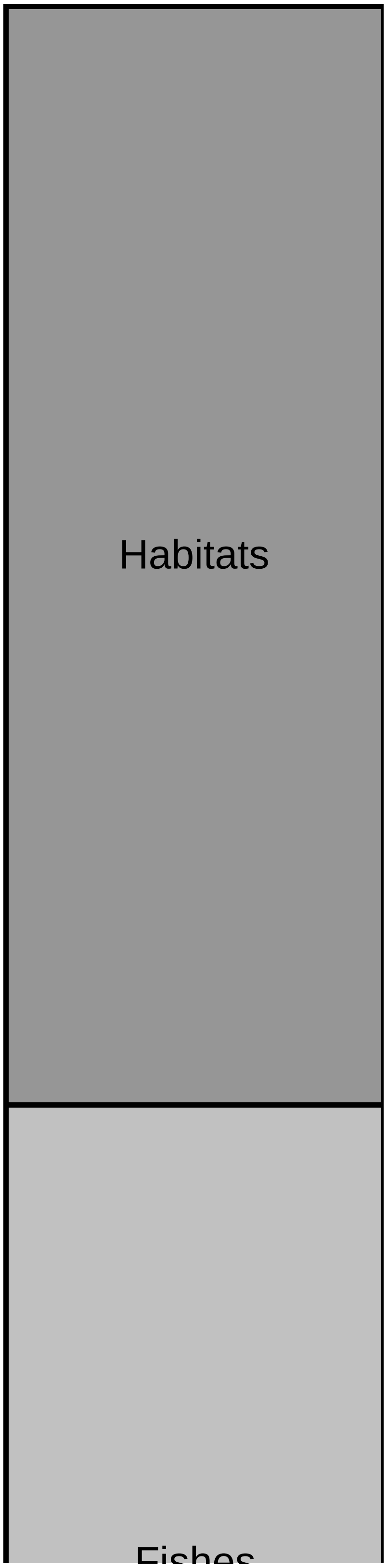
Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence
x	x	x	x	x	x	x	x	x
SC	SC	SC	SC	SC	SC	SE	SC	SE
None	None	None	FE	None	None	None	None	FT
x	x	x	x	x	x	x	x	x
					x			
				x			x	
					x			
					x			

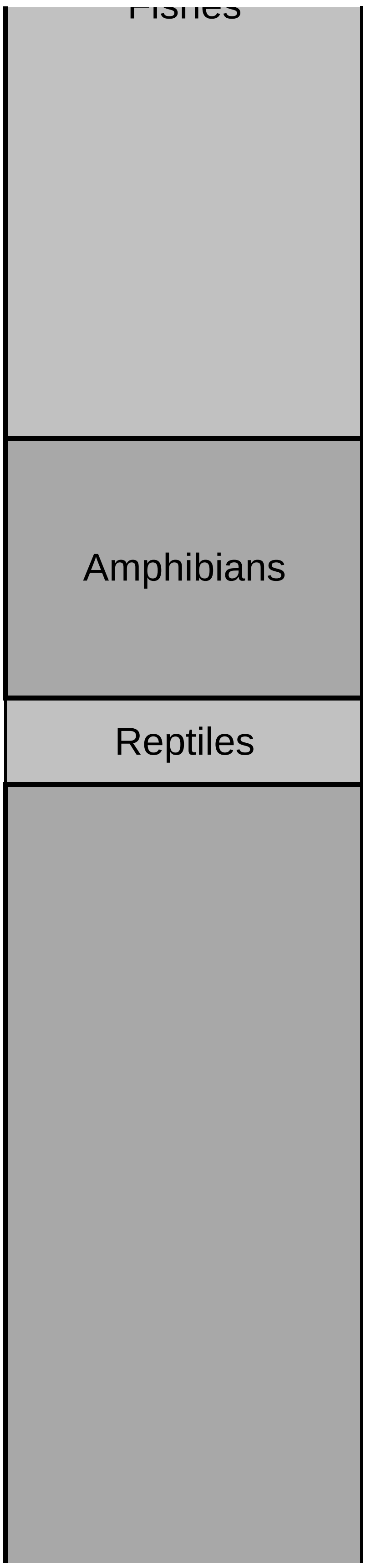
					x			
				x		x	x	
				x			x	
				x				
					x			
					x	x		
				x				
				x				
					x			
							x	x
				x		x		
		x	x					
				x				
	x			x		x		
				x				
x						x		
				x				
						x		

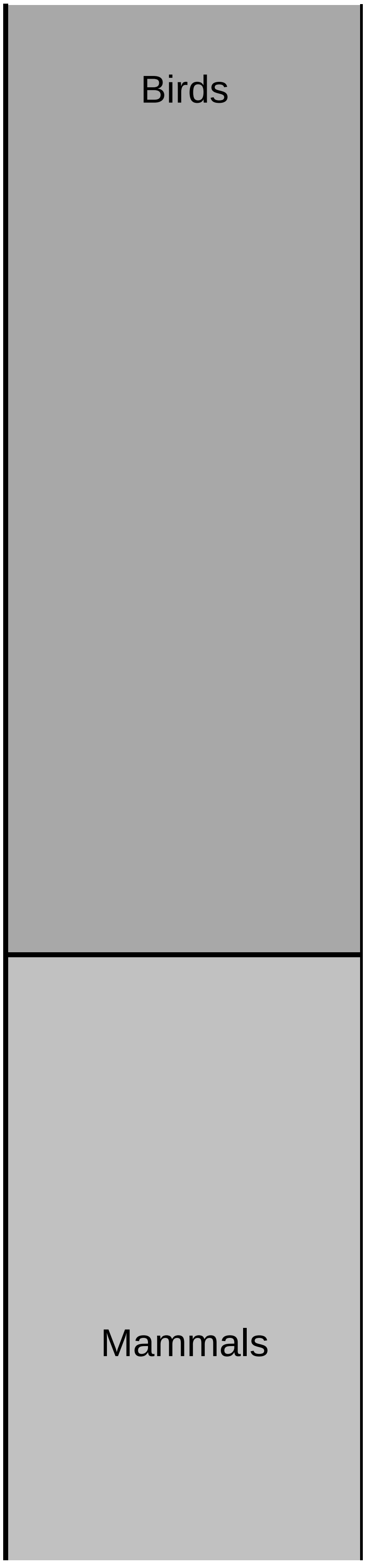
Urchins	Red Sea Urchin	*Mesocentrotus franciscanus*
	Yuma Skipper	*Ochlodes yuma*
	Taylor's Checkerspot	*Euphydryas editha taylori*
	Valley Silverspot	*Speyeria zerene bremnerii*
	Silver-bordered Fritillary	*Boloria selene atrocostalis*
	Shepard's Parnassian	*Parnassius clodius shepardi*
	Sand-verbena Moth	*Copablepharon fuscum*
	Puget Blue	*Icarica icarioides blackmorei*

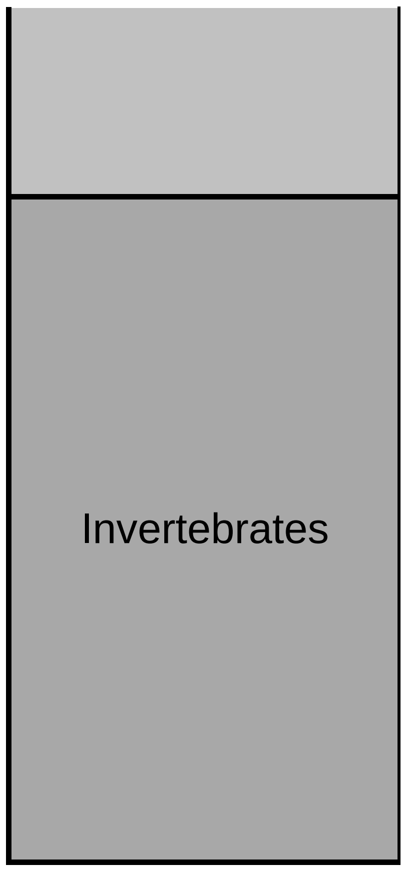
Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	Any occurrence	RC
x	x	x	x	x	x	x	
							x
SC	SC	SC	SC	SC	SE	SC	None
None	None	None	None	None	FE	None	None
x	x		x	x	x	x	
		x					
x	x			x	x		x
				x			
			x				

		x					
			x			x	
x							x
	x				x		x
x	x			x	x		x
				x			
x							
			x				
				x	x		
x					x		
			x				
							x
			x				
x				x	x		
	x			x	x		x
				x			x
			x				
			x				
x				x	x		
				x			
							x
		x	x				
			x				


Habitats
Fishes


Amphibians
Reptiles


Birds
Mammals


Invertebrates

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Juniper Savannah
Old-Growth/Mature Forest
Riparian
Shrub-Steppe
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Leopard Dace
Mountain Sucker

Bull Trout/ Dolly Varden
Chinook Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Rocky Mountain Tailed Frog
Western Toad
Sagebrush Lizard
Western grebe
Great Blue Heron
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Prairie Falcon
Chukar
Dusky Grouse
Mountain Quail

Ring-necked Pheasant
Wild Turkey
Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Flammulated Owl
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Gray Wolf
Marten
Wolverine
Bighorn Sheep
Northwest White-tailed Deer

Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Shortface Lanx (formerly Giant Columbia River Limpet)
Columbia Pebblesnail
Poplar Oregonian
Columbia River Tiger Beetle
Mann's mollusk-eating Ground Beetle
Juniper Hairstreak
Shepard's Parnassian

State Status

Candidate

Candidate

Candidate

Candidate *
Candidate
Candidiate **
Candidiate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

* Bull Trout only

** Steelhead only

*** Federally listed west of north-south line fo

Federal Status	** Im
	These are the species a This list of species and h distribution maps found List (see http://wdfw.wa. distribution maps depict known to occur as well a associated with the spec when developing distribu 1) There is a high likelih if it has not been directly primarily associated exis . 2) Over time, species ca move to new counties w Distribution maps in the information available. A known distribution for sc WDFW will periodically r in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Endangered ***

Candidate

llowing Highways 97, 17, and 395.

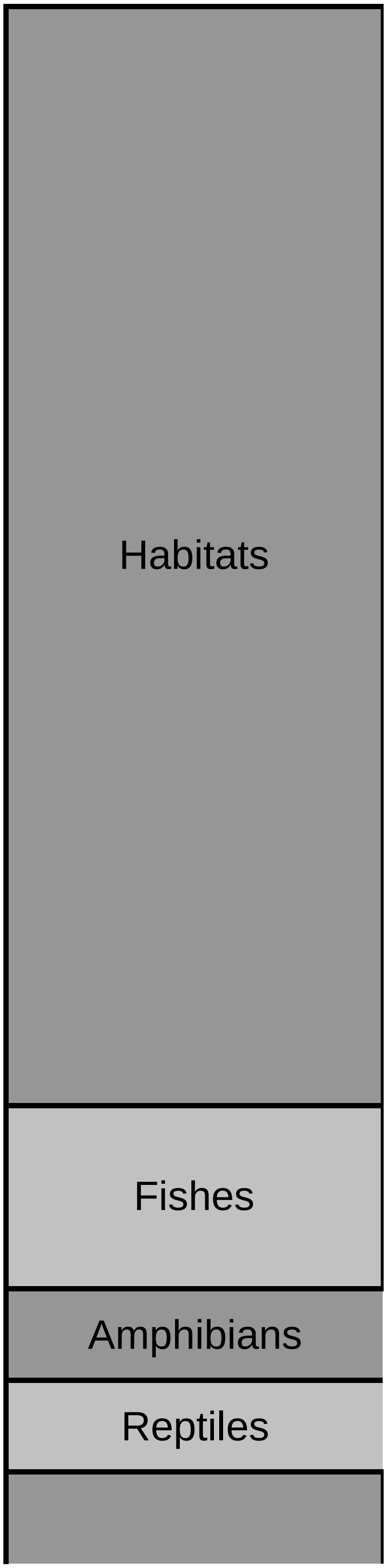
ıportant Note **

.nd habitats identified for Asotin County.
ıabitats was developed using the
in the Priority Habitat and Species (PHS)
gov/conservation/phs/). Species
counties where each priority species is
ıs other counties where habitat primarily
cies exists. Two assumptions were made
ıtion maps for each species:

ood a species is present in a county, even
' observed, if the habitat with which it is
sts.

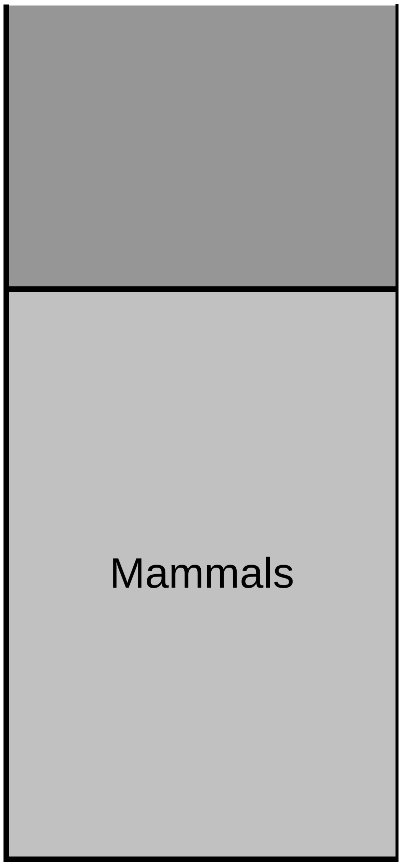
ın naturally change their distribution and
here usable habitat exists.

PHS List were developed using the best
s new information becomes available,
ıme species may expand or contract.
review and update the the distribution maps



Habitats
Fishes
Amphibians
Reptiles

Birds


Mammals

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Eastside Steppe
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Rainbow Trout/ Steelhead/ Inland Redband Trout
Westslope Cutthroat
Columbia Spotted Frog
Sagebrush Lizard
American White Pelican

Clark's Grebe
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Prairie Falcon
Ring-necked Pheasant
Greater Sage-grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
Sandhill Crane
Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Yellow-billed Cuckoo
Burrowing Owl

Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Washington Ground Squirrel
Mule Deer (formerly called Rocky Mountain Mule Deer)

State Status
Candidate *
Candidate
Candidate
Endangered

Candidate
Candidate
Threatened
Candidate
Threatened
Endangered
Endangered
Endangered
Endangered
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

* Steelhead only

Federal Status	** Importa
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict counties known to occur as well as other associated with the species exis made when developing distributi 1) There is a high likelihood a sp even if it has not been directly ol which it is primarily associated e . 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis best information available. As n available, known distribution for contract. WDFW will periodically distribution maps in PHS list.
Threatened *	

Species of Concern
Threatened

Candidate

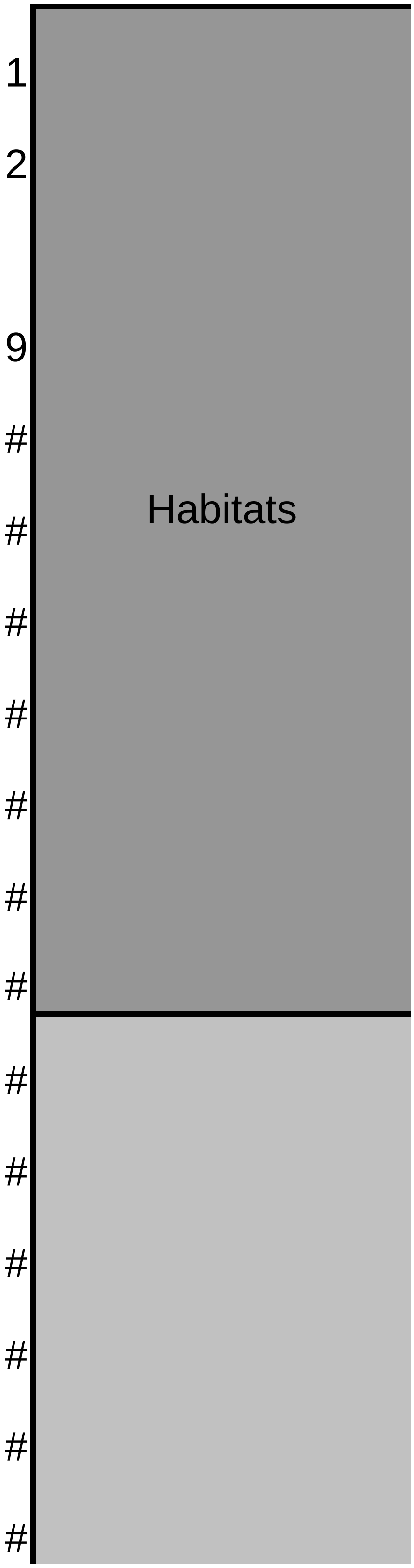
nt Note **

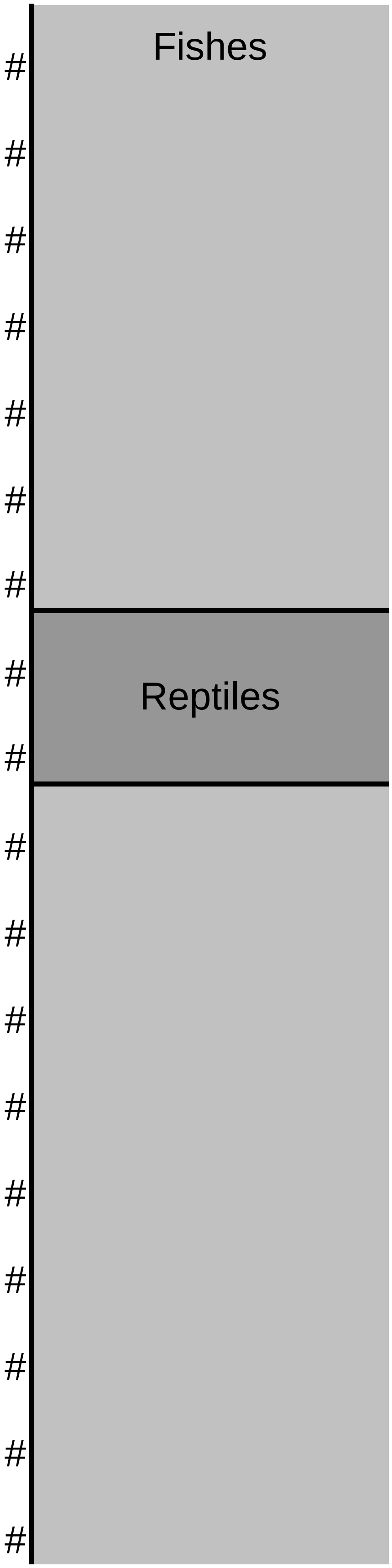
ats identified for Adams
habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were
on maps for each species:

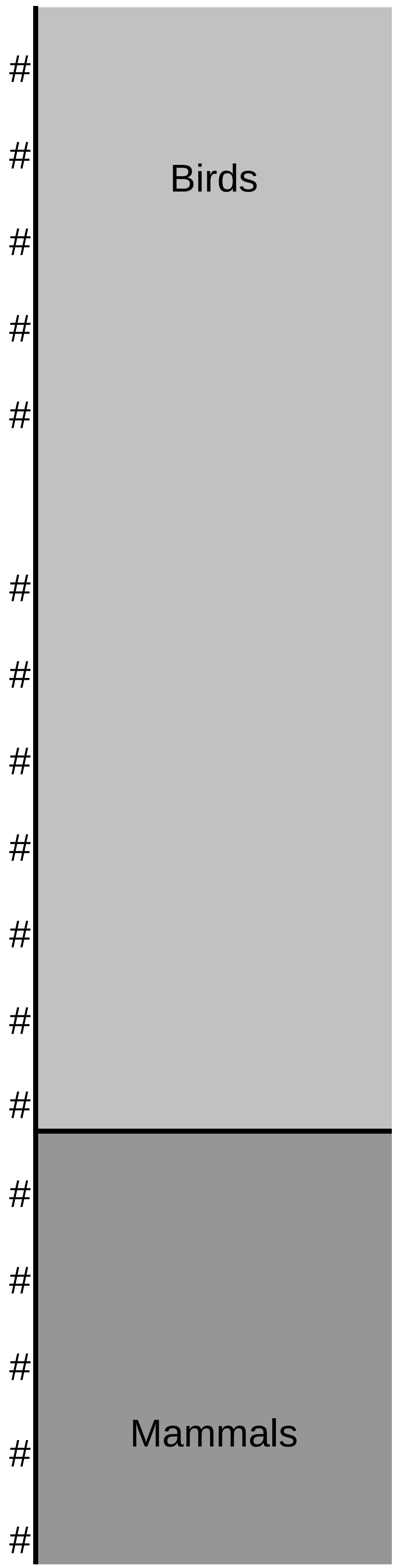
ecies is present in a county,
oserved, if the habitat with
xists.

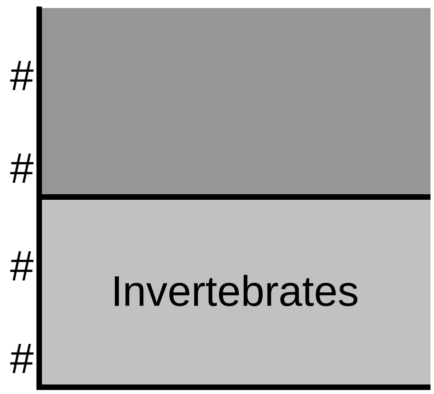
lly change their distribution and
able habitat exists.

t were developed using the
ew information becomes
some species may expand or
review and update the the


1
2
9
#
Habitats
#
#
#
#
#
#
#
#
#
#
#
#


Fishes
Reptiles
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#


#
#
Birds
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Mammals
#
#


#
#
#
Invertebrates
#

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Leopard Dace
Umatilla Dace
Mountain Sucker

Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coho Salmon
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Striped Whipsnake
Sagebrush Lizard
American White Pelican
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Tundra Swan
Waterfowl Concentrations

Ferruginous Hawk
Golden Eagle
Prairie Falcon
Chukar
Ring-necked Pheasant
Greater Sage-grouse
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Yellow-billed Cuckoo
Burrowing Owl
Vaux’s Swift
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Townsend’s Ground Squirrel

Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater
Columbia Clubtail

State Status

Candidate
Candidate
Candidate
Candidate

Candidate *
Candidate
Candidate
Candidiate **
Candidiate
Candidate
Candidate
Endangered
Candidate

Threatened
Candidate
Threatened
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict countie known to occur as well as other primarily associated with the spe were made when developing dis species: . 1) There is a high likelihood a sp even if it has not been directly ol which it is primarily associated e . 2) Over time, species can natura and move to new counties where Distribution maps in the PHS Lis best information available. As n available, known distribution for contract. WDFW will periodically distribution maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Species of Concern
Threatened

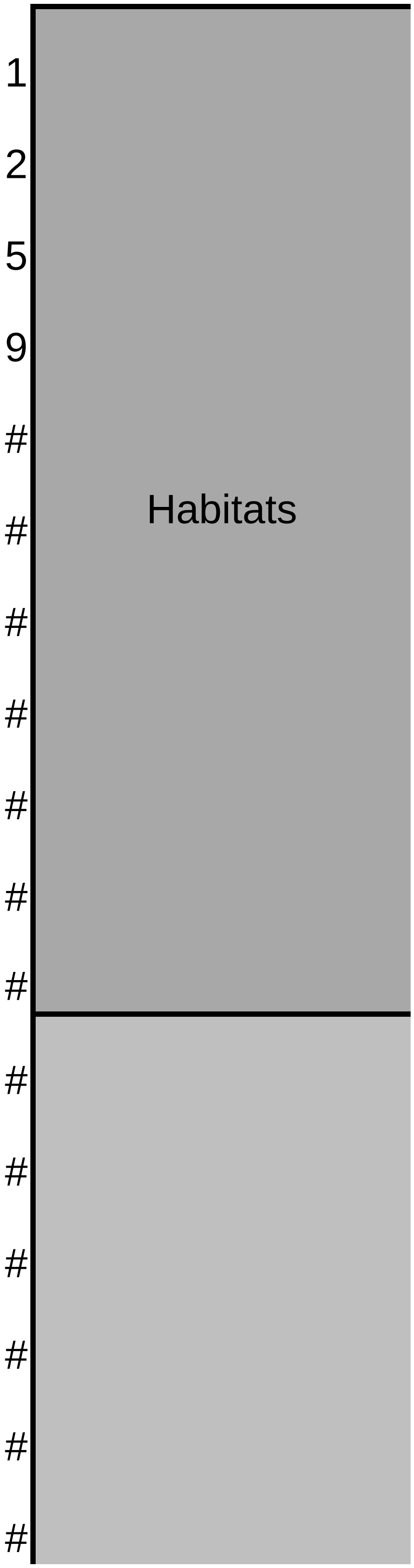
nt Note **

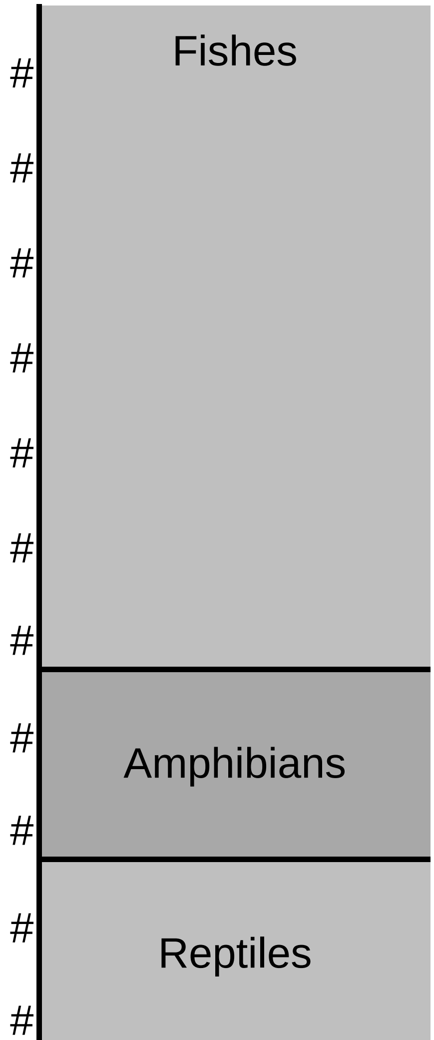
ats identified for Benton
habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat
ecies exists. Two assumptions
tribution maps for each

pecies is present in a county,
bserved, if the habitat with
xists.

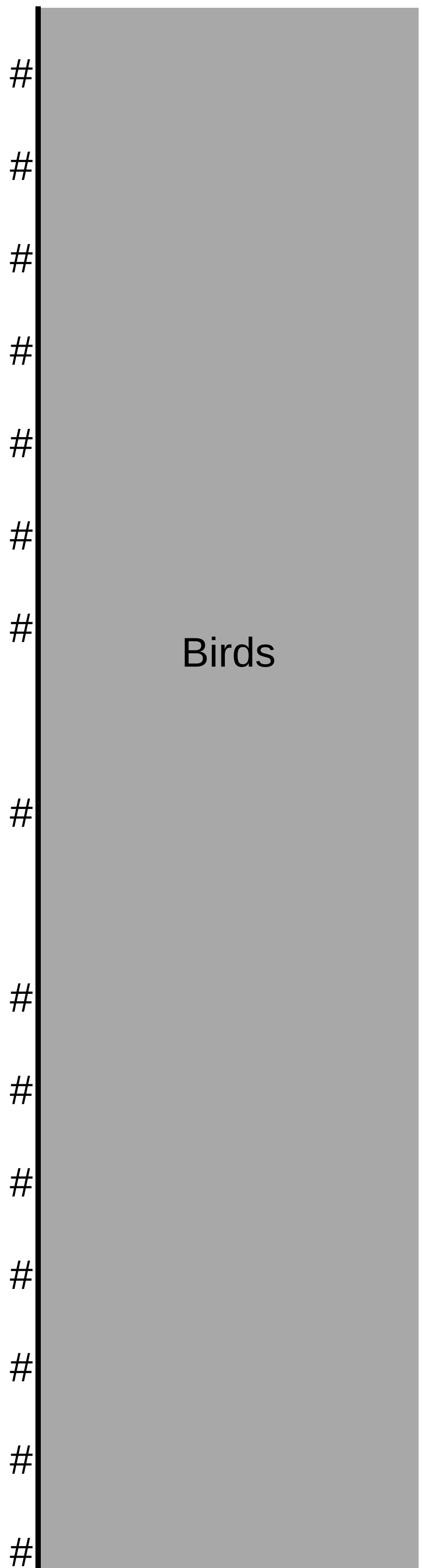
ally change their distribution
e usable habitat exists.

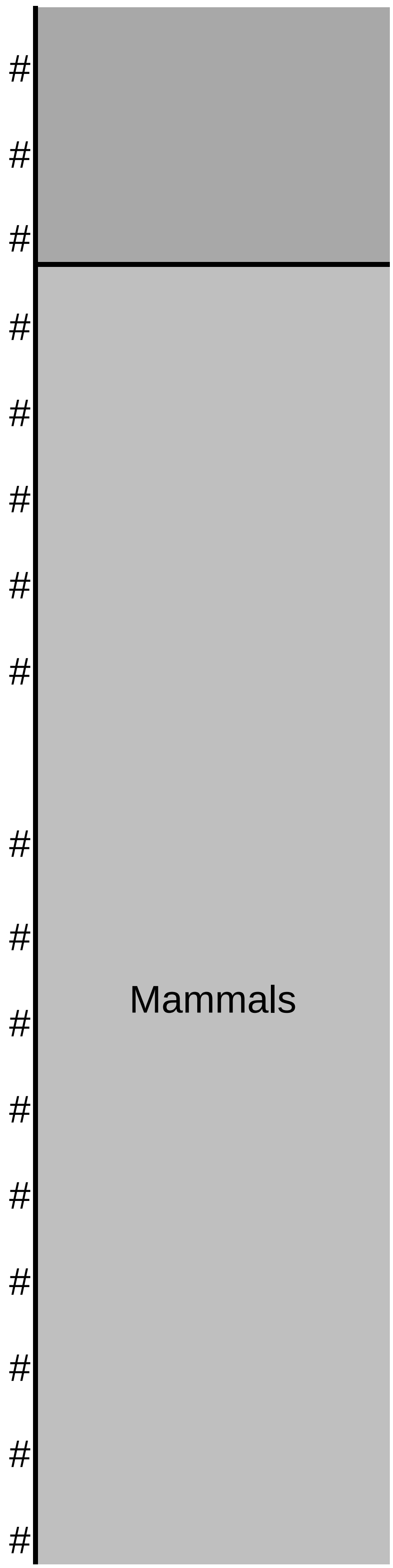
st were developed using the
ew information becomes
some species may expand or
review and update the the

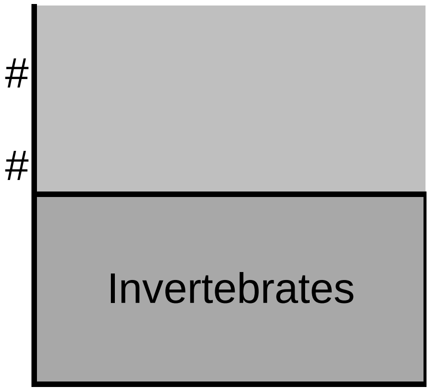

1
2
5
9
#
#
#
#
#
#
#
#
#
#
#
#
#
Habitats



Fishes
Amphibians
Reptiles
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
#
Birds
#
#
#
#
#
#
#
#
#


Mammals


#
#
Invertebrates

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Old-Growth/Mature Forest
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
White Sturgeon
Leopard Dace
Umatilla Dace
Mountain Sucker
Bull Trout/ Dolly Varden

Chinook Salmon
Coho Salmon
Kokanee
Pygmy Whitefish
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Western Toad
Sharp-tailed Snake (formerly Common Sharptail Snake)
Sagebrush Lizard
American White Pelican
Common Loon
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser

Harlequin Duck
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Prairie Falcon
Chukar
Dusky Grouse
Mountain Quail
Sooty Grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Flammulated Owl
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker

Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Western Gray Squirrel
Cascade Red Fox
Fisher
Gray Wolf
Grizzly Bear
Lynx
Marten
Wolverine
Bighorn Sheep
Mountain Goat
Northwest White-tailed Deer

Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater
Giant Palouse Earthworm

State Status
Candidate
Candidate
Candidate
Candidate *

Candidate
Sensitive
Candidiate **
Candidiate
Candidate
Candidate
Candidate
Candidate
Endangered
Sensitive
Candidate

Candidate
Candidate
Endangered
Candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Endangered
Endangered
Endangered
Threatened
Candidate

Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit This list of species and habitats distribution maps found in the Pr List (see http://wdfw.wa.gov/con distribution maps depict counties known to occur as well as other associated with the species exis when developing distribution ma 1) There is a high likelihood a sp if it has not been directly observe primarily associated exists. 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.
Threatened *	

Threatened (Upper Columbia Spring run is Endangered)
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Threatened

Species of Concern
Endangered
Threatened
Threatened
Candidate

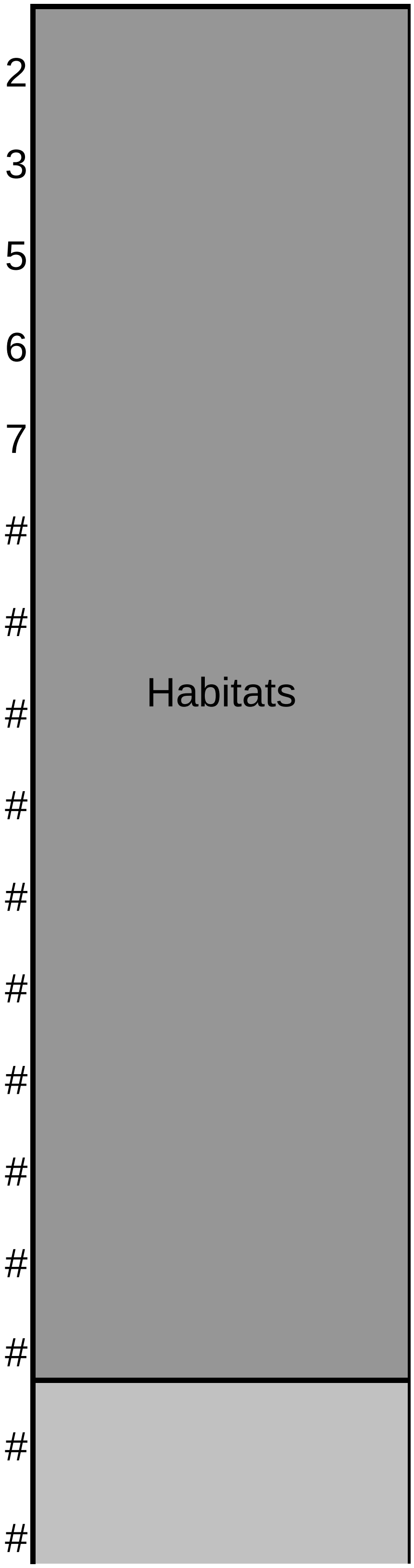
ant Note **

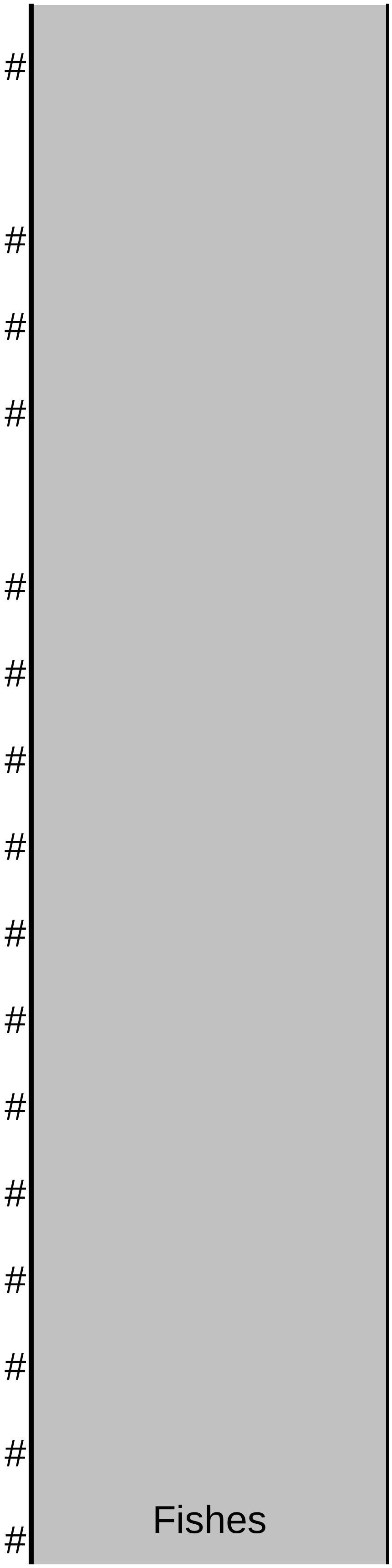
ats identified for Chelan County. was developed using the iority Habitat and Species (PHS) servation/phs/). Species s where each priority species is counties where habitat primarily ts. Two assumptions were made ps for each species:

pecies is present in a county, even ed, if the habitat with which it is .

ally change their distribution and able habitat exists. .

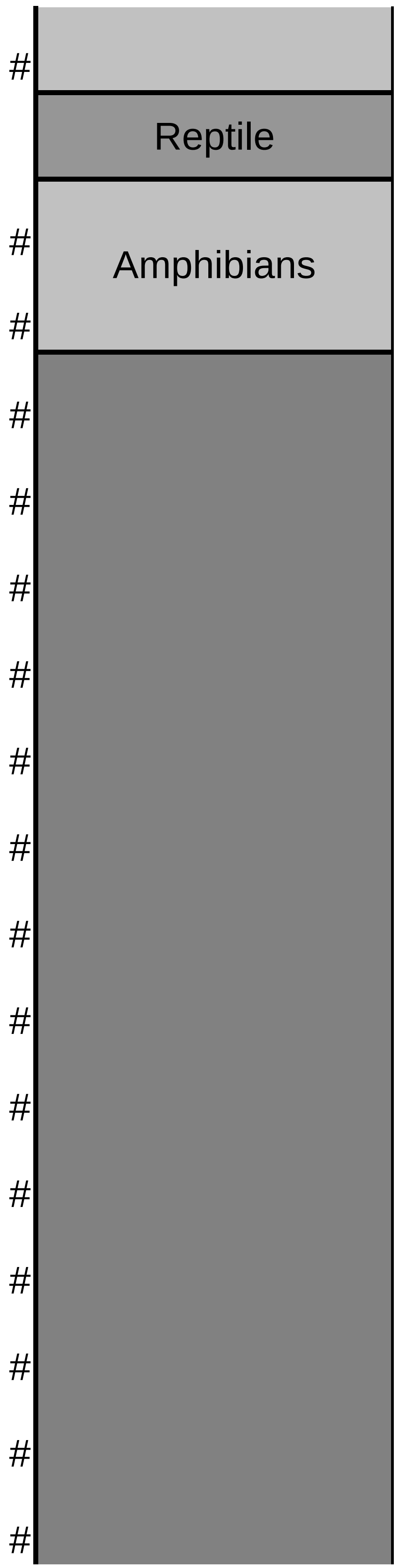
t were developed using the best formation becomes available, cies may expand or contract. nd update the the distribution


2
3
5
6
7
#
#
#
#
#
#
#
#
#
#
#
#
Habitats

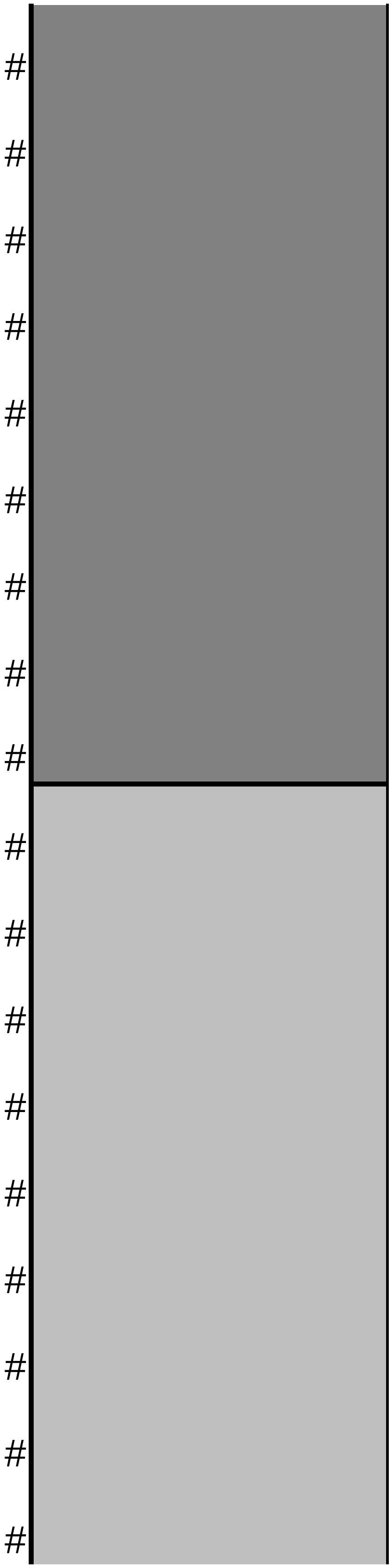


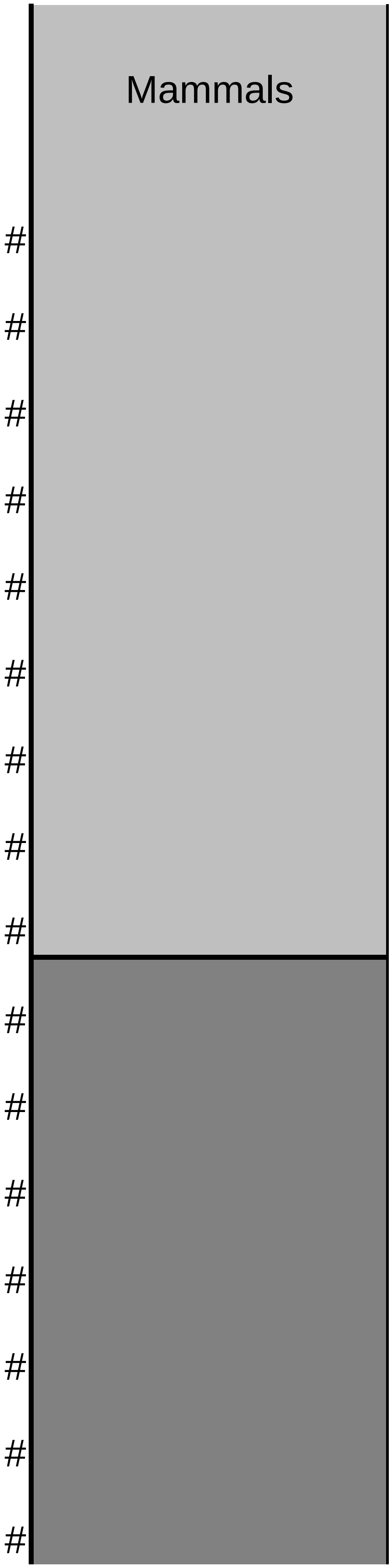
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes

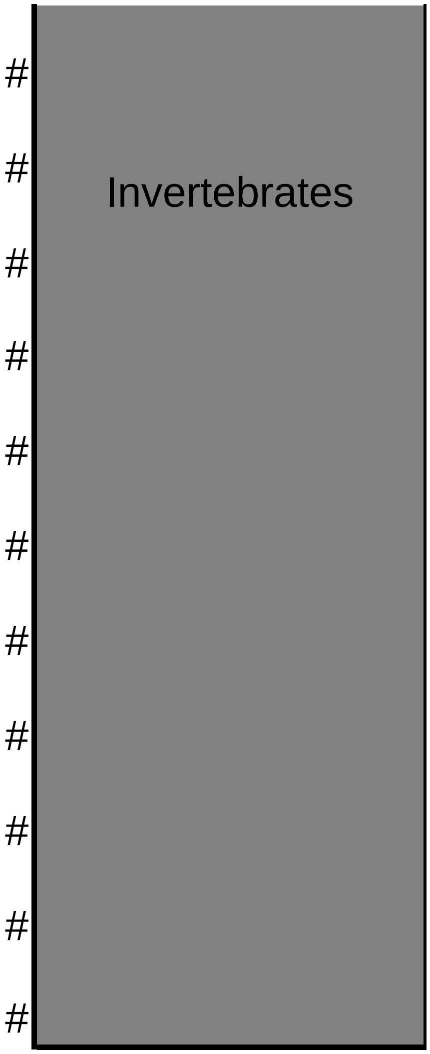
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	
#	



#
Reptile
#
Amphibians
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#




Mammals
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#


#
#
Invertebrates
#
#
#
#
#
#
#
#
#

Species/ Habitats

Species/ Habitats
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Open Coast Nearshore
Coastal Nearshore
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey

Green Sturgeon
White Sturgeon
Olympic Mudminnow
Pacific Herring
Eulachon
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Pygmy Whitefish
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod

Pacific Hake
Walleye Pollock
Black Rockfish
Bocaccio Rockfish
Brown Rockfish
Canary Rockfish
China Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Tiger Rockfish
Widow Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole

Rock Sole
Western Pond Turtle (formerly Pacific Pond Turtle)
Van Dyke's Salamander
Western Toad
Brown Pelican
Cassin's Auklet
Common Loon
Marbled Murrelet
Short-tailed Albatross
Tufted Puffin
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Harlequin Duck
Waterfowl Concentrations

Golden Eagle
Northern Goshawk
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Pileated Woodpecker
Oregon Vesper Sparrow
Dall's Porpoise
Blue Whale
Humpback Whale
Gray Whale
Sperm Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
Northern Sea Otter (formerly called Sea Otter)

California Sea Lion
Steller Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Olympic Marmot
Fisher
Marten
Columbian Black-tailed Deer
Mountain Goat
Elk
Pinto (Northern) Abalone
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster

Pacific Razor Clam (formerly Razor Clam)
Dungeness Crab
Pandalid shrimp (Pandalidae)
Beller's Ground Beetle
Johnson's Hairstreak
Makah Copper (formerly Queen Charlotte's Copper)
Puget Blue
Sand-verbena Moth
Valley Silverspot
Taylor's Checkerspot
Red Sea Urchin (formerly Red Urchin)

State Status

Candidate

Sensitive
Candidate
Candidate
Candidate *
Candidate
Candidate
Sensitive
Candidiate **
Candidiate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Endangered
Candidate
Candidate
Candidate
Sensitive
Threatened
Candidate
Endangered
Candidate

Candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Endangered
Endangered
Sensitive
Endangered
Endangered
Candidate
Threatened

Candidate
Candidate
Candidate
Endangered
Endangered
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Status

** Importa

These are the species and habit
This list of species and habitats
distribution maps found in the Pr
List (see http://wdfw.wa.gov/con
distribution maps depict countie
known to occur as well as other
associated with the species exis
when developing distribution ma

1) There is a high likelihood a sp
it has not been directly observec
primarily associated exists.
.
2) Over time, species can natura
move to new counties where usa

Distribution maps in the PHS Lis
information available. As new in
known distribution for some spec
WDFW will periodically review a
in PHS list.

Threatened
Threatened
Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern

Species of Concern
Endangered
Threatened
Threatened

Species of Concern

Threatened

Endangered

Threatened
Endangered
Endangered
Endangered
Endangered
Species of Concern

Species of Concern

Species of Concern

Endangered

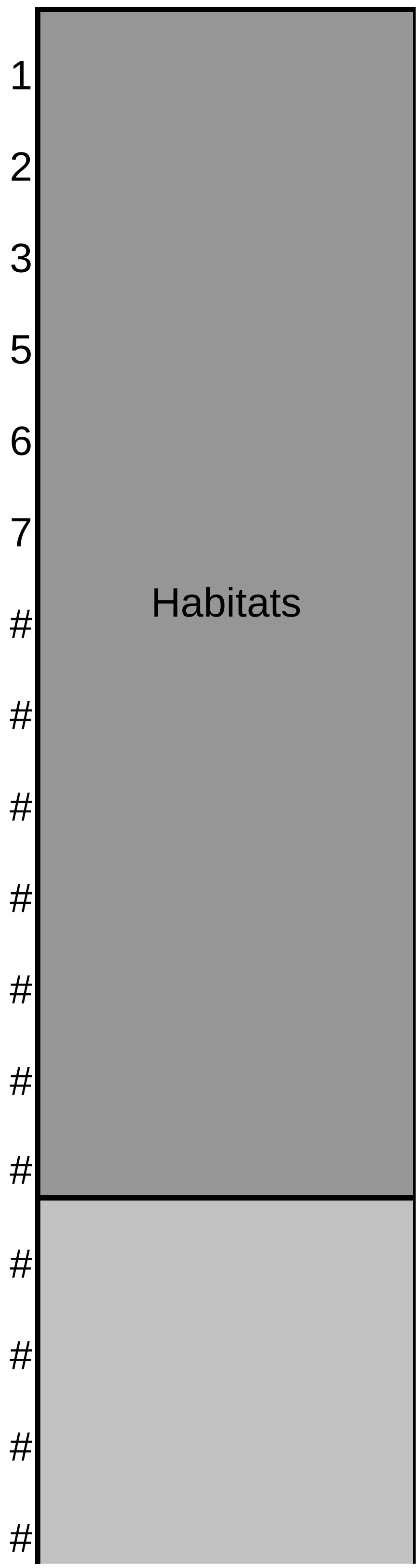
ınt Note **

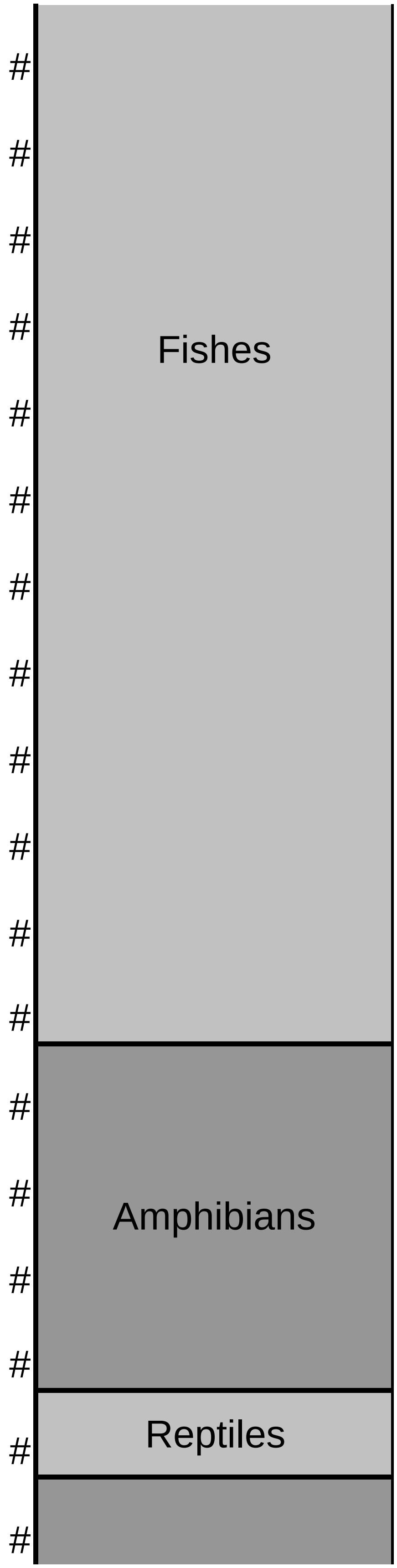
ıats identified for Clallam County. was developed using the ·iority Habitat and Species (PHS) servation/phs/). Species ; where each priority species is counties where habitat primarily ts. Two assumptions were made ps for each species:

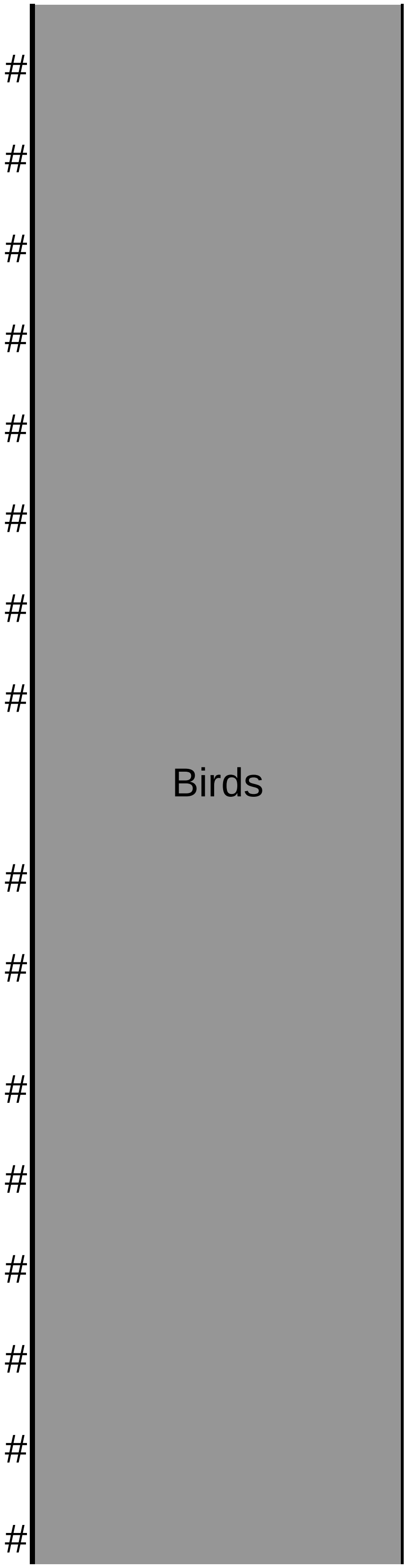
ɔecies is present in a county, even if l, if the habitat with which it is

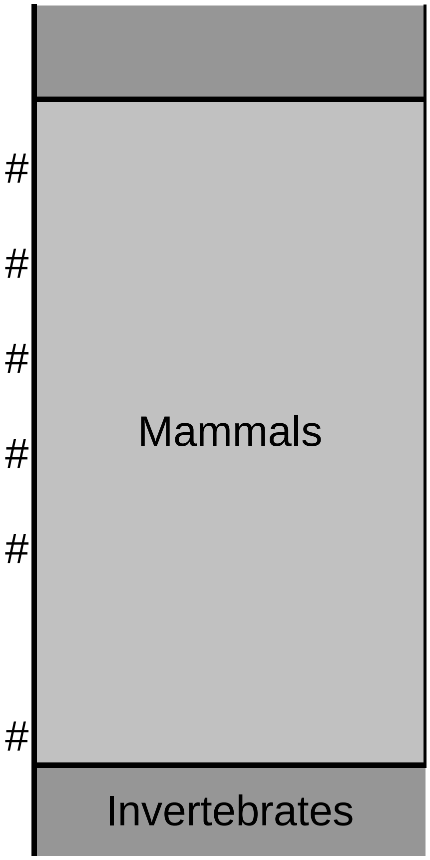
ılly change their distribution and ıble habitat exists.

;t were developed using the best ıformation becomes available, cies may expand or contract. nd update the the distribution maps


1
2
3
5
6
7
Habitats
#
#
#
#
#
#
#
#
#
#
#


#
#
#
#
Fishes
#
#
#
#
#
#
#
#
#
#
Amphibians
#
#
Reptiles
#
#


#
#
#
#
#
#
#
#
Birds
#
#
#
#
#
#
#
#


#
#
#
Mammals
#
#
#
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
Green Sturgeon
White Sturgeon

Leopard Dace
Mountain Sucker
Eulachon
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Cascade Torrent Salamander
Larch Mountain Salamander
Oregon Spotted Frog
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Western grebe

Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
Sandhill Crane
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Pileated Woodpecker
Slender-billed White-breasted Nuthatch

Oregon Vesper Sparrow
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
Fisher
Marten
Columbian Black-tailed Deer
Columbian White-tailed Deer
Elk
California Floater

State Status

Candidate

Candidate
Candidate
Candidate
Candidate *
Candidate
Candidate
Candidate **
Candidate
Candidate
Sensitive
Endangered
Candidate
Endangered
Candidate

Candidate
Candidate
Endangered
Endangered
Candidate
Candidate
Candidate

Candidate
Candidate
Endangered
Endangered
Candidates

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit of species and habitats was dev found in the Priority Habitat and http://wdfw.wa.gov/conservation/ counties where each priority spe counties where habitat primarily Two assumptions were made wh each species: 1) There is a high likelihood a sp has not been directly observed, associated exists. . 2) Over time, species can natura to new counties where usable ha Distribution maps in the PHS Lis information available. As new in distribution for some species ma periodically review and update th
Threatened	

Threatened
Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Threatened

Threatened
Species of Concern

Species of Concern
Endangered

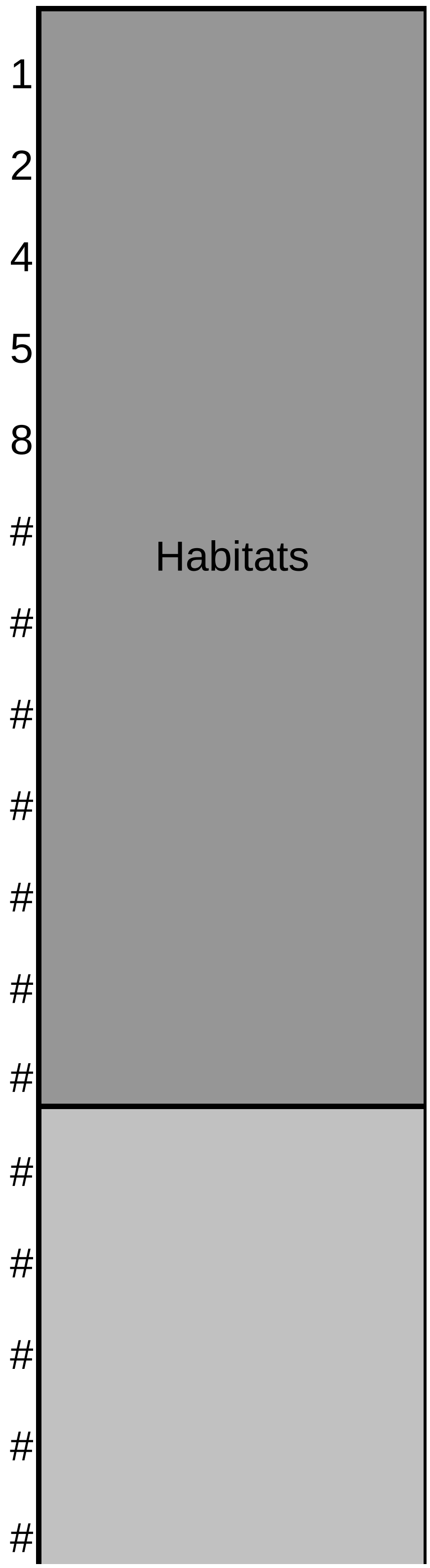
ınt Note **

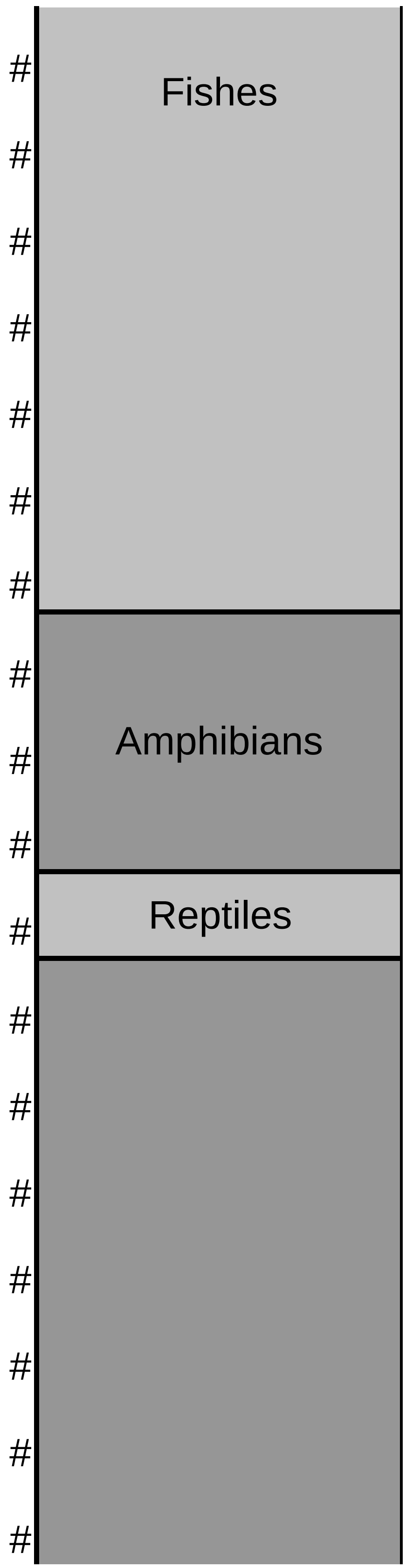
ːats identified for Clark County. This list
eloped using the distribution maps
Species (PHS) List (see
/phs/). Species distribution maps depict
ːcies is known to occur as well as other
associated with the species exists.
ıen developing distribution maps for

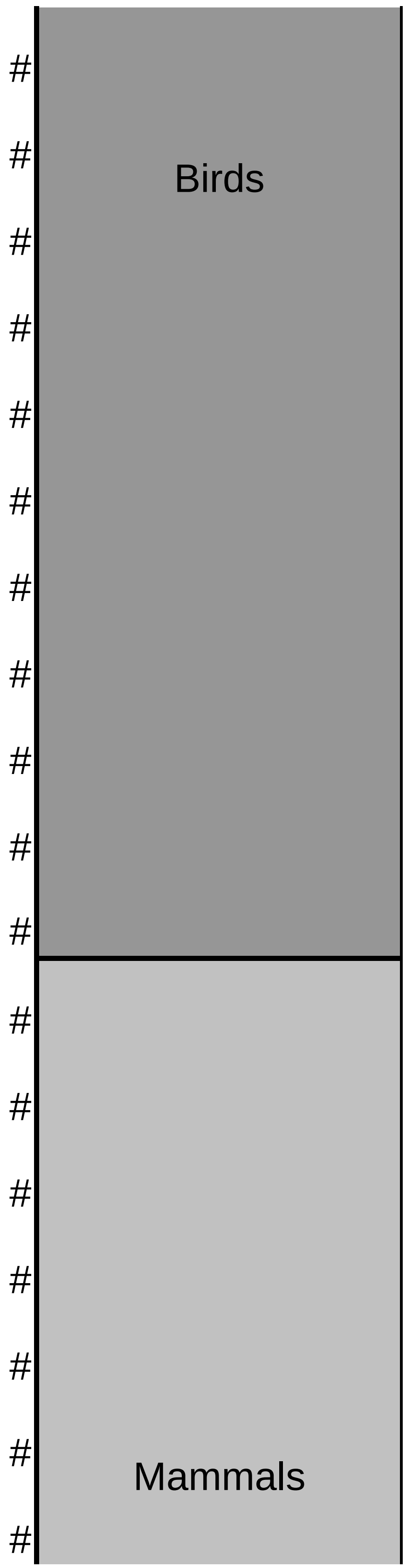
ɔecies is present in a county, even if it
if the habitat with which it is primarily

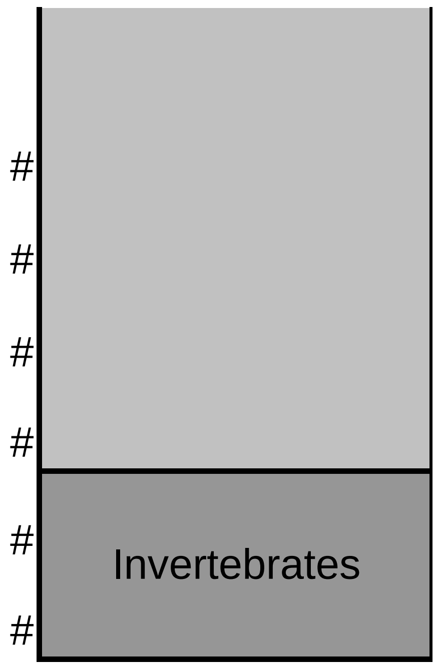
ılly change their distribution and move
ɑbitat exists.

ːt were developed using the best
ıformation becomes available, known
ıy expand or contract. WDFW will
ıe the distribution maps in PHS list.


1
2
4
5
8
#
#
#
#
#
#
#
#
#
#
#
#
Habitats


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes
Amphibians
Reptiles


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Birds
Mammals


#
#
#
#
#
#
Invertebrates

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Juniper Savannah
Old-Growth/Mature Forest
Eastside Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Leopard Dace
Mountain Sucker

Bull Trout/ Dolly Varden
Chinook Salmon
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Margined Sculpin
Columbia Spotted Frog
Rocky Mountain Tailed Frog
Western Toad
Sagebrush Lizard
Great Blue Heron
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Northern Goshawk
Prairie Falcon
Chukar

Dusky Grouse
Mountain Quail
Ring-necked Pheasant
Wild Turkey
Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Flammulated Owl
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Washington Ground Squirrel
Gray Wolf
Marten

Wolverine
Bighorn Sheep
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Mann's mollusk-eating Ground Beetle
Juniper Hairstreak

State Status

Candidate
Candidate
Candidate

Candidate *
Candidate
Candidiate **
Candidiate
Sensitive
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Candidate

Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered

Candidate

Candidate

Candidate

* Bull Trout only
** Steelhead only
*** Federally listed west of north-south line follo

Federal Status

** Importa

These are the species and habit County. This list of species and distribution maps found in the Pr List (see http://wdfw.wa.gov/con: distribution maps depict counties known to occur as well as other associated with the species exis when developing distribution ma

1) There is a high likelihood a sp if it has not been directly observe primarily associated exists.
2) Over time, species can natura move to new counties where usa

Distribution maps in the PHS Lis information available. As new in known distribution for some spec WDFW will periodically review a maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Candidate
Endangered ***

Candidate

wing Highways 97, 17, and 395.

ant Note **

ats identified for Columbia
habitats was developed using the
iority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

ecies is present in a county, even
ed, if the habitat with which it is
.
lly change their distribution and
able habitat exists.

t were developed using the best
formation becomes available,
cies may expand or contract.
nd update the the distribution

Species/ Habitats

1	Habitats	Aspen Stands
2		Biodiversity Areas & Corridors
3		Herbaceous Balds
5		Old-Growth/Mature Forest
6		Oregon White Oak Woodlands
7		West Side Prairie
#		Riparian
#		Freshwater Wetlands & Fresh Deepwater
#		Instream
#		Caves
#		Cliffs
#		Snags and Logs

#		Talus
#	Fishes	Pacific Lamprey
#		River Lamprey
#		Green Sturgeon
#		White Sturgeon
#		Leopard Dace
#		Mountain Sucker
#		Eulachon
#		Bull Trout/ Dolly Varden
#		Chinook Salmon
#		Chum Salmon
#		Coastal Res./ Searun Cutthroat
#		Coho Salmon

#		Kokanee
#		Pink Salmon
#		Rainbow Trout/ Steelhead/ Inland Redband Trout
#		Sockeye Salmon
#	Amphibians	Cascade Torrent Salamander
#		Dunn's Salamander
#		Larch Mountain Salamander
#		Van Dyke's Salamander
#		Western Toad
#	Reptiles	Western Pond Turtle (formerly Pacific Pond Turtle)
#		Western grebe
		Marbled Murrelet
#		Great Blue Heron

#	Birds	Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
#		Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
#		Harlequin Duck
#		Trumpeter Swan
#		Tundra Swan
#		Waterfowl Concentrations
#		Golden Eagle
#		Northern Goshawk
#		Sooty Grouse
#		Wild Turkey
#		Sandhill Crane
#		W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae

#		Band-tailed Pigeon
#		Northern Spotted Owl (formerly called Spotted Owl)
#		Vaux’s Swift
#		Pileated Woodpecker
#		Oregon Vesper Sparrow
		Streaked Horned Lark
		Slender-billed White-breasted Nuthatch
#	Mammals	Harbor Seal
#		Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
#		Townsend’s Big-eared Bat
#		Fisher
#		Marten
#		Columbian Black-tailed Deer

#		Columbian White-tailed Deer
#		Elk
#	Invertebrates	Blue-gray Taildropper
#		Valley Silverspot

State Status

Federal Status

These a
This list
distribut
List (see
distribut
known t
associa
when de

1) There
even if i
it is prim
2) Over
move to

Distribu
informat
known c
WDFW
maps in

Candidate	
	Threatened
Candidate	
Candidate	
Candidate	Threatened
Candidate *	Threatened *
Candidate	Threatened (Upper Columbia Spring run is Endangered)
Candidate	Threatened
	Species of Concern
	Threatened – Lower Columbia Species of Concern – Puget Sound

Candidiate **	Threatened **
Candidate	Threatened – Ozette Lake Endangered – Snake River
Candidate	
Candidate	
Sensitive	
Candidate	
Candidate	
Endangered	
Candidate	
Threatened	Threatened

Candidate
Candidate
Endangered

Endangered	Threatened
Candidate	
Candidate	
Candidate	
Endangered	Threatened
Candidate	
Candidate	
Endangered	Species of Concern

Endangered	Endangered
Candidate	
Candidate	

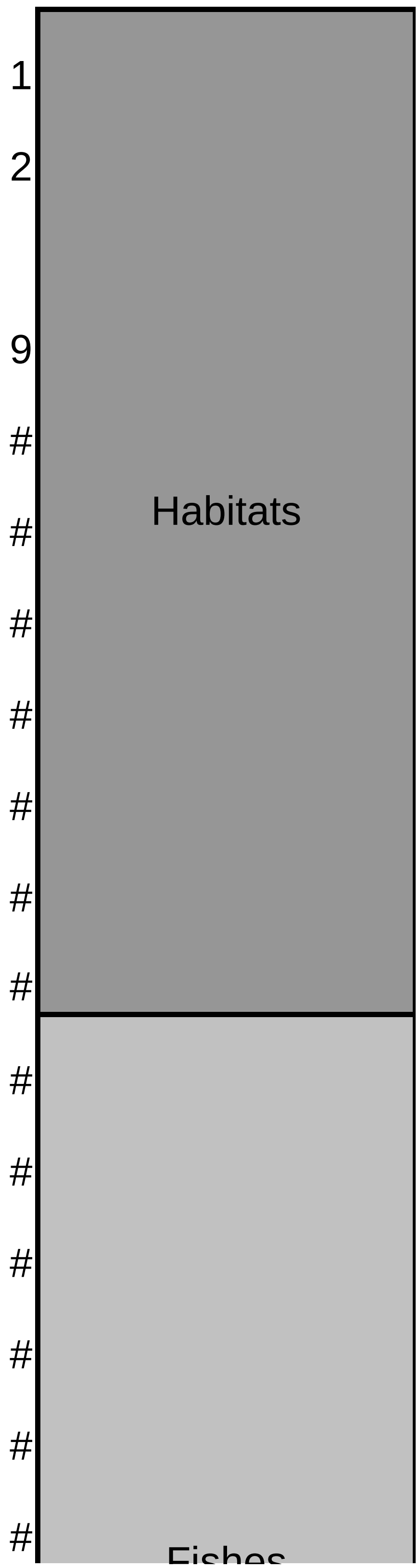
* Bull Trout only
** Steelhead only

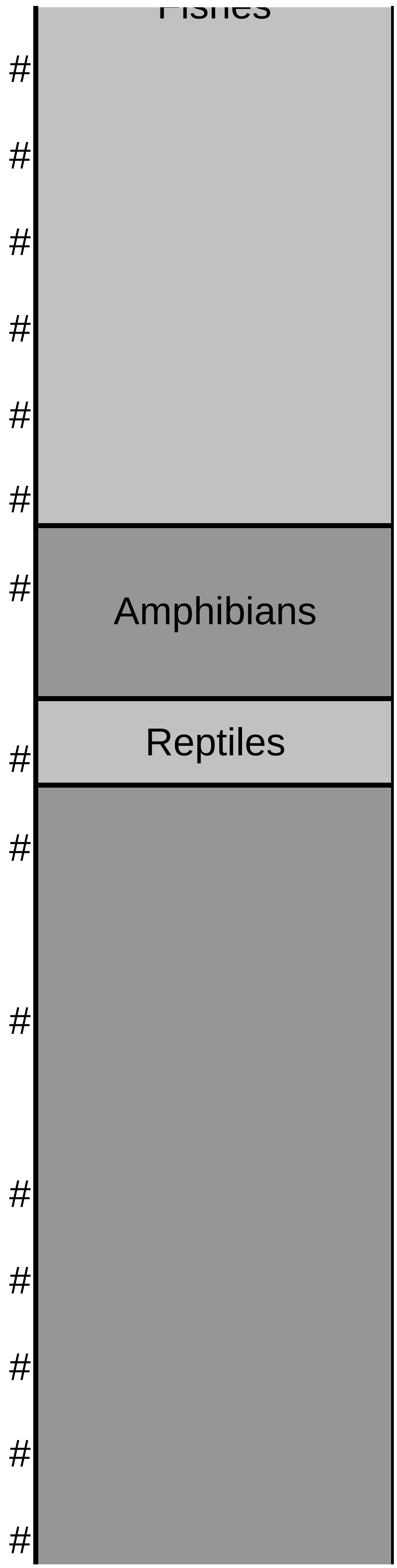
** Important Note **

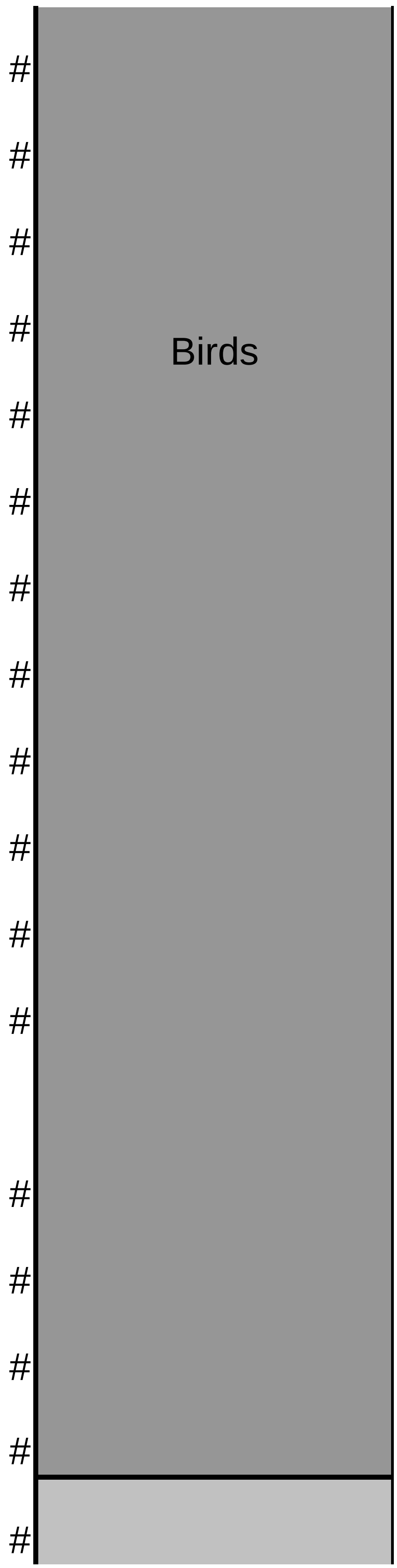
ıre the species and habitats identified for Cowlitz County.
of species and habitats was developed using the
:ion maps found in the Priority Habitat and Species (PHS)
e http://wdfw.wa.gov/conservation/phs/). Species
:ion maps depict counties where each priority species is
o occur as well as other counties where habitat primarily
ted with the species exists. Two assumptions were made
eveloping distribution maps for each species:

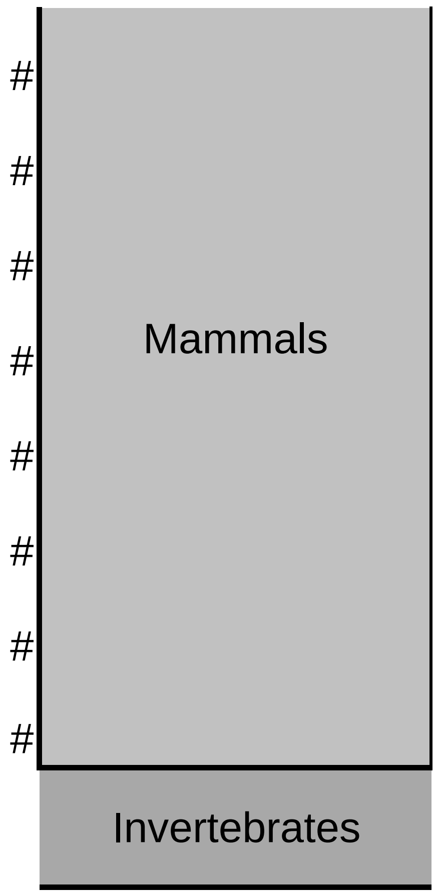
e is a high likelihood a species is present in a county,
t has not been directly observed, if the habitat with which
ıarily associated exists. .
time, species can naturally change their distribution and
new counties where usable habitat exists.

tion maps in the PHS List were developed using the best
tion available. As new information becomes available,
distribution for some species may expand or contract.
will periodically review and update the the distribution
PHS list.


1
2
9
#
#
#
#
#
#
#
#
#
#
#
#
#
Habitats
Fishes


Amphibians
Reptiles


#
#
#
#
Birds
#
#
#
#
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
#
#
Mammals
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
White Sturgeon
Leopard Dace
Umatilla Dace
Mountain Sucker
Bull Trout/ Dolly Varden

Chinook Salmon
Coho Salmon
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Western Toad
Sagebrush Lizard
American White Pelican
Clark's Grebe
Western grebe
Common Loon
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser

Tundra Swan
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Prairie Falcon
Chukar
Dusky Grouse
Ring-necked Pheasant
Greater Sage-grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Vaux's Swift
Pileated Woodpecker
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat

Townsend’s Big-eared Bat
Black-tailed Jackrabbit
Pygmy Rabbit
White-tailed Jackrabbit
Washington Ground Squirrel
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater

State Status

Candidate
Candidate
Candidate
Candidate *

Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Endangered
Candidate
Candidate
Sensitive

Threatened
Candidate
Threatened
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Endangered
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit This list of species and habitats maps found in the Priority Habita http://wdfw.wa.gov/conservation/ depict counties where each prior as other counties where habitat exists. Two assumptions were r maps for each species: 1) There is a high likelihood a sp it has not been directly observed primarily associated exists. . 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in distribution for some species ma periodically review and update th
Threatened *	

Threatened (Upper Columbia Spring run is Endangered)
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Species of Concern

Endangered
Candidate

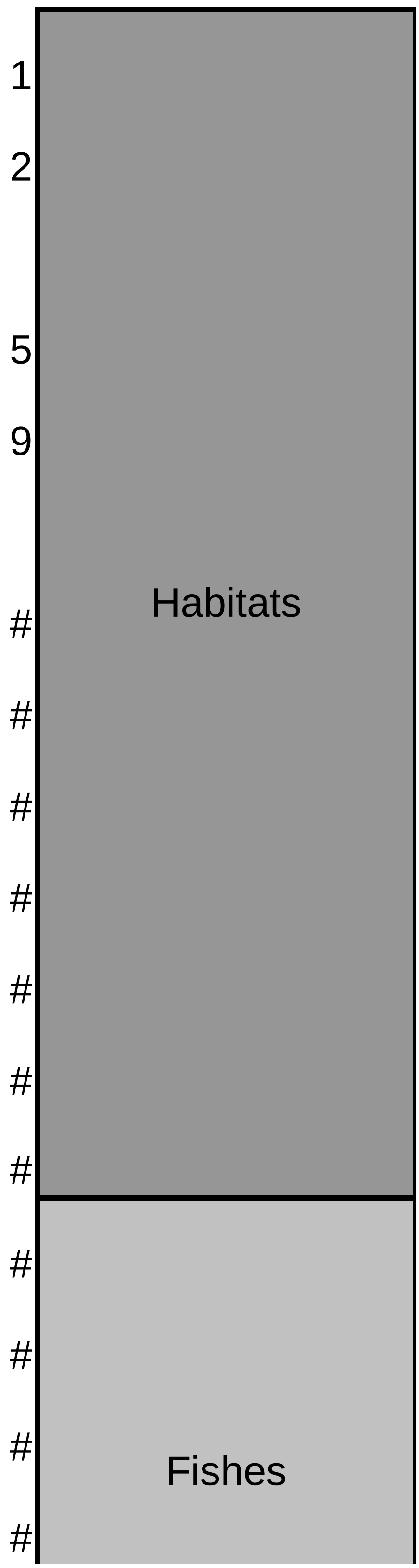
ınt Note **

ıats identified for Douglas County.
was developed using the distribution
ıt and Species (PHS) List (see
/phs/). Species distribution maps
ity species is known to occur as well
primarily associated with the species
nade when developing distribution

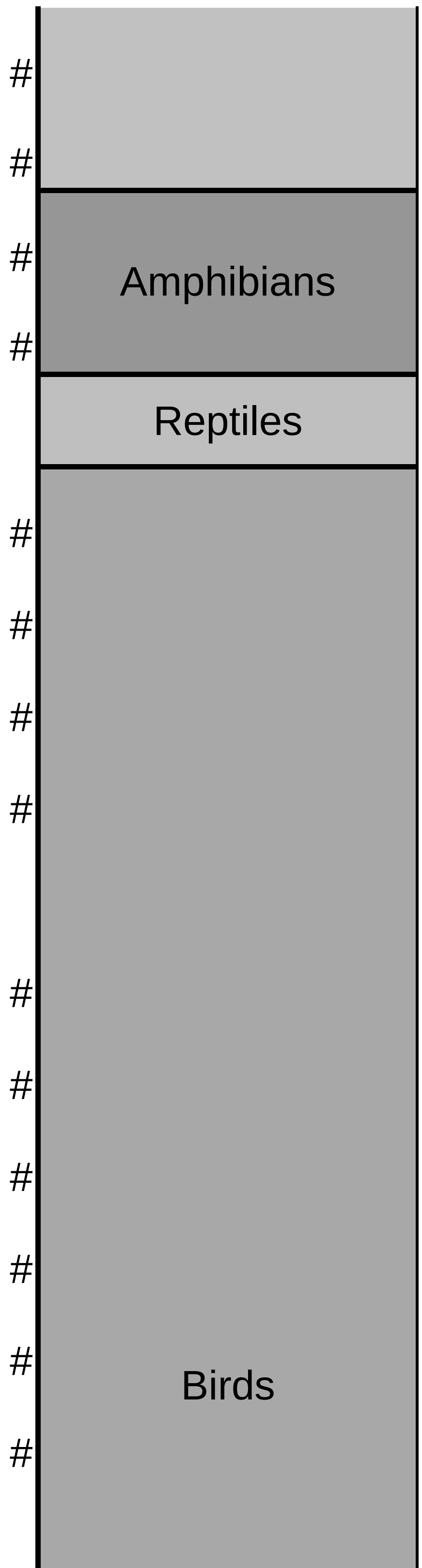
ecies is present in a county, even if
l, if the habitat with which it is

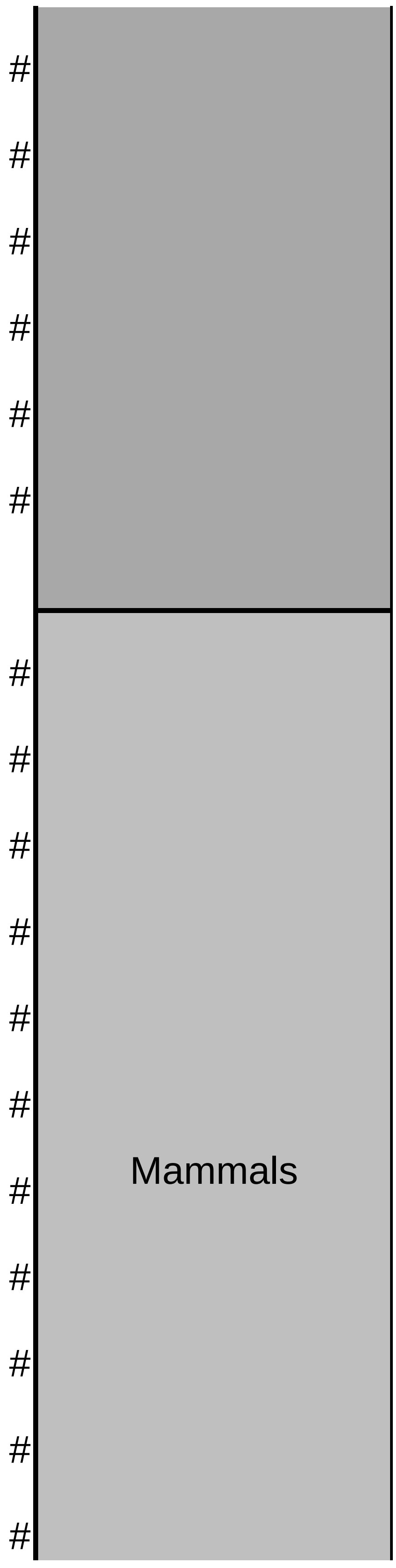
ılly change their distribution and
ıble habitat exists.

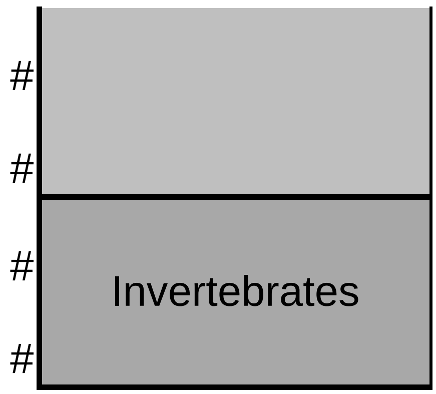
ıt were developed using the best
ıformation becomes available, known
ıy expand or contract. WDFW will
ıe the distribution maps in PHS list.



1
2
5
9
#
#
#
#
#
#
#
#
#
#
#
Habitats
Fishes


#
#
#
Amphibians
#
Reptiles
#
#
#
#
#
#
#
#
#
Birds
#
#


#
#
#
#
#
#
#
#
#
#
#
#
Mammals
#
#
#
#
#



#
#
#
Invertebrates
#

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Old-Growth/Mature Forest
Shrub-Steppe
Eastide Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
White Sturgeon
Umatilla Dace
Bull Trout/ Dolly Varden
Kokanee

Rainbow Trout/ Steelhead/ Inland Redband Trout
Westslope Cutthroat
Columbia Spotted Frog
Western Toad
Sagebrush Lizard
Common Loon
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Harlequin Duck
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Dusky Grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
E WA breeding occurrences of: Phalaropes, Stilts and Avocets

Burrowing Owl
Flammulated Owl
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Loggerhead Shrike
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
White-tailed Jackrabbit
Gray Wolf
Grizzly Bear
Lynx
Marten
Wolverine
Bighorn Sheep
Moose
Northwest White-tailed Deer

Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater
Silver-bordered Fritillary

State Status

Candidate
Candidate *

Candidiate **
Candidate
Candidate
Candidate
Sensitive
Candidate
Candidate
Candidate
Endangered

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered
Endangered
Threatened
Candidate

Candidate
Candidate

* Bull Trout only
** Steelhead only
*** Federally listed west of north-south line follc

Federal Status	** Importa
	These are the species and habit This list of species and habitats distribution maps found in the Pr (PHS) List (see http://wdfw.wa.g distribution maps depict countie known to occur as well as other associated with the species exis made when developing distributi 1) There is a high likelihood a sp even if it has not been directly ol it is primarily associated exists. 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.
Threatened *	

Threatened **

Endangered ***
Threatened
Threatened
Candidate

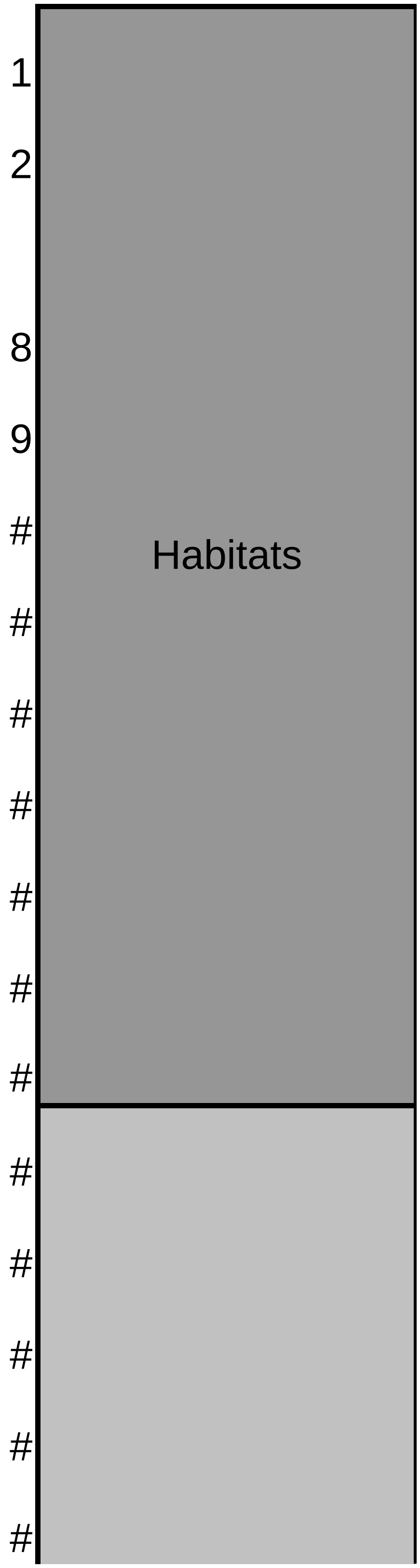
owing Highways 97, 17, and 395.

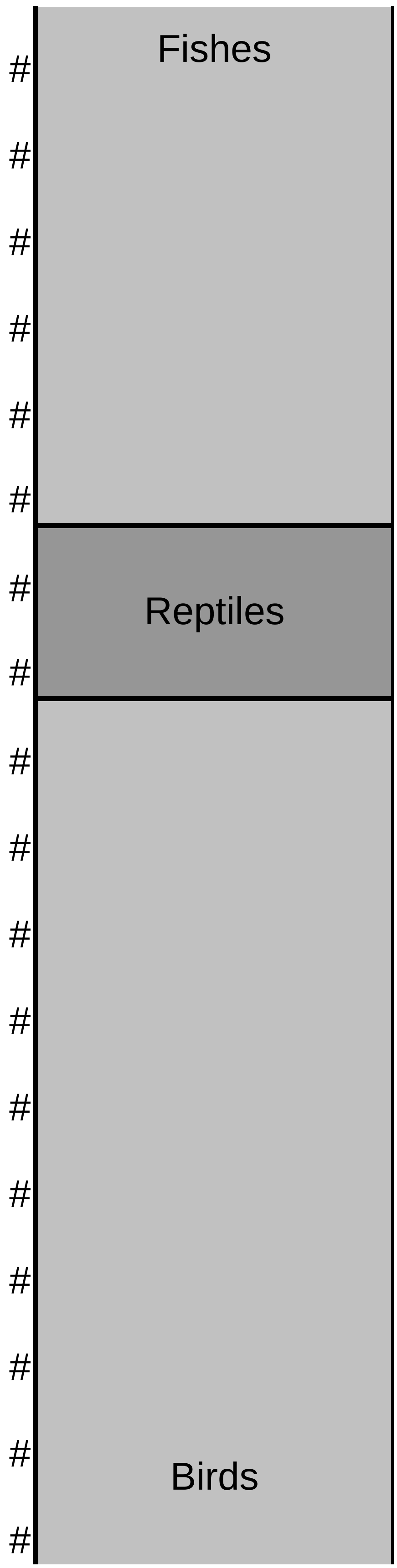
ınt Note **

ıats identified for Ferry County.
was developed using the
'iority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were
on maps for each species:

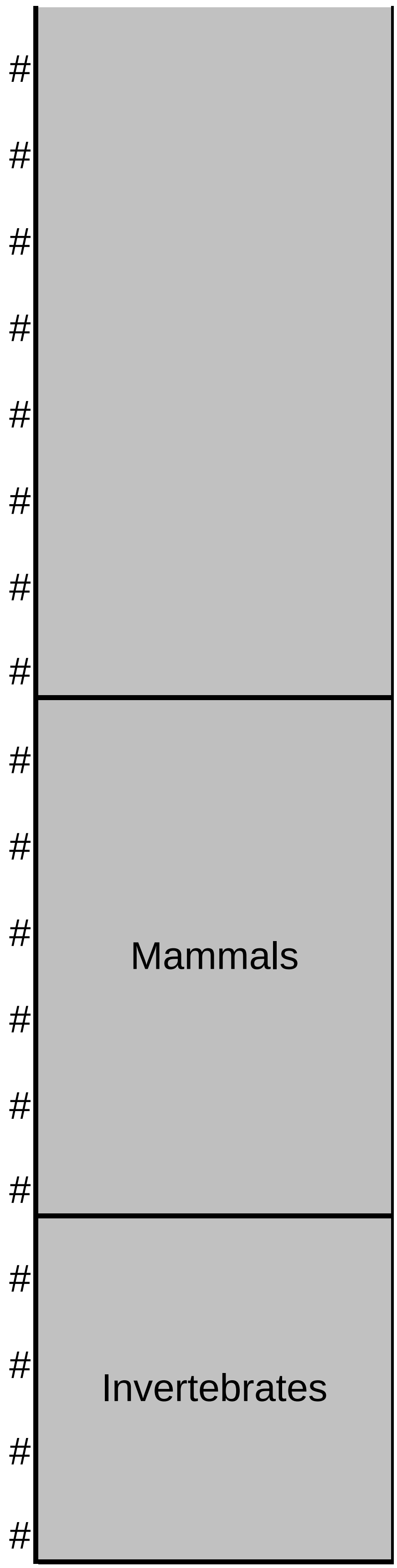
ɔecies is present in a county,
ɔserved, if the habitat with which
.
ılly change their distribution and
ıble habitat exists.

ɜt were developed using the best
ıformation becomes available,
cies may expand or contract.
nd update the the distribution


1
2
8
9
#
Habitats
#
#
#
#
#
#
#
#
#
#
#



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes
Reptiles
Birds



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Mammals
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Eastside Steppe
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Leopard Dace
Mountain Sucker

Bull Trout/ Dolly Varden
Chinook Salmon
Coho Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Striped Whipsnake
Sagebrush Lizard
American White Pelican
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Tundra Swan
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle

Prairie Falcon
Ring-necked Pheasant
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Yellow-billed Cuckoo
Burrowing Owl
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Washington Ground Squirrel
Mule Deer (formerly called Rocky Mountain Mule Deer)
Shortface Lanx (formerly Giant Columbia River Limpet)
Columbia Pebblesnail
Columbia River Tiger Beetle
Juniper Hairstreak

State Status

Candidate
Candidate
Candidate

Candidate *
Candidate
Candidiate **
Candidate
Candidate
Candidate
Endangered
Candidate
Threatened
Candidate

Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict counties known to occur as well as other primarily associated with the spe were made when developing dis species: 1) There is a high likelihood a sp even if it has not been directly ol which it is primarily associated e . 2) Over time, species can natura and move to new counties where Distribution maps in the PHS Lis best information available. As n available, known distribution for contract. WDFW will periodically distribution maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Threatened

Candidate

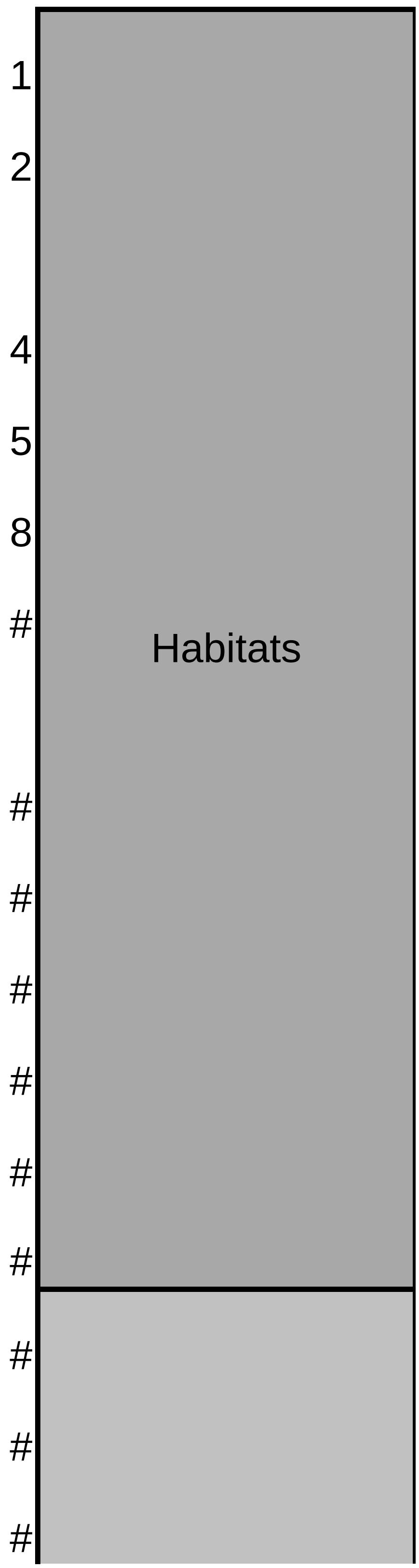
nt Note **

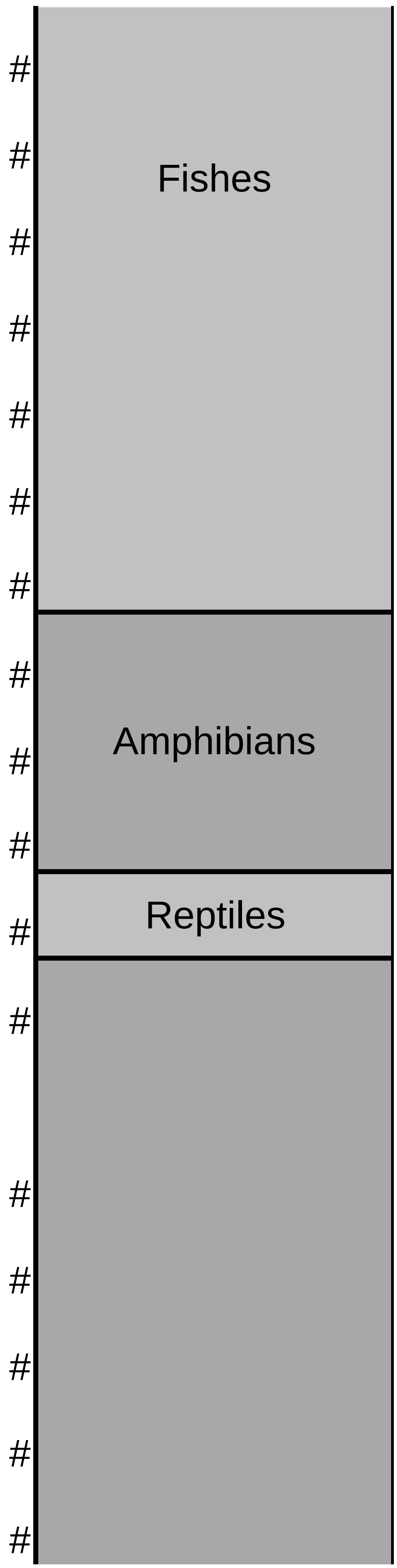
ats identified for Franklin
habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat
ecies exists. Two assumptions
tribution maps for each

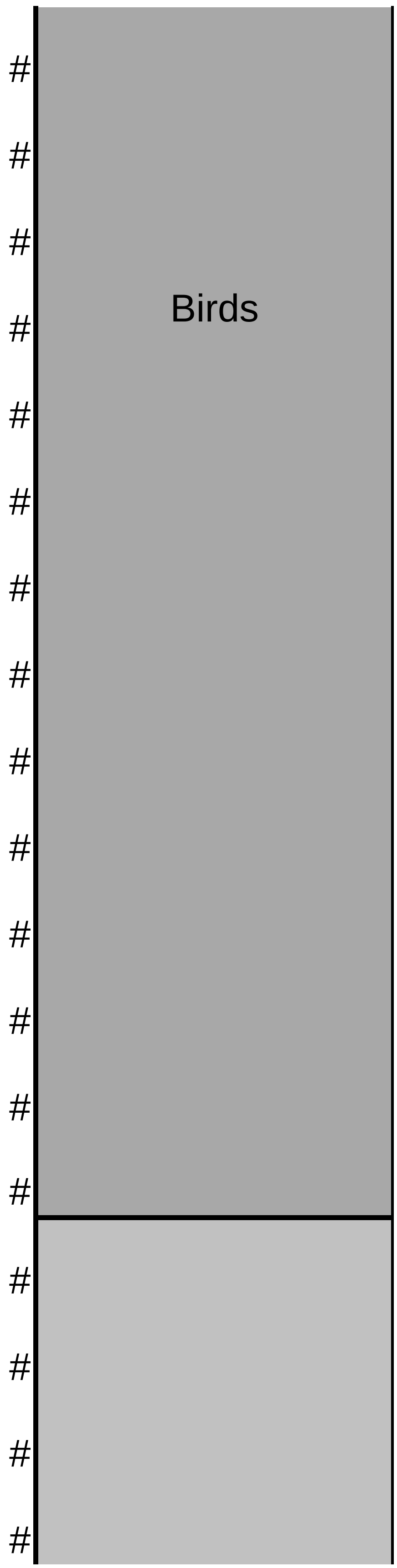
pecies is present in a county,
oserved, if the habitat with
xists.

ally change their distribution
e usable habitat exists.

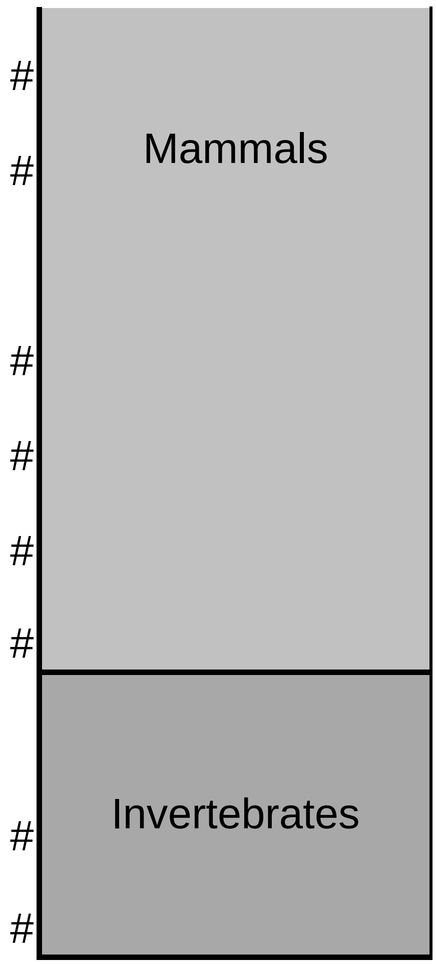
st were developed using the
ew information becomes
some species may expand or
r review and update the the


1
2
4
5
8
#
Habitats
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes
Amphibians
Reptiles



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Birds



#
Mammals
#
#
#
#
#
Invertebrates
#
#

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Juniper Savannah
Old-Growth/Mature Forest
Eastside Steppe
Riparian
Shrub-Steppe
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon

Leopard Dace
Mountain Sucker
Bull Trout/ Dolly Varden
Chinook Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Rocky Mountain Tailed Frog
Western Toad
Sagebrush Lizard
Great Blue Heron
Clark's Grebe
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Northern Goshawk
Prairie Falcon

Chukar
Dusky Grouse
Mountain Quail
Ring-necked Pheasant
Wild Turkey
Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Flammulated Owl
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit

Gray Wolf
Marten
Wolverine
Bighorn Sheep
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater
Juniper Hairstreak
Shepard's Parnassian

State Status

Candidate

Candidate
Candidate
Candidate *
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Candidate

Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Endangered
Candidate
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only
*** Federally listed west of north-south line follo

Federal Status

** Important

These are the species and habit
County. This list of species and
the distribution maps found in th
(PHS) List (see http://wdfw.wa.g
distribution maps depict countie
known to occur as well as other
associated with the species exis
made when developing distributi

1) There is a high likelihood a sp
even if it has not been directly o
it is primarily associated exists.
.
2) Over time, species can natura
move to new counties where us

Distribution maps in the PHS Lis
information available. As new in
known distribution for some spe
WDFW will periodically review a
maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Endangered ***
Candidate

owing Highways 97, 17, and 395.

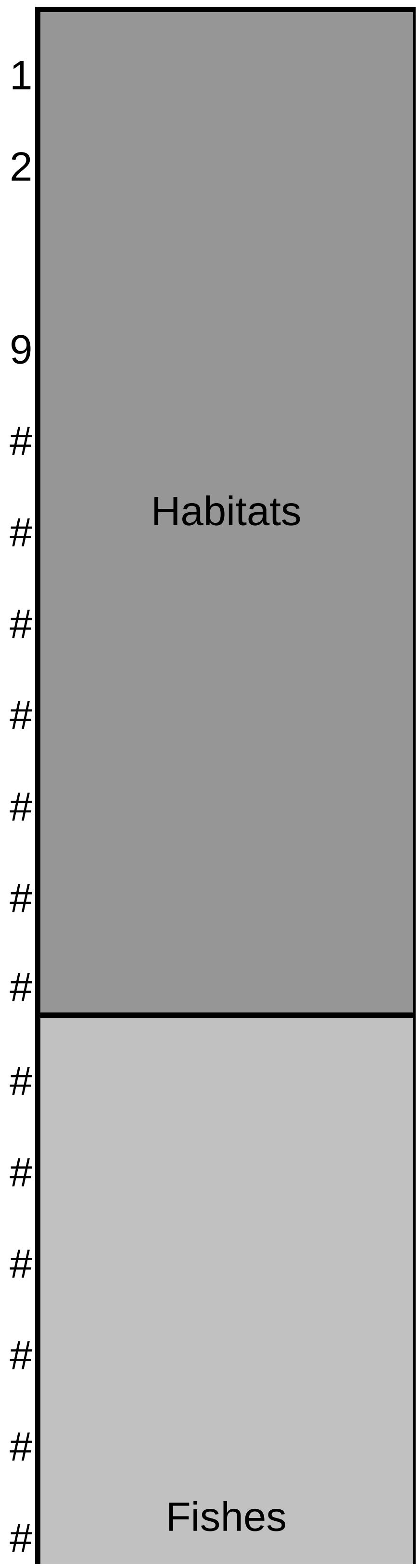
: Note **

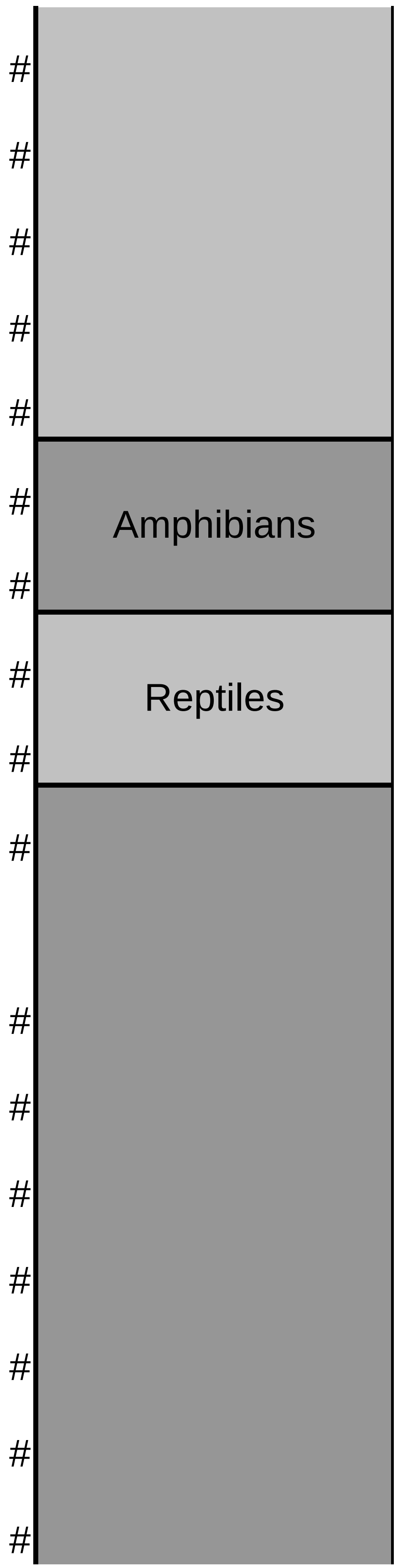
ats identified for Garfield
habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were
on maps for each species:

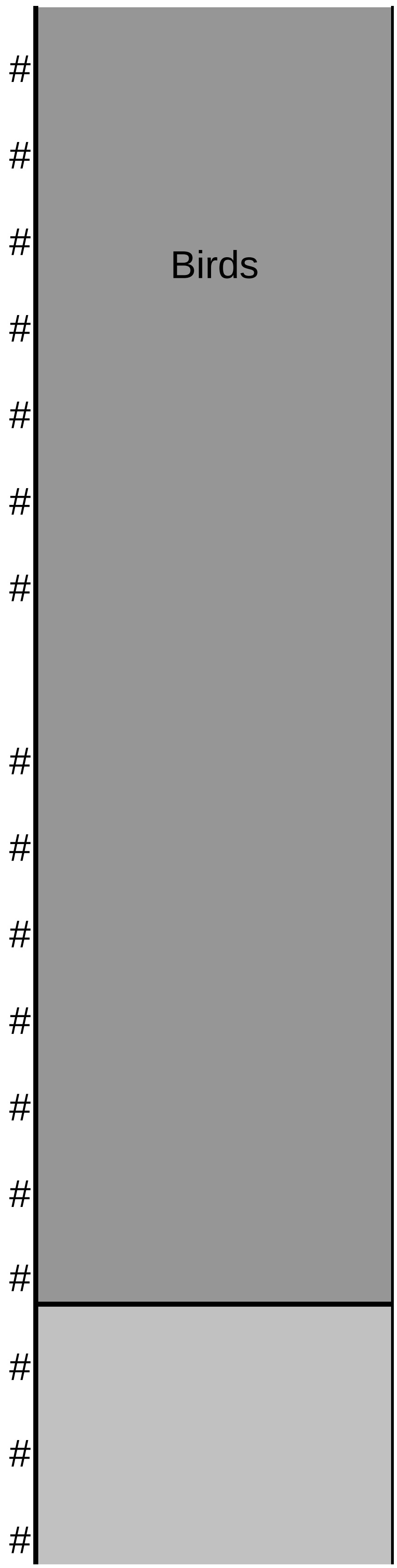
pecies is present in a county,
bserved, if the habitat with which

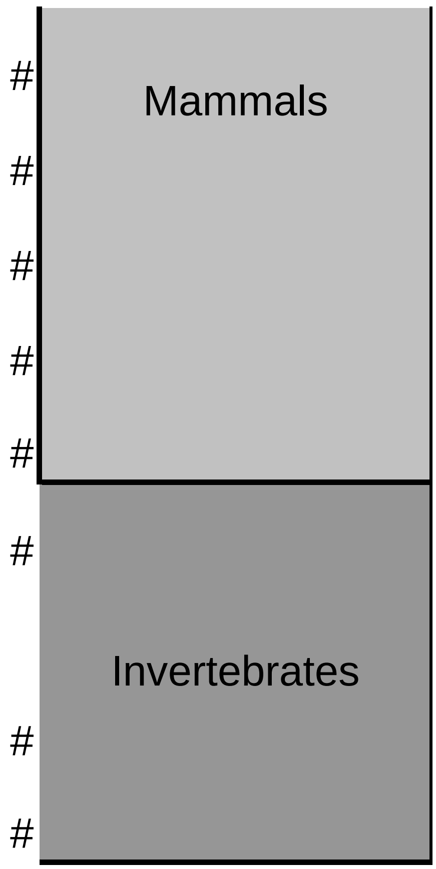
ally change their distribution and
able habitat exists.

st were developed using the best
nformation becomes available,
cies may expand or contract.
nd update the the distribution


1
2
9
#
Habitats
#
#
#
#
#
#
#
#
#
#
#
Fishes
#


Amphibians
Reptiles


#
#
#
Birds
#
#
#
#
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
#
#
Mammals
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
White Sturgeon
Leopard Dace
Mountain Sucker
Bull Trout/ Dolly Varden
Chinook Salmon

Coho Salmon
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Northern Leopard Frog
Striped Whipsnake
Sagebrush Lizard
American White Pelican
Clark's Grebe
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Tundra Swan

Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Prairie Falcon
Chukar
Ring-necked Pheasant
Greater Sage-grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
Sandhill Crane
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Yellow-billed Cuckoo
Burrowing Owl
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit

Pygmy Rabbit
White-tailed Jackrabbit
Washington Ground Squirrel
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Silver-bordered Fritillary
Yuma Skipper
California Floater
Columbia Clubtail

State Status

Candidiate
Candidiate
Candidate *
Candidate

Candidiate **
Candidate
Candidate
Endangered
Candidate
Candidate
Endangered
Candidate
Candidate

Threatened
Candidate
Threatened
Endangered
Endangered
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit This list of species and habitats distribution maps found in the Pr List (see http://wdfw.wa.gov/con distribution maps depict countie known to occur as well as other associated with the species exis when developing distribution ma 1) There is a high likelihood a sp it has not been directly observed primarily associated exists. . 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a in PHS list.
Threatened *	
Threatened (Upper Columbia Spring run is Endangered)	

Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Species of Concern

Threatened

Endangered
Candidate

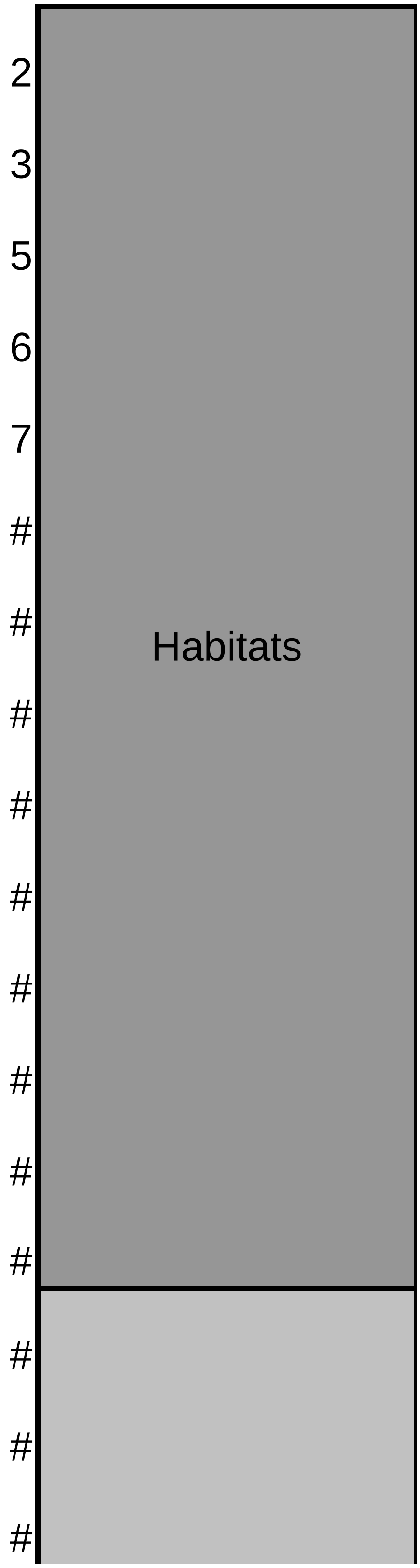
ınt Note **

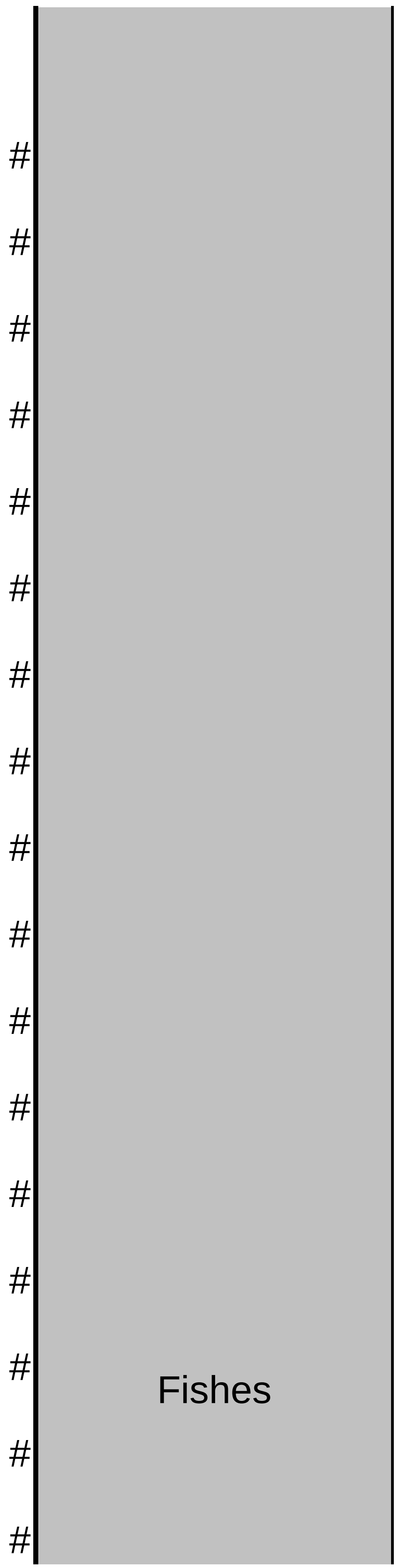
ıats identified for Grant County.
was developed using the
riority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

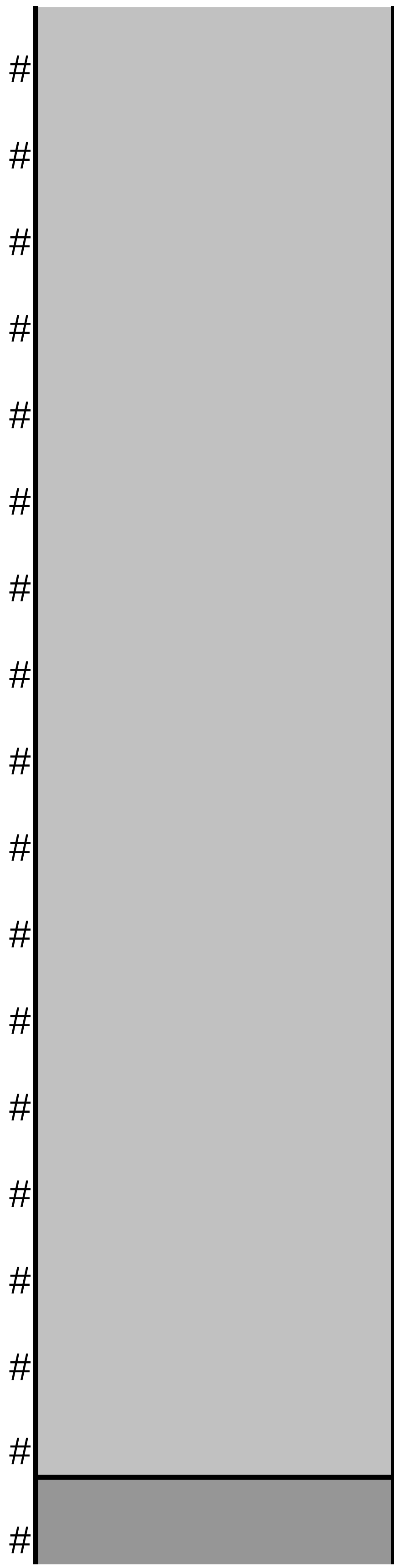
ɔecies is present in a county, even if
l, if the habitat with which it is

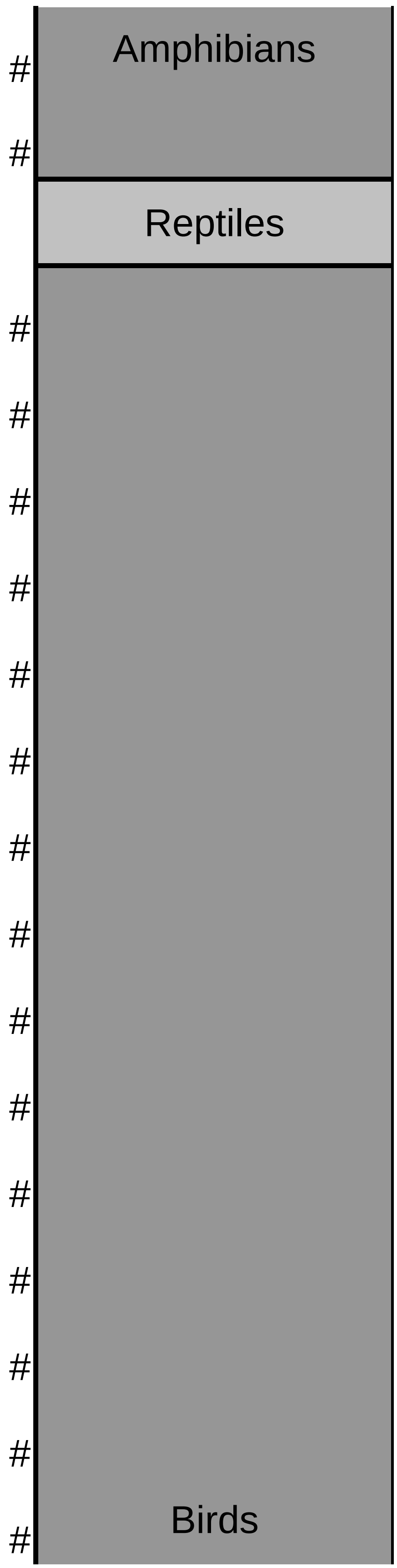
ılly change their distribution and
ıble habitat exists.

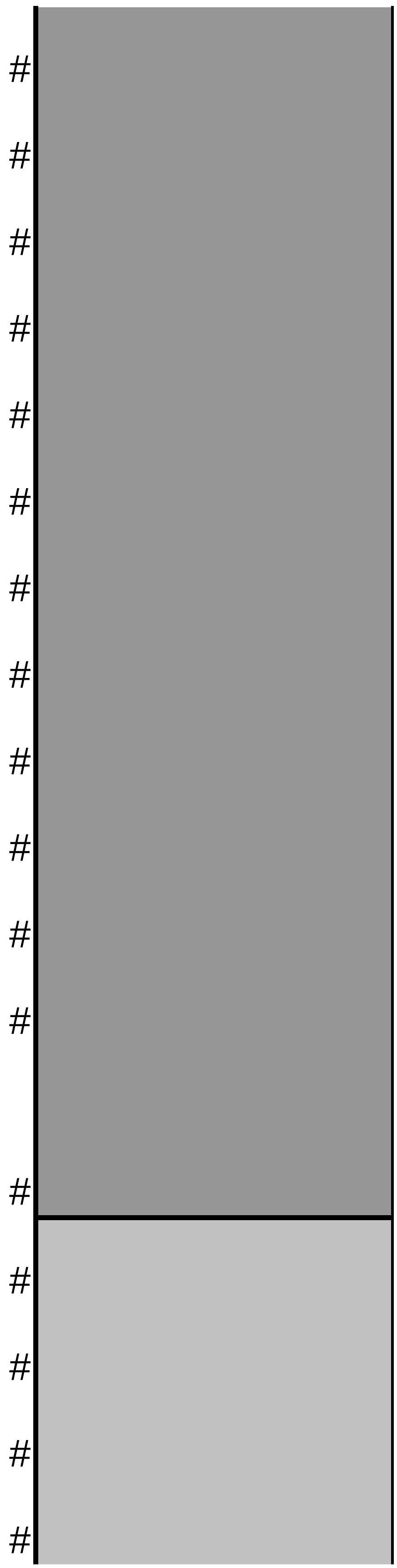
ɜt were developed using the best
ıformation becomes available,
cies may expand or contract.
nd update the the distribution maps

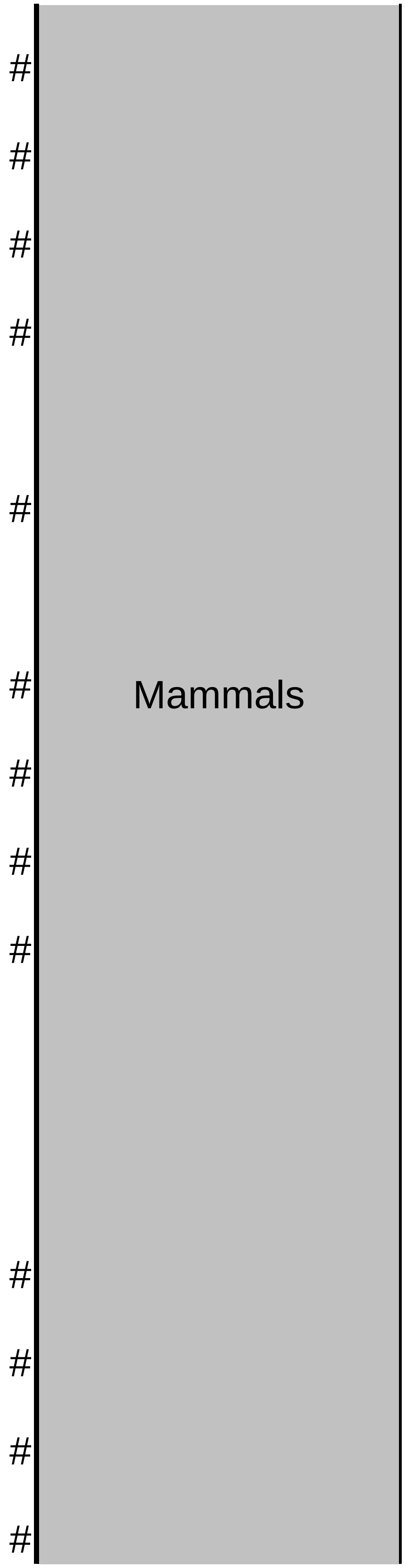

2
3
5
6
7
#
#
Habitats
#
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes




Amphibians
Reptiles
Birds
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#





#
#
#
#
#
#
#
#
#
#
#
#
#
Mammals

#
#
#
#
#
#
#
#
#
#
#
#
#
#

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Open Coast Nearshore
Coastal Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
Green Sturgeon

White Sturgeon
Olympic Mudminnow
Pacific Herring
Eulachon
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock

Black Rockfish
Bocaccio Rockfish
Brown Rockfish
Canary Rockfish
China Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Tiger Rockfish
Widow Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Dunn's Salamander

Van Dyke's Salamander
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Brown Pelican
Common Loon
Marbled Murrelet
Short-tailed Albatross
Tufted Puffin
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Trumpeter Swan
Waterfowl Concentrations

Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
Wild Turkey
Western Snowy Plover (formerly called Snowy Plover)
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Yellow-billed Cuckoo
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Pileated Woodpecker
Oregon Vesper Sparrow
Streaked Horned Lark
Dall's Porpoise
Blue Whale
Humpback Whale
Gray Whale

Sperm Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
California Sea Lion
Northern Sea Otter (formerly called Sea Otter)
Steller Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Olympic Marmot
Western Gray Squirrel
Mazama (Western) Pocket Gopher
Fisher
Marten
Columbian Black-tailed Deer

Mountain Goat
Elk
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Pacific Razor Clam (formerly Razor Clam)
Dungeness Crab
Pandalid shrimp (Pandalidae)
Johnson's Hairstreak
Mardon Skipper
Makah Copper (formerly Queen Charlotte's Copper)
Puget Blue
Red Sea Urchin (formerly Red Urchin)

State Status

Candidiate

Candidiate
Candidiate
Candidate
Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Endangered
Sensitive
Threatened
Candidate
Endangered
Candidate

Candidate
Candiate
Endangered
Endangered
Endangered
Candiate
Candiate
Candidate
Endangered
Endangered
Endangered
Sensitive

Endangered
Endangered
Candidate
Threatened
Candidate
Candidate
Candidate
Threatened
Threatened
Endangered

Candidate
Candidate
Endangered
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit This list of species and habitats maps found in the Priority Habita http://wdfw.wa.gov/conservation/ counties where each priority spe counties where habitat primarily assumptions were made when d species: 1) There is a high likelihood a sp has not been directly observed, associated exists. . 2) Over time, species can natura new counties where usable habi Distribution maps in the PHS Lis information available. As new in distribution for some species ma periodically review and update th
Threatened	

Threatened
Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern

Endangered
Threatened
Threatened

Threatened

Endangered

Threatened
Threatened
Threatened
Threatened
Endangered
Endangered

Endangered
Endangered
Species of Concern
Threatened - glacialis, pugetensis, tumuli, yelmensis subspecies **Species of Concern** - couchi louiei, melanops subspecies
Species of Concern

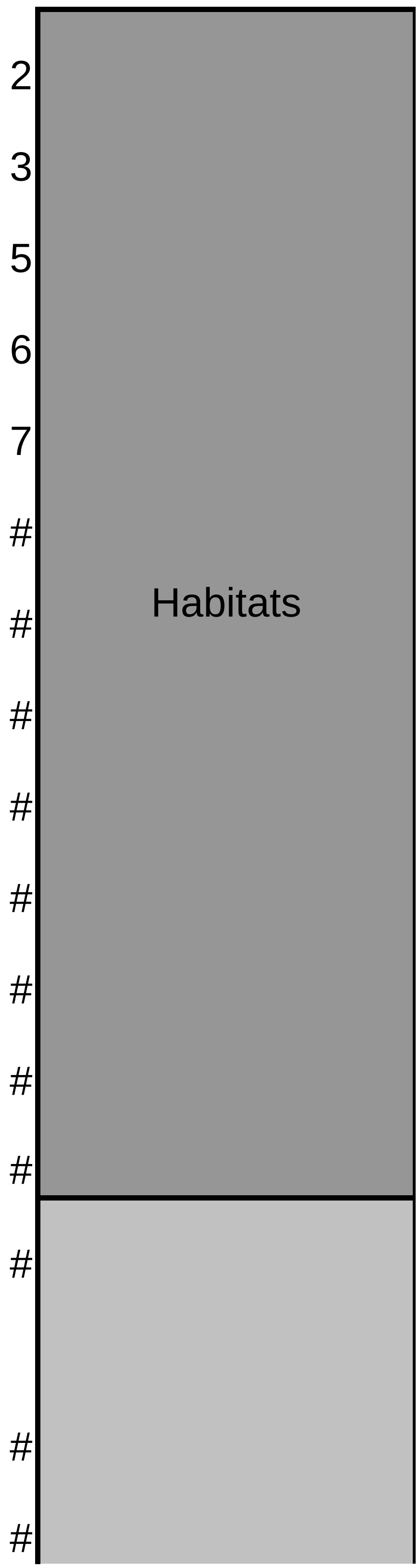
ınt Note **

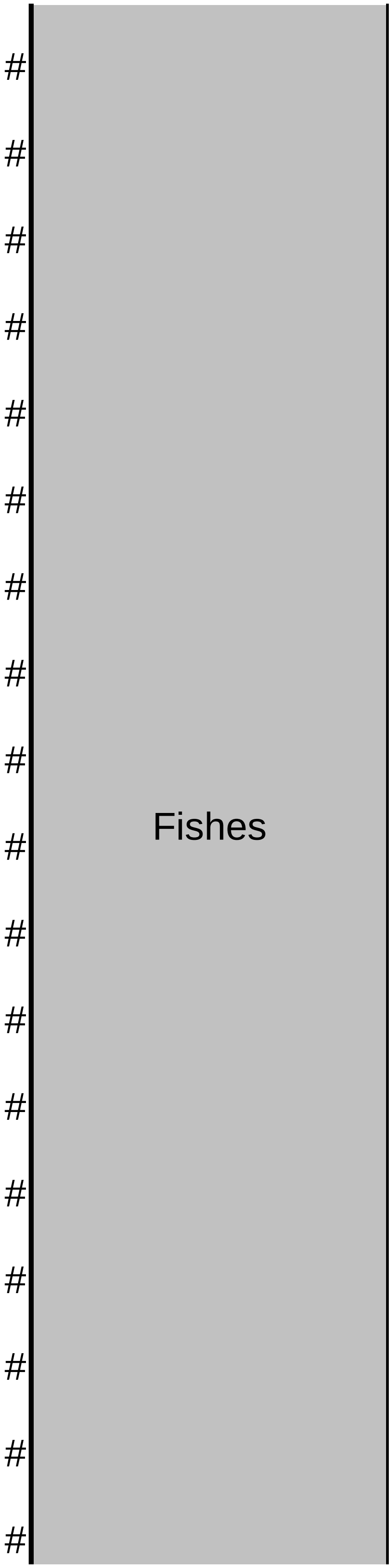
ats identified for Grays Harbor County.
was developed using the distribution
ıt and Species (PHS) List (see
/phs/). Species distribution maps depict
ecies is known to occur as well as other
associated with the species exists. Two
leveloping distribution maps for each

ecies is present in a county, even if it
if the habitat with which it is primarily

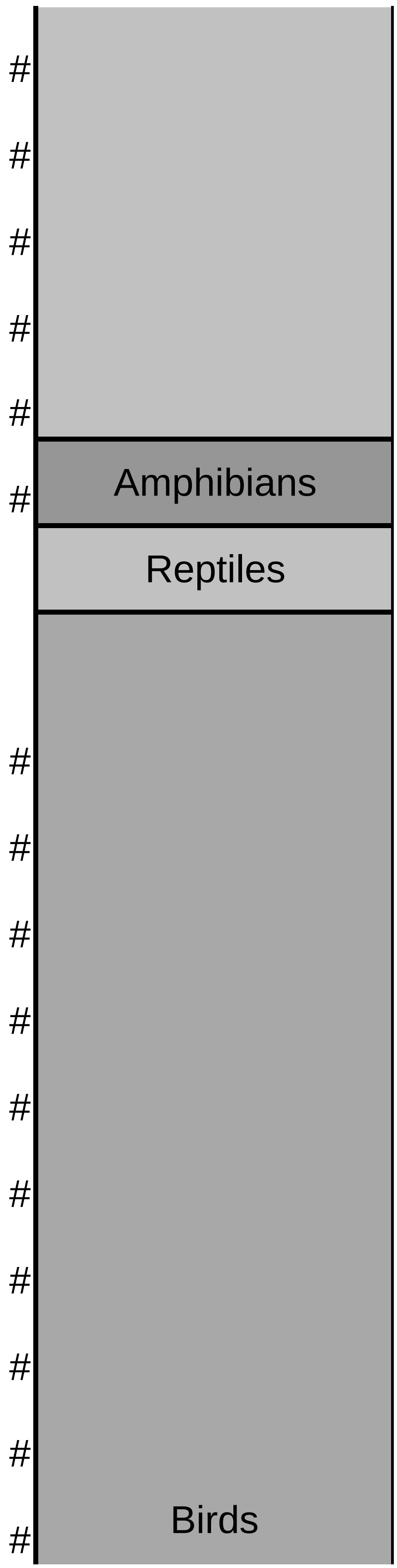
ılly change their distribution and move to
tat exists.

ıt were developed using the best
ıformation becomes available, known
ıy expand or contract. WDFW will
ıe the distribution maps in PHS list.

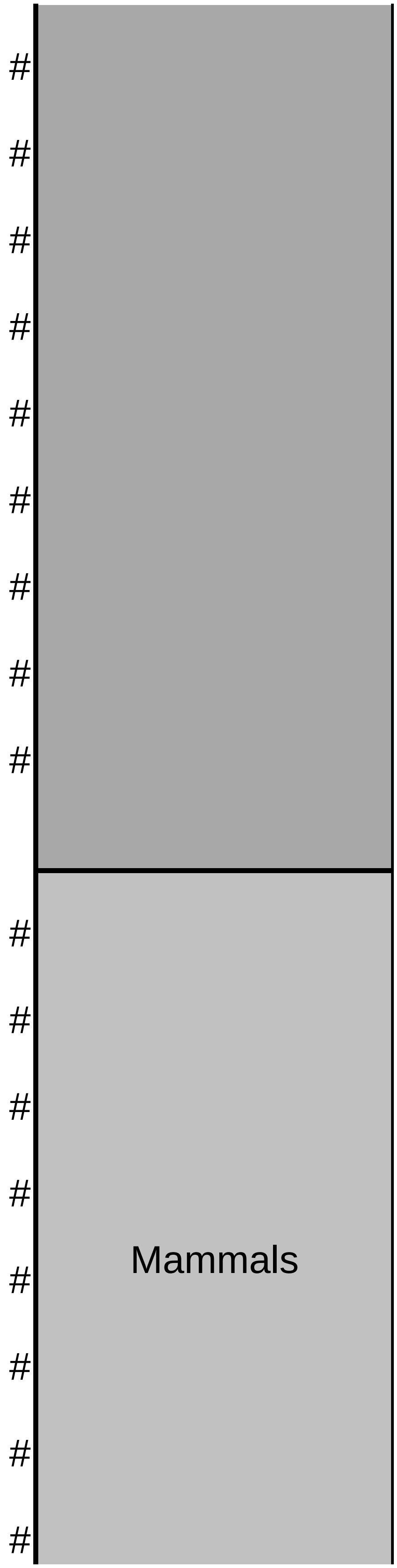

2
3
5
6
7
#
Habitats
#
#
#
#
#
#
#
#
#

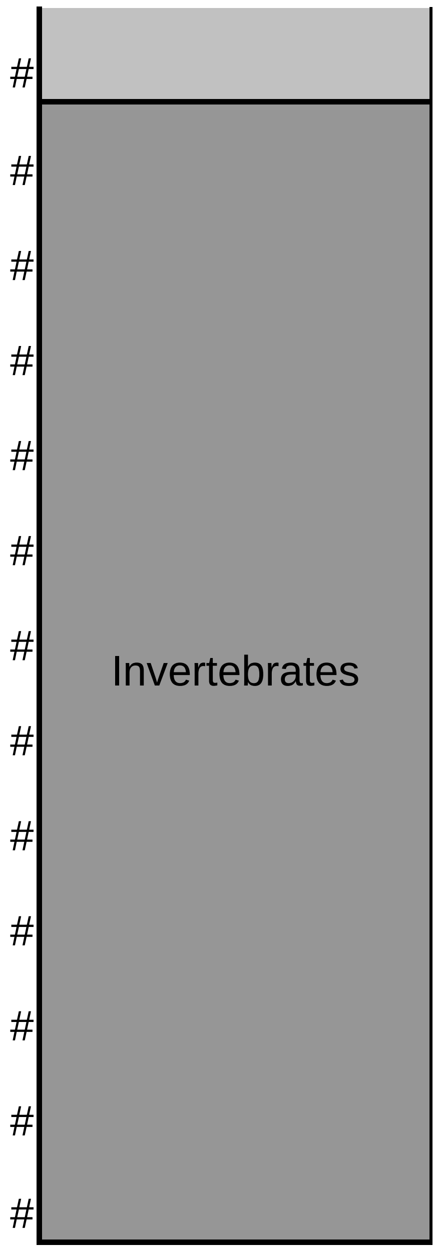


#
#
#
#
#
#
#
#
#
Fishes
#
#
#
#
#
#
#
#
#



#
#
#
#
#
#
Amphibians
Reptiles
#
#
#
#
#
#
#
#
#
#
Birds


Mammals


#
#
#
#
#
#
#
Invertebrates
#
#
#
#
#
#

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
White Sturgeon
Pacific Herring
Longfin Smelt
Surfsmelt

Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Pink Salmon
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Bocaccio Rockfish
Brown Rockfish
Canary Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Yelloweye Rockfish

Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Common Loon
Marbled Murrelet
Short-tailed Albatross
Tufted Puffin
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead

Harlequin Duck
Snow Goose
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Vaux’s Swift
Pileated Woodpecker
Oregon Vesper Sparrow
Dall's Porpoise
Gray Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)

Columbian Black-tailed Deer
Pinto (Northern) Abalone
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Sand-verbena Moth
Taylor's Checkerspot
Red Sea Urchin (formerly Red Urchin)

State Status

Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Endangered
Sensitive
Threatened
Candidate
Endangered
Candidate

Candidate
Candidate
Candidate
Sensitive
Endangered
Candidate
Candidate
Candidate

Endangered
Candidate
Candidate
Endangered

Federal Status

** Importa

These are the species and habit
This list of species and habitats
maps found in the Priority Habita
http://wdfw.wa.gov/conservation/
depict counties where each prior
well as other counties where hab
species exists. Two assumption
distribution maps for each speci

1) There is a high likelihood a sp
it has not been directly observed
primarily associated exists.
.
2) Over time, species can natura
move to new counties where usa

Distribution maps in the PHS Lis
information available. As new in
known distribution for some spec
will periodically review and upda
list.

Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Endangered
Threatened
Threatened

Threatened
Endangered

Endangered

Species of Concern
Endangered

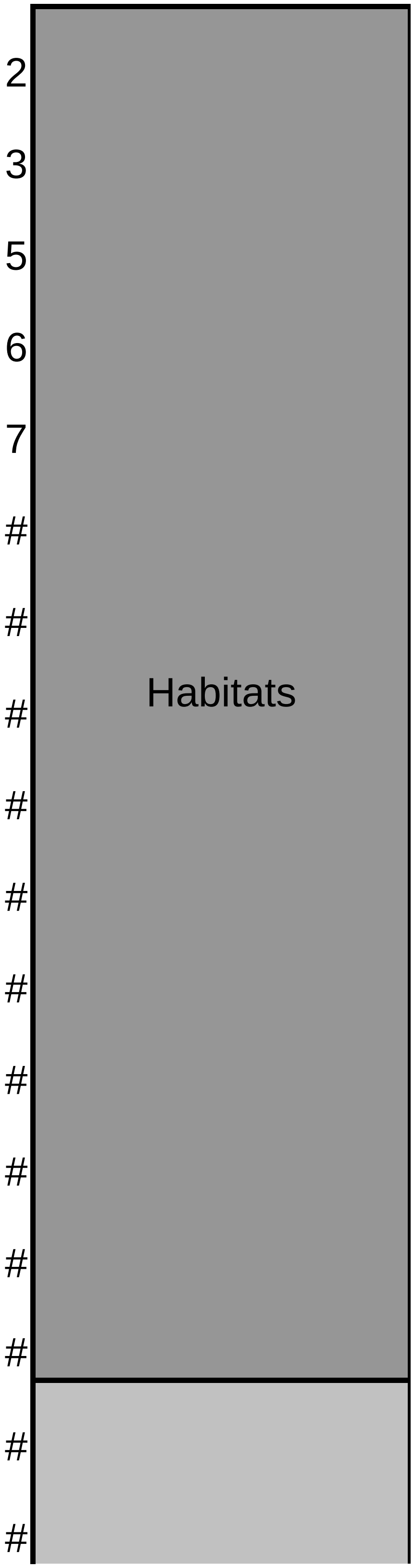
ınt Note **

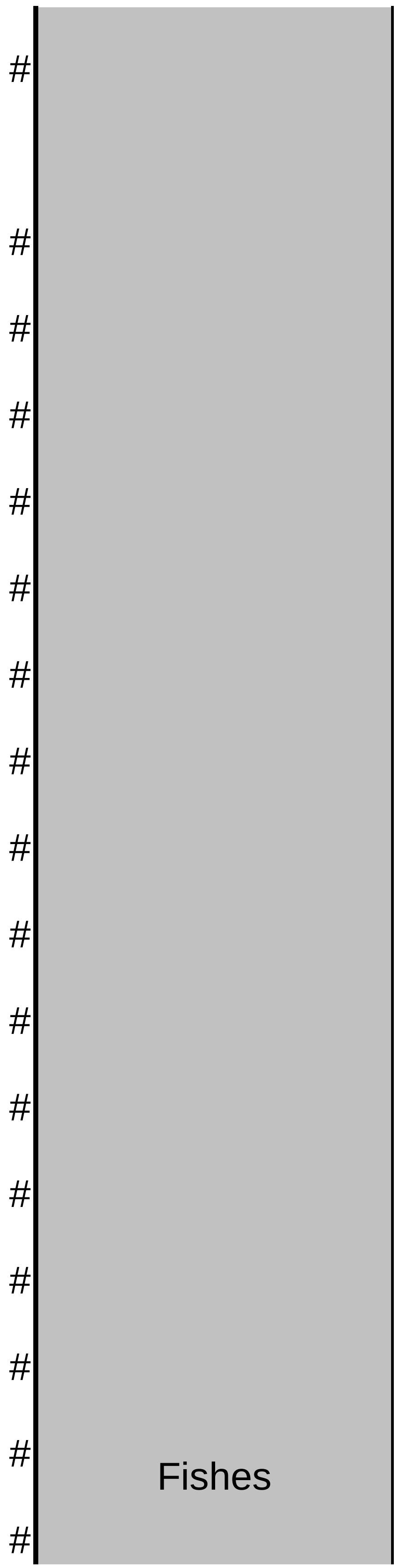
ats identified for Island County.
was developed using the distribution
ıt and Species (PHS) List (see
/phs/). Species distribution maps
rity species is known to occur as
bitat primarily associated with the
ıs were made when developing
es:

ecies is present in a county, even if
l, if the habitat with which it is

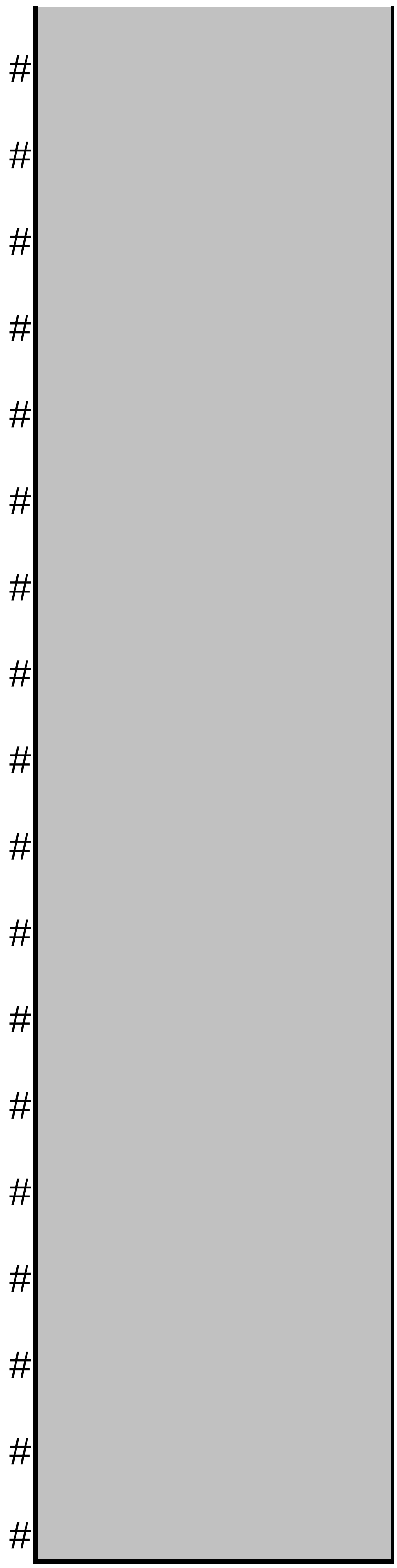
ılly change their distribution and
able habitat exists.

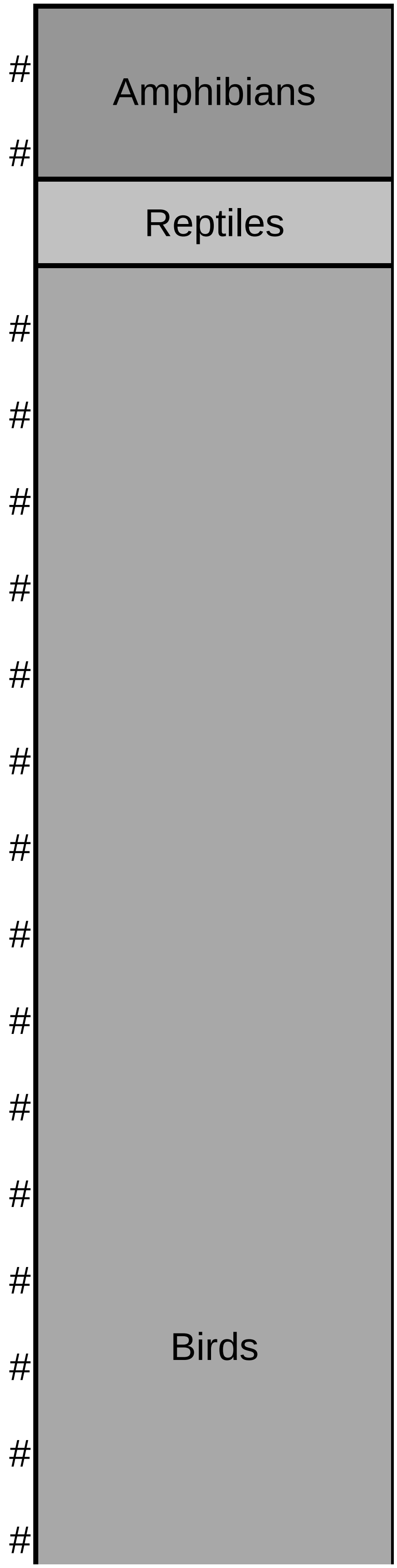
ıt were developed using the best
ıformation becomes available,
cies may expand or contract. WDFW
te the the distribution maps in PHS

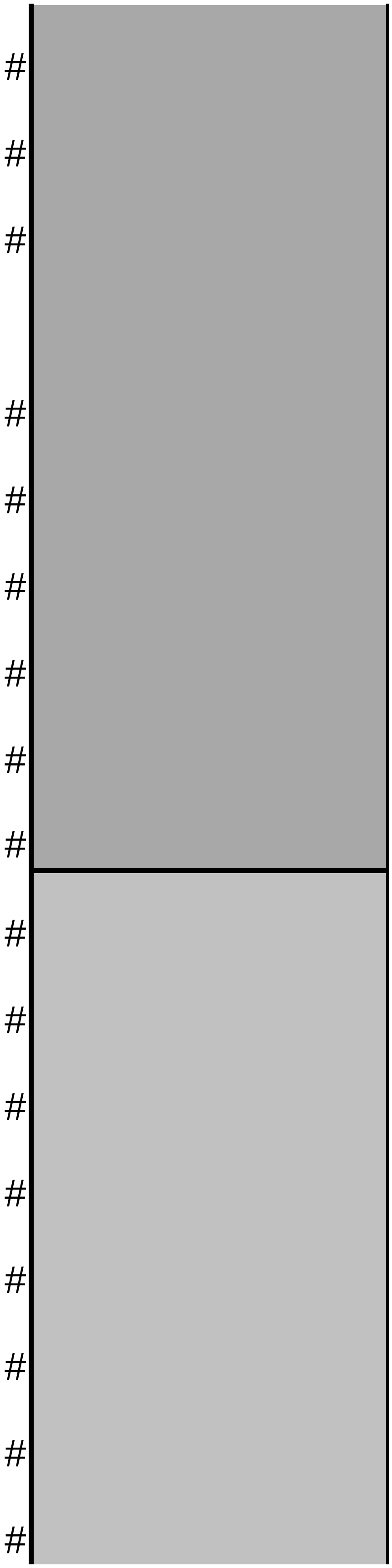

2
3
5
6
7
#
#
#
#
#
#
#
#
#
#
#
#
Habitats

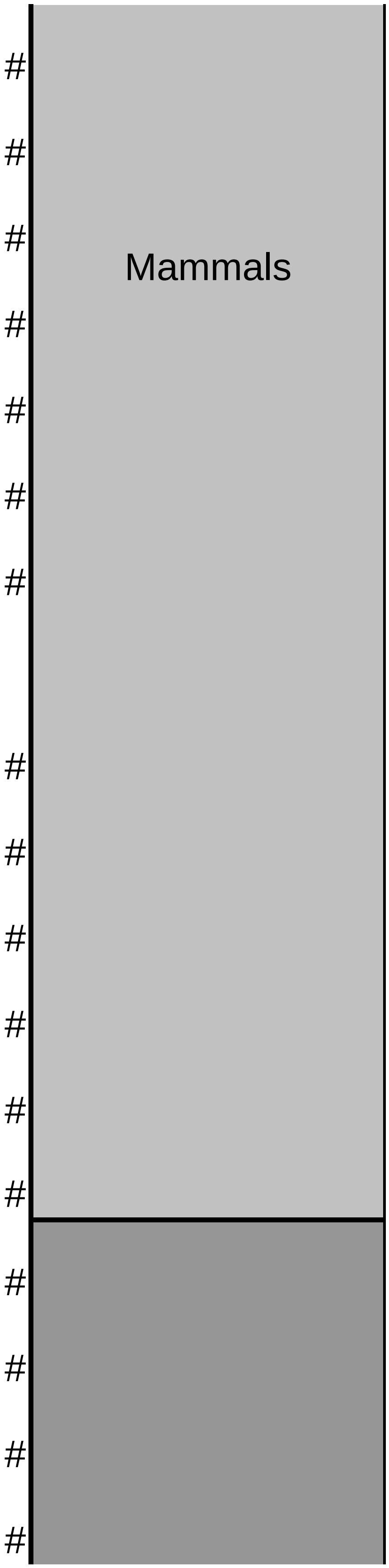


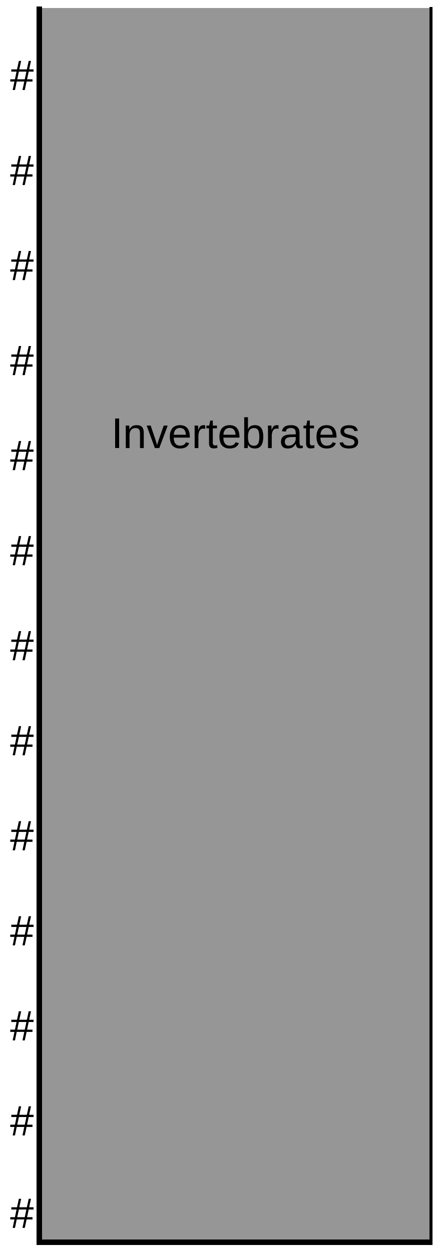
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes




Amphibians
Reptiles
Birds
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#




#
#
#
Mammals
#
#
#
#
#
#
#
#
#
#
#
#
#
#



#
#
#
#
#
#
#
#
#
#
#
#
#
Invertebrates

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Open Coast Nearshore
Coastal Nearshore
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey

Green Sturgeon
Whire Sturgeon
Olympic Mudminnow
Pacific Herring
Eulachon
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake

Walleye Pollock
Black Rockfish
Bocaccio Rockfish
Brown Rockfish
Canary Rockfish
China Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Tiger Rockfish
Widow Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole

Van Dyke's Salamander
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Brown Pelican
Cassin's Auklet
Common Loon
Marbled Murrelet
Short-tailed Albatross
Tufted Puffin
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Trumpeter Swan

Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Pileated Woodpecker
Dall's Porpoise
Blue Whale
Humpback Whale
Gray Whale
Sperm Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)

California Sea Lion
Steller (Northern) Sea Lion
Northern Sea Otter (formerly called Sea Otter)
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Olympic Marmot
Mazama (Western) Pocket Gopher
Fisher
Marten
Columbian Black-tailed Deer
Mountain Goat
Elk
Pinto (Northern) Abalone
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam

Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Pacific Razor Clam (formerly Razor Clam)
Dungeness Crab
Pandalid shrimp (Pandalidae)
Johnson's Hairstreak
Makah Copper (formerly Queen Charlotte's Copper)
Puget Blue
Sand-verbena Moth
Valley Silverspot
Taylor's Checkerspot
Red Sea Urchin (formerly Red Urchin)

State Status

Candidate

Sensitive
Candidate
Candidate
Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Endangered
Candidate
Sensitive
Threatened
Candidate
Endangered
Candidate

Candidate
Candidate
Endangered
Candidate
Candidate
Endangered
Endangered
Sensitive
Endangered
Endangered
Candidate

Threatened
Candidate
Candidate
Candidate
Threatened
Endangered
Endangered

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Status

** Importa

These are the species and habit
This list of species and habitats
maps found in the Priority Habita
http://wdfw.wa.gov/conservation/
depict counties where each prior
as other counties where habitat
exists. Two assumptions were r
maps for each species:

1) There is a high likelihood a sp
has not been directly observed,
associated exists.
2) Over time, species can natura
to new counties where usable ha

Distribution maps in the PHS Lis
information available. As new in
distribution for some species ma
periodically review and update th

Threatened
Threatened
Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern

Endangered
Threatened
Threatened

Threatened
Endangered

Threatened
Endangered
Endangered
Endangered
Endangered

Species of Concern
Threatened - glacialis, pugetensis, tumuli, yelmensis subspecies **Species of Concern** - couchi louiei, melanops subspecies
Species of Concern
Species of Concern

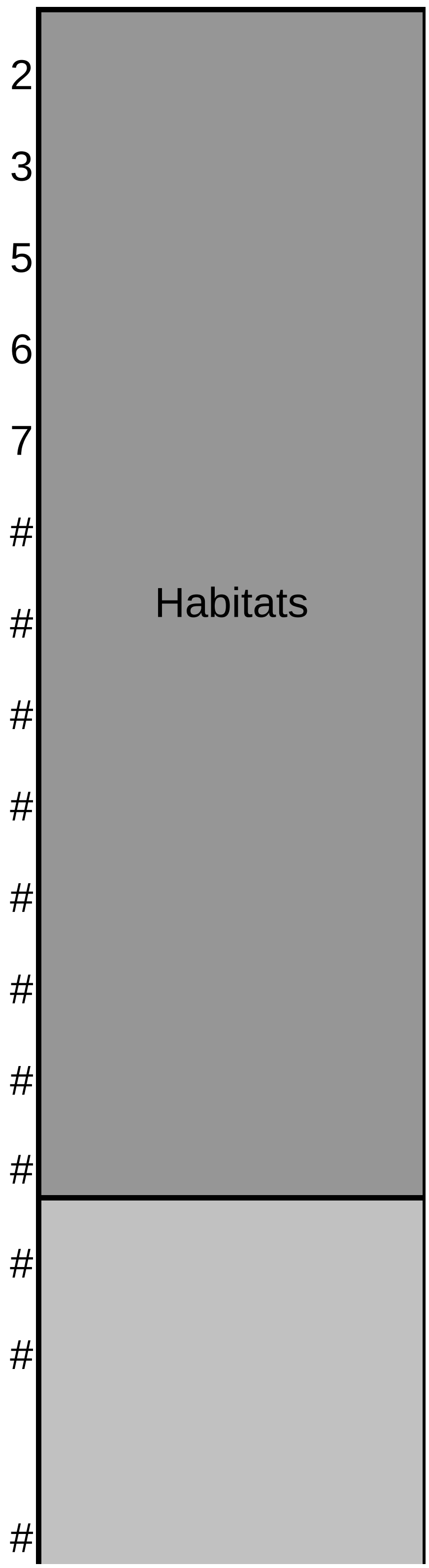
Endangered

ınt Note **

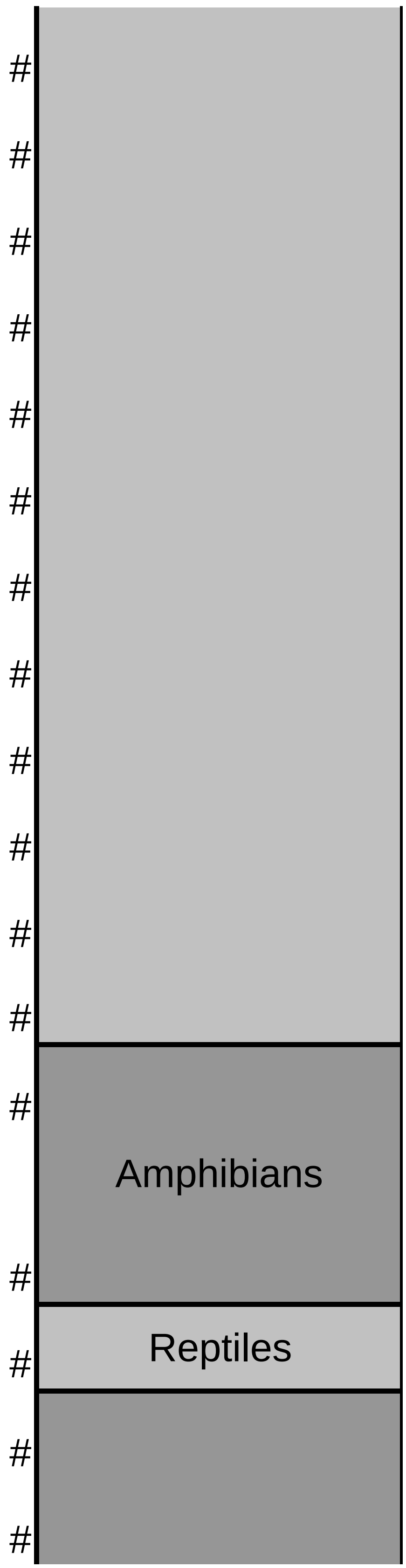
ats identified for Jefferson County.
was developed using the distribution
at and Species (PHS) List (see
/phs/). Species distribution maps
rity species is known to occur as well
primarily associated with the species
nade when developing distribution

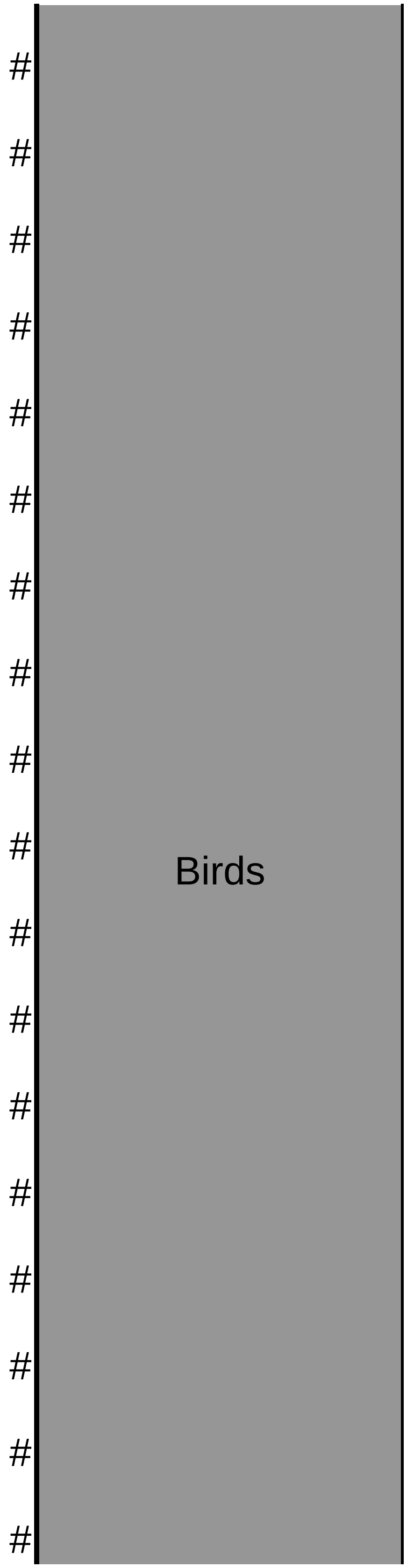
ɔecies is present in a county, even if it
if the habitat with which it is primarily
.
ally change their distribution and move
abitat exists.

t were developed using the best
formation becomes available, known
y expand or contract. WDFW will
ie the distribution maps in PHS list.

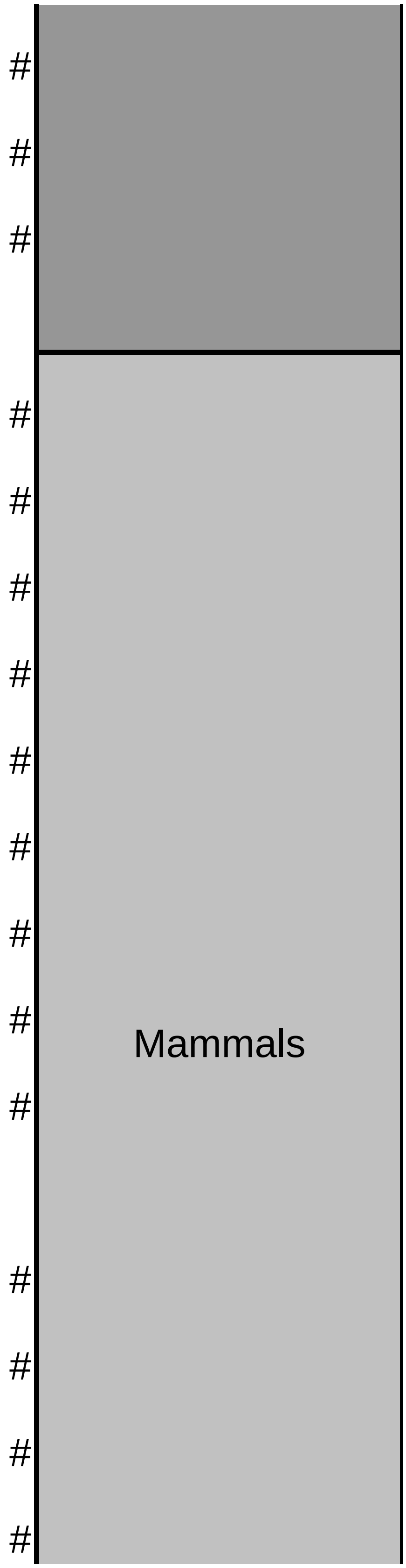

2
3
5
6
7
#
#
#
#
#
#
#
#
#
#
#
Habitats

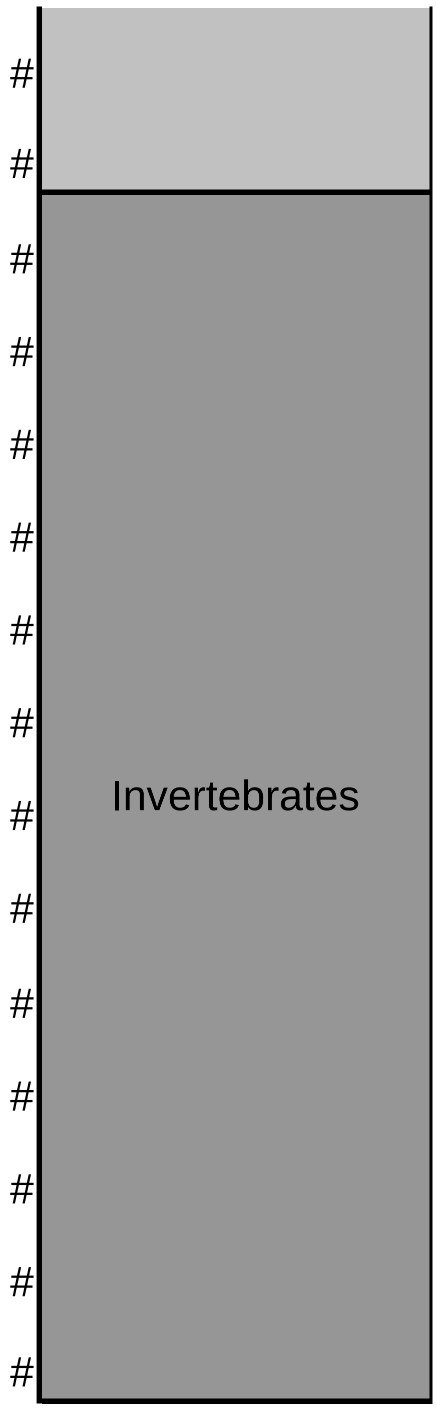
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes
#
#
#
#
#


#
#
#
#
#
#
#
#
#
#
#
#
#
Amphibians
#
Reptiles
#
#
#



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Birds


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Mammals



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Invertebrates

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Olympic Mudminnow

Pacific Herring
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Pygmy Whitefish
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Bocaccio Rockfish

Brown Rockfish
Canary Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Larch Mountain Salamander
Oregon Spotted Frog
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Common Loon
Marbled Murrelet

Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Yellow-billed Cuckoo
Northern Spotted Owl (formerly called Spotted Owl)

Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
Oregon Vesper Sparrow
Dall's Porpoise
Gray Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
California Sea Lion
Steller (Northern) Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Cascade Red Fox
Fisher
Marten
Wolverine
Columbian Black-tailed Deer

Mountain Goat
Elk
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Pacific Clubtail
Beller's Ground Beetle
Hatch's Click Beetle
Johnson's Hairstreak
Valley Silverspot

State Status

Candidate
Sensitive

Candidate
Candidate *
Candidate
Candidiate
Sensitive
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Sensitive
Endangered
Candidate
Endangered
Sensitive
Threatened

Candidate
Candidate
Candidate
Endangered
Endangered

Candidate
Candidate
Candidate
Candidate
Sensitive
Endangered
Candidate
Candidate
Candidate
Endangered
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status

** Im

These are the species a
list of species and habita
found in the Priority Hab
http://wdfw.wa.gov/cons
depict counties where ea
as other counties where
exists. Two assumption
maps for each species:

1) There is a high likelih
has not been directly ob
associated exists.
2) Over time, species ca
move to new counties w

Distribution maps in the
information available. A
distribution for some spe
periodically review and u

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Endangered

Threatened
Threatened
Threatened
Threatened

Threatened
Threatened

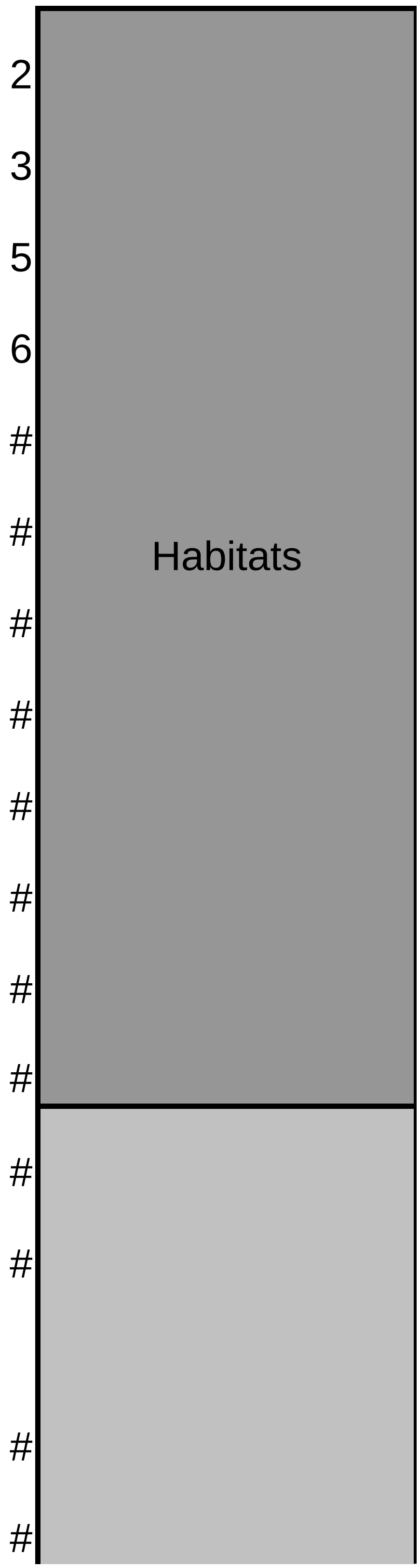
Endangered
Species of Concern
Candidate

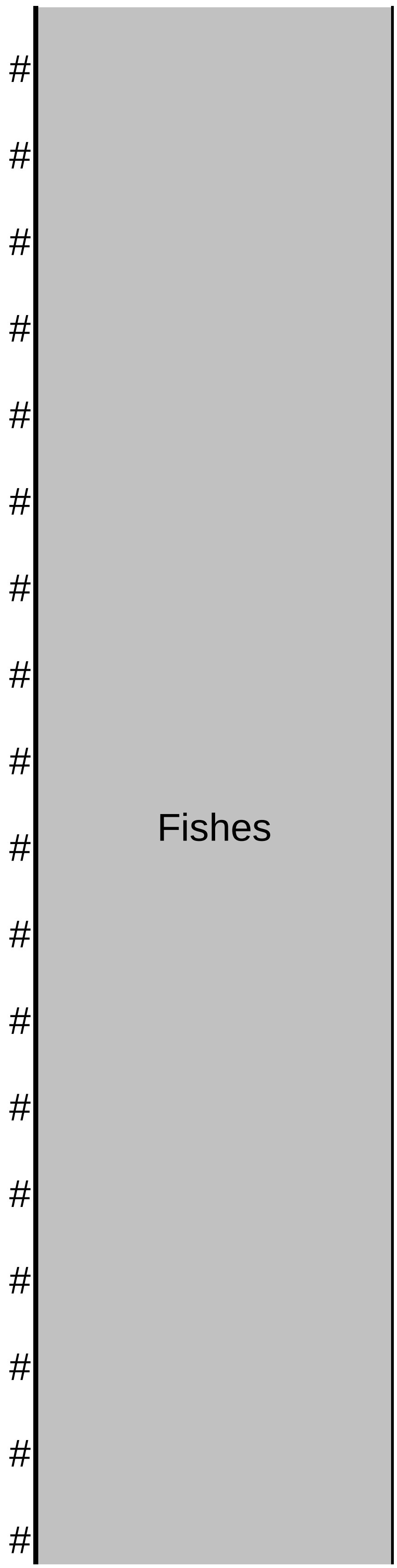
ıportant Note **

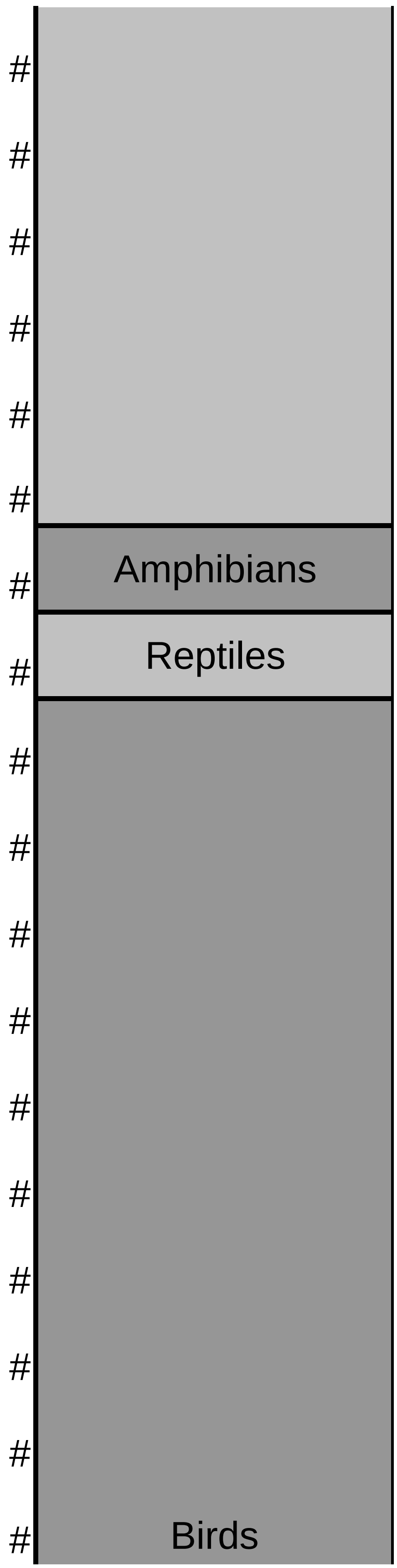
.nd habitats identified for King County. This
ats was developed using the distribution maps
ıitat and Species (PHS) List (see
ervation/phs/). Species distribution maps
ach priority species is known to occur as well
habitat primarily associated with the species
s were made when developing distribution

ood a species is present in a county, even if it
served, if the habitat with which it is primarily
.
ın naturally change their distribution and
here usable habitat exists.

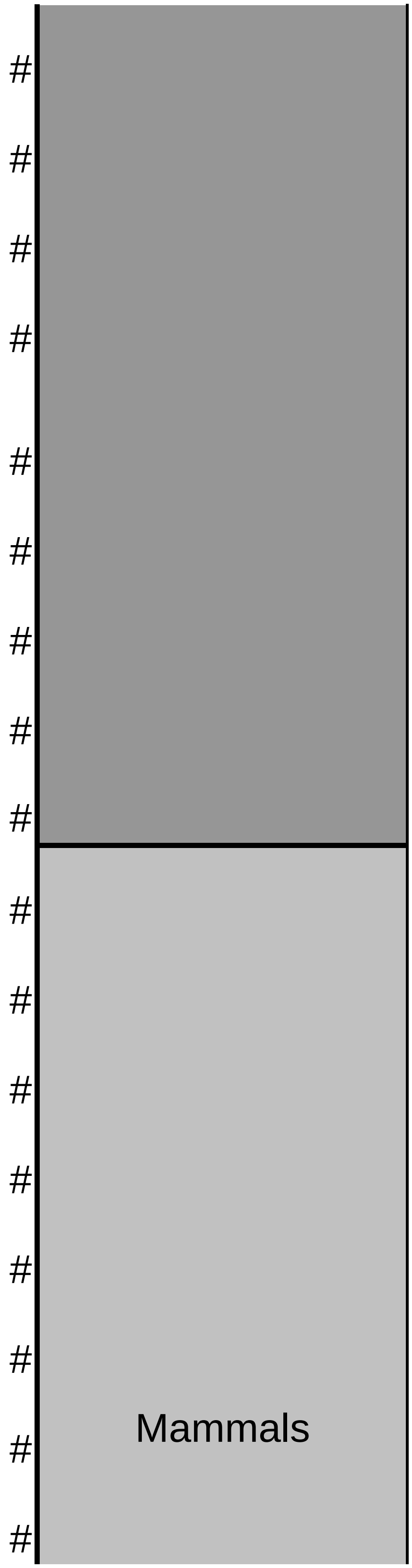
PHS List were developed using the best
s new information becomes available, known
ecies may expand or contract. WDFW will
ıpdate the the distribution maps in PHS list.

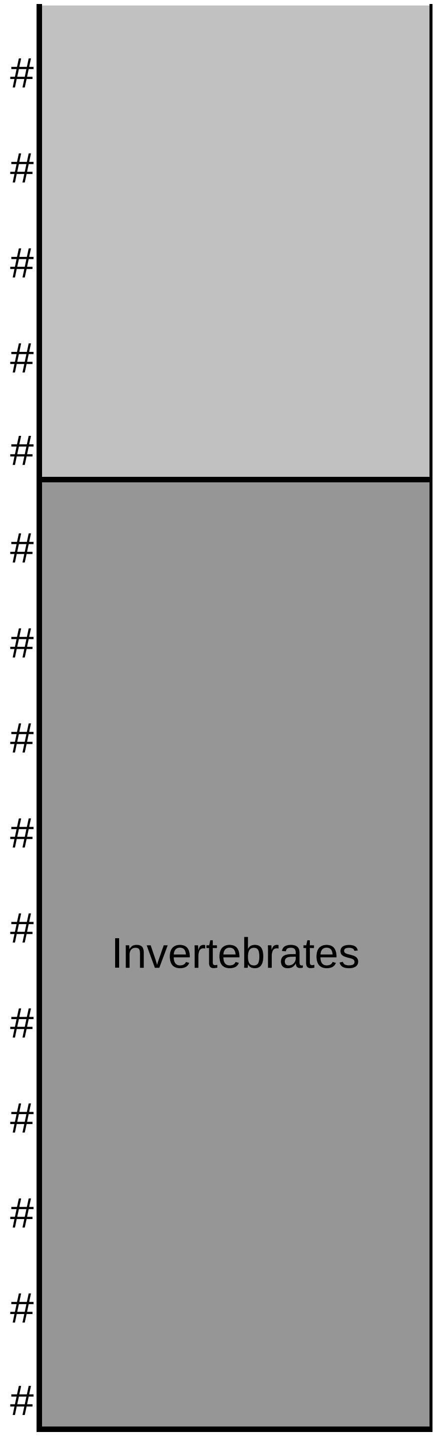

2
3
5
6
#
#
#
#
#
#
#
#
#
#
#
#
Habitats


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Amphibians
Reptiles
Birds


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Mammals



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Invertebrates

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Pacific Herring
Longfin Smelt

Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Bocaccio Rockfish
Brown Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish

Tiger Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Common Loon
Marbled Murrelet
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck

Trumpeter Swan
Waterfowl Concentrations
Mountain Quail
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Yellow-billed Cuckoo
Vaux’s Swift
Pileated Woodpecker
Dall's Porpoise
Humpback Whale
Gray Whale
Sperm Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
California Sea Lion

Steller (Northern) Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Columbian Black-tailed Deer
Pinto (Northern) Abalone
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Puget Blue

State Status

Candidate
Candidate

Candidate *
Candidate
Candidiate
Candidiate **
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate

Candidiate
Candidiate
Candidate
Endangered
Sensitive
Threatened
Candidate

Endangered
Candidate
Candidate
Endangered
Sensitive
Endangered
Endangered
Candidate

Candidate
Candidate
Endangered
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status

** Importa

These are the species and habit
This list of species and habitats
distribution maps found in the Pr
List (see http://wdfw.wa.gov/con
distribution maps depict countie
known to occur as well as other
associated with the species exis
when developing distribution ma

1) There is a high likelihood a sp
it has not been directly observec
primarily associated exists.
.
2) Over time, species can natura
move to new counties where usa

Distribution maps in the PHS Lis
information available. As new in
known distribution for some spe
WDFW will periodically review a
in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Species of Concern
Species of Concern
Endangered

Threatened

Threatened
Endangered
Endangered
Endangered

Species of Concern

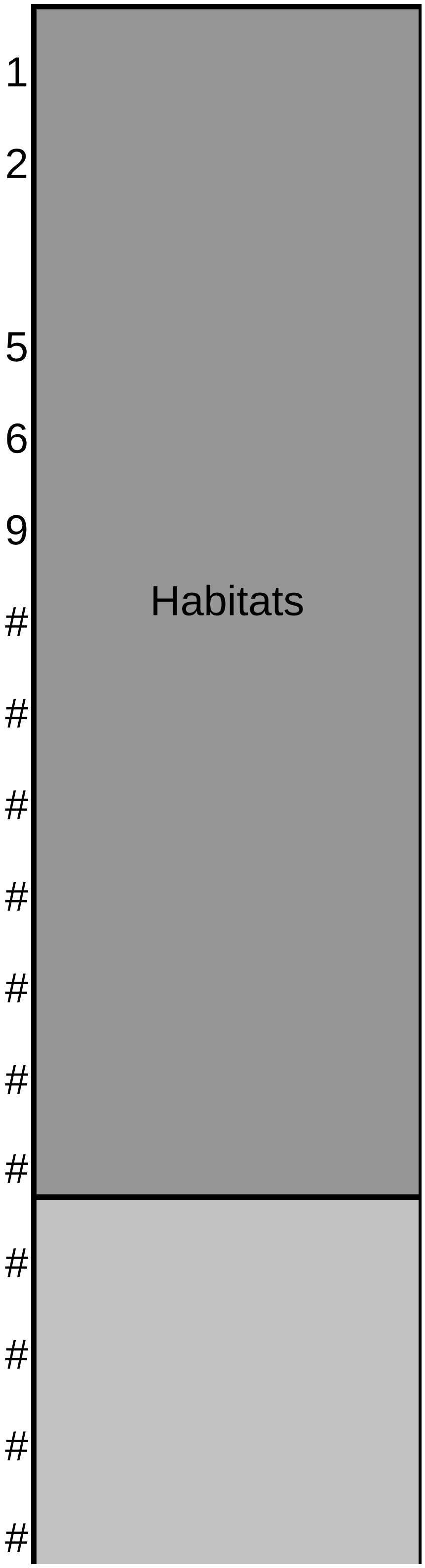
ınt Note **

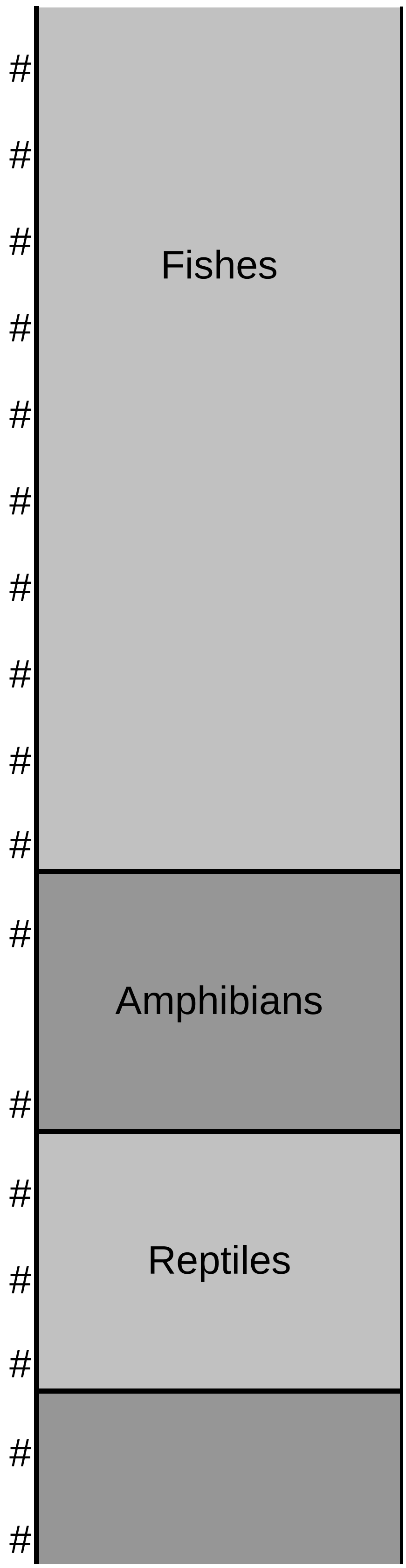
ıats identified for Kitsap County.
was developed using the
riority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

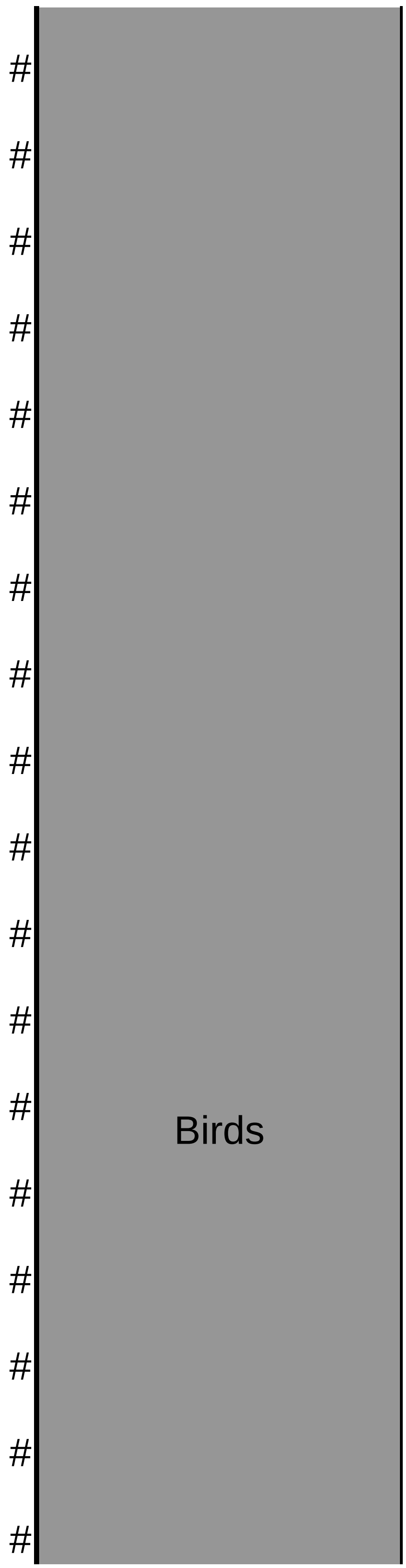
ɔecies is present in a county, even if
l, if the habitat with which it is

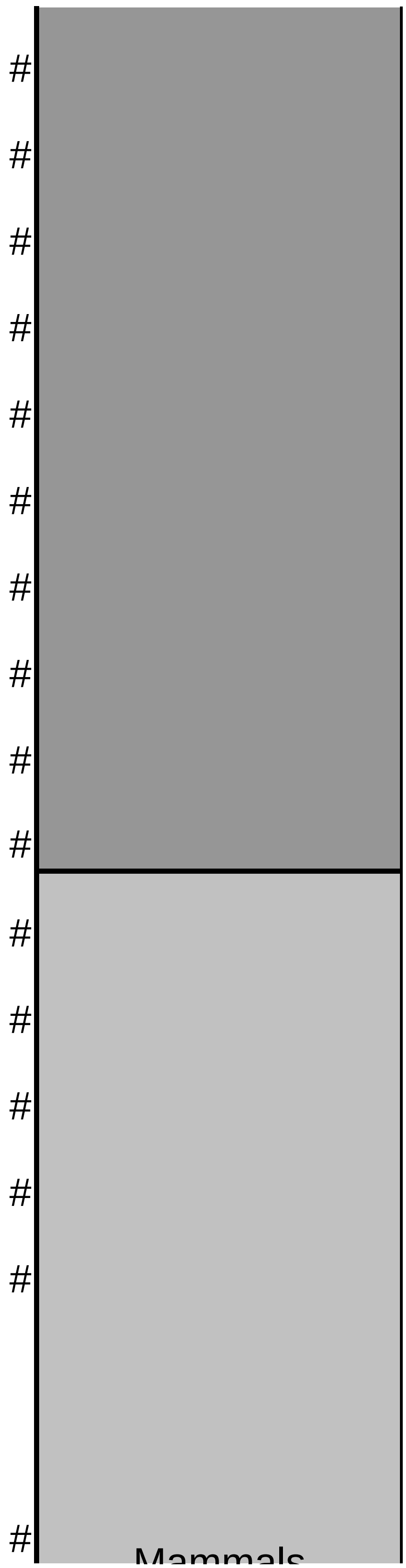
ılly change their distribution and
ıble habitat exists.

ıt were developed using the best
ıformation becomes available,
cies may expand or contract.
nd update the the distribution maps

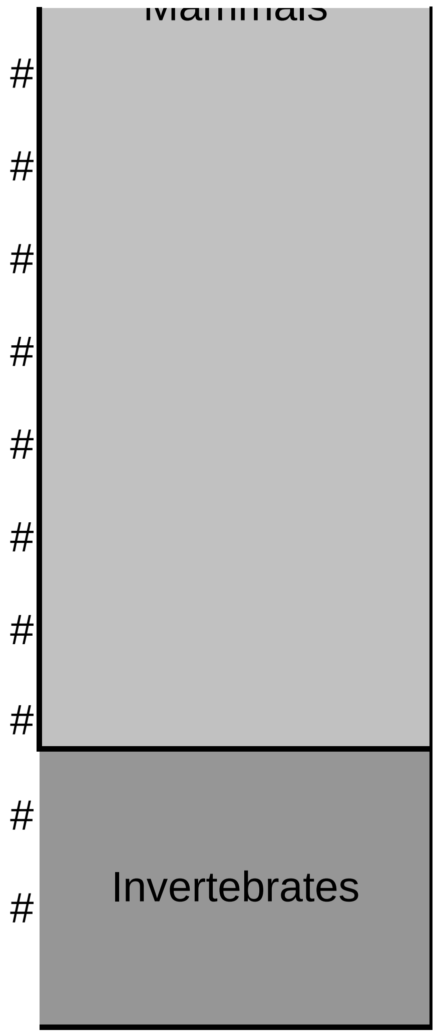

1
2
5
6
9
#
#
#
#
#
#
#
#
#
#
#
Habitats


#
#
#
Fishes
#
#
#
#
#
#
#
#
Amphibians
#
#
Reptiles
#
#
#
#


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Birds



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Mammals


Mammals
#
#
#
#
#
#
#
#
#
#
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Leopard Dace

Umatilla Dace
Mountain Sucker
Bull Trout/ Dolly Varden
Chinook Salmon
Coho Salmon
Kokanee
Pygmy Whitefish
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Larch Mountain Salamander
Western Toad
Sharp-tailed Snake (formerly Common Sharptail Snake)
Striped Whipsnake
Sagebrush Lizard
American White Pelican
Western grebe

E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Harlequin Duck
Tundra Swan
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Northern Goshawk
Prairie Falcon
Chukar
Dusky Grouse
Greater Sage-grouse
Sooty Grouse
Wild Turkey
E WA breeding occurrences of: Phalaropes, Stilts and Avocets

Burrowing Owl
Flammulated Owl
Northern Spotted Owl (formerly called Spotted Owl)
Vaux's Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Townsend's Ground Squirrel
Western Gray Squirrel
Cascade Red Fox
Fisher

Gray Wolf
Marten
Wolverine
Bighorn Sheep
Mountain Goat
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Juniper Hairstreak
Silver-bordered Fritillary
Giant Palouse Earthworm

State Status

Candidate
Candidate

Candidate
Candidate
Candidate *
Candidate
Senstive
Candidiate **
Candidate
Candidate
Senstive
Candidate
Candidate
Candidate
Candidate
Endangered
Candidate

Threatened
Candidate
Candidate
Threatened

Candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Endangered

Endangered
Candidate
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status

** Im

These are the species a
This list of species and h
distribution maps found
List (see http://wdfw.wa.
distribution maps depict
known to occur as well a
associated with the spec
when developing distribu

1) There is a high likeliho
even if it has not been d
it is primarily associated
2) Over time, species ca
move to new counties w

Distribution maps in the
information available. A
known distribution for sc
WDFW will periodically r
maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Species of Concern

Threatened
Species of Concern

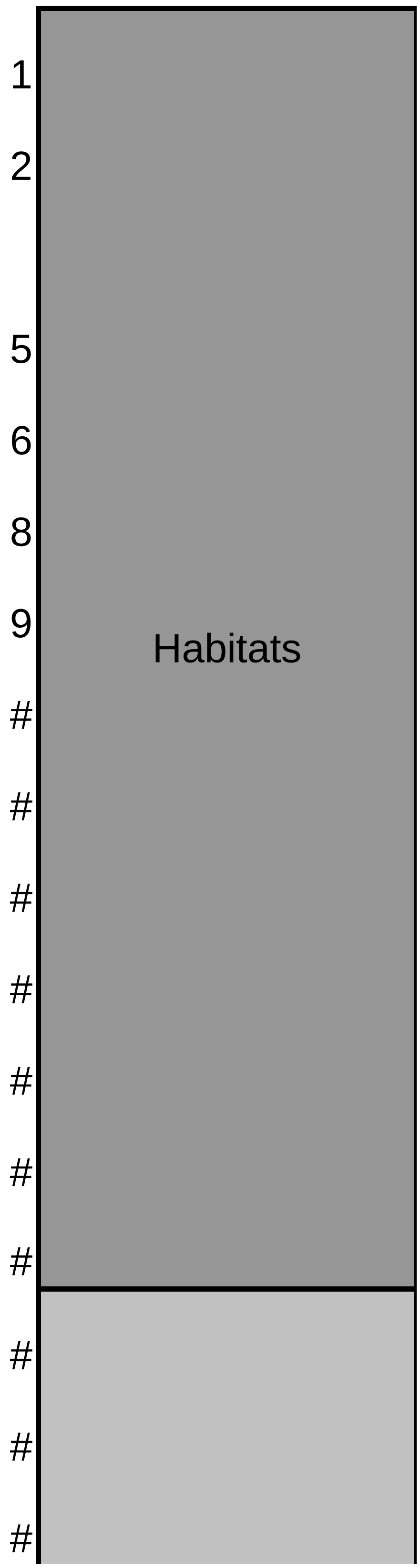
Endangered
Candidate

ıportant Note **

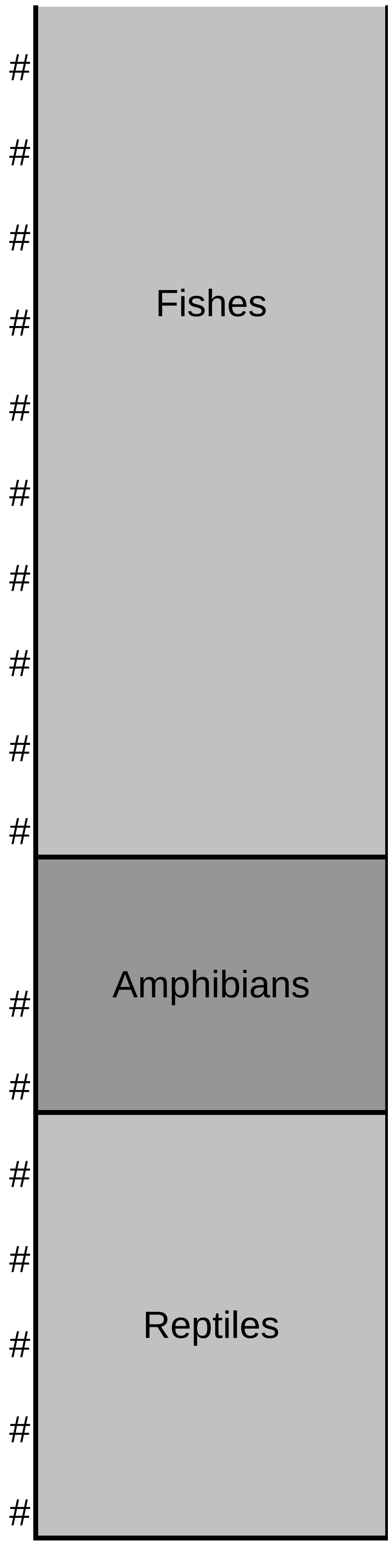
.nd habitats identified for Kittitas County.
ıabitats was developed using the
in the Priority Habitat and Species (PHS)
gov/conservation/phs/). Species
counties where each priority species is
ıs other counties where habitat primarily
cies exists. Two assumptions were made
ıtion maps for each species:

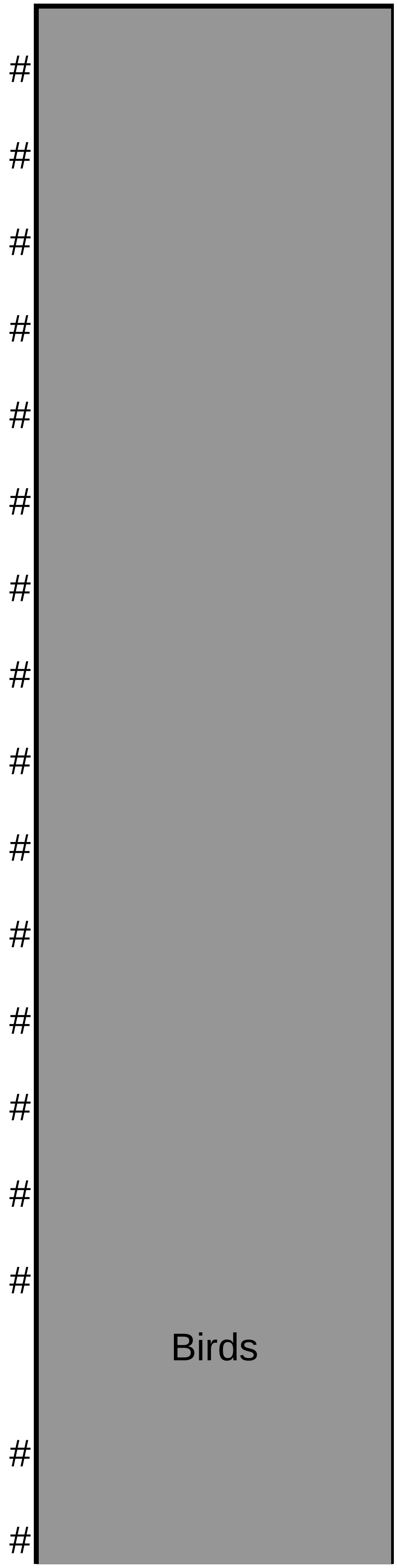
ood a species is present in a county,
irectly observed, if the habitat with which
exists. .
ın naturally change their distribution and
here usable habitat exists.

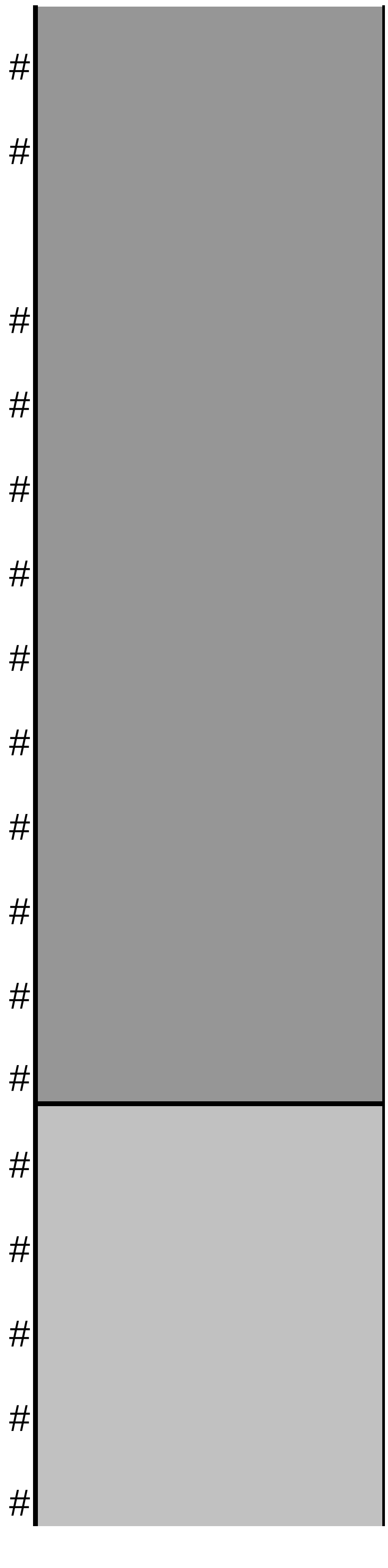
PHS List were developed using the best
s new information becomes available,
ıme species may expand or contract.
review and update the the distribution

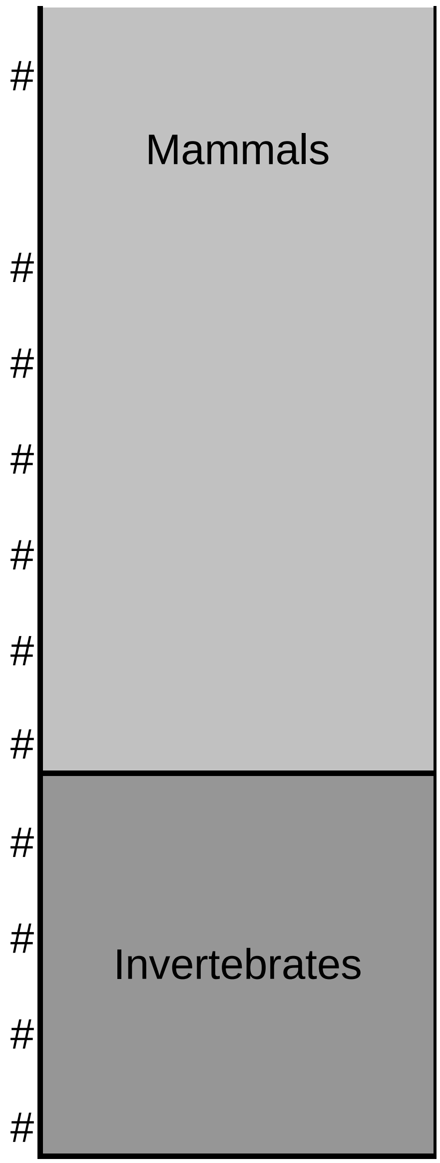


1
2
5
6
8
9
Habitats
#
#
#
#
#
#
#
#
#
#


Fishes
Amphibians
Reptiles


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Birds
#
#





#
Mammals
#
#
#
#
#
#
#
#
Invertebrates
#
#

Species/ Habitats

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Eastside Steppe
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Sgs and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon

Leopard Dace
Mountain Sucker
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Larch Mountain Salamander
Oregon Spotted Frog
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
California Mountain Kingsnake
Sharp-tailed Snake (formerly Common Sharptail Snake)
Striped Whipsnake
Sagebrush Lizard

Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Harlequin Duck
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Northern Goshawk
Prairie Falcon
Chukar
Mountain Quail
Ring-necked Pheasant
Greater Sage-grouse
Sooty Grouse
Wild Turkey

Sandhill Crane
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Band-tailed Pigeon
Burrowing Owl
Flammulated Owl
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Western Gray Squirrel

Townsend's Ground Squirrel
Cascade Red Fox
Fisher
Marten
Wolverine
Columbian Black-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Columbia Oregonian
Dalles Sideband
Juniper Hairstreak
Mardon Skipper

State Species Status

Candidate

Candidate
Candidate
Candidate *
Candidate
Candidate
Candidate **
Candidate
Sensitive
Endangered
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate

Candidate
Threatened
Candidate
Candidate
Threatened

Endangered
Candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened

Candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Species Status

** Importa

These are the species and habit
list of species and habitats was c
found in the Priority Habitat and S
http://wdfw.wa.gov/conservation/
depict counties where each prior
as other counties where habitat p
exists. Two assumptions were m
maps for each species:

1) There is a high likelihood a sp
has not been directly observed, i
associated exists.
2) Over time, species can natura
to new counties where usable ha

Distribution maps in the PHS Lis
information available. As new in
distribution for some species ma
periodically review and update th

Threatened *
Threatened
Threatened
Threatened
Threatened **
Endangered
Threatened

Species of Concern

Threatened

Species of Concern
Candidate

ınt Note **

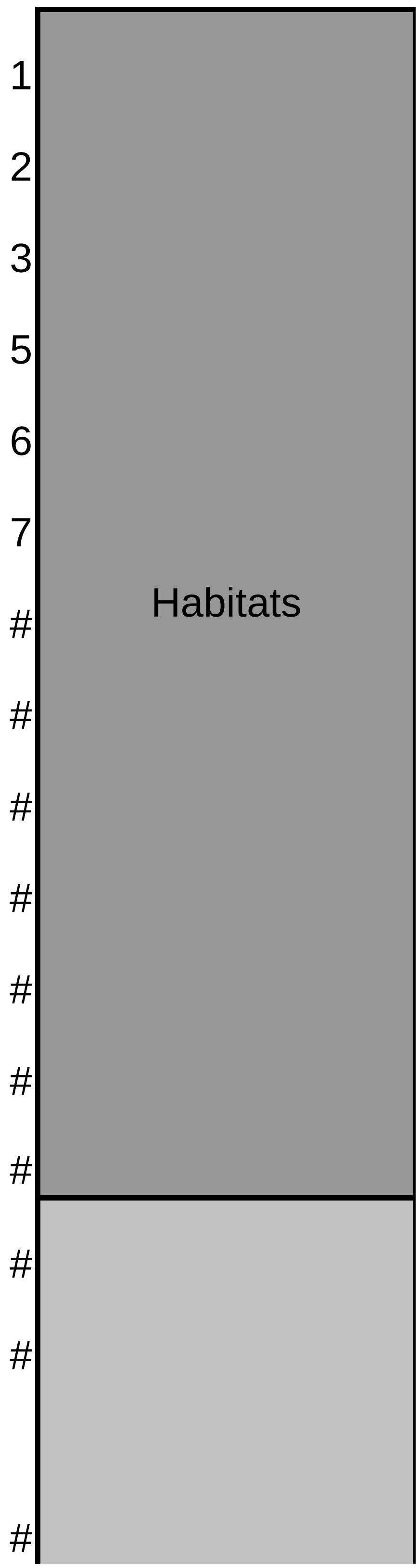
ıts identified for Klickitat County. This ıeveloped using the distribution maps Species (PHS) List (see ̸phs/). Species distribution maps ity species is known to occur as well ɔrimarily associated with the species ɿade when developing distribution

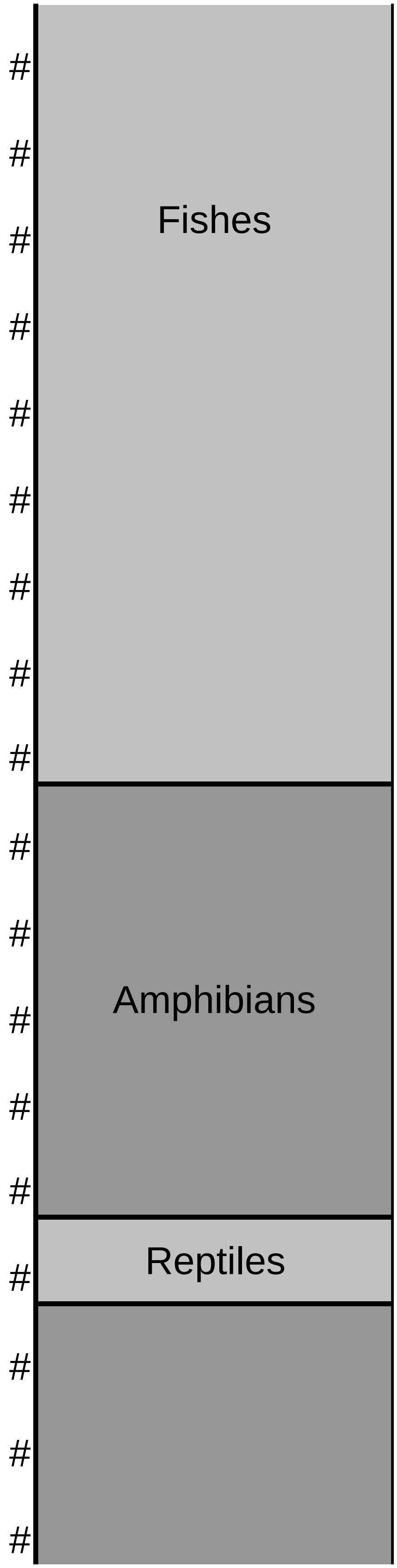
ecies is present in a county, even if it f the habitat with which it is primarily

.

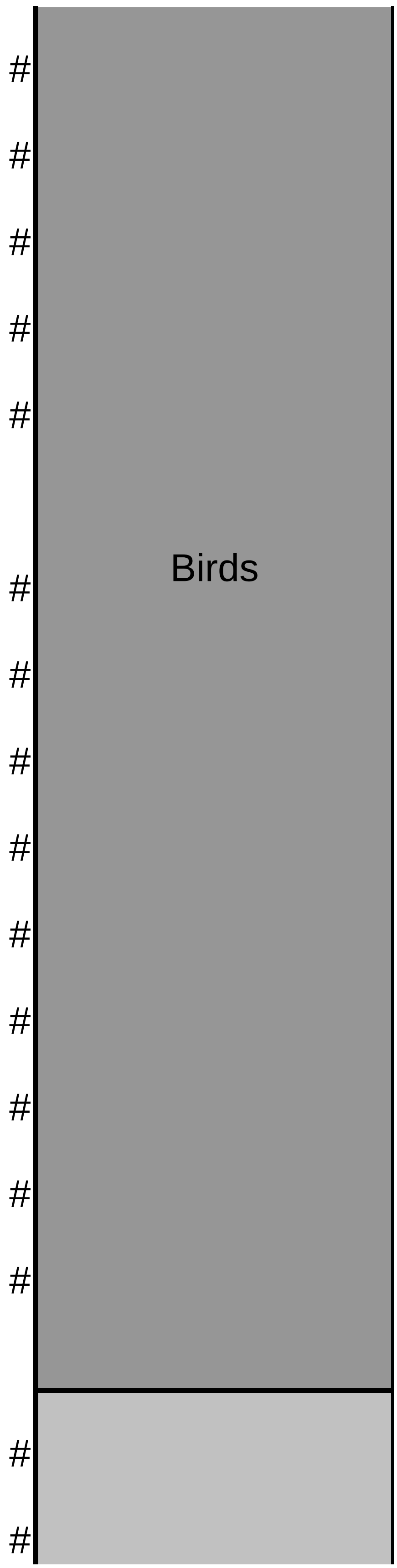
lly change their distribution and move ıbitat exists.

t were developed using the best formation becomes available, known y expand or contract. WDFW will ıe the distribution maps in PHS list.

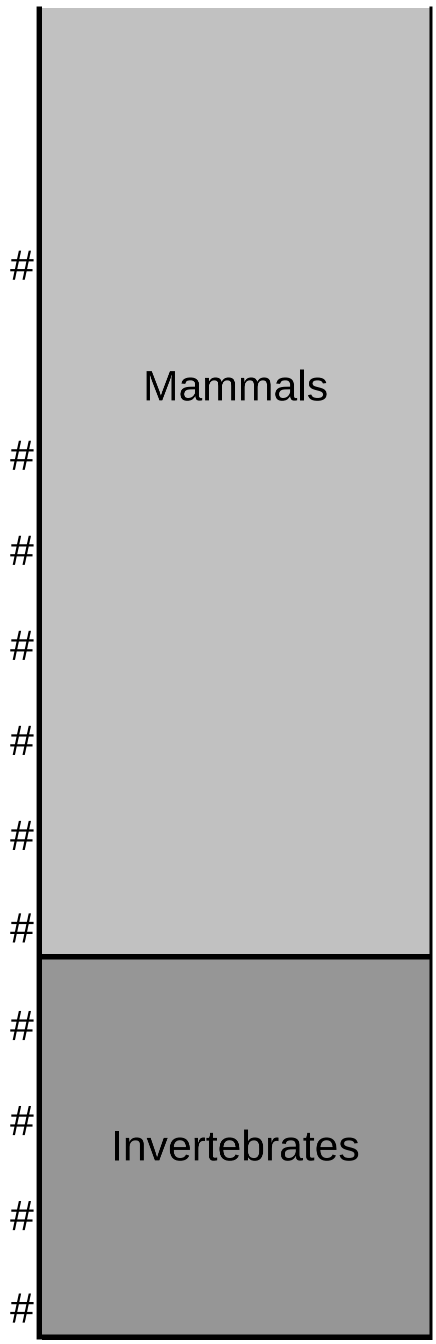

1
2
3
5
6
7
#
#
#
#
#
#
#
#
#
#
Habitats



#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes
Amphibians
Reptiles



Birds



#
Mammals
#
#
#
#
#
#
#
#
Invertebrates
#
#

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Olympic Mudminnow

Leopard Dace
Mountain Sucker
Eulachon
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Cascade Torrent Salamander
Dunn's Salamander
Larch Mountain Salamander
Van Dyke's Salamander
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Marbled Murrelet
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser

Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
Wild Turkey
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
Oregon Vesper Sparrow
Slender-billed White-breasted Nuthatch
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat

Western Gray Squirrel
Mazama (Western) Pocket Gopher
Cascade Red Fox
Fisher
Marten
Wolverine
Columbian Black-tailed Deer
Mountain Goat
Elk
Blue-gray Taildropper
Johnson's Hairstreak
Valley Silverspot
Taylor's Checkerspot

State Status

Candidate
Senstive

Candidate
Candidate
Candidate
Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Senstive
Candidate
Candidate
Endangered
Threatened

Candidate
Candidate
Endangered
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate
Candidiate

Threatened
Threatened
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit This list of species and habitats distribution maps found in the Pr (PHS) List (see http://wdfw.wa.g distribution maps depict countie known to occur as well as other associated with the species exis made when developing distributi 1) There is a high likelihood a sp even if it has not been directly o which it is primarily associated e 2) Over time, species can natura move to new counties where us Distribution maps in the PHS Lis best information available. As n available, known distribution for contract. WDFW will periodically distribution maps in PHS list.

Threatened
Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened

Threatened

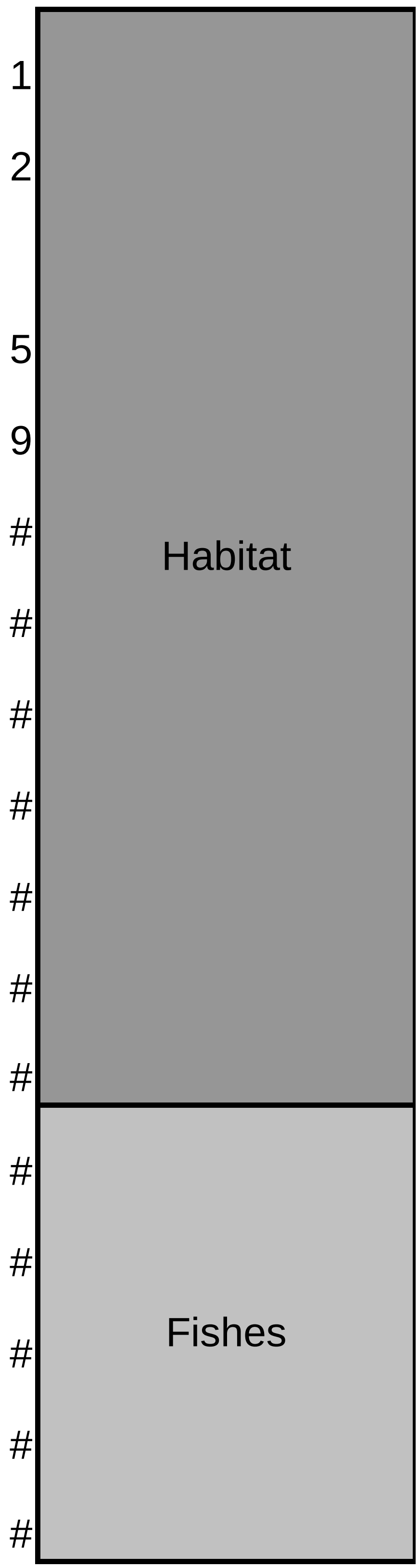
Threatened - glacialis, pugetensis, tumuli, yelmensis subspecies **Species of Concern** - couchi louiei, melanops subspecies
Species of Concern
Candidate
Endangered

ınt Note **

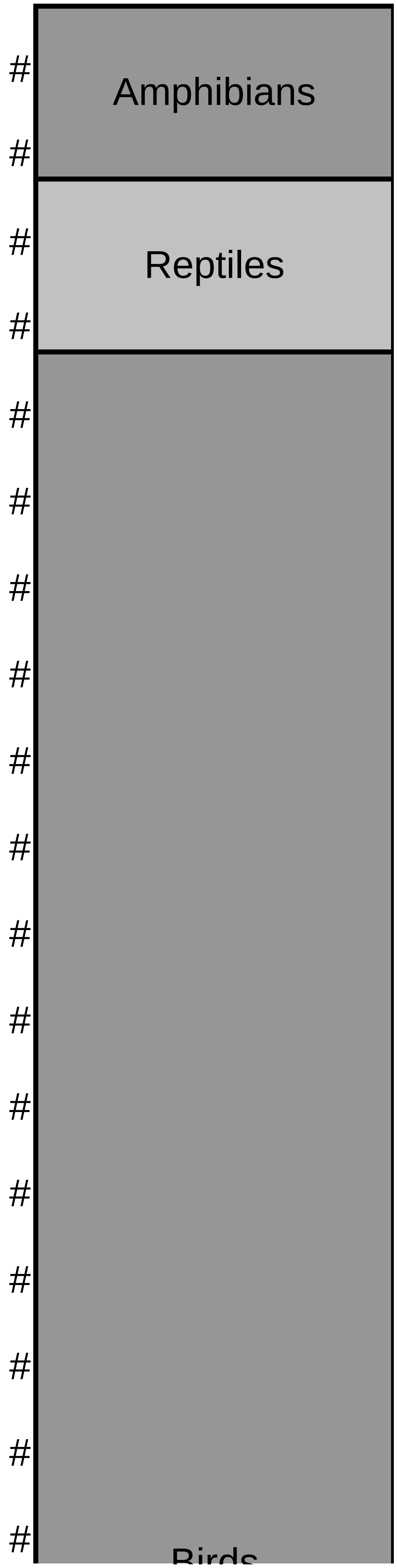
ıats identified for Lewis County.
was developed using the
riority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were
on maps for each species:

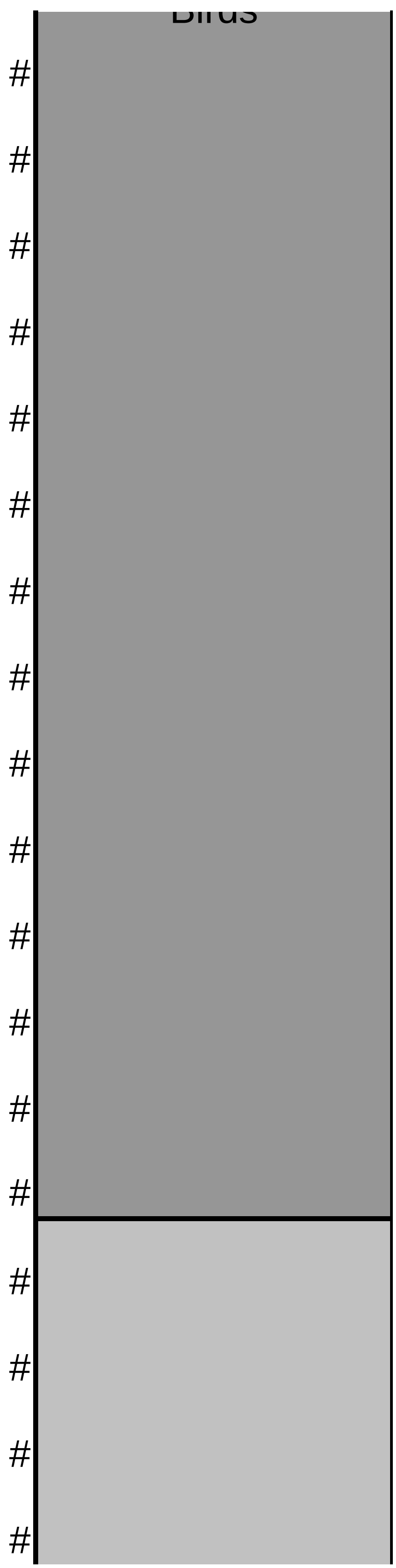
ɔecies is present in a county,
ɔserved, if the habitat with
xists. .
ılly change their distribution and
ıble habitat exists.

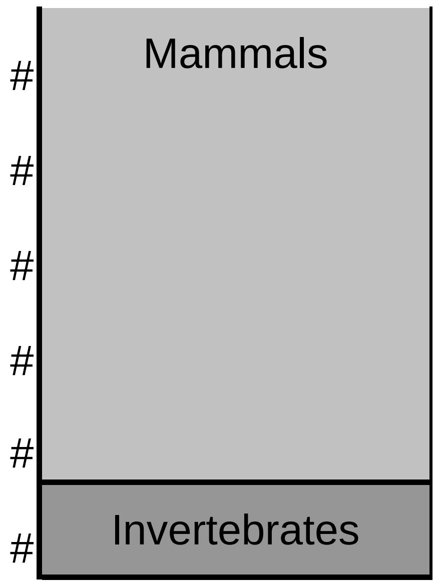
ıt were developed using the
ew information becomes
some species may expand or
review and update the the



1
2
5
9
#
#
#
#
#
#
#
#
#
#
#
#
Habitat
Fishes


Amphibians
Reptiles


Birds
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
Mammals
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Old-Growth/Mature Forest
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
White Sturgeon
Bull Trout/ Dolly Varden
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout
Westslope Cutthroat

Columbia Spotted Frog
Western Toad
Striped Whipsnake
Sagebrush Lizard
American White Pelican
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Tundra Swan
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Prairie Falcon
Dusky Grouse
Ring-necked Pheasant

Greater Sage-grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
Sandhill Crane
Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Flammulated Owl
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit

Washington Ground Squirrel
Bighorn Sheep
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater

State Status

Candidate *
Candidiate **

Candidate
Candidate
Candidate
Candidate
Endangered
Candidate
Threatened
Candidate

Threatened
Endangered
Endangered
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit list of species and habitats was found in the Priority Habitat and http://wdfw.wa.gov/conservation/ depict counties where each prior as other counties where habitat exists. Two assumptions were r maps for each species: 1) There is a high likelihood a sp has not been directly observed, associated exists. 2) Over time, species can natura to new counties where usable ha Distribution maps in the PHS Lis information available. As new in distribution for some species ma periodically review and update th
Threatened *	
Threatened **	

Species of Concern

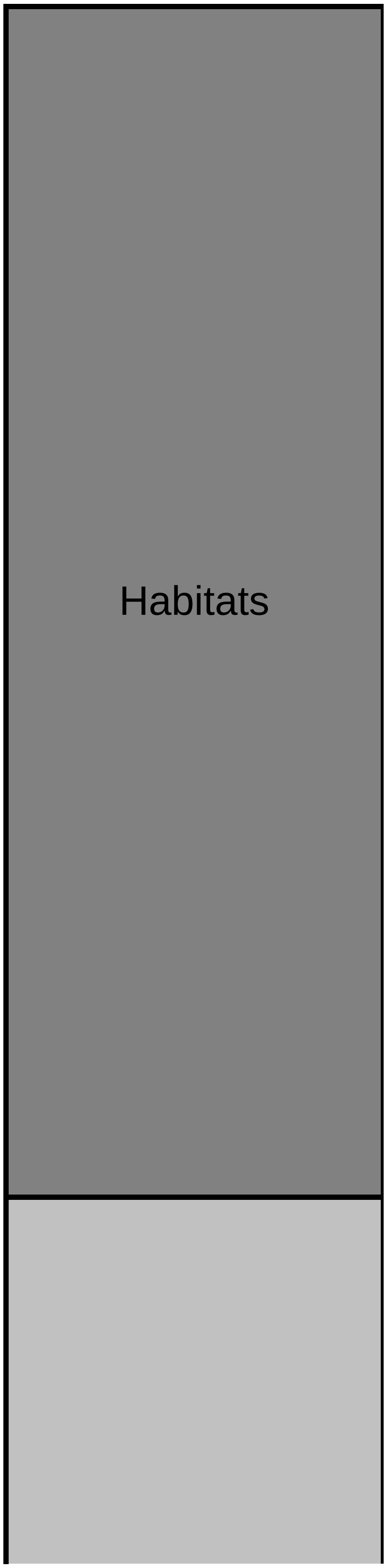
Candidate

ınt Note **

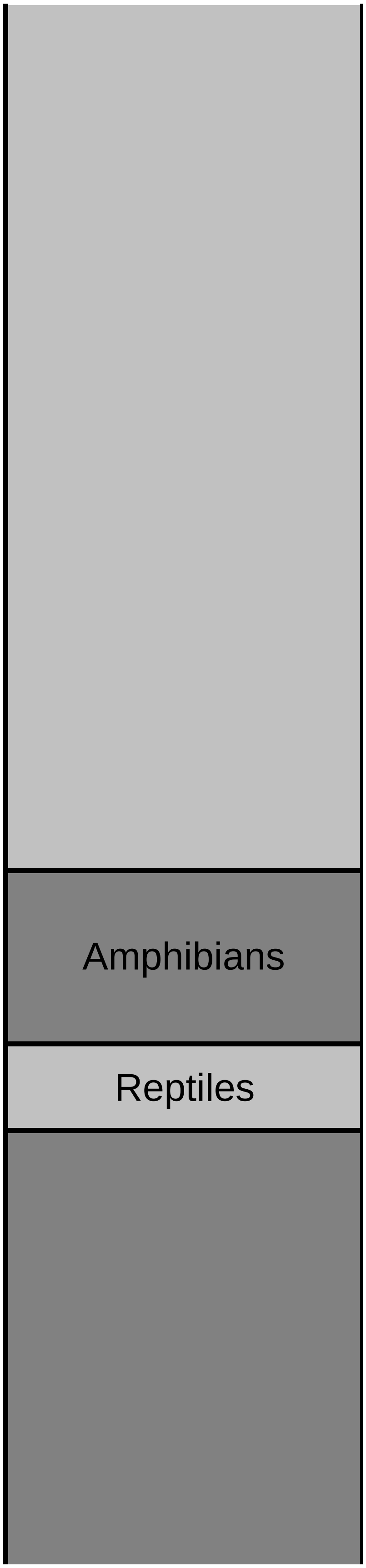
ıats identified for Lincoln County. This
developed using the distribution maps
Species (PHS) List (see
/phs/). Species distribution maps
rity species is known to occur as well
primarily associated with the species
nade when developing distribution

ɔecies is present in a county, even if it
if the habitat with which it is primarily
.
ılly change their distribution and move
ıbitat exists.

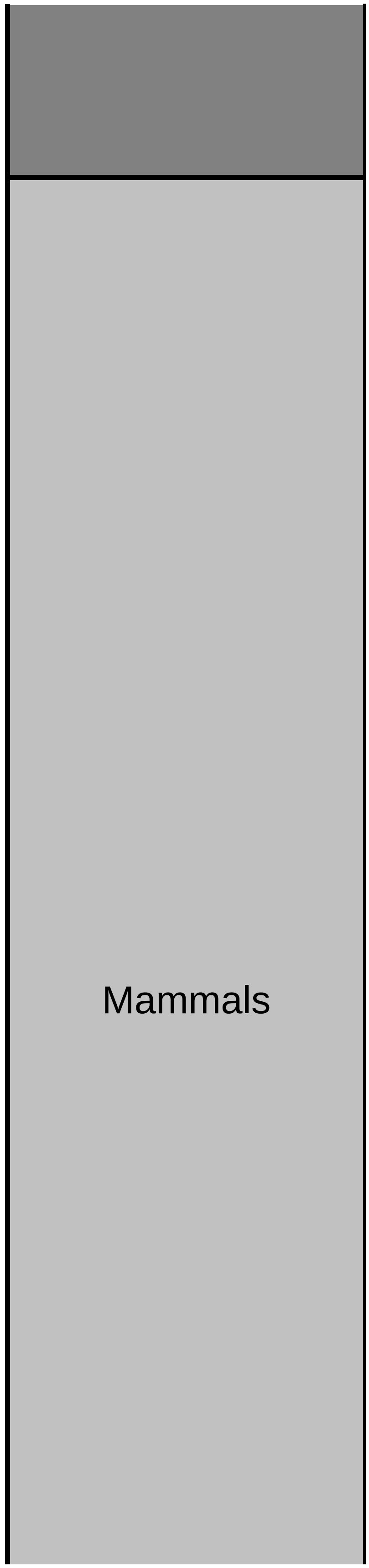
ıt were developed using the best
ıformation becomes available, known
ıy expand or contract. WDFW will
ıe the distribution maps in PHS list.

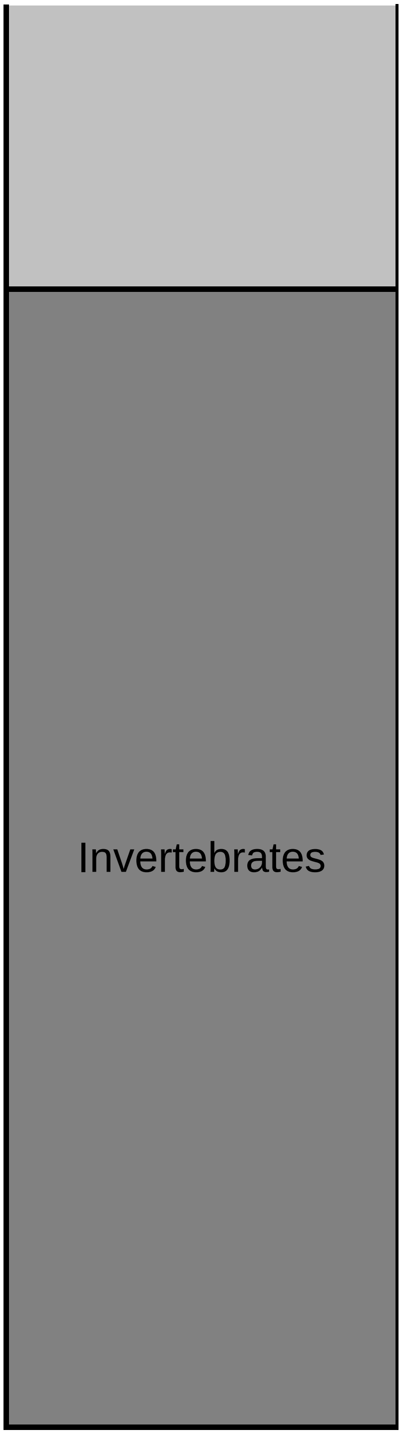

Habitats

Fishes


Amphibians
Reptiles

Birds


Mammals


Invertebrates

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Olympic Mudminnow

Pacific Herring
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Brown Rockfish
Canary Rockfish

Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Van Dyke's Salamander
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Common Loon
Marbled Murrelet
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids

Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Trumpeter Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
Wild Turkey
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Yellow-billed Cuckoo
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Oregon Vesper Sparrow

Pileated Woodpecker
Streaked Horned Lark
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Olympic Marmot
Mazama (Western) Pocket Gopher
Fisher
Marten
California Sea Lion
Harbor Seal
Steller (Northern) Sea Lion
Dall's Porpoise
Gray Whale
Humpback Whale
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)

Columbian Black-tailed Deer
Mountain Goat
Elk
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Beller's Ground Beetle
Johnson's Hairstreak
Puget Blue
Taylor's Checkerspot

State Status

Candidate
Sensitive

Candidiate
Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered
Sensitive
Threatened
Candidate

Candidate
Candidate
Endangered
Endangered
Candidate
Candidate

Candidate
Endangered
Candidate
Candidate
Candidate
Threatened
Endangered
Sensitive
Endangered
Endangered
Candidate

Candidate
Candidate
Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Status

** Importa

These are the species and habit
This list of species and habitats
distribution maps found in the Pr
List (see http://wdfw.wa.gov/con
distribution maps depict counties
known to occur as well as other
associated with the species exis
when developing distribution ma

1) There is a high likelihood a sp
even if it has not been directly ob
it is primarily associated exists.
2) Over time, species can natura
move to new counties where usa

Distribution maps in the PHS Lis
information available. As new in
known distribution for some spec
WDFW will periodically review a
maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Threatened

Threatened
Threatened

Species of Concern
Threatened
Threatened

Threatened
Threatened - glacialis, pugetensis, tumuli, yelmensis subspecies **Species of Concern** - couchi louiei, melanops subspecies
Species of Concern
Endangered
Endangered

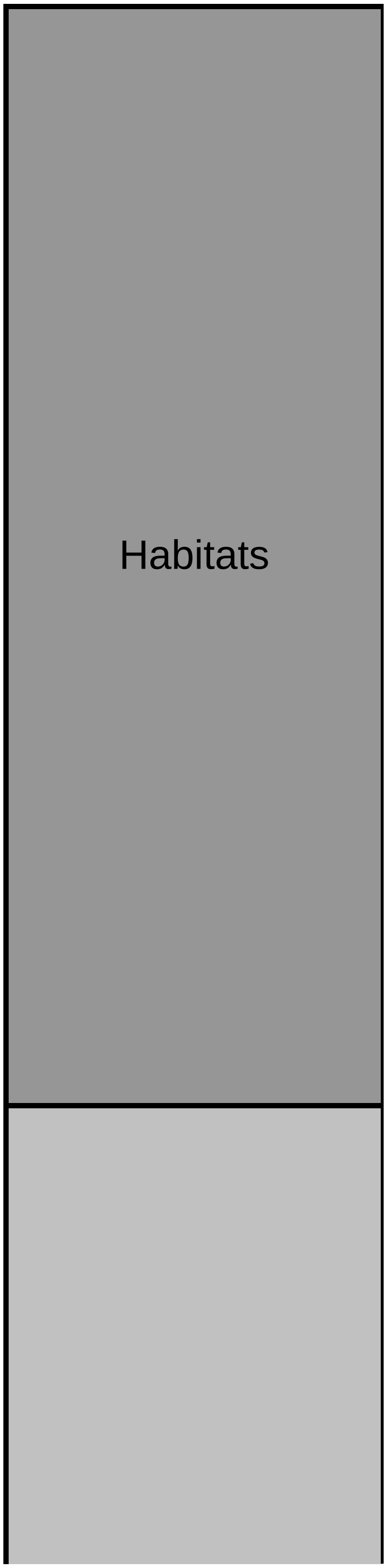
Endangered

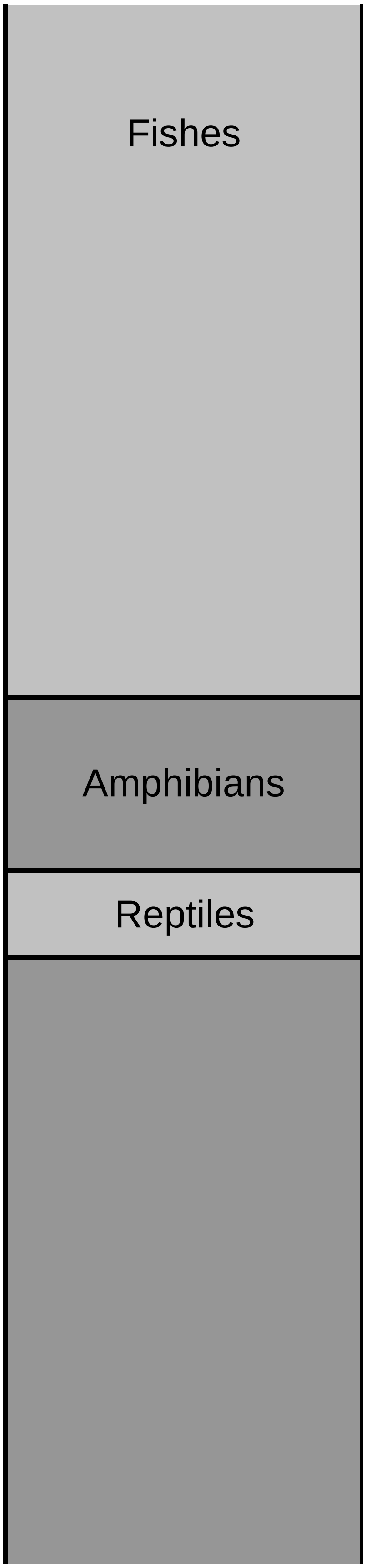
ant Note **

ats identified for Mason County.
was developed using the
riority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

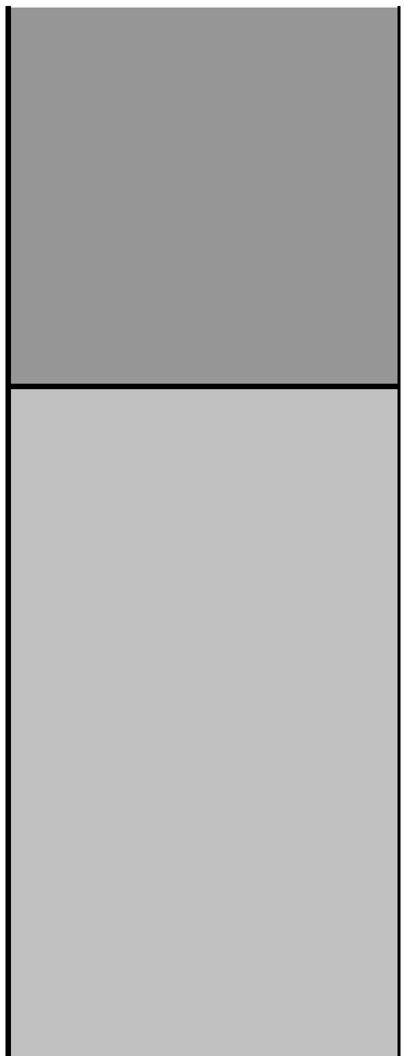
pecies is present in a county,
bserved, if the habitat with which
.
ally change their distribution and
able habitat exists.

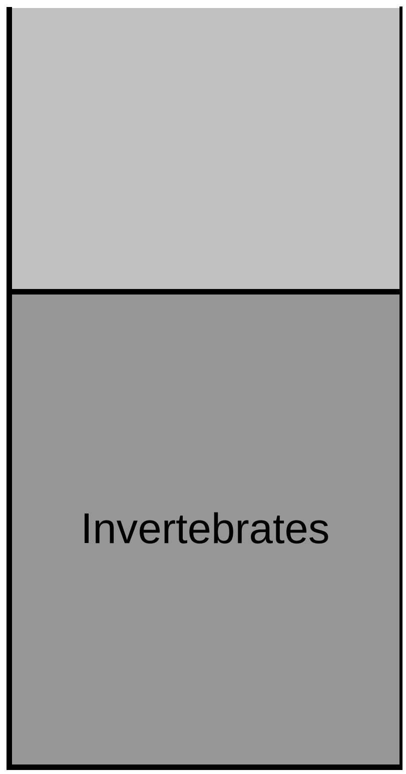
st were developed using the best
nformation becomes available,
cies may expand or contract.
nd update the the distribution


Habitats


Fishes
Amphibians
Reptiles

Birds


Mammals


Invertebrates

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Old-Growth/Mature Forest
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
White Sturgeon
Lake Chub
Leopard Dace
Umatilla Dace

Bull Trout/ Dolly Varden
Chinook Salmon
Coho Salmon
Kokanee
Pygmy Whitefish
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Western Toad
Sagebrush Lizard
Common Loon
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser

Harlequin Duck
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Prairie Falcon
Chukar
Dusky Grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
Greater Sage-grouse
Sooty Grouse
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Yellow-billed Cuckoo
Burrowing Owl
Flammulated Owl
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker

White-headed Woodpecker
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
White-tailed Jackrabbit
Western Gray Squirrel
Cascade Red Fox
Fisher
Gray Wolf
Grizzly Bear
Lynx
Marten
Wolverine
Bighorn Sheep
Moose
Mountain Goat

Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Shortface Lanx (formerly Giant Columbia River Limpet)
Columbia Pebblesnail
California Floater
Juniper Hairstreak
Silver-bordered Fritillary

State Status

Candidate
Candidate
Candidate

Candidate *
Candidate
Sensitive
Candidiate **
Candidate
Candidate
Candidate
Candidate
Sensitive
Candidate

Candidate
Candidate
Endangered
Threatened
Endangered
Candidate
Candidate
Endangered
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Endangered
Endangered
Endangered
Threatened
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only
*** Federally listed west of north-south line fol

Federal Status

** Im

These are the species a
County. This list of spec
the distribution maps fou
(PHS) List (see http://wc
distribution maps depict
known to occur as well a
associated with the spec
made when developing

1) There is a high likelih
even if it has not been d
it is primarily associated
2) Over time, species ca
move to new counties w

Distribution maps in the
information available. A
known distribution for sc
WDFW will periodically r
maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Species of Concern
Threatened
Threatened

Species of Concern
Endangered ***
Threatened
Threatened
Candidate

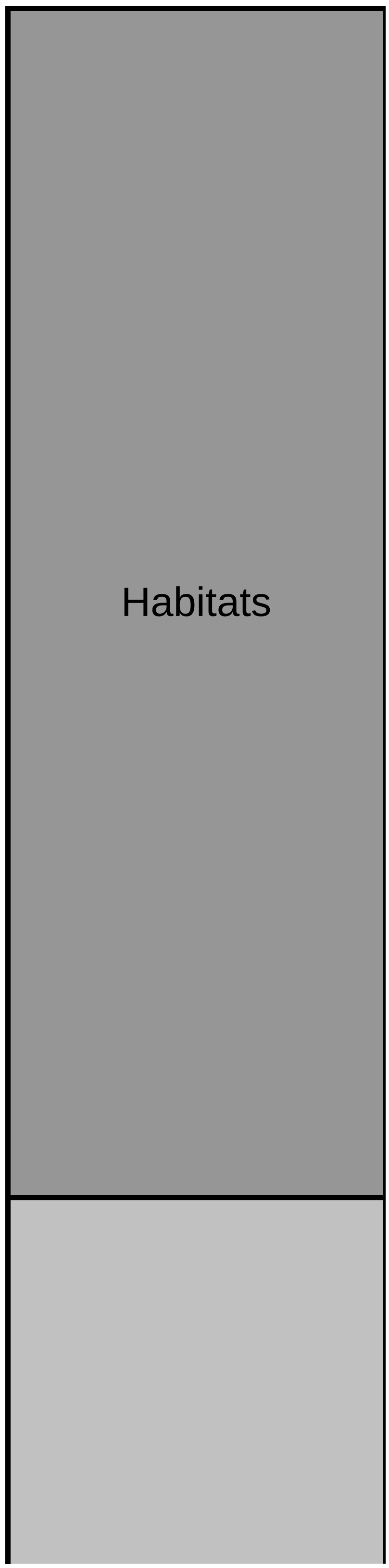
lowing Highways 97, 17, and 395.

ıportant Note **

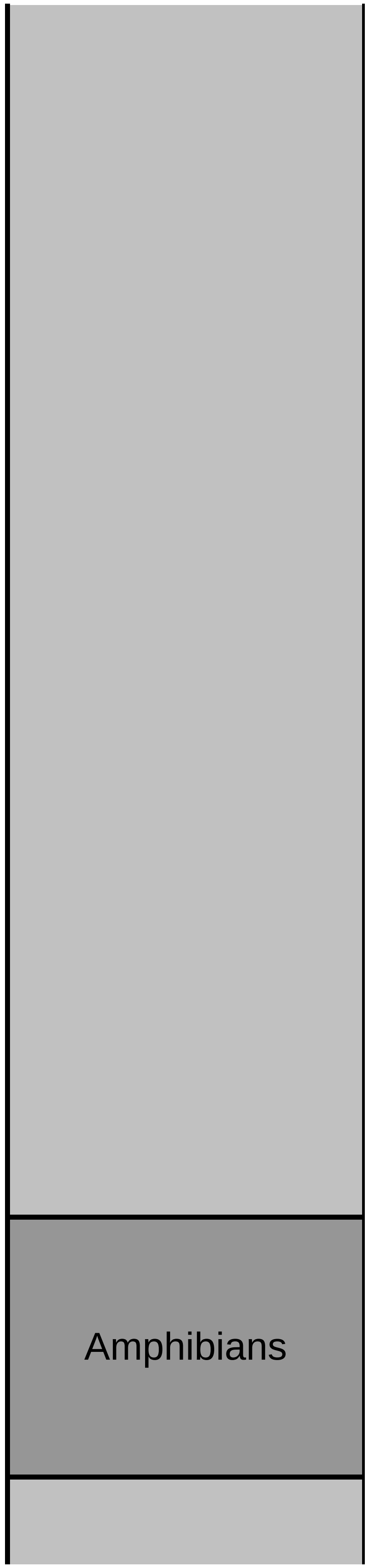
ınd habitats identified for Okanogan
:ies and habitats was developed using
ınd in the Priority Habitat and Species
lfw.wa.gov/conservation/phs/). Species
counties where each priority species is
ıs other counties where habitat primarily
:ies exists. Two assumptions were
distribution maps for each species:

ood a species is present in a county,
irectly observed, if the habitat with which
exists. .
ın naturally change their distribution and
here usable habitat exists.

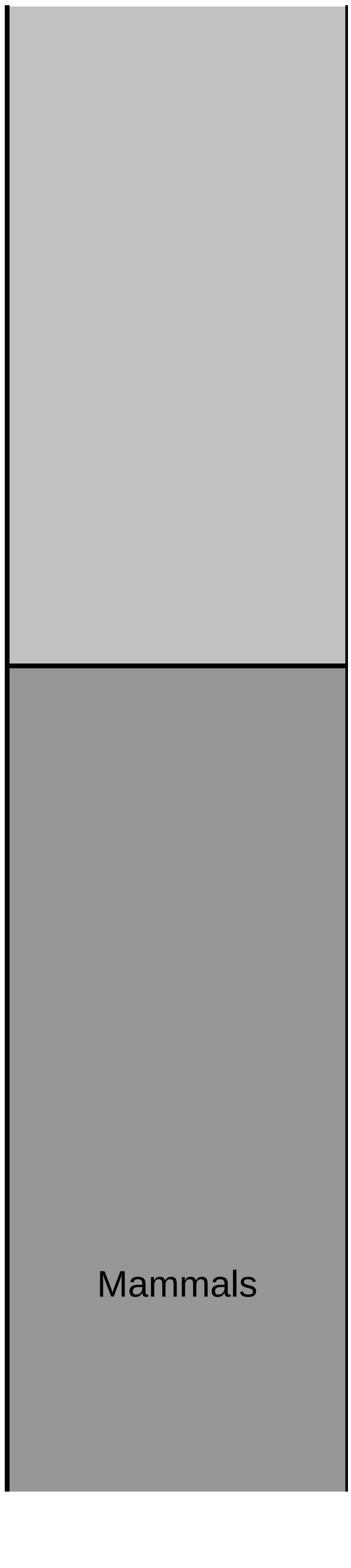
PHS List were developed using the best
s new information becomes available,
ıme species may expand or contract.
review and update the the distribution

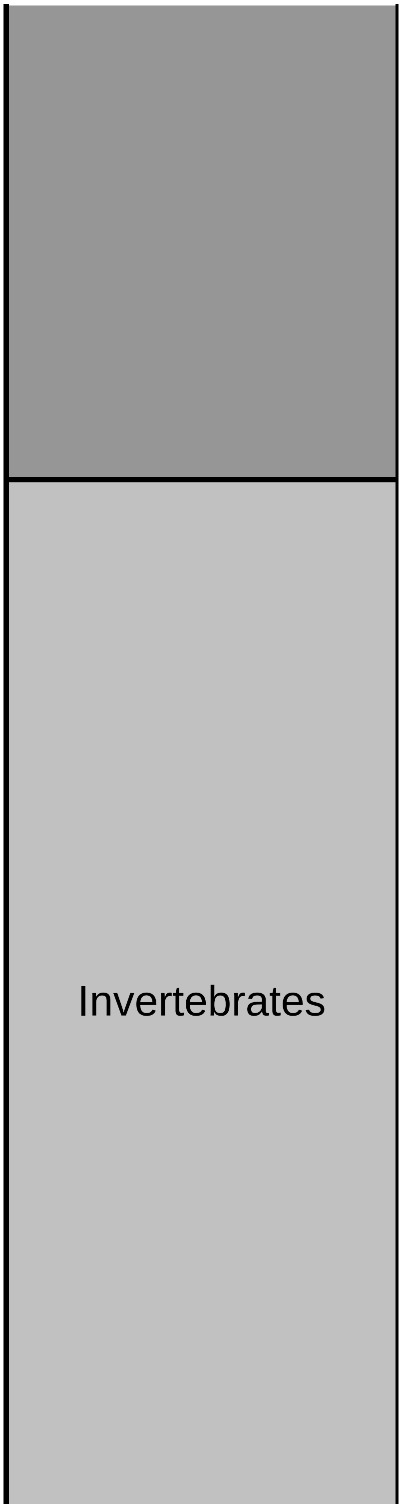

Habitats

Fishes


Amphibians

Birds


Mammals


Invertebrates

Species/ Habitats
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Open Coast Nearshore
Coastal Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
Green Sturgeon
White Sturgeon

Pacific Herring
Eulachon
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Bocaccio Rockfish
Brown Rockfish

Canary Rockfish
China Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Tiger Rockfish
Widow Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Dunn's Salamander
Van Dyke's Salamander
Western Toad
Brown Pelican

Common Loon
Marbled Murrelet
Short-tailed Albatross
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
Wild Turkey

Western Snowy Plover (formerly called Snowy Plover)
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux's Swift
Pileated Woodpecker
Oregon Vesper Sparrow
Streaked Horned Lark
Dall's Porpoise
Blue Whale
Humpback Whale
Gray Whale
Sperm Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
California Sea Lion
Steller (Northern) Sea Lion

Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Marten
Columbian Black-tailed Deer
Elk
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Pacific Razor Clam (formerly Razor Clam)
Dungeness Crab
Pandalid shrimp (Pandalidae)
Makah Copper (formerly Queen Charlotte's Copper)
Oregon Silverspot (formerly Oregon Silverspot Butterfly)
Red Sea Urchin (formerly Red Urchin)

State Status

Candidate

Candidate
Candidate
Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Sensitive
Threatened
Candidate
Candidate
Candidate
Candidate

Endangered
Endangered
Candidate
Candidate
Candidate
Endangered
Endangered
Endangered
Sensitive
Endangered
Endangered
Candidate

Candidate
Candidate
Candidate
Threatened

* Bull Trout only
** Steelhead only

Federal Status	** Import
	These are the species and habit This list of species and habitats distribution maps found in the Pr List (see http://wdfw.wa.gov/con distribution maps depict counties known to occur as well as other associated with the species exis when developing distribution ma 1) There is a high likelihood a sp if it has not been directly observe primarily associated exists. . 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.
Threatened	

Threatened
Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Endangered

Threatened

Threatened

Threatened
Endangered

Threatened
Threatened
Threatened
Endangered
Endangered
Endangered
Endangered

Endangered

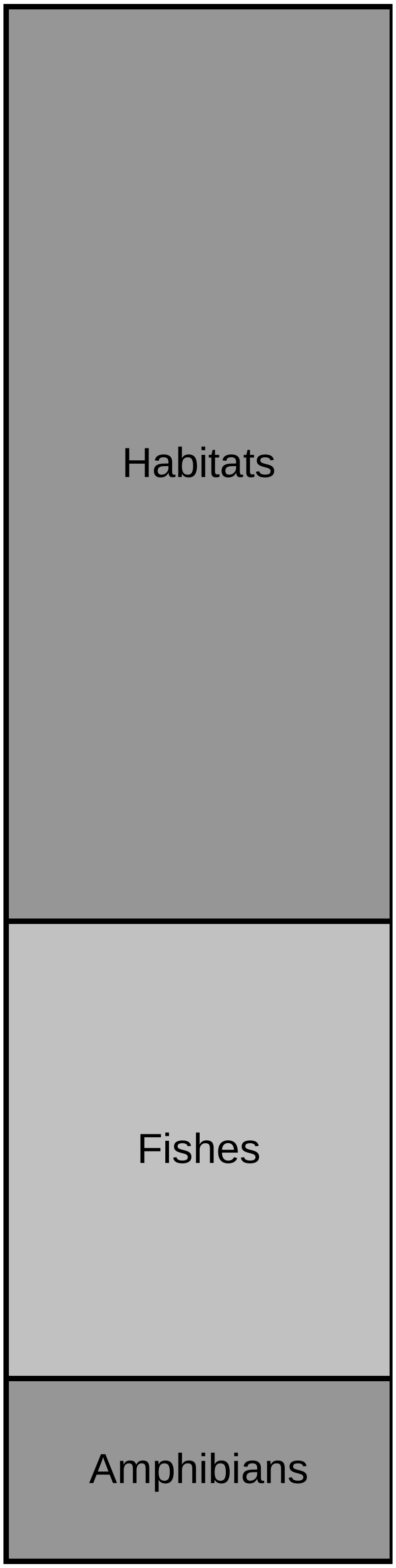
ant Note **

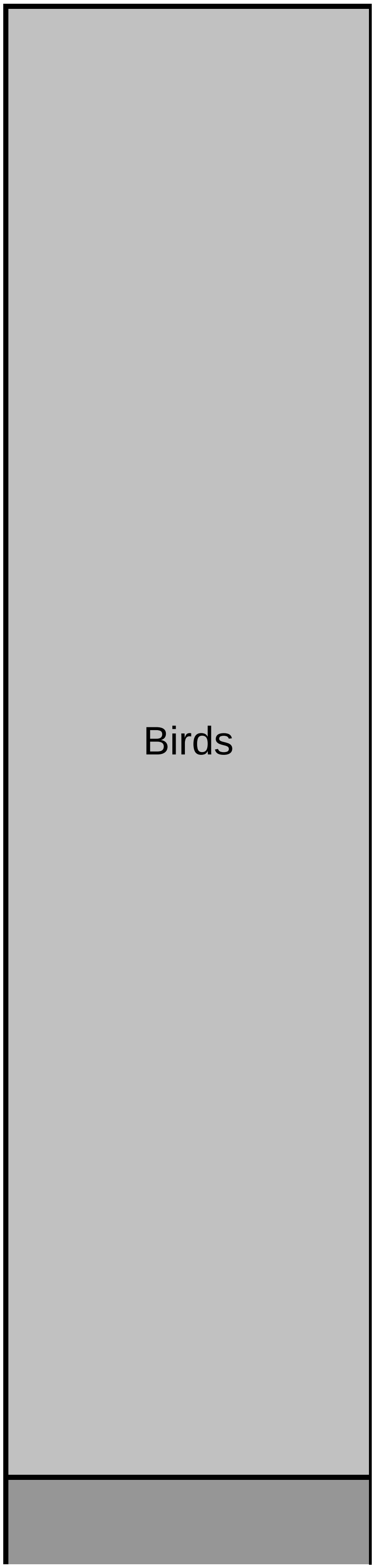
ats identified for Pacific County.
was developed using the
iority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

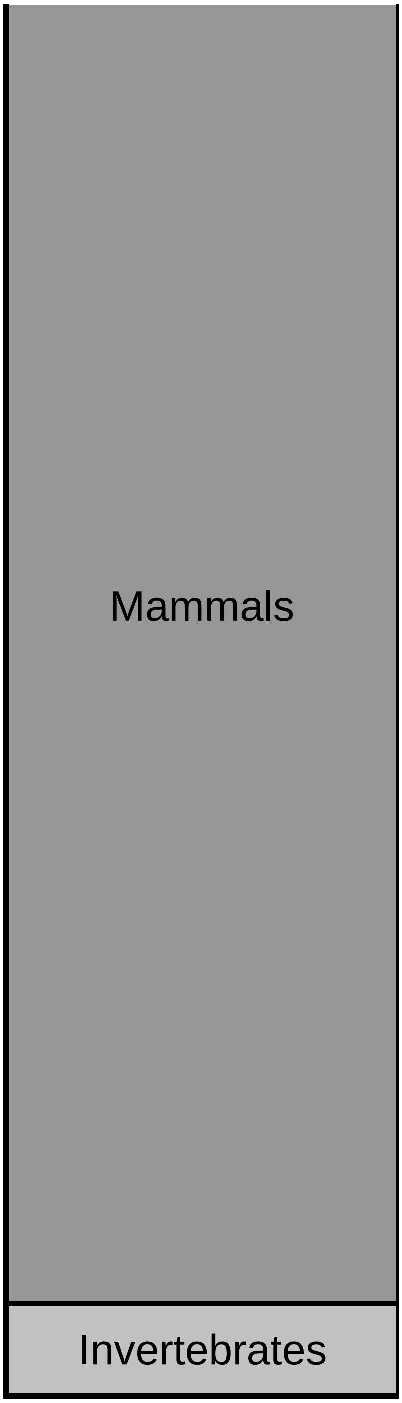
ecies is present in a county, even
ed, if the habitat with which it is

lly change their distribution and
able habitat exists.

t were developed using the best
formation becomes available,
cies may expand or contract.
nd update the the distribution


Habitats
Fishes
Amphibians


Birds


Mammals
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Old-Growth/Mature Forest
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Bull Trout/ Dolly Varden
Kokanee
Pygmy Whitefish
Rainbow Trout/ Steelhead/ Inland Redband Trout
Westslope Cutthroat
Columbia Spotted Frog
Western Toad

American White Pelican
Common Loon
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Harlequin Duck
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Dusky Grouse
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Flammulated Owl
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat

Townsend’s Big-eared Bat
Fisher
Gray Wolf
Grizzly Bear
Lynx
Marten
Wolverine
Bighorn Sheep
Moose
Mountain Goat
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Woodland Caribou
Silver-bordered Fritillary

State Status

Candidate *
Sensitive
Candidiate **
Candidate
Candidate

Endangered
Sensitive
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Endangered
Endangered
Endangered
Threatened
Candidate
Endangered
Candidate

* Bull Trout only
** Steelhead only
*** Federally listed west of north-south line foll

Federal Status	** Im
	These are the species a County. This list of spec the distribution maps fou (PHS) List (see http://wc distribution maps depict known to occur as well a associated with the spec made when developing 1) There is a high likelih even if it has not been d which it is primarily asso 2) Over time, species ca move to new counties w Distribution maps in the information available. A known distribution for sc WDFW will periodically r maps in PHS list.
Threatened *	
Threatened **	

Species of Concern
Endangered ***
Threatened
Threatened
Candidate
Endangered

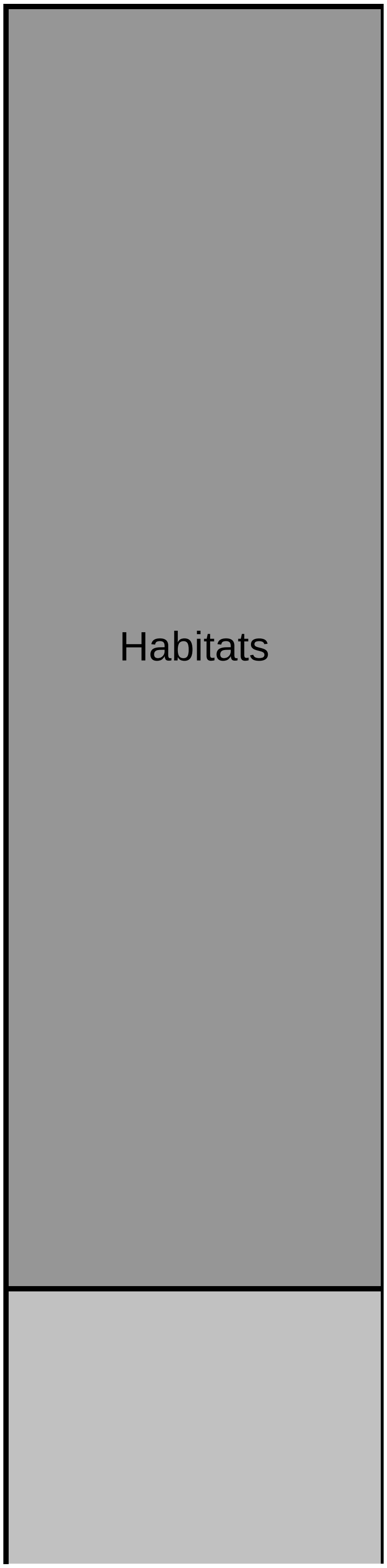
owing Highways 97, 17, and 395.

ıportant Note **

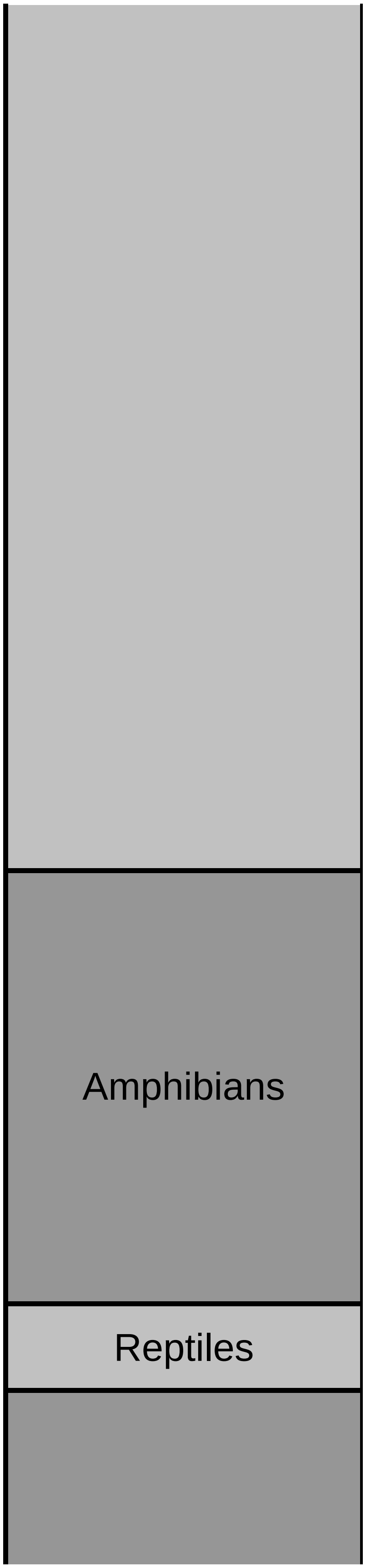
ınd habitats identified for Pend Oreille
:ies and habitats was developed using
ınd in the Priority Habitat and Species
dfw.wa.gov/conservation/phs/). Species
counties where each priority species is
ıs other counties where habitat primarily
:ies exists. Two assumptions were
distribution maps for each species:

ood a species is present in a county,
irectly observed, if the habitat with
ɔciated exists. .
ın naturally change their distribution and
here usable habitat exists.

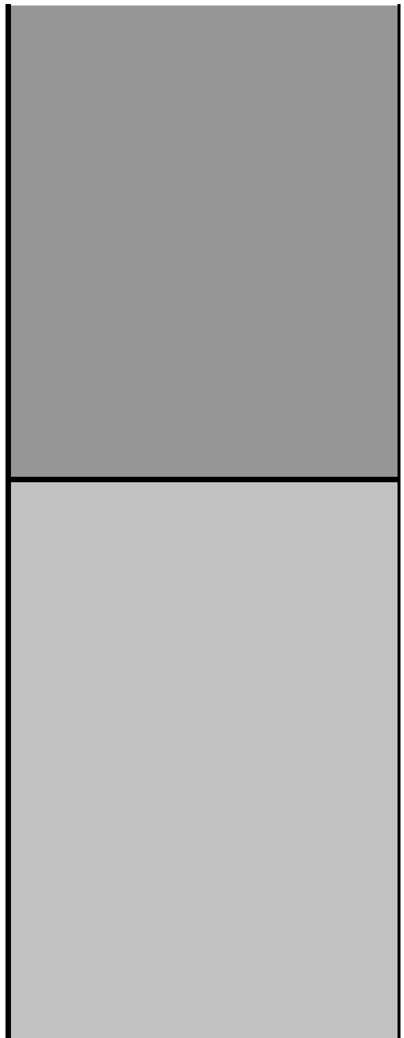
PHS List were developed using the best
s new information becomes available,
ɔme species may expand or contract.
review and update the the distribution

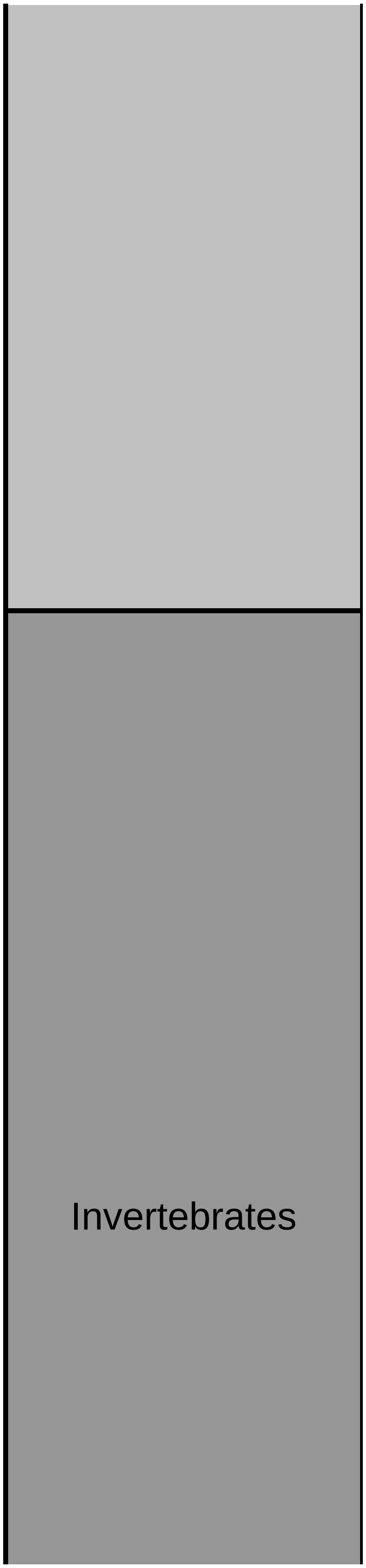

Habitats

Fishes


Amphibians
Reptiles

Birds


Mammals


Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon

Pacific Herring
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Bocaccio Rockfish
Brown Rockfish

Canary Rockfish
Copper Rockfish
Quillback Rockfish
Redstripe Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Cascade Torrent Salamander
Larch Mountain Salamander
Van Dyke's Salamander
Oregon Spotted Frog
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Common Loon
Marbled Murrelet

Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Yellow-billed Cuckoo
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift

Black-backed Woodpecker
Pileated Woodpecker
Oregon Vesper Sparrow
Slender-billed White-breasted Nuthatch
Streaked Horned Lark
Dall's Porpoise
Gray Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
California Sea Lion
Steller (Northern) Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Townsend’s Big-eared Bat
Western Gray Squirrel
Mazama (Western) Pocket Gopher

Cascade Red Fox
Fisher
Marten
Wolverine
Columbian Black-tailed Deer
Mountain Goat
Elk
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Pacific Clubtail
Johnson's Hairstreak
Mardon Skipper

Puget Blue
Valley Silverspot
Taylor's Checkerspot

State Status

Candidate

Candidate
Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Sensitive
Candidate
Endangered
Candidate
Endangered
Sensitive
Threatened

Candidate
Candidate
Candidate
Endangered
Threatened
Candidate

Candidate
Candidate
Candidate
Candidate
Endangered
Sensitive
Endangered
Candidate
Candidate
Candidate
Threatened
Threatened

Candidate
Endangered
Candidate
Candidate
Candidate
Candidate
Endangered

Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Status

** Importan

These are the species and habit
This list of species and habitats
distribution maps found in the Pr
List (see http://wdfw.wa.gov/con
distribution maps depict countie
known to occur as well as other
associated with the species exis
made when developing distributi

1) There is a high likelihood a sp
even if it has not been directly o
it is primarily associated exists.
2) Over time, species can natura
move to new counties where usa

Distribution maps in the PHS Lis
information available. As new in
known distribution for some spe
WDFW will periodically review a
maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Endangered

Threatened
Threatened
Threatened
Threatened

Threatened
Endangered

Threatened
Endangered
Threatened - glacialis, pugetensis, tumuli, yelmensis subspecies **Species of Concern** - couchi louiei, melanops subspecies

Species of Concern

Candidate

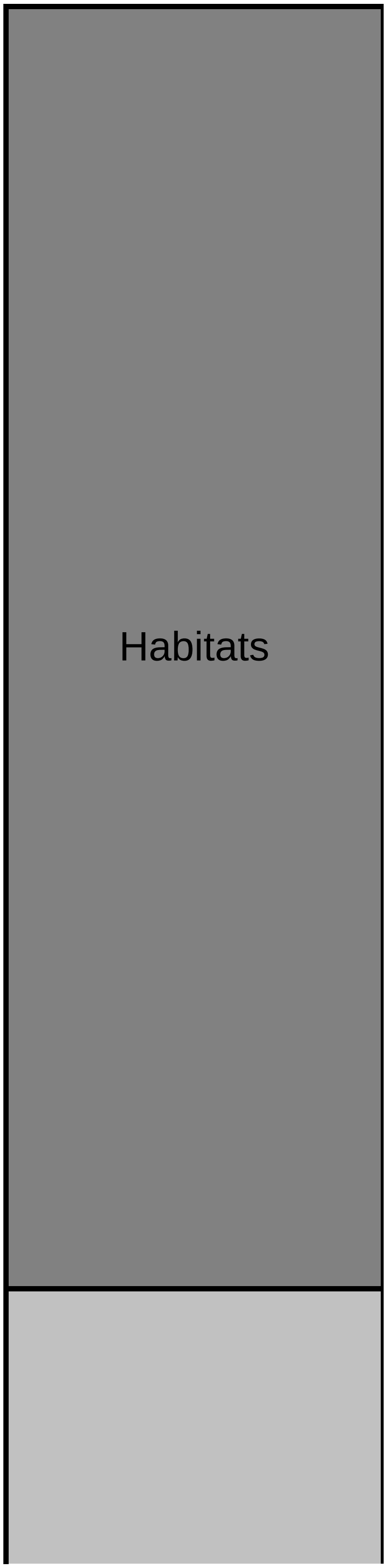
Endangered

t Note **

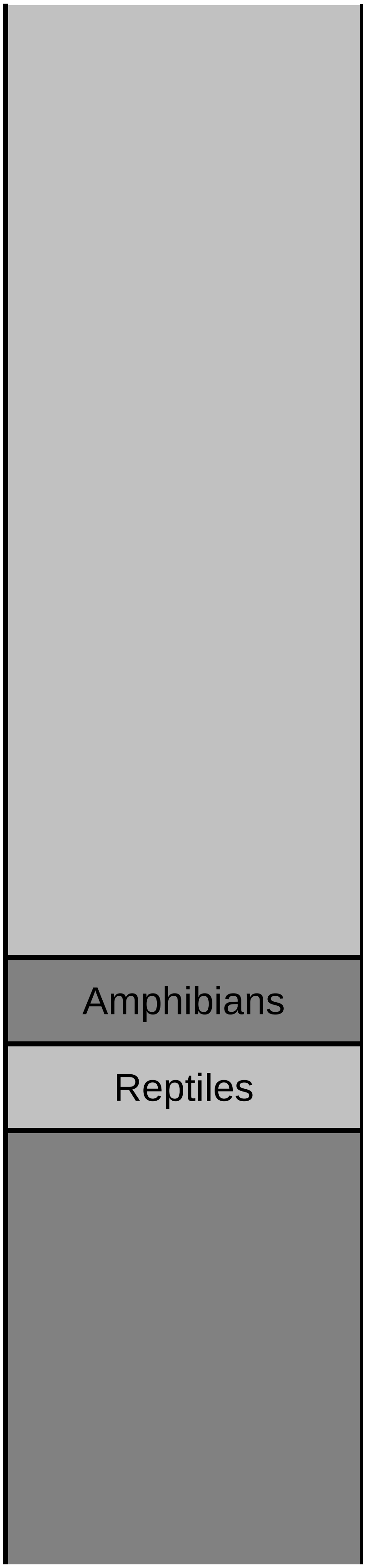
ats identified for Pierce County.
was developed using the
iority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were
on maps for each species:

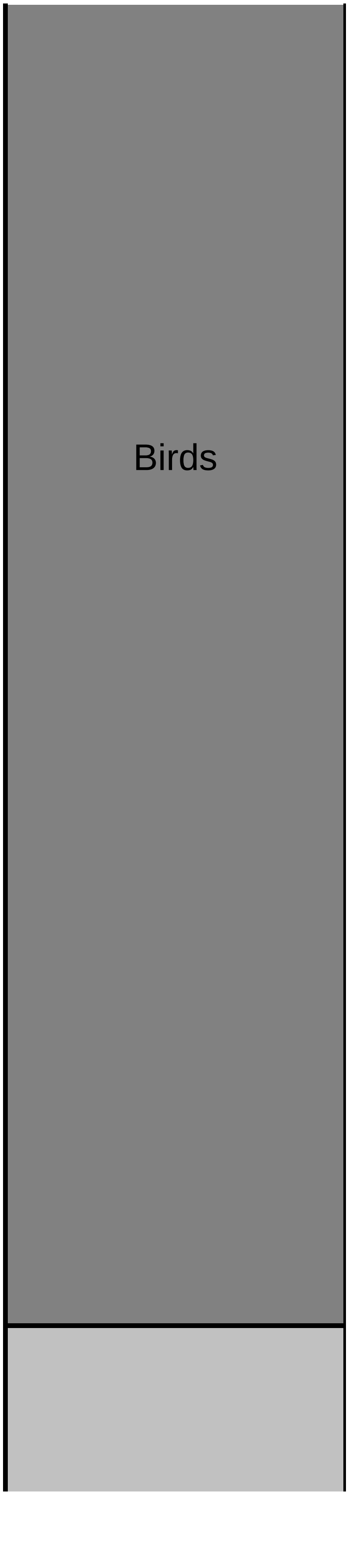
ecies is present in a county,
served, if the habitat with which
.
lly change their distribution and
able habitat exists.

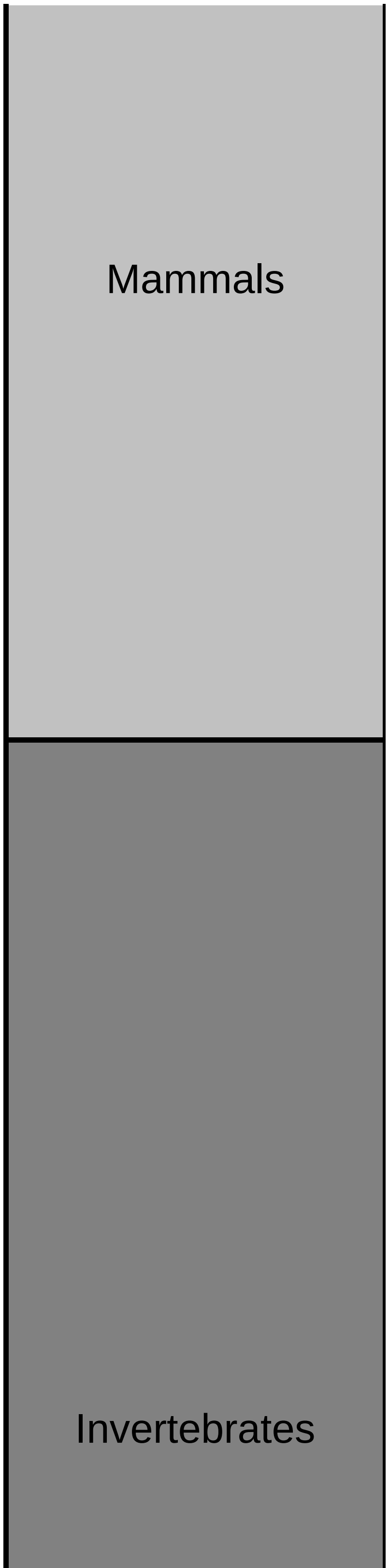
t were developed using the best
formation becomes available,
cies may expand or contract.
nd update the the distribution

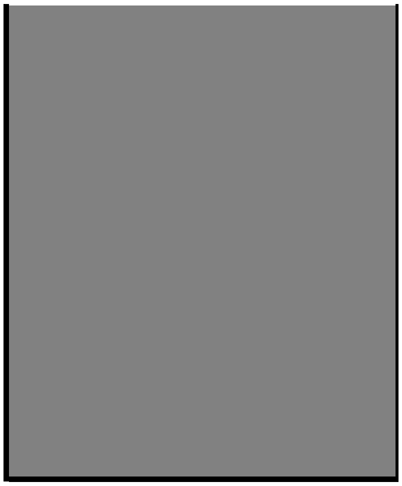

Habitats

Fishes


Amphibians
Reptiles


Birds


Mammals
Invertebrates



Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
White Sturgeon
Pacific Herring
Longfin Smelt

Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Brown Rockfish
Canary Rockfish
China Rockfish
Copper Rockfish

Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Tiger Rockfish
Widow Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Western Toad
Sharp-tailed Snake (formerly Common Sharptail Snake)
Cassin's Auklet
Marbled Murrelet
Short-tailed Albatross
Tufted Puffin
Western grebe

W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Trumpeter Swan
Waterfowl Concentrations
Golden Eagle
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Vaux’s Swift
Pileated Woodpecker
Oregon Vesper Sparrow
Dall's Porpoise
Gray Whale

Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
Steller (Northern) Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Columbian Black-tailed Deer
Pinto (Northern) Abalone
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Great Arctic

Island Marble
Sand-verbena Moth
Valley Silverspot
Taylor's Checkerspot
Red Sea Urchin (formerly Red Urchin)

State Status

Candidate

Candidate *
Candidate
Candidate
Candididate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Endangered
Candidate

Candidate
Candidate
Candidate
Candidate
Sensitive

Endangered
Candidate
Candidate
Candidate
Endangered
Candidate
Candidate

Candidate
Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Status	** Importan
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict countie known to occur as well as other associated with the species exis made when developing distributi 1) There is a high likelihood a sp even if it has not been directly o which it is primarily associated e . 2) Over time, species can natura move to new counties where us Distribution maps in the PHS Lis best information available. As n available, known distribution for contract. WDFW will periodically distribution maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Threatened

Threatened
Threatened
Endangered

Endangered

Species of Concern

Endangered
Endangered

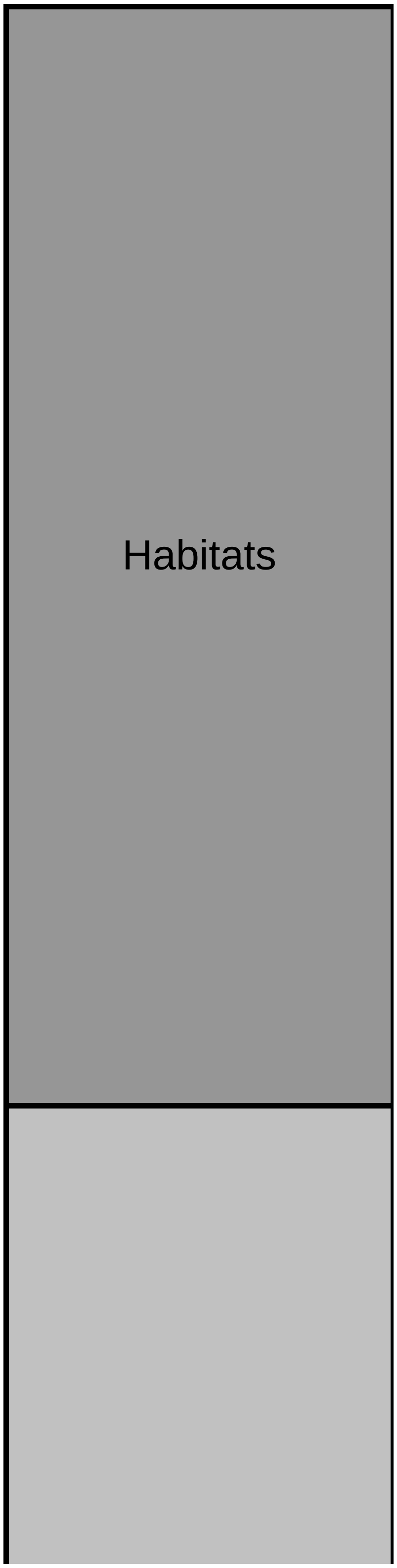
t Note **

ats identified for San Juan
habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were
on maps for each species:

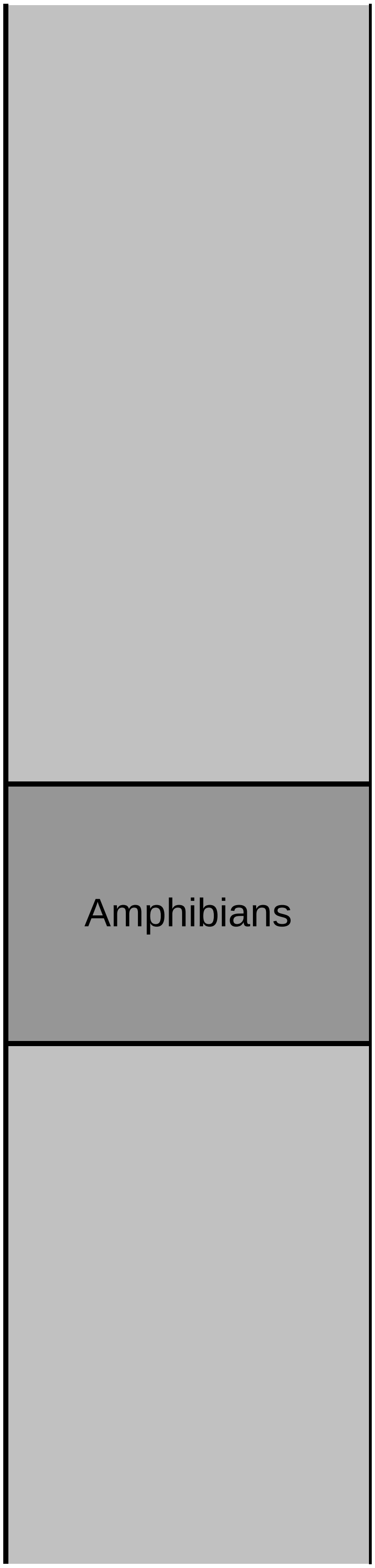
ecies is present in a county,
oserved, if the habitat with
xists.

ally change their distribution and
able habitat exists.

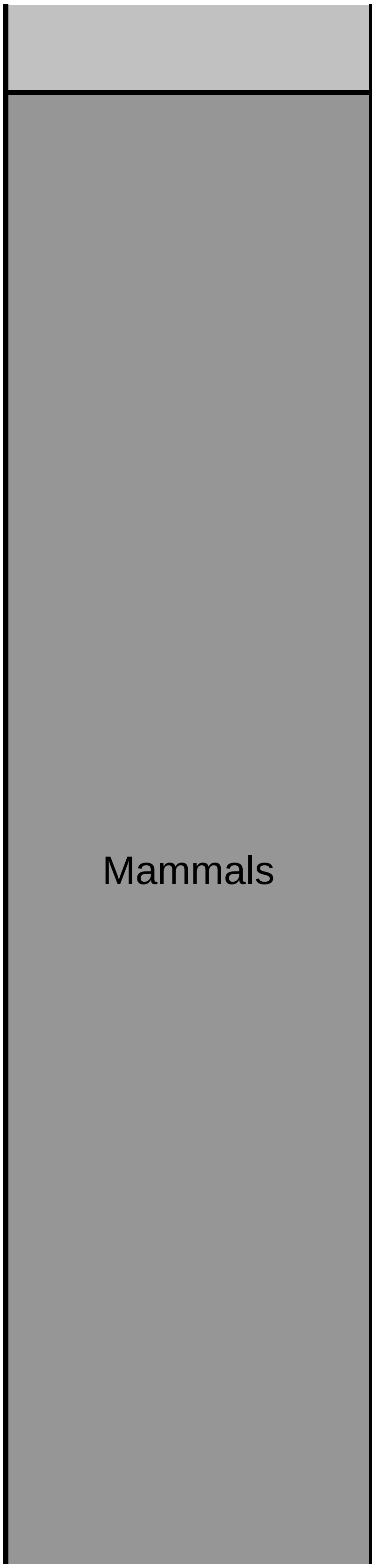
t were developed using the
ew information becomes
some species may expand or
review and update the the

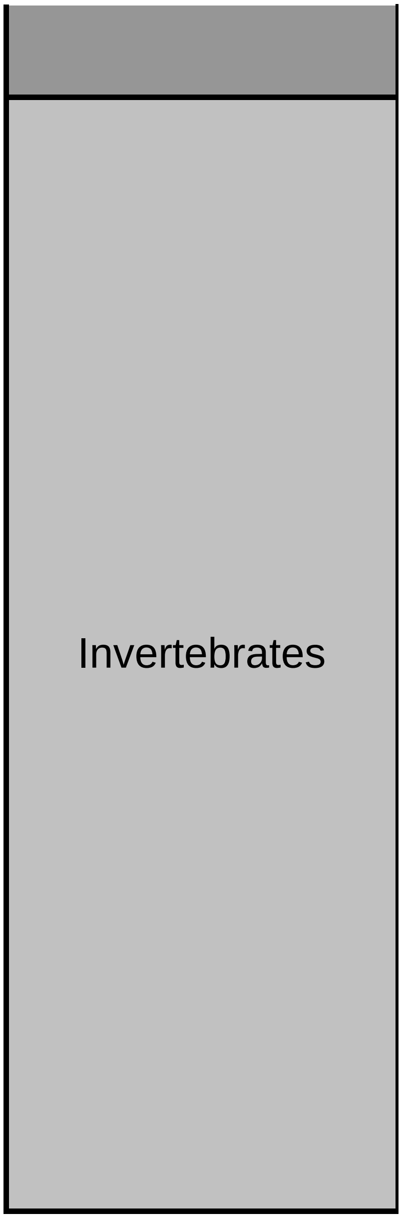

Habitats

Fishes


Amphibians

Birds


Mammals


Invertebrates

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Pacific Herring
Longfin Smelt

Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Brown Rockfish
Canary Rockfish
China Rockfish
Copper Rockfish

Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Tiger Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Columbia Spotted Frog
Oregon Spotted Frog
Western Toad
Common Loon
Marbled Murrelet
Short-tailed Albatross
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids

Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Snow Goose
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker

Oregon Vesper Sparrow
Dall's Porpoise
Gray Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Cascade Red Fox
Fisher
Gray Wolf
Grizzly Bear
Lynx
Marten
Wolverine
Columbian Black-tailed Deer
Mountain Goat

Elk
Pinto (Northern) Abalone
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Johnson's Hairstreak
Valley Silverspot
Red Sea Urchin (formerly Red Urchin)

State Status

Candidate
Candidate

Candidate *
Candidate
Candidate
Candidate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered
Candidate
Sensitive
Threatened
Candidate
Candidate

Candidate
Candidate
Endangered
Candidate
Candidate
Candidate

Candidate
Sensitive
Endangered
Candidate
Candidate
Candidate
Candidate
Endangered
Endangered
Endangered
Threatened
Candidate

Endangered
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Im
	These are the species a This list of species and h distribution maps found List (see http://wdfw.wa. distribution maps depict known to occur as well a associated with the spec when developing distribu 1) There is a high likeliho it has not been directly o primarily associated exis . 2) Over time, species ca move to new counties w Distribution maps in the information available. A known distribution for so WDFW will periodically r in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Threatened

Threatened
Threatened
Endangered

Threatened

Endangered
Species of Concern
Endangered
Threatened
Threatened
Candidate

Species of Concern

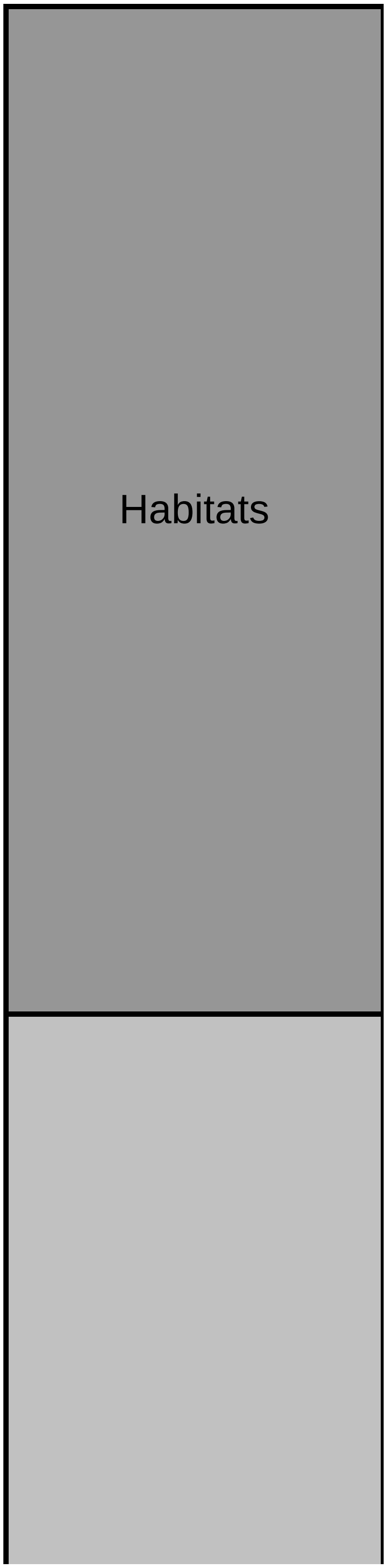
ıportant Note **

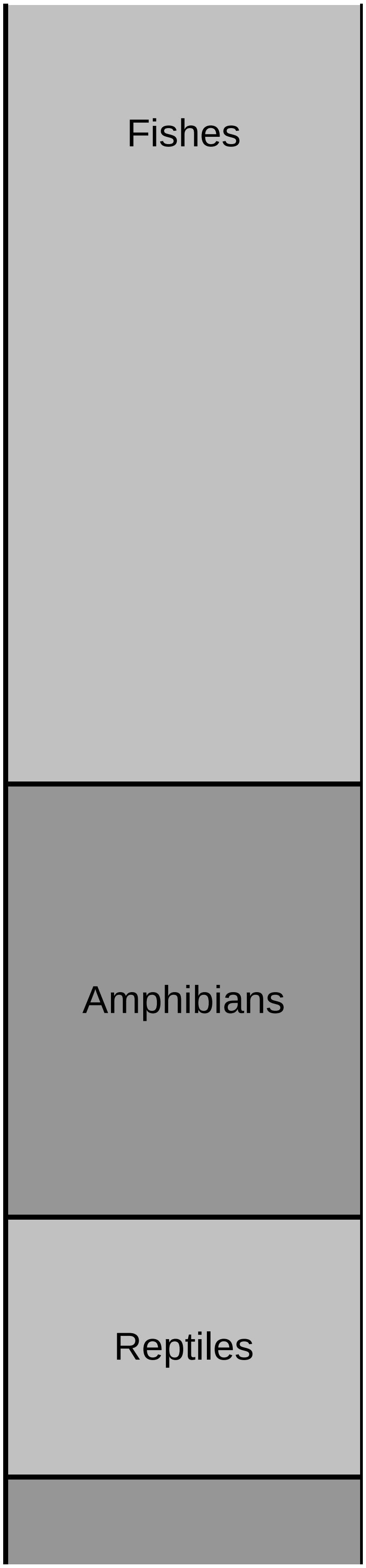
ınd habitats identified for Skagit County.
ıabitats was developed using the
in the Priority Habitat and Species (PHS)
gov/conservation/phs/). Species
counties where each priority species is
ıs other counties where habitat primarily
cies exists. Two assumptions were made
ıtion maps for each species:

ood a species is present in a county, even if
ıbserved, if the habitat with which it is
sts.

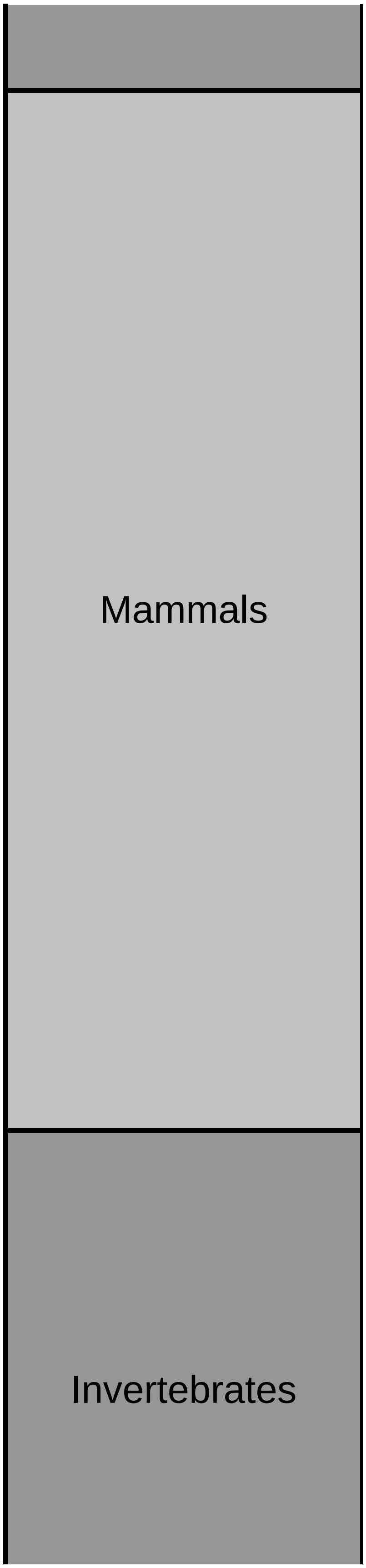
ın naturally change their distribution and
here usable habitat exists.

PHS List were developed using the best
s new information becomes available,
ıme species may expand or contract.
review and update the the distribution maps


Habitats


Fishes
Amphibians
Reptiles

Birds


Mammals
Invertebrates

Species/ Habitats
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
Green Sturgeon
White Sturgeon
Leopard Dace
Mountain Sucker

Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Cascade Torrent Salamander
Larch Mountain Salamander
Van Dyke's Salamander
Oregon Spotted Frog
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
California Mountain Kingsnake
Sharp-tailed Snake (formerly Common Sharptail Snake)
Western grebe

Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Mountain Quail
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Flammulated Owl
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker

Slender-billed White-breasted Nuthatch
California Sea Lion
Steller (Northern) Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Western Gray Squirrel
Cascade Red Fox
Fisher
Marten
Wolverine
Columbian Black-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Columbia Oregonian
Columbia River Tiger Beetle
Pacific Clubtail
Chinquapin Hairstreak
Johnson's Hairstreak

Mardon Skipper

State Status

Candidate
Candidate
Candidate

Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Sensitive
Candidate
Endangered
Candidate
Endangered
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Threatened
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Endangered

* Bull Trout only
** Steelhead only

Federal Status	** Import
	These are the species and habit County. This list of species and distribution maps found in the Pr List (see http://wdfw.wa.gov/con: distribution maps depict counties known to occur as well as other associated with the species exis when developing distribution ma 1) There is a high likelihood a sp if it has not been directly observe primarily associated exists. 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.
Threatened	

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Threatened

Threatened

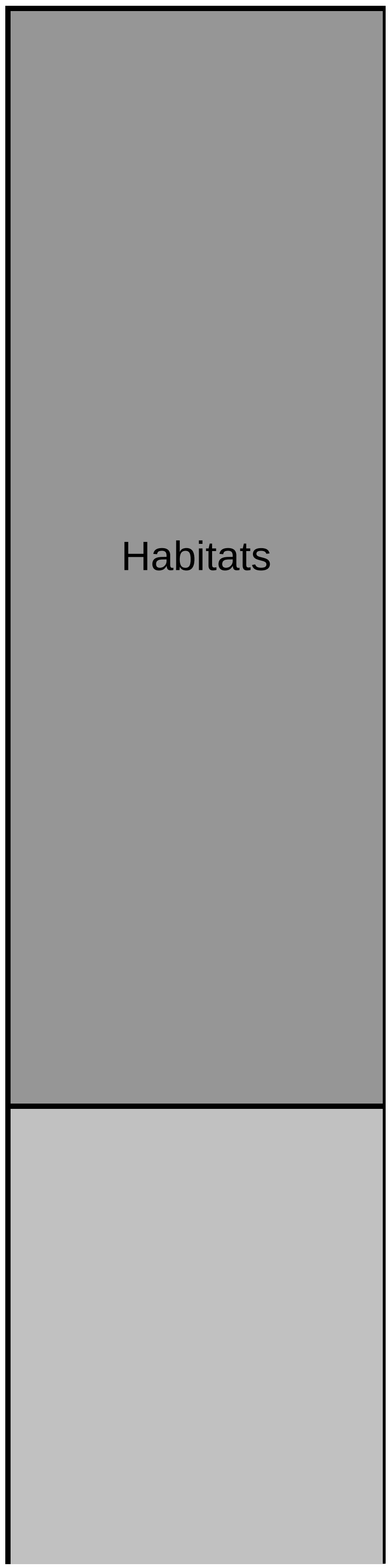
Species of Concern
Candidate

ant Note **

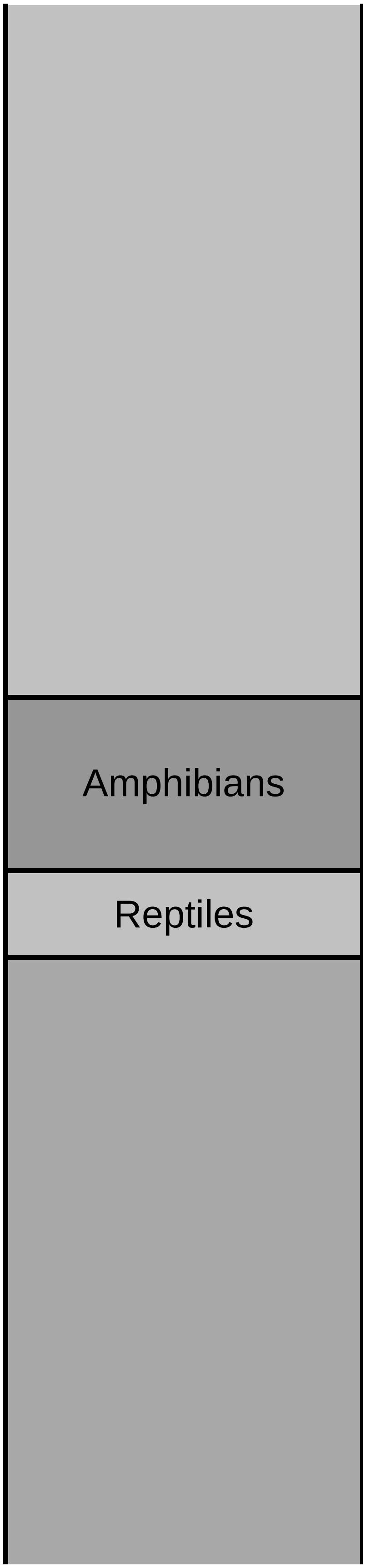
ats identified for Skamania
habitats was developed using the
iority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

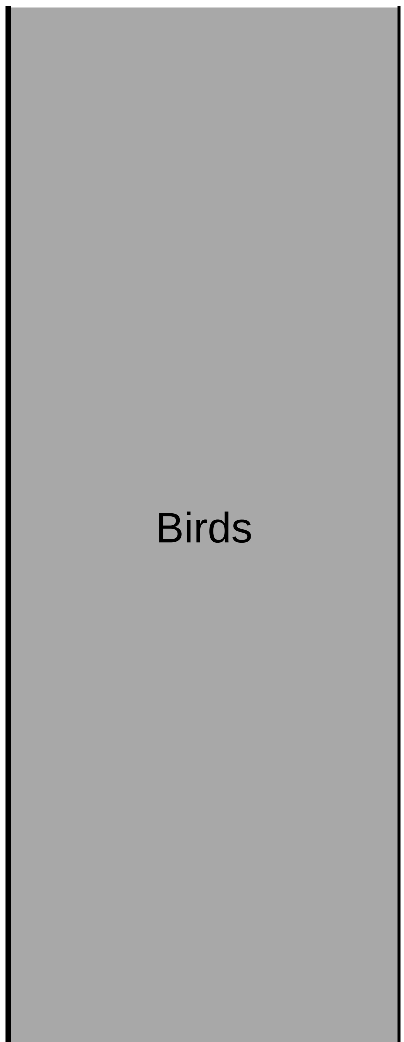
ecies is present in a county, even
ed, if the habitat with which it is
.
ally change their distribution and
able habitat exists.

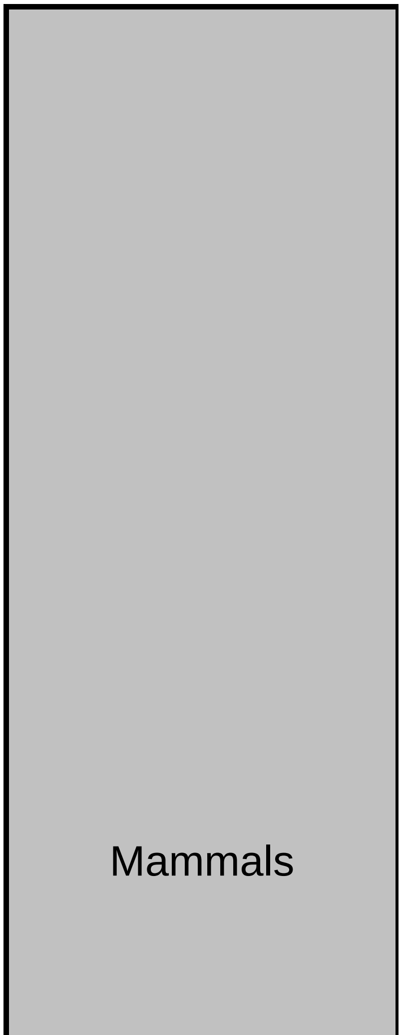
t were developed using the best
formation becomes available,
cies may expand or contract.
nd update the the distribution

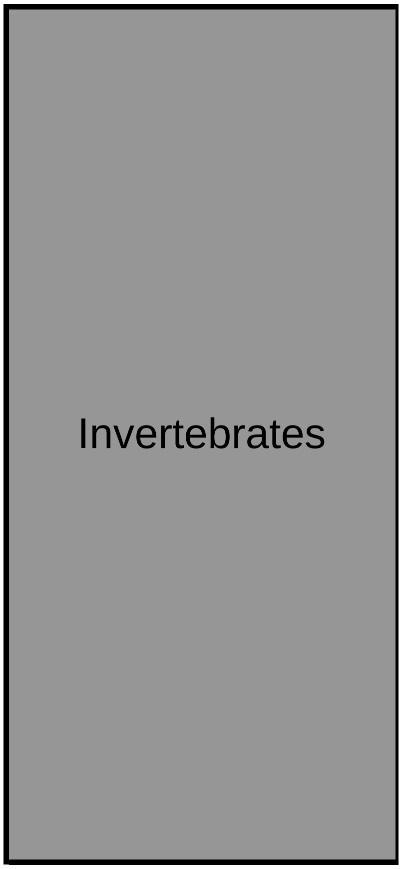

Habitats

Fishes


Amphibians
Reptiles


Birds


Mammals


Invertebrates

Species/ Habitats

Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
Olympic Mudminnow
Pacific Herring
Longfin Smelt

Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Bocaccio Rockfish
Brown Rockfish
Canary Rockfish
Copper Rockfish

Greenstriped Rockfish
Quillback Rockfish
Redstripe Rockfish
Yelloweye Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Oregon Spotted Frog
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Common Loon
Marbled Murrelet
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)

Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Snow Goose
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Yellow-billed Cuckoo
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
Oregon Vesper Sparrow

Dall's Porpoise
Gray Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
California Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Cascade Red Fox
Fisher
Grizzly Bear
Lynx
Marten
Wolverine
Columbian Black-tailed Deer
Mountain Goat
Elk

Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Johnson's Hairstreak

State Status
Candidate
Sensitive
Candidate

Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Endangered
Candidate
Endangered
Sensitive
Threatened
Candidate

Candidate
Candidate
Endangered
Endangered
Candidate
Candidate
Candidate
Candidate

Endangered
Endangered
Candidate
Candidate
Candidate
Candidate
Endangered
Endangered
Threatened
Candidate

Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status

** Im

These are the species a
County. This list of spec
the distribution maps fou
(PHS) List (see http://wo
distribution maps depict
known to occur as well a
associated with the spec
when developing distribu

1) There is a high likelih
even if it has not been d
it is primarily associated
2) Over time, species ca
move to new counties w

Distribution maps in the
information available. A
known distribution for so
WDFW will periodically r
maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Endangered
Threatened

Threatened
Threatened
Threatened

Threatened
Threatened

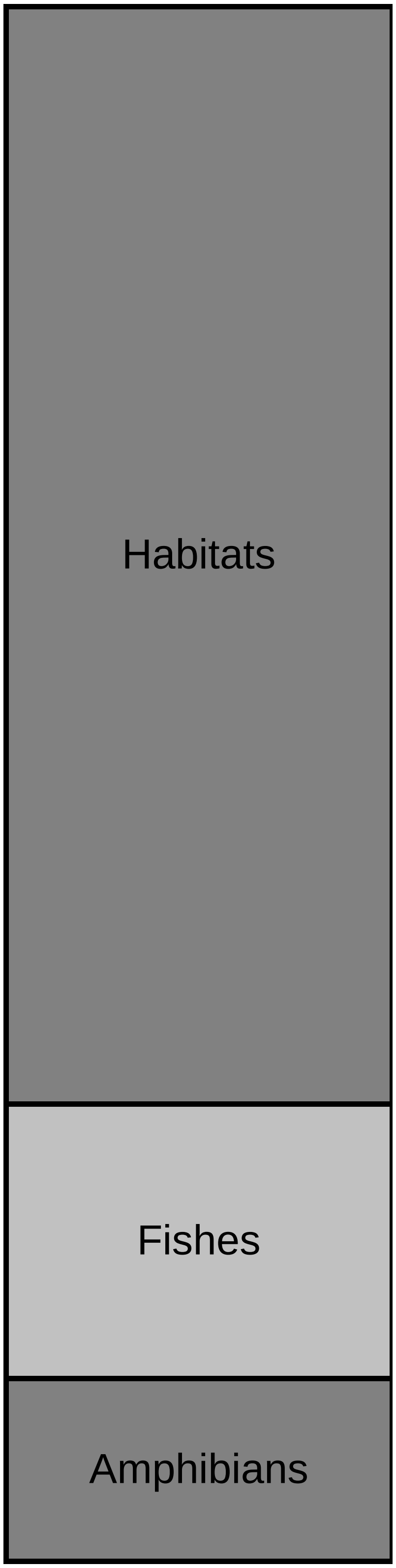
Endangered
Endangered
Species of Concern
Threatened
Threatened
Candidate

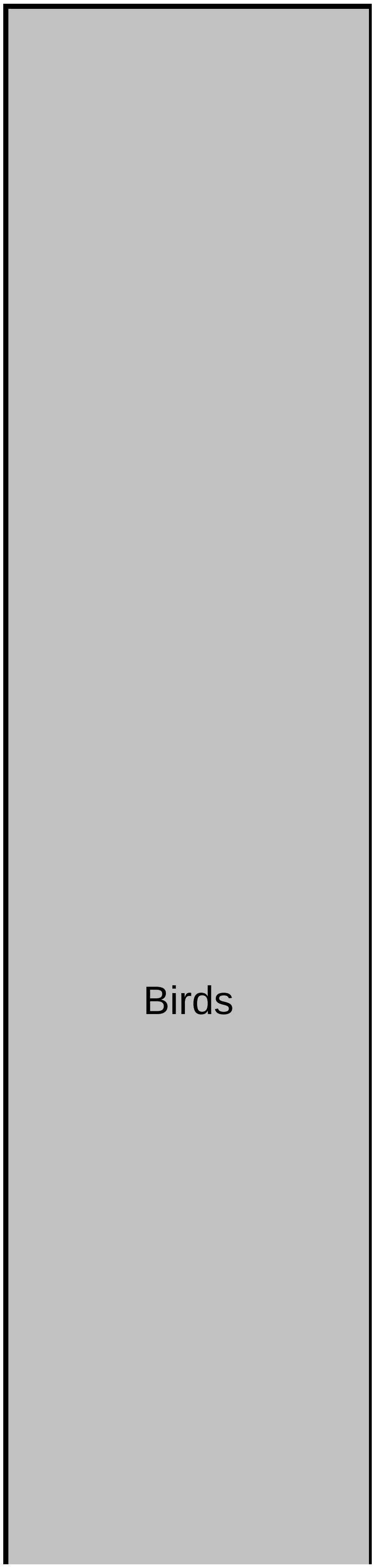
ıportant Note **

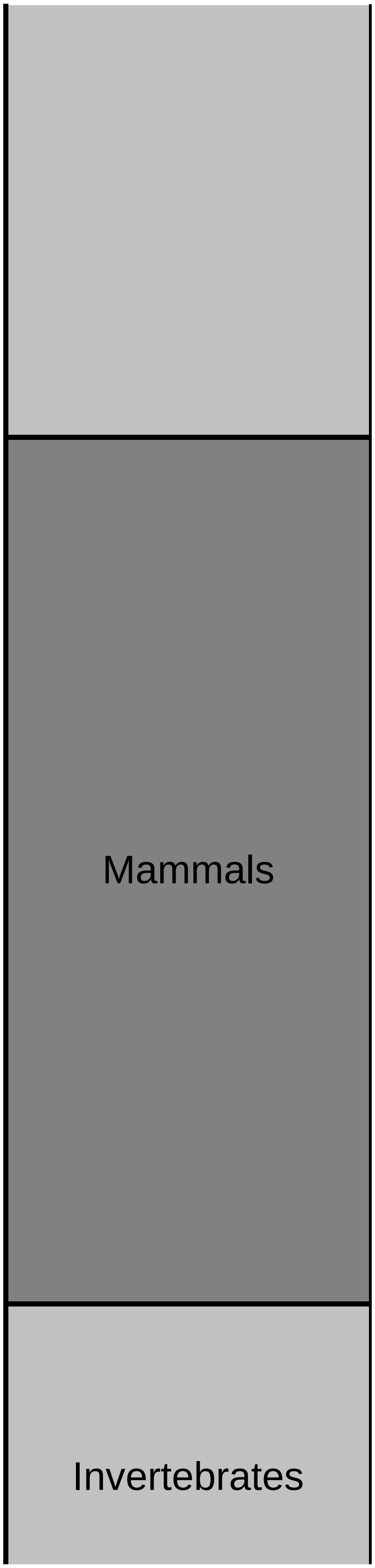
.nd habitats identified for Snohomish
:ies and habitats was developed using
ınd in the Priority Habitat and Species
lfw.wa.gov/conservation/phs/). Species
counties where each priority species is
ıs other counties where habitat primarily
:ies exists. Two assumptions were made
ıtion maps for each species:

ood a species is present in a county,
irectly observed, if the habitat with which
exists. .
ın naturally change their distribution and
here usable habitat exists.

PHS List were developed using the best
s new information becomes available,
ıme species may expand or contract.
review and update the the distribution


Habitats
Fishes
Amphibians


Birds


Mammals
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Old-Growth/Mature Forest
Eastside Steppe
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout
Westslope Cutthroat
Columbia Spotted Frog
Western Toad

American White Pelican
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Ferruginous Hawk
Northern Goshawk
Prairie Falcon
Dusky Grouse
Sandhill Crane
Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Flammulated Owl

Vaux's Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
White-tailed Jackrabbit
Marten
Lynx
Wolverine
Moose
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Shortface Lanx (formerly Giant Columbia River Limpet)
Columbia Pebblesnail
California Floater

Silver-bordered Fritillary

State Status

Candidate *
Candidate
Candidate

Endangered
Candidate
Candidate
Threatened
Candidate
Endangered
Endangered
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Candidate
Candidate
Candidate

Candidate

* Steelhead only

Federal Status	** Important
	These are the species and habit This list of species and habitats distribution maps found in the Pr List (see http://wdfw.wa.gov/con distribution maps depict countie known to occur as well as other associated with the species exis when developing distribution ma 1) There is a high likelihood a sp if it has not been directly observ primarily associated exists. . 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a in PHS list.
Threatened *	

Threatened
Candidate

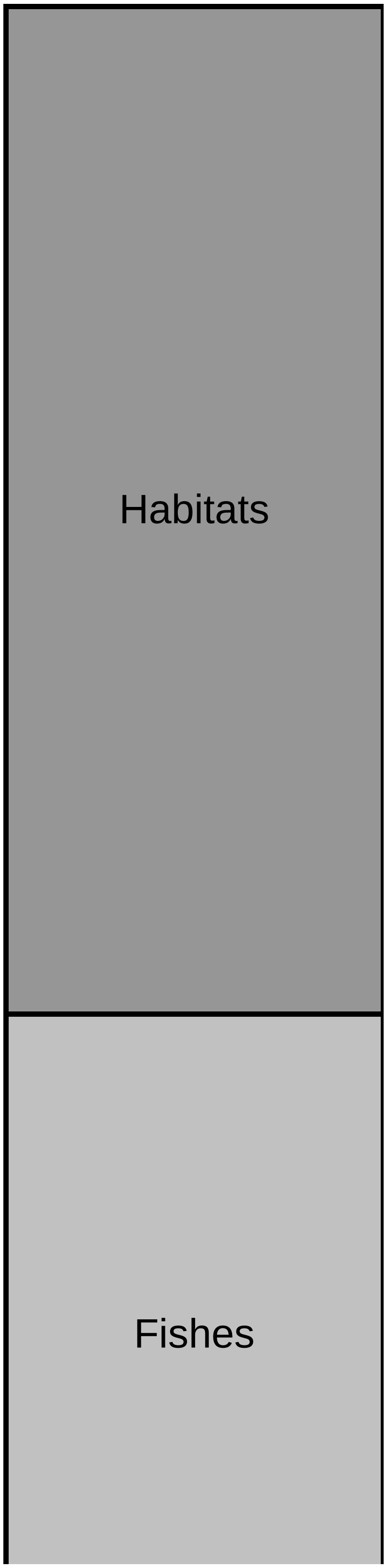
: Note **

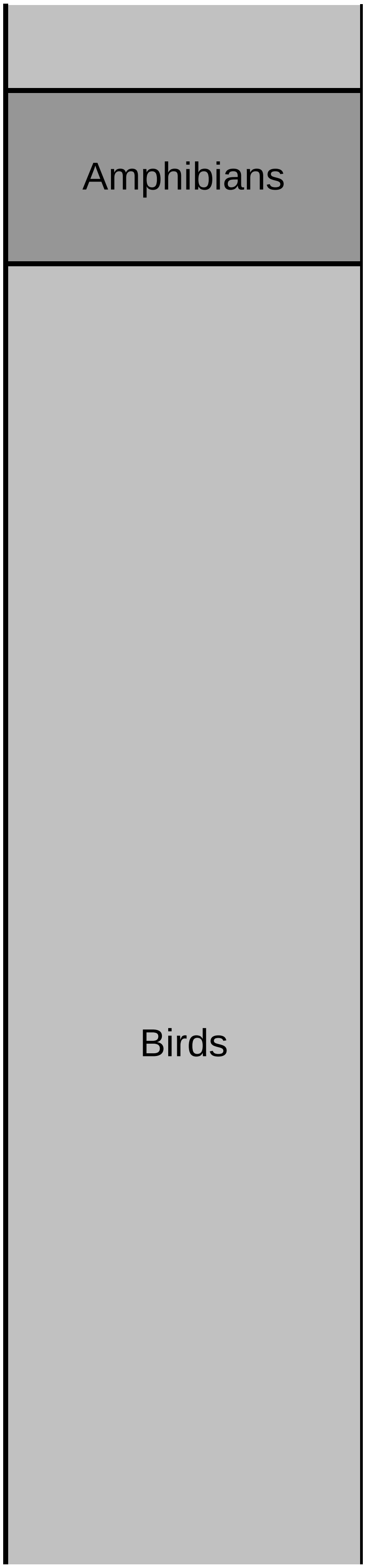
ats identified for Spokane County.
was developed using the
riority Habitat and Species (PHS)
servation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

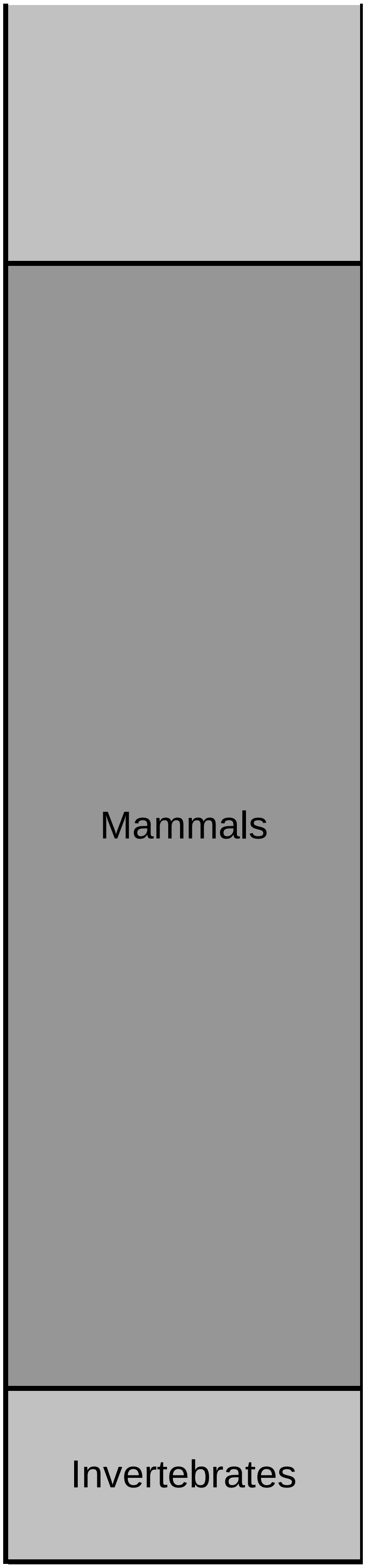
pecies is present in a county, even
ed, if the habitat with which it is

ally change their distribution and
able habitat exists.

st were developed using the best
nformation becomes available,
cies may expand or contract.
nd update the the distribution maps


Habitats
Fishes


Amphibians
Birds


Mammals
Invertebrates

Species/ Habitats

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Old-Growth/Mature Forest
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
White Sturgeon
Lake Chub
Umatilla Dace
Bull Trout/ Dolly Varden
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout

Westslope Cutthroat
Columbia Spotted Frog
Western Toad
Common Loon
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Dusky Grouse
Columbian Sharp-tailed Grouse (formerly Sharp-tailed Grouse)
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Yellow-billed Cuckoo
Flammulated Owl
Vaux's Swift

Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
Fisher
Gray Wolf
Grizzly Bear
Lynx
Marten
Wolverine
Moose
Mountain Goat
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater
Silver-bordered Fritillary

State Status

Candidate
Candidate
Candidate *
Candidiate **

Candidate
Candidate
Sensitive
Candidate
Candidate
Candidate
Endangered
Endangered
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Endangered
Endangered
Endangered
Threatened
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only
*** Federally listed west of north-south line fol

Federal Status	** Im
	These are the species a This list of species and h distribution maps found List (see http://wdfw.wa. distribution maps depict known to occur as well a associated with the spec when developing distribu 1) There is a high likelih if it has not been directly primarily associated exis . 2) Over time, species ca move to new counties w Distribution maps in the information available. A known distribution for sc WDFW will periodically r in PHS list.
Threatened *	
Threatened **	

Threatened

Species of Concern
Endangered ***
Threatened
Threatened
Candidate

llowing Highways 97, 17, and 395.

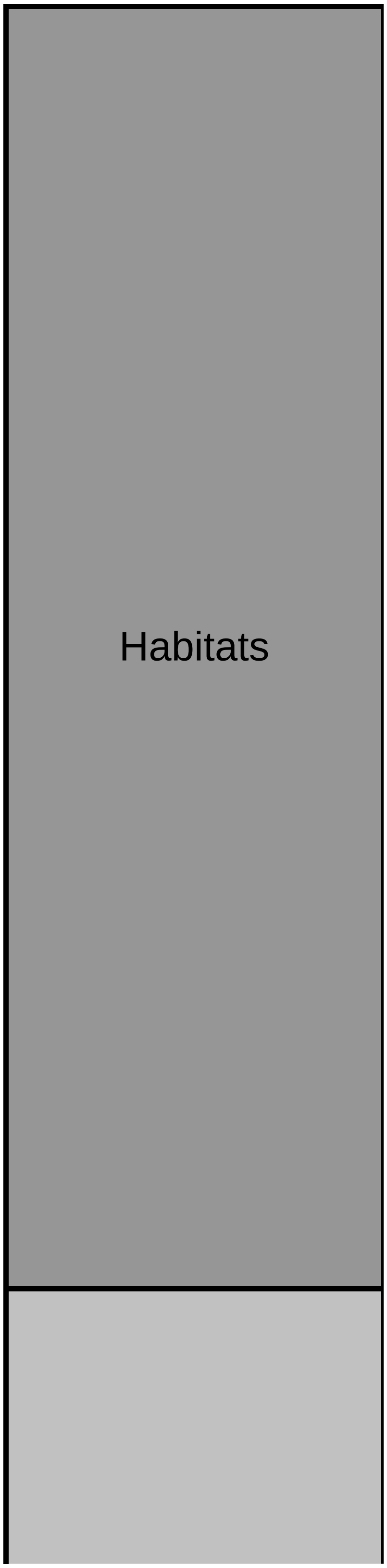
ıportant Note **

.nd habitats identified for Stevens County.
ıabitats was developed using the
in the Priority Habitat and Species (PHS)
gov/conservation/phs/). Species
counties where each priority species is
ıs other counties where habitat primarily
:ies exists. Two assumptions were made
ıtion maps for each species:

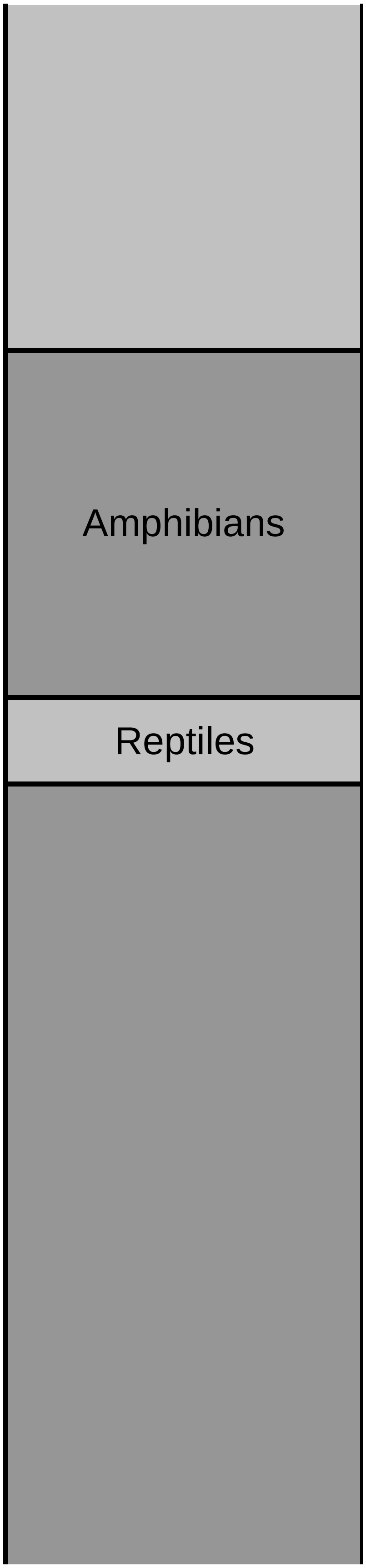
ood a species is present in a county, even
' observed, if the habitat with which it is
sts.

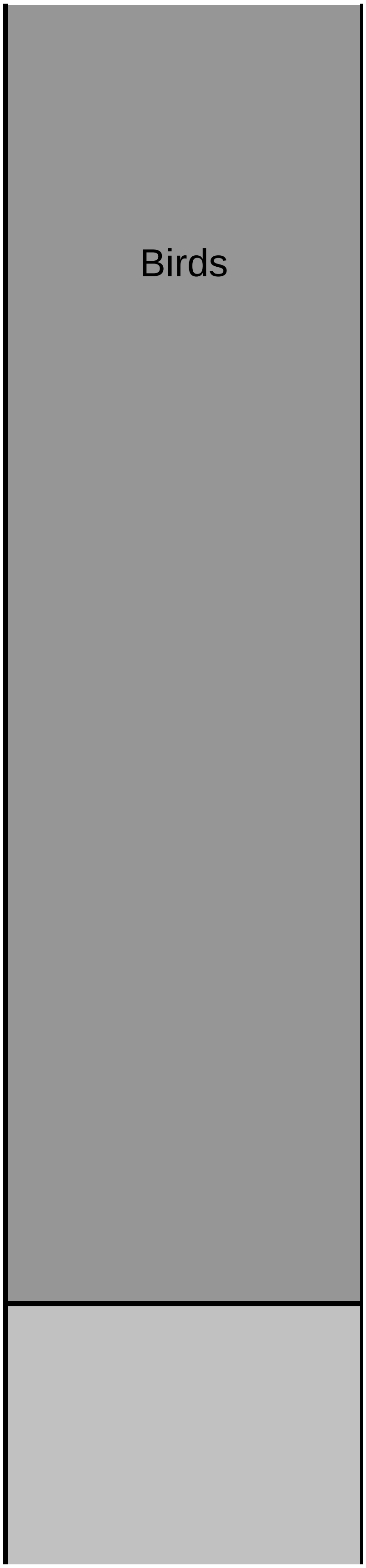
ın naturally change their distribution and
here usable habitat exists.

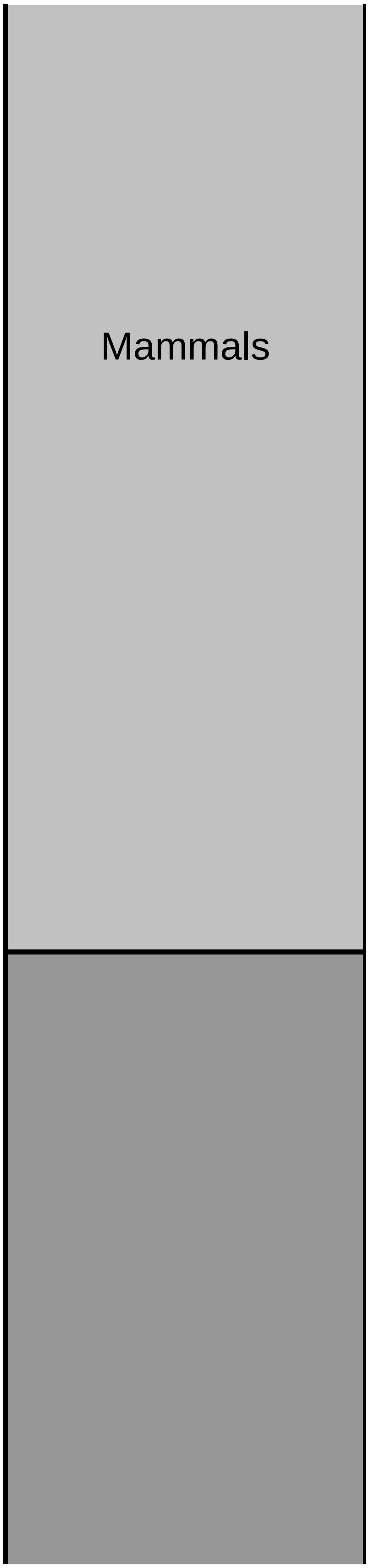
PHS List were developed using the best
s new information becomes available,
ıme species may expand or contract.
review and update the the distribution maps

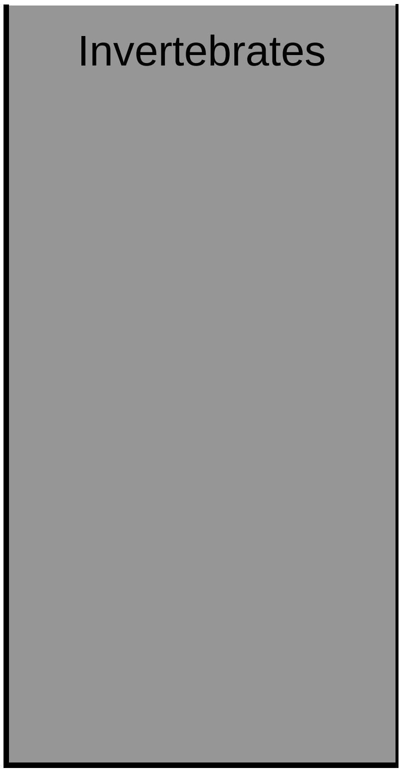

Habitats

Fishes


Amphibians
Reptiles


Birds


Mammals


Invertebrates

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
West Side Prairie
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon

Olympic Mudminnow
Pacific Herring
Longfin Smelt
Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Brown Rockfish
Copper Rockfish
Quillback Rockfish

Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Cascade Torrent Salamander
Van Dyke's Salamander
Oregon Spotted Frog
Western Toad
Western Pond Turtle (formerly Pacific Pond Turtle)
Common Loon
Marbled Murrelet
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead

Harlequin Duck
Waterfowl Concentrations
Golden Eagle
Mountain Quail
Sooty Grouse
Wild Turkey
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Yellow-billed Cuckoo
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Pileated Woodpecker
Oregon Vesper Sparrow
Slender-billed White-breasted Nuthatch
Streaked Horned Lark
Dall's Porpoise
Harbor Seal
Orca (Killer Whale)

Harbor Porpoise (formerly called Pacific Harbor Porpoise)
California Sea Lion
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
Western Gray Squirrel
Mazama (Western) Pocket Gopher
Fisher
Marten
Columbian Black-tailed Deer
Elk
Pacific Geoduck (fomerly Geoduck)
Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab

Pandalid shrimp (Pandalidae)
Beller's Ground Beetle
Pacific Clubtail
Leschi's Millipede
Mardon Skipper
Puget Blue
Valley Silverspot
Taylor's Checkerspot

State Status

Candidate

Sensitive
Candidate
Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Endangered
Candidate
Endangered
Sensitive
Threatened
Candidate

Candidate
Endangered
Endangered
Candidate
Candidate
Candidate
Candidate
Endangered
Endangered

Candidate
Candidate
Threatened
Threatened
Endangered
Candidate

Candidate
Candidate
Candidate
Endangered
Candidate
Candidate
Endangered

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict countie known to occur as well as other associated with the species exis made when developing distributi 1) There is a high likelihood a sp even if it has not been directly ol it is primarily associated exists. 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern

Threatened
Threatened

Threatened
Threatened
Threatened
Endangered

Threatened - glacialis, pugetensis, tumuli, yelmensis subspecies
Species of Concern - couchi louiei, melanops subspecies

Species of Concern

Endangered

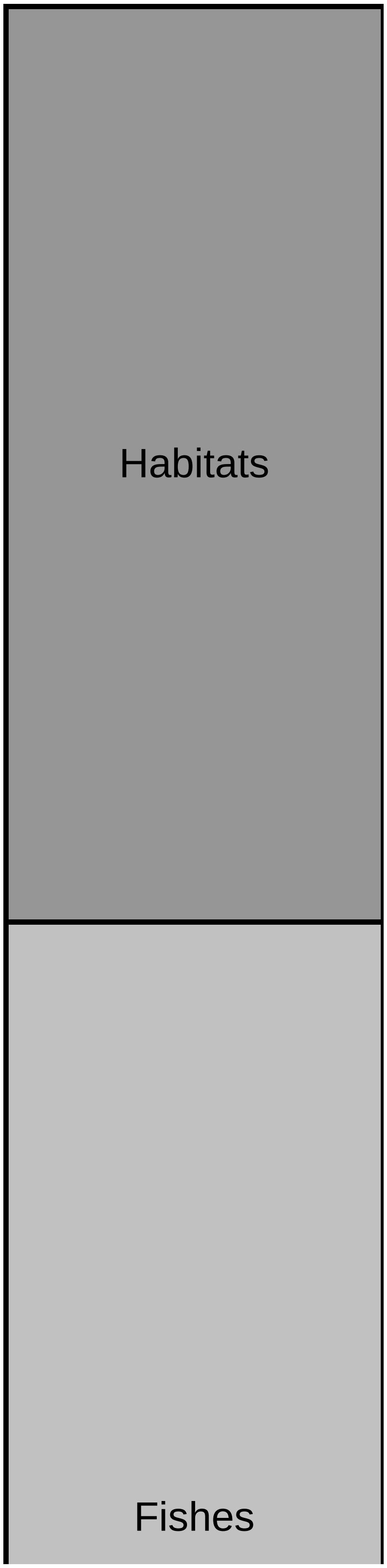
ınt Note **

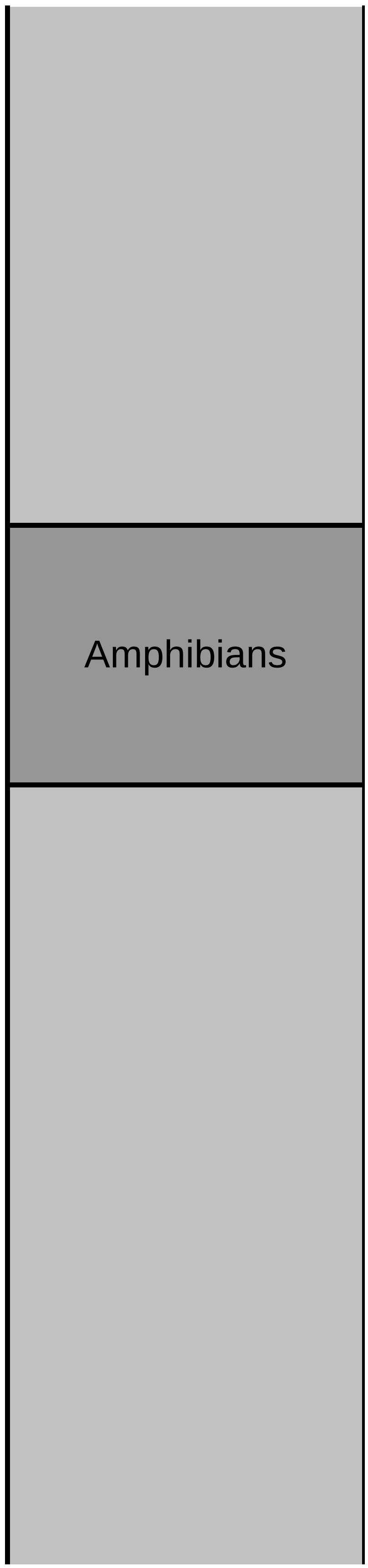
ıats identified for Thurston habitats was developed using e Priority Habitat and Species ov/conservation/phs/). Species s where each priority species is counties where habitat primarily ts. Two assumptions were on maps for each species:

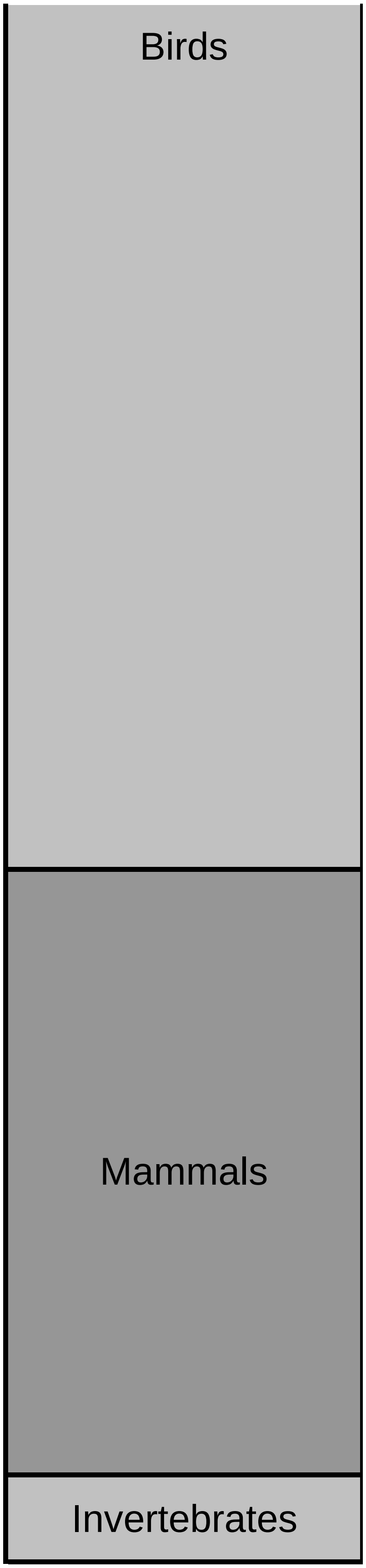
ɔecies is present in a county, ɔserved, if the habitat with which .

ılly change their distribution and ıble habitat exists.

ıt were developed using the best ıformation becomes available, cies may expand or contract. nd update the the distribution


Habitats
Fishes


Amphibians


Birds
Mammals
Invertebrates

Species/ Habitats

Species/ Habitats
Biodiversity Areas & Corridors
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
Green Sturgeon
White Sturgeon
Eulachon
Bull Trout/ Dolly Varden
Chinook Salmon

Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Dunn's Salamander
Van Dyke's Salamander
Western Toad
Marbled Murrelet
Western grebe
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
Golden Eagle

Northern Goshawk
Sooty Grouse
Wild Turkey
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux's Swift
Pileated Woodpecker
Oregon Vesper Sparrow
Streaked Horned Lark
Harbor Seal
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend's Big-eared Bat
Marten
Columbian Black-tailed Deer
Columbian White-tailed Deer
Elk
Valley Silverspot

State Status

Candidate
Candidate
Candidate *
Candidate

Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Threatened
Candidate
Candidate

Candidate
Endangered
Candidate
Candidate
Candidate
Endangered
Candidate
Endangered
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict countie known to occur as well as other associated with the species exis when developing distribution ma 1) There is a high likelihood a sp even if it has not been directly ol it is primarily associated exists. 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.
Threatened	
Threatened	
Threatened *	
Threatened (Upper Columbia Spring run is Endangered)	

Threatened (Upper Columbia Spring run is Endangered)
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Threatened

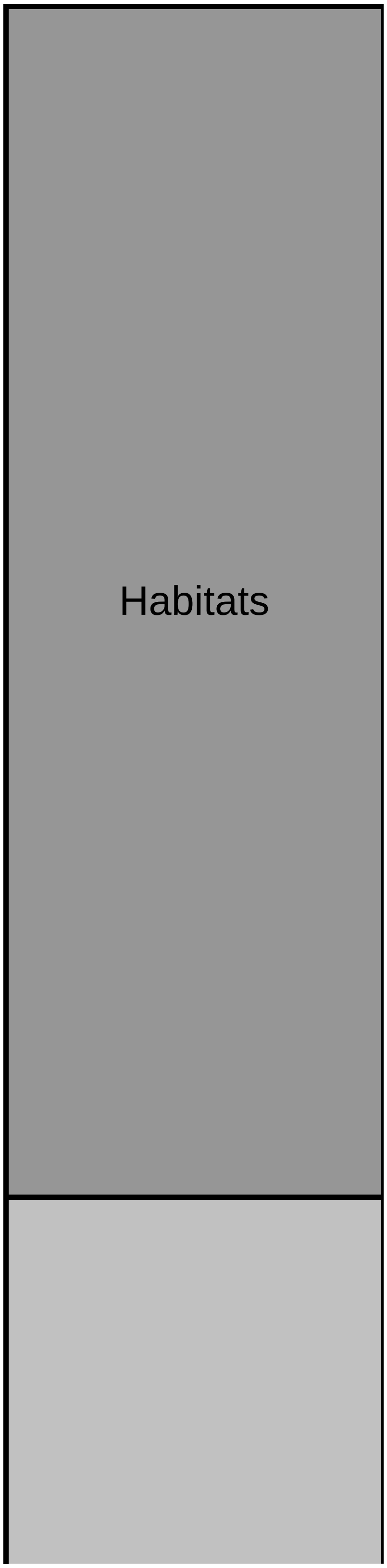
Threatened
Threatened
Endangered

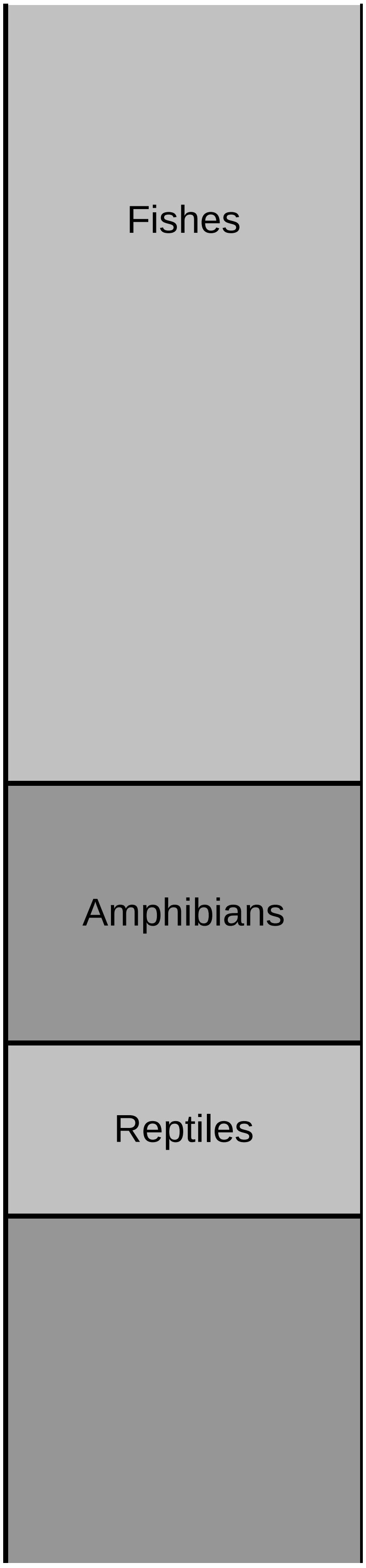
ınt Note **

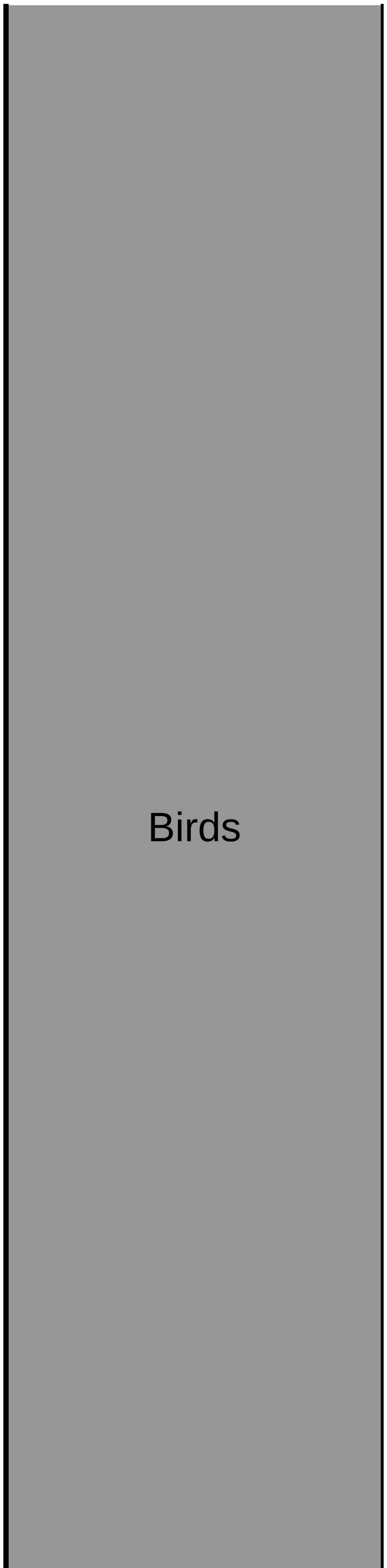
ıats identified for Wahkiakum
 habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

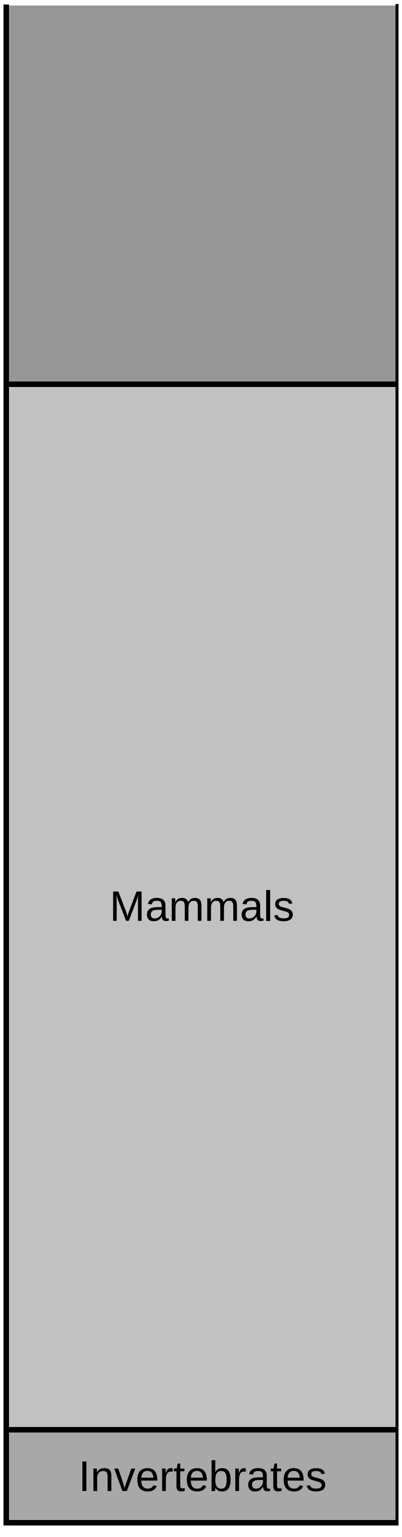
ɔecies is present in a county,
ɔserved, if the habitat with which
.
ılly change their distribution and
ıble habitat exists.

ıt were developed using the best
ıformation becomes available,
cies may expand or contract.
nd update the the distribution


Habitats


Fishes
Amphibians
Reptiles


Birds


Mammals
Invertebrates

Species/ Habitats

Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Juniper Savannah
Eastside Steppe
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
White Sturgeon
Leopard Dace
Umatilla Dace

Mountain Sucker
Bull Trout/ Dolly Varden
Chinook Salmon
Coho Salmon
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Margined Sculpin
Columbia Spotted Frog
Rocky Mountain Tailed Frog
Western Toad
Striped Whipsnake
Sagebrush Lizard
American White Pelican
Western grebe
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns

Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Tundra Swan
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Northern Goshawk
Prairie Falcon
Dusky Grouse
Mountain Quail
Ring-necked Pheasant
Wild Turkey
Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Flammulated Owl
Vaux's Swift

Black-backed Woodpecker
Pileated Woodpecker
Loggerhead Shrike
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Washington Ground Squirrel
Gray Wolf
Marten
Bighorn Sheep
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
California Floater

State Status

Candidate
Candidate

Candidate
Candidate *
Candidate
Candidiate **
Candidate
Sensitive
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered
Candidate

Threatened
Candidate
Candidate
Endangered
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Endangered
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Im
	These are the species a County. This list of spec the distribution maps fou (PHS) List (see http://wc distribution maps depict known to occur as well a associated with the spec made when developing 1) There is a high likelih even if it has not been d it is primarily associated 2) Over time, species ca move to new counties w Distribution maps in the information available. A known distribution for sc WDFW will periodically maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

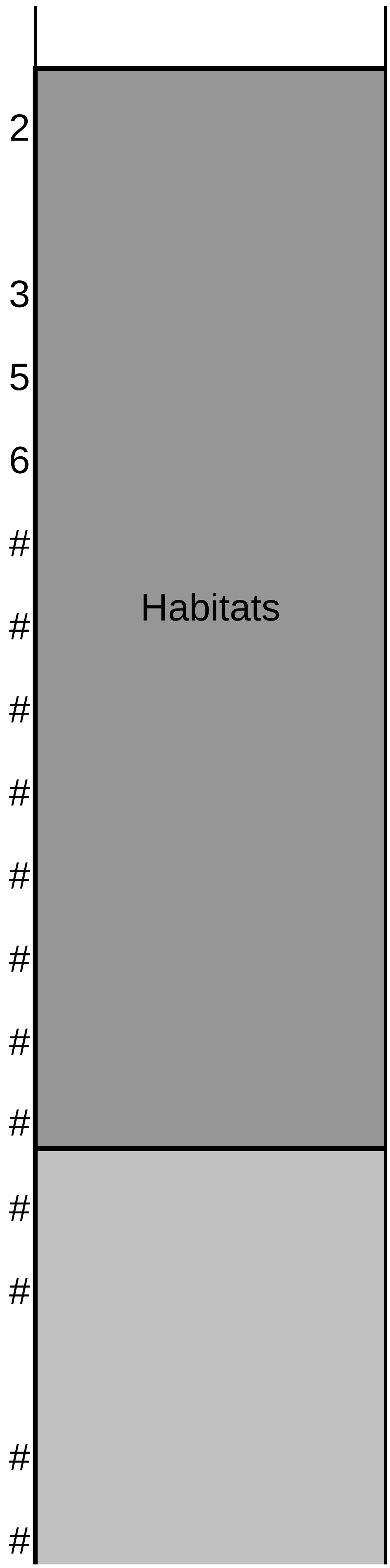
Candidate

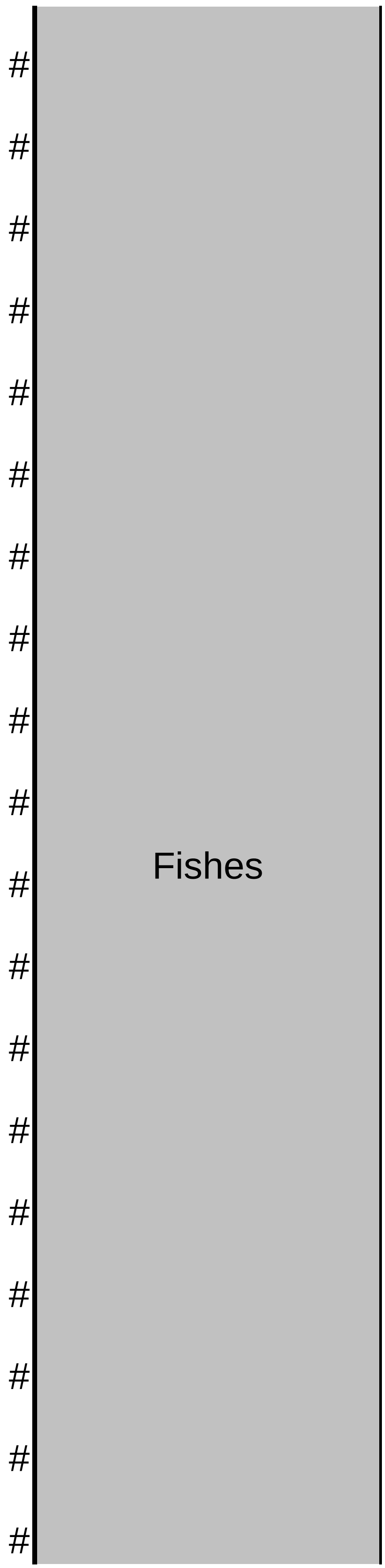
portant Note **

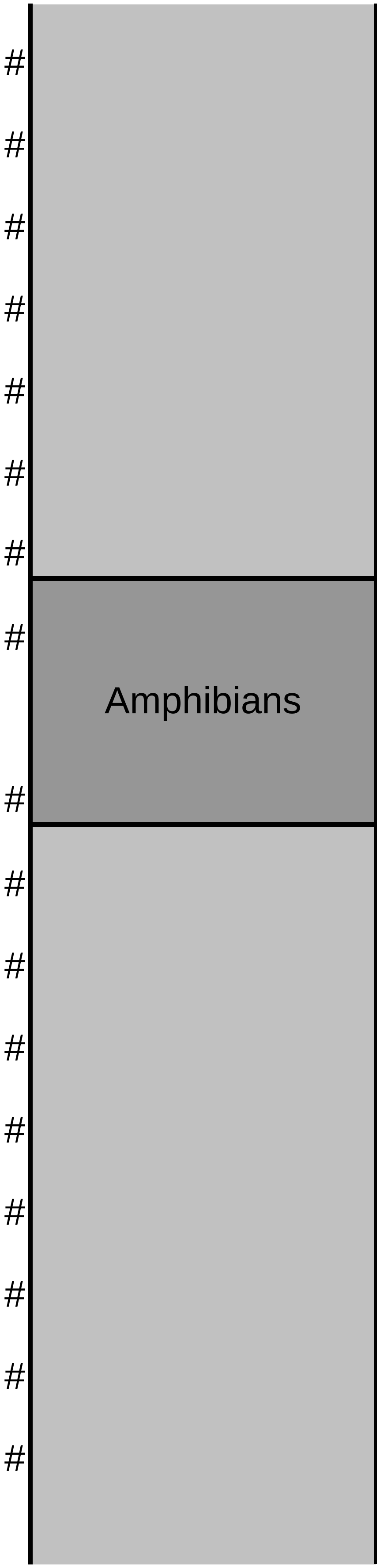
nd habitats identified for Walla Walla
cies and habitats was developed using
und in the Priority Habitat and Species
lfw.wa.gov/conservation/phs/). Species
counties where each priority species is
as other counties where habitat primarily
cies exists. Two assumptions were
distribution maps for each species:

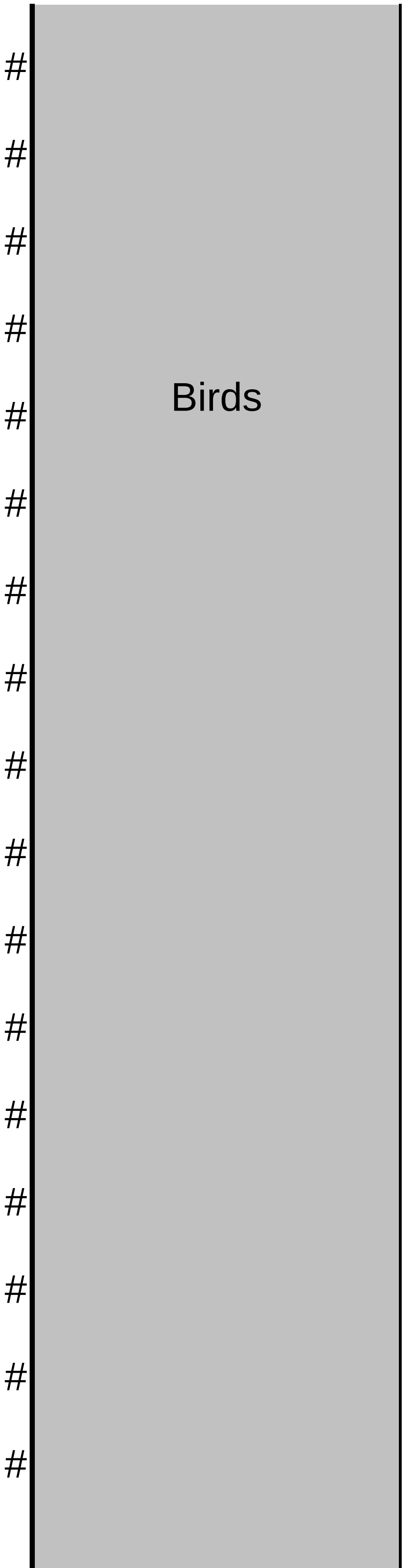
ood a species is present in a county,
irectly observed, if the habitat with which
exists. .
n naturally change their distribution and
here usable habitat exists.

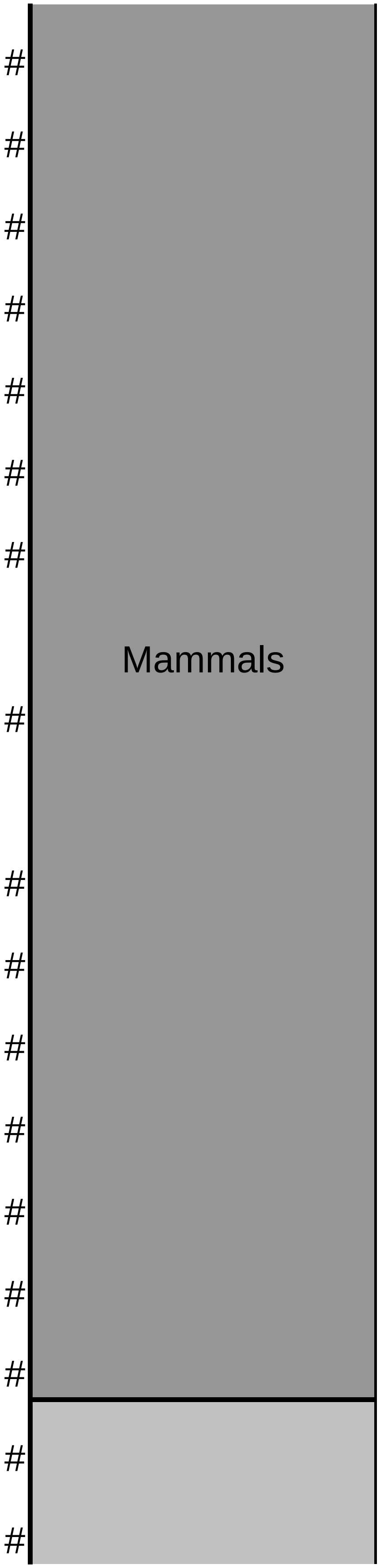
PHS List were developed using the best
s new information becomes available,
me species may expand or contract.
review and update the the distribution

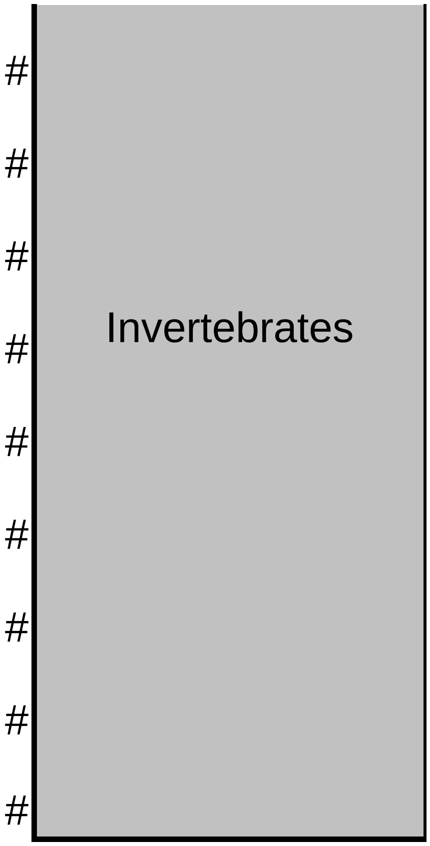

2
3
5
6
#
#
#
#
#
#
#
#
#
#
#
#
Habitats


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Fishes


#
#
#
#
#
#
#
#
Amphibians
#
#
#
#
#
#
#
#
#


#
#
#
#
Birds
#
#
#
#
#
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
#
Mammals
#
#
#
#
#
#
#
#
#
#


#
#
#
#
#
#
#
#
#
Invertebrates

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Herbaceous Balds
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Puget Sound Nearshore
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Pacific Herring
Longfin Smelt

Surfsmelt
Bull Trout/ Dolly Varden
Chinook Salmon
Chum Salmon
Coastal Res./ Searun Cutthroat
Coho Salmon
Kokanee
Pink Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Pacific Cod
Pacific Hake
Walleye Pollock
Black Rockfish
Brown Rockfish
Canary Rockfish
Copper Rockfish
Greenstriped Rockfish
Quillback Rockfish

Redstripe Rockfish
Yelloweye Rockfish
Yellowtail Rockfish
Lingcod
Pacific Sand Lance
English Sole
Rock Sole
Columbia Spotted Frog
Oregon Spotted Frog
Western Toad
American White Pelecan
Common Loon
Marbled Murrelet
Short-tailed Albatross
Western grebe
W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids
W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids
Great Blue Heron
Sandhill Crane

Western High Arctic Brant (formerly called Brant)
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead
Harlequin Duck
Snow Goose
Trumpeter Swan
Tundra Swan
Waterfowl Concentrations
Golden Eagle
Northern Goshawk
Sooty Grouse
W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae
Band-tailed Pigeon
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
Oregon Vesper Sparrow
Dall's Porpoise

Gray Whale
Harbor Seal
Orca (Killer Whale)
Harbor Porpoise (formerly called Pacific Harbor Porpoise)
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Keen's Myotis (formerly Keen’s Long-eared Bat)
Cascade Red Fox
Fisher
Gray Wolf
Grizzly Bear
Lynx
Marten
Wolverine
Columbian Black-tailed Deer
Mountain Goat
Elk
Pinto (Northern) Abalone
Pacific Geoduck (fomerly Geoduck)

Butter Clam
Native Littleneck Clam
Manila (Japanese) Littleneck Clam (formerly called Manila Clam)
Olympia Oyster
Pacific Oyster
Dungeness Crab
Pandalid shrimp (Pandalidae)
Johnson's Hairstreak
Red Sea Urchin (formerly Red Urchin)

State Status

Candidate
Candidate

Candidate *
Candidate
Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate
Endangered
Candidate
Endangered
Sensitive
Threatened
Candidate
Candidate
Endangered

Candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate

Sensitive
Endangered
Candidate
Candidate
Candidate
Candidate
Endangered
Endangered
Endangered
Threatened
Candidate
Endangered

Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Im
	These are the species a County. This list of spec the distribution maps fou (PHS) List (see http://wc distribution maps depict known to occur as well a associated with the spec made when developing (1) There is a high likelih even if it has not been d which it is primarily asso . 2) Over time, species ca move to new counties w Distribution maps in the best information availabl available, known distribu contract. WDFW will per distribution maps in PHS

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened
Species of Concern
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River
Species of Concern
Species of Concern
Threatened

Threatened
Threatened
Threatened
Endangered

Threatened

Endangered
Species of Concern
Endangered
Threatened
Threatened
Candidate
Species of Concern

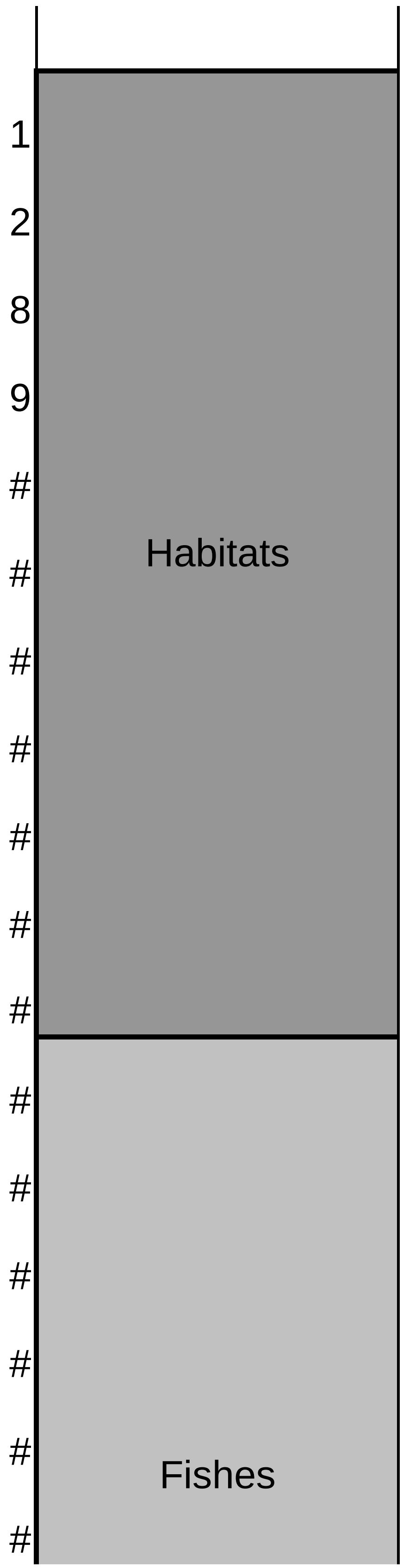
ıportant Note **

.nd habitats identified for Whatcom
cies and habitats was developed using
ınd in the Priority Habitat and Species
lfw.wa.gov/conservation/phs/). Species
counties where each priority species is
as other counties where habitat primarily
cies exists. Two assumptions were
distribution maps for each species:

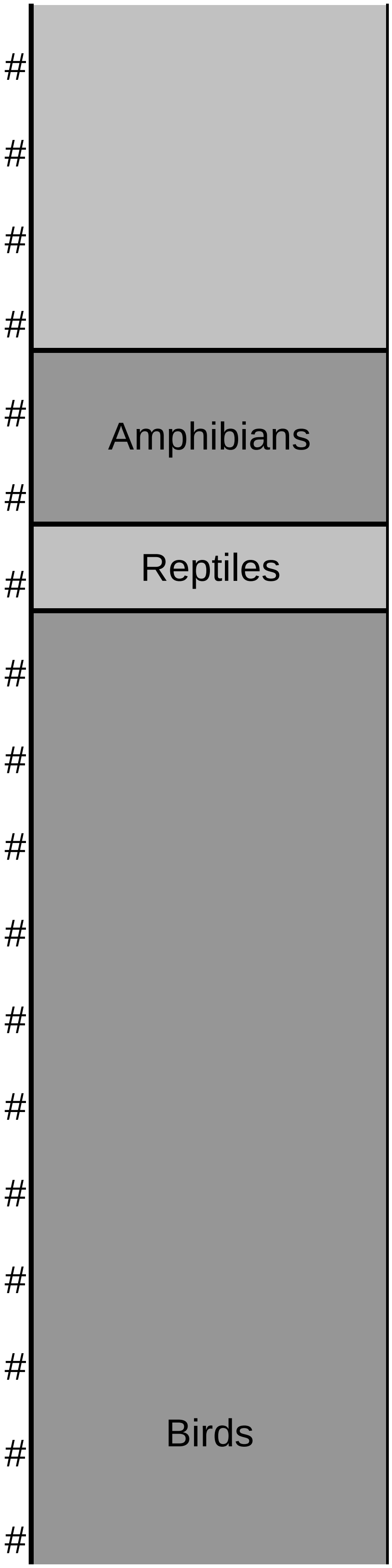
ood a species is present in a county,
irectly observed, if the habitat with
ociated exists.

ın naturally change their distribution and
here usable habitat exists.

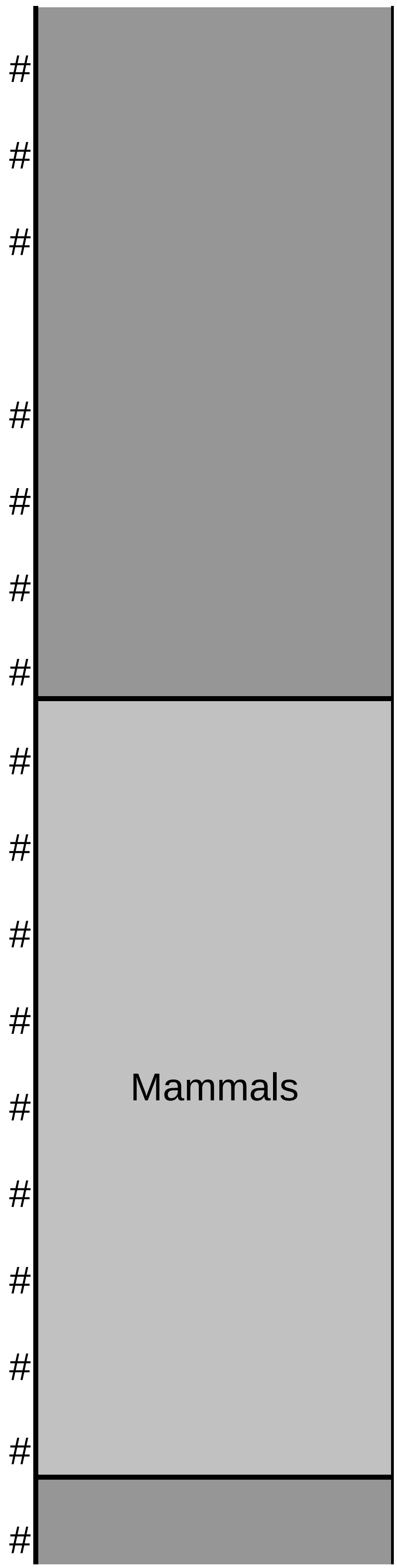
PHS List were developed using the
le. As new information becomes
ıtion for some species may expand or
riodically review and update the the
S list.

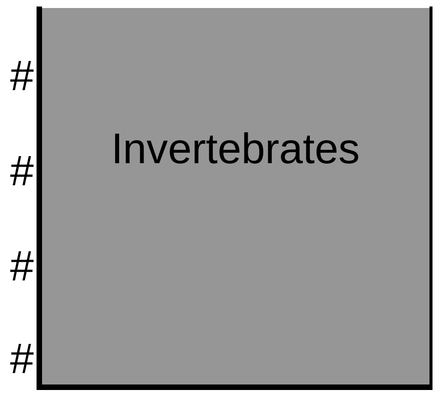


1
2
8
9
#
#
#
#
#
#
#
#
#
#
#
#
#
Habitats
Fishes



#
#
#
#
#
Amphibians
#
Reptiles
#
#
#
#
#
#
#
#
#
#
Birds
#
#


#
#
#
#
#
#
#
#
#
#
#
Mammals
#
#
#
#
#
#


#
#
#
#
Invertebrates

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Eastside Steppe
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Leopard Dace
Mountain Sucker
Bull Trout/ Dolly Varden

Chinook Salmon
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Columbia Spotted Frog
Western Toad
Sagebrush Lizard
American White Pelican
E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Great Blue Heron
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Prairie Falcon
Chukar
Ring-necked Pheasant
Wild Turkey

Upland Sandpiper
E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Burrowing Owl
Vaux's Swift
Pileated Woodpecker
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Washington Ground Squirrel
Moose
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Columbia River Tiger Beetle

Mann's mollusk-eating Ground Beetle
Giant Palouse Earthworm
Shepard's Parnassian
Silver-bordered Fritillary

State Status

State Status
Candidate
Candidate
Candidate
Candidate *

Candidate
Candidiate **
Candidate
Candidate
Candidate
Candidate
Endangered
Threatened
Candidate

Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Candidate
Candidate
Candidate
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importar
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict counties known to occur as well as other associated with the species exis when developing distribution ma 1) There is a high likelihood a sp even if it has not been directly ol it is primarily associated exists. 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.
Threatened *	

Threatened (Upper Columbia Spring run is Endangered)
Threatened **
Threatened – Ozette Lake Endangered – Snake River

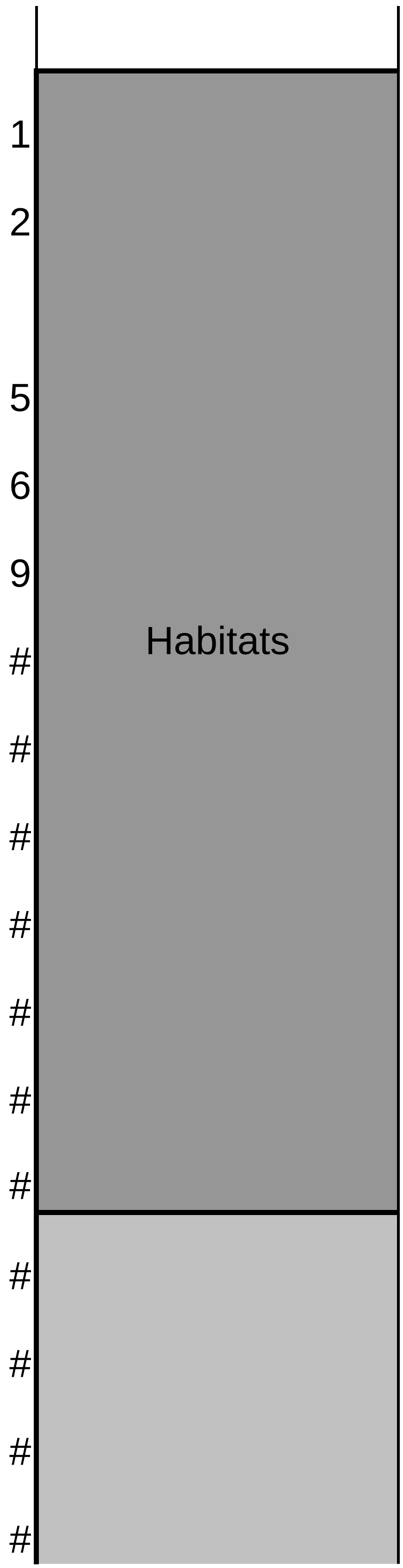
Candidate

ıt Note **

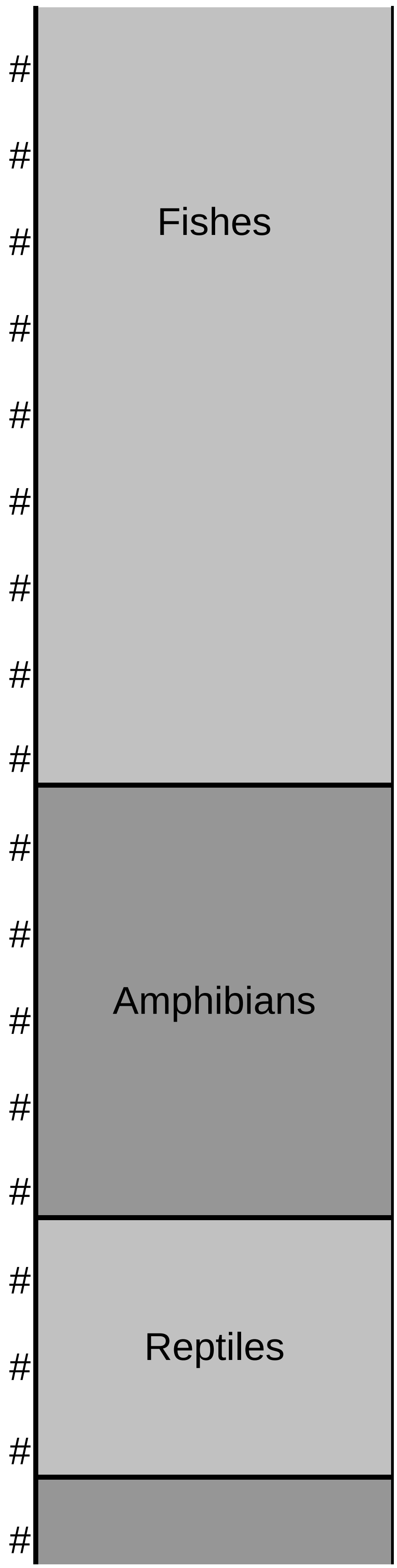
ats identified for Whitman
habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were made
ps for each species:

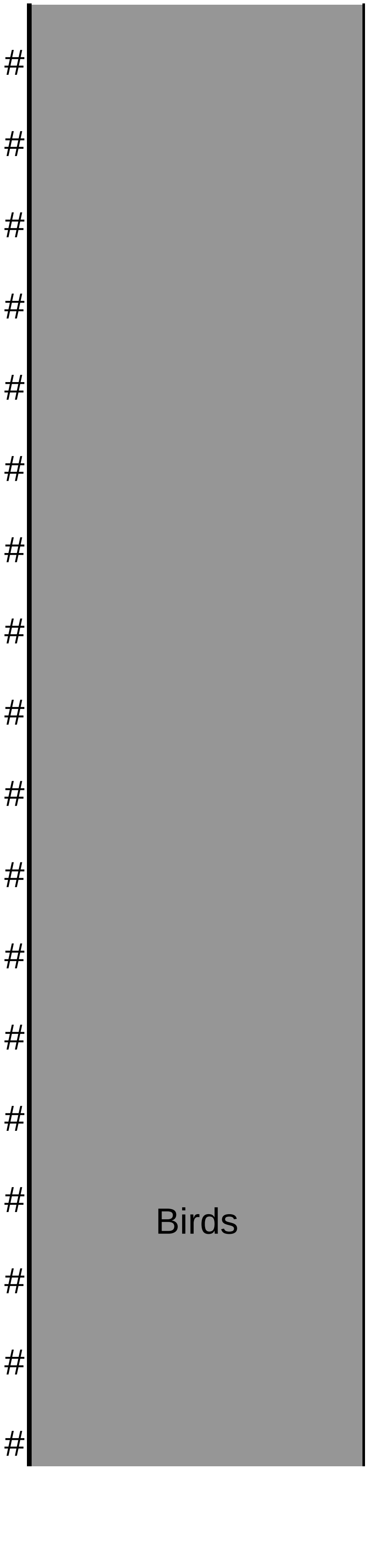
ecies is present in a county,
oserved, if the habitat with which
.
ally change their distribution and
able habitat exists.

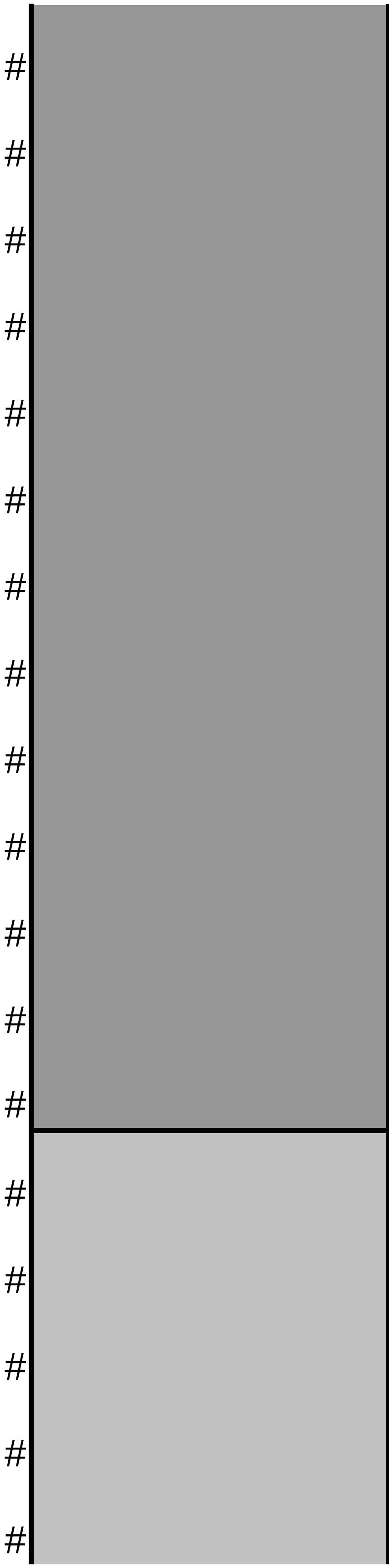
t were developed using the best
formation becomes available,
cies may expand or contract.
nd update the the distribution

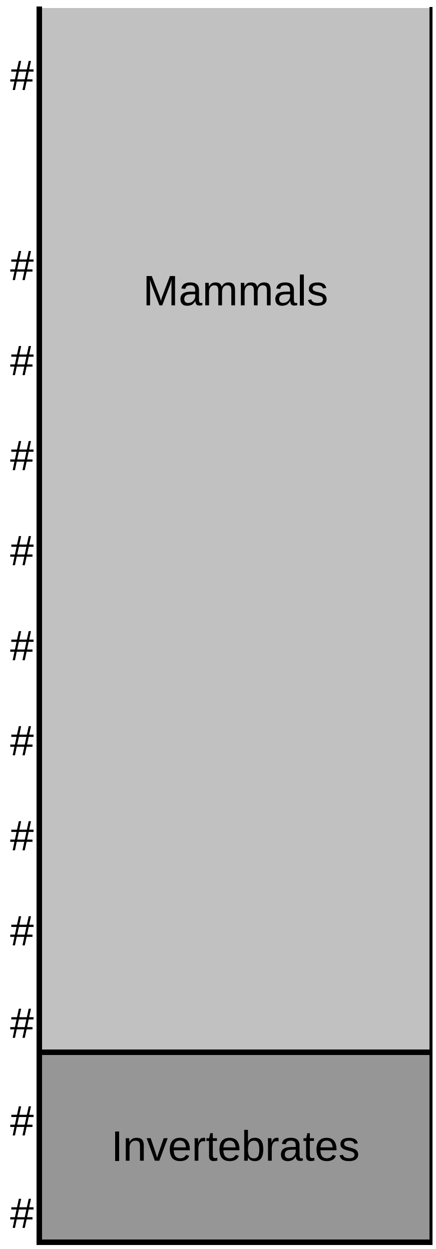


1
2
5
6
9
#
#
#
#
#
#
#
#
#
#
#
Habitats


#
#
Fishes
#
#
#
#
#
#
#
#
#
Amphibians
#
#
#
#
Reptiles
#
#
#


#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
#
Birds





#
#
Mammals
#
#
#
#
#
#
#
#
#
Invertebrates
#

Species/ Habitats
Aspen Stands
Biodiversity Areas & Corridors
Inland Dunes
Old-Growth/Mature Forest
Oregon White Oak Woodlands
Shrub-Steppe
Riparian
Freshwater Wetlands & Fresh Deepwater
Instream
Caves
Cliffs
Snags and Logs
Talus
Pacific Lamprey
River Lamprey
White Sturgeon
Leopard Dace

Umatilla Dace
Mountain Sucker
Bull Trout/ Dolly Varden
Chinook Salmon
Coho Salmon
Kokanee
Rainbow Trout/ Steelhead/ Inland Redband Trout
Sockeye Salmon
Westslope Cutthroat
Cascade Torrent Salamander
Larch Mountain Salamander
Van Dyke's Salamander
Columbia Spotted Frog
Western Toad
Sharp-tailed Snake (formerly Common Sharptail Snake)
Striped Whipsnake
Sagebrush Lizard
Western grebe

E WA breeding concentrations of: Grebes, Cormorants
E WA breeding: Terns
Black-crowned Night-heron
Great Blue Heron
Cavity-nesting ducks: Wood Duck, Barrow’s Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser
Harlequin Duck
Tundra Swan
Waterfowl Concentrations
Ferruginous Hawk
Golden Eagle
Northern Goshawk
Prairie Falcon
Chukar
Ring-necked Pheasant
Greater Sage-grouse
Sooty Grouse
Wild Turkey
Sandhill Crane

E WA breeding occurrences of: Phalaropes, Stilts and Avocets
Band-tailed Pigeon
Yellow-billed Cuckoo
Burrowing Owl
Flammulated Owl
Northern Spotted Owl (formerly called Spotted Owl)
Vaux’s Swift
Black-backed Woodpecker
Pileated Woodpecker
White-headed Woodpecker
Loggerhead Shrike
Sagebrush Sparrow (formerly Sage Sparrow)
Sage Thrasher
Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat
Townsend’s Big-eared Bat
Black-tailed Jackrabbit
White-tailed Jackrabbit
Western Gray Squirrel

Townsend’s Ground Squirrel
Cascade Red Fox
Fisher
Marten
Wolverine
Bighorn Sheep
Columbian Black-tailed Deer
Mountain Goat
Northwest White-tailed Deer
Elk
Mule Deer (formerly called Rocky Mountain Mule Deer)
Mardon Skipper
Silver-bordered Fritillary

State Status

Candidate

Candidate

Candidate
Candidate
Candidate *
Candidate
Candidiate **
Candidate
Candidate
Sensitive
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate

Threatened
Candidate
Candidate
Threatened
Endangered

Endangered
candidate
Candidate
Endangered
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Candidate
Threatened

Candidate
Candidate
Endangered
Candidate
Endangered
Candidate

* Bull Trout only
** Steelhead only

Federal Status	** Importa
	These are the species and habit County. This list of species and the distribution maps found in th (PHS) List (see http://wdfw.wa.g distribution maps depict counties known to occur as well as other associated with the species exis made when developing distributi 1) There is a high likelihood a sp even if it has not been directly ol it is primarily associated exists. 2) Over time, species can natura move to new counties where usa Distribution maps in the PHS Lis information available. As new in known distribution for some spe WDFW will periodically review a maps in PHS list.

Threatened *
Threatened (Upper Columbia Spring run is Endangered)
Threatened – Lower Columbia Species of Concern – Puget Sound
Threatened **
Threatened – Ozette Lake Endangered – Snake River

Species of Concern

Threatened
Threatened

Species of Concern
Candidate

ınt Note **

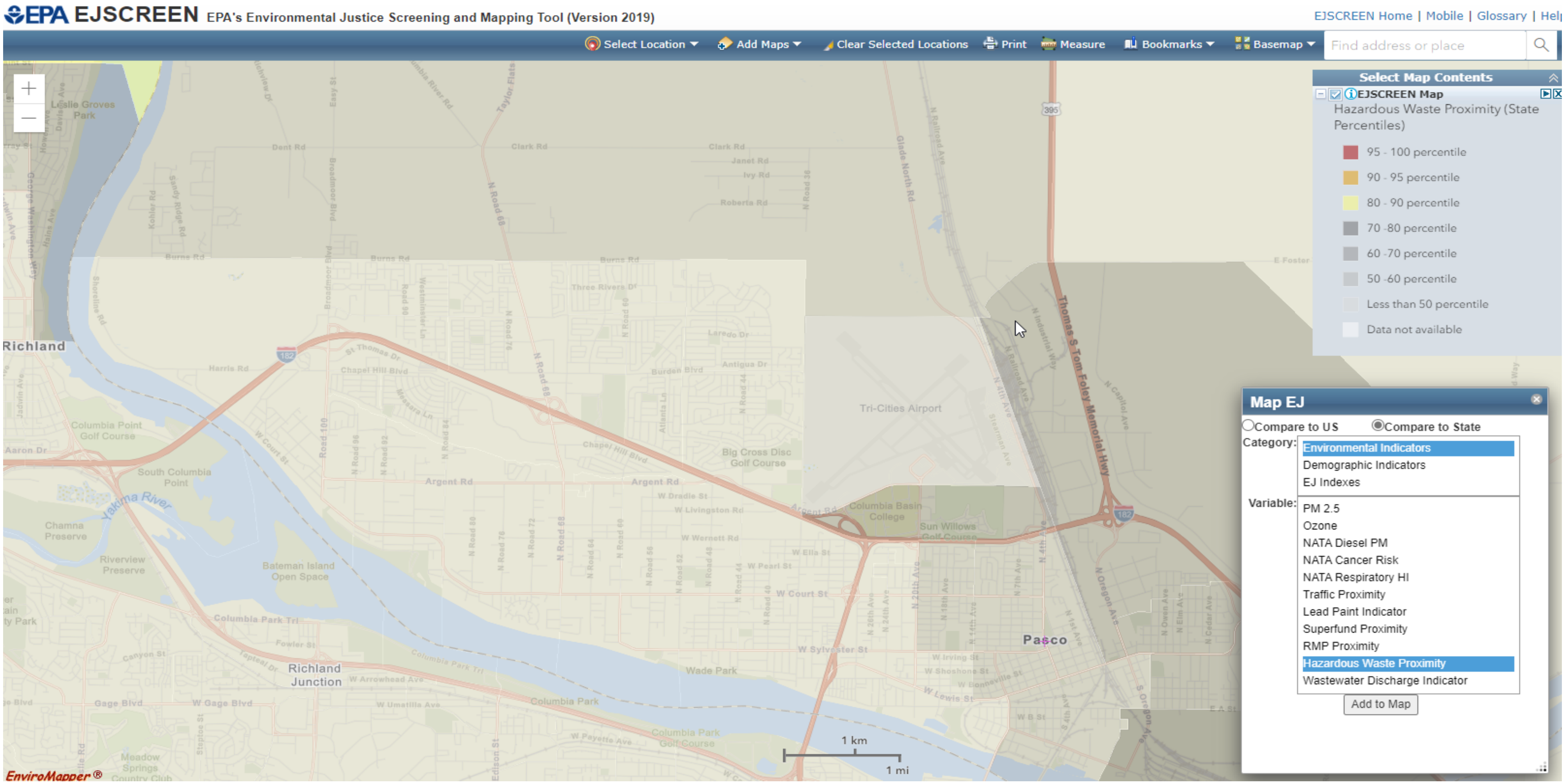
ats identified for Yakima
 habitats was developed using
e Priority Habitat and Species
ov/conservation/phs/). Species
s where each priority species is
counties where habitat primarily
ts. Two assumptions were
on maps for each species:

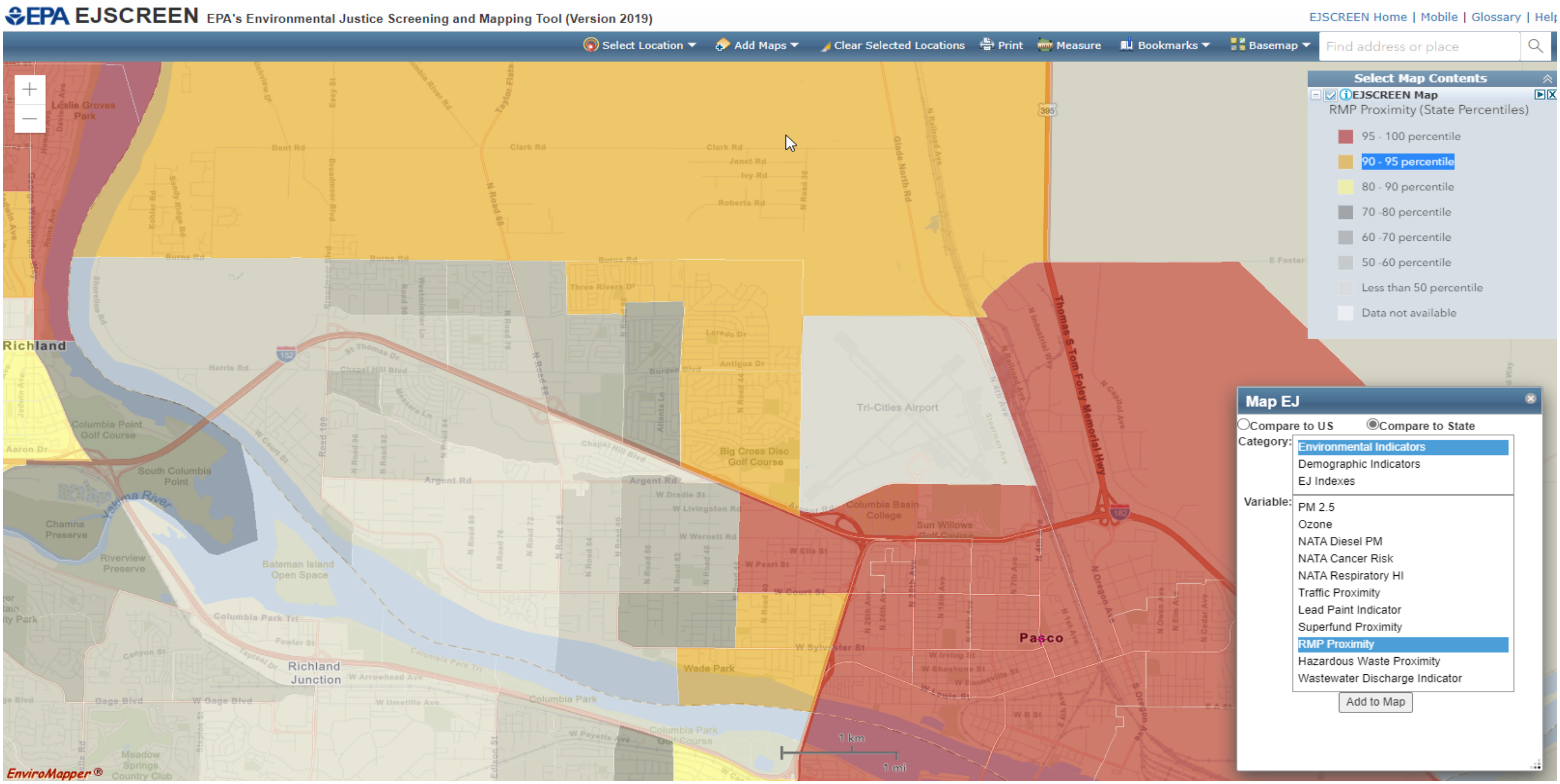
ecies is present in a county,
oserved, if the habitat with which
.
ılly change their distribution and
able habitat exists.

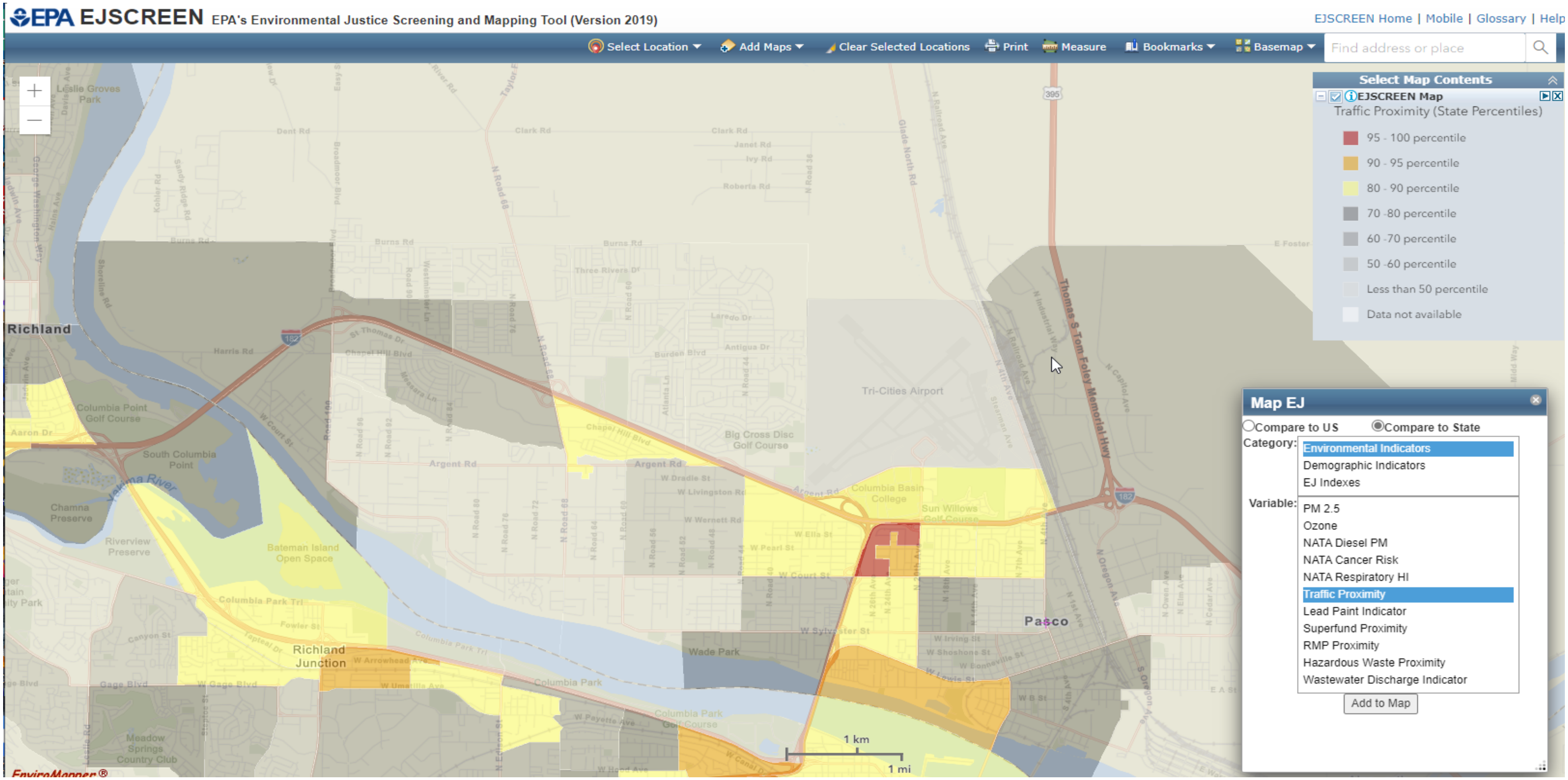
st were developed using the best
ıformation becomes available,
cies may expand or contract.
nd update the the distribution

- **Diesel Particulate Matter level in air (NATA Diesel PM)**
  Diesel particulate matter level in air in micrograms per cubic meter (µg/m3). Source: EPA National Air Toxics Assessments
- **Ozone level in air**
  Ozone summer seasonal avg. of daily maximum 8-hour concentration in air in parts per billion. Source: EPA Office of Air and Radiation
- **PM2.5 level in air**
  Particulate matter (PM2.5) levels in air, micrograms per cubic meter (µg/m3) annual average. Source: EPA Office of Air and Radiation
- **Traffic Proximity and Volume**
  Count of vehicles per day (average annual daily traffic) at major roads within 500 meters (or nearest one beyond 500 m), divided by distance in meters. Calculated from U.S. Department of Transportation National Transportation Atlas Database, Highway Performance Monitoring System.
- **Lead Paint Indicator (% pre-1960 housing)**
  Percent of housing units built before 1960, as indicator of potential exposure to lead paint. Calculated from the Census Bureau's American Community Survey 5-year summary estimates.
- **Proximity National Priority List Sites (NPL)**
  Count of proposed and listed NPL sites within 5 km (or nearest one beyond 5 km), each divided by distance in km. Count excludes deleted sites. Source: Calculated from EPA CERCLIS database.
- **Proximity to Risk Management Plan (RMP) Facilities**
  Count of RMP (potential chemical accident management plan) facilities within 5 km (or nearest one beyond 5 km), each divided by distance in km. Calculated from EPA RMP database.
- **Proximity to Treatment Storage and Disposal Facilities (TSDF)**
  Count of TSDF (hazardous waste management facilities) within 5 km (or nearest one beyond 5 km), each divided by distance in km. Calculated from EPA RCRAInfo database.
- **Wastewater Dischargers Indicator (Stream Proximity and Toxic Concentration)**
  RSEI modeled Toxic Concentrations at stream segments within 500 meters, divided by distance in kilometers (km). Calculated from RSEI modeled toxic concentrations to stream reach segments.

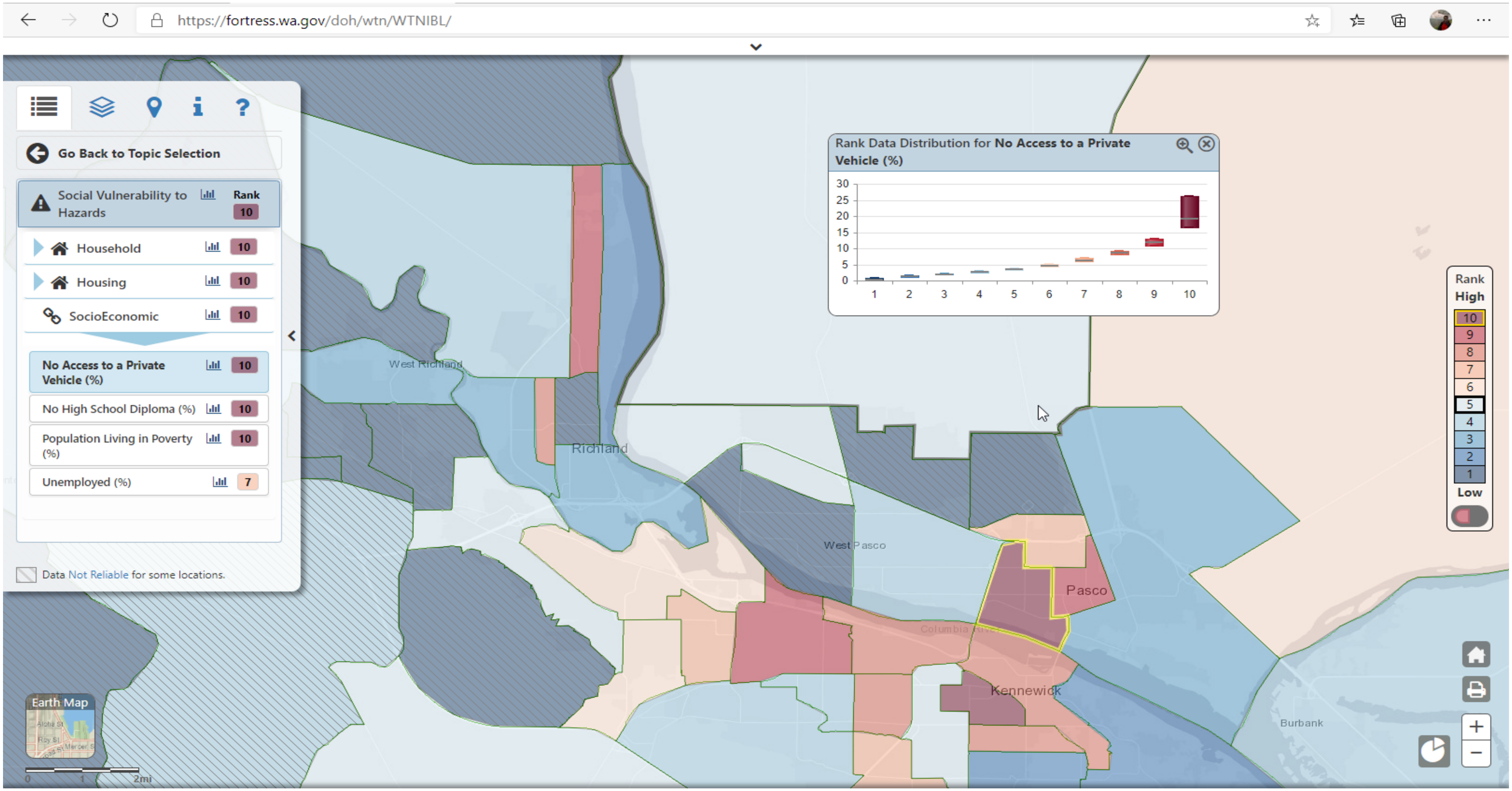
Top of Page


EPA EJSCREEN EPA's Environmental Justice Screening and Mapping Tool (Version 2019)
EJSCREEN Home | Mobile | Glossary | Help
Select Location
Add Maps
Clear Selected Locations
Print
Measure
Bookmarks
Basemap
Find address or place
Select Map Contents
EJSCREEN Map
Hazardous Waste Proximity (State Percentiles)
95 - 100 percentile
90 - 95 percentile
80 - 90 percentile
70 -80 percentile
60 -70 percentile
50 -60 percentile
Less than 50 percentile
Data not available
Map EJ
Compare to US
Compare to State
Category:
Environmental Indicators
Demographic Indicators
EJ Indexes
Variable:
PM 2.5
Ozone
NATA Diesel PM
NATA Cancer Risk
NATA Respiratory HI
Traffic Proximity
Lead Paint Indicator
Superfund Proximity
RMP Proximity
Hazardous Waste Proximity
Wastewater Discharge Indicator
Add to Map
Richland
Tri-Cities Airport
Pasco
Richland Junction
Columbia Basin College
Big Cross Disc Golf Course
1 km
1 mi
EnviroMapper®


EPA EJSCREEN EPA's Environmental Justice Screening and Mapping Tool (Version 2019)
EJSCREEN Home | Mobile | Glossary | Help
Select Location
Add Maps
Clear Selected Locations
Print
Measure
Bookmarks
Basemap
Find address or place
Select Map Contents
EJSCREEN Map
RMP Proximity (State Percentiles)
95 - 100 percentile
90 - 95 percentile
80 - 90 percentile
70 -80 percentile
60 -70 percentile
50 -60 percentile
Less than 50 percentile
Data not available
Map EJ
Compare to US
Compare to State
Category:
Environmental Indicators
Demographic Indicators
EJ Indexes
Variable:
PM 2.5
Ozone
NATA Diesel PM
NATA Cancer Risk
NATA Respiratory HI
Traffic Proximity
Lead Paint Indicator
Superfund Proximity
RMP Proximity
Hazardous Waste Proximity
Wastewater Discharge Indicator
Add to Map
Richland
Pasco
Tri-Cities Airport
Richland Junction
Columbia Point Golf Course
South Columbia Point
Bateman Island Open Space
Big Cross Disc Golf Course
Columbia Basin College
Wade Park
Columbia Park
Chamna Preserve
Riverview Preserve
Leslie Groves Park
Yakima River
Thomas S Tom Foley Memorial Hwy
1 km
1 mi
EnviroMapper®



EPA EJSCREEN EPA's Environmental Justice Screening and Mapping Tool (Version 2019)
EJSCREEN Home | Mobile | Glossary | Help
Select Location
Add Maps
Clear Selected Locations
Print
Measure
Bookmarks
Basemap
Find address or place
Select Map Contents
EJSCREEN Map
Traffic Proximity (State Percentiles)
95 - 100 percentile
90 - 95 percentile
80 - 90 percentile
70 -80 percentile
60 -70 percentile
50 -60 percentile
Less than 50 percentile
Data not available
Map EJ
Compare to US
Compare to State
Category:
Environmental Indicators
Demographic Indicators
EJ Indexes
Variable:
PM 2.5
Ozone
NATA Diesel PM
NATA Cancer Risk
NATA Respiratory HI
Traffic Proximity
Lead Paint Indicator
Superfund Proximity
RMP Proximity
Hazardous Waste Proximity
Wastewater Discharge Indicator
Add to Map
Richland
Tri-Cities Airport
Pasco
Richland Junction
Columbia Point Golf Course
South Columbia Point
Chamna Preserve
Riverview Preserve
Bateman Island Open Space
Big Cross Disc Golf Course
Columbia Basin College
Sun Willows Golf Course
Wade Park
Columbia Park
Columbia Park Golf Course
Meadow Springs Country Club
Leslie Groves Park
Yakima River
Thomas S Tom Foley Memorial Hwy
1 km
1 mi
EnviroMapper®



https://fortress.wa.gov/doh/wtn/WTNIBL/
Go Back to Topic Selection
Social Vulnerability to Hazards
Rank
10
Household 10
Housing 10
SocioEconomic 10
No Access to a Private Vehicle (%) 10
No High School Diploma (%) 10
Population Living in Poverty (%) 10
Unemployed (%) 7
Data Not Reliable for some locations.
Rank Data Distribution for No Access to a Private Vehicle (%)
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10
Rank
High
10
9
8
7
6
5
4
3
2
1
Low
West Richland
Richland
West Pasco
Pasco
Columbia River
Kennewick
Burbank
Earth Map
0 1 2mi

Washington State Department of Health

Washington Tracking Network (WTN)
A Source for Environmental Public Health Data

Home
Version Main

Home ▸ Data and Statistical Reports ▸ Environmental Health ▸ Washington Tracking Network (WTN)

Information By Location (IBL)

Selection Criteria

View two measures together ☐ ?

Measure 1

Keyword Search
Search measures

Section
Community

Topics
Transportation

Sub Topic
Transportation Safety

Measure
Crashes Involving a Pedestrian or Bicyc...

Filters

Submit

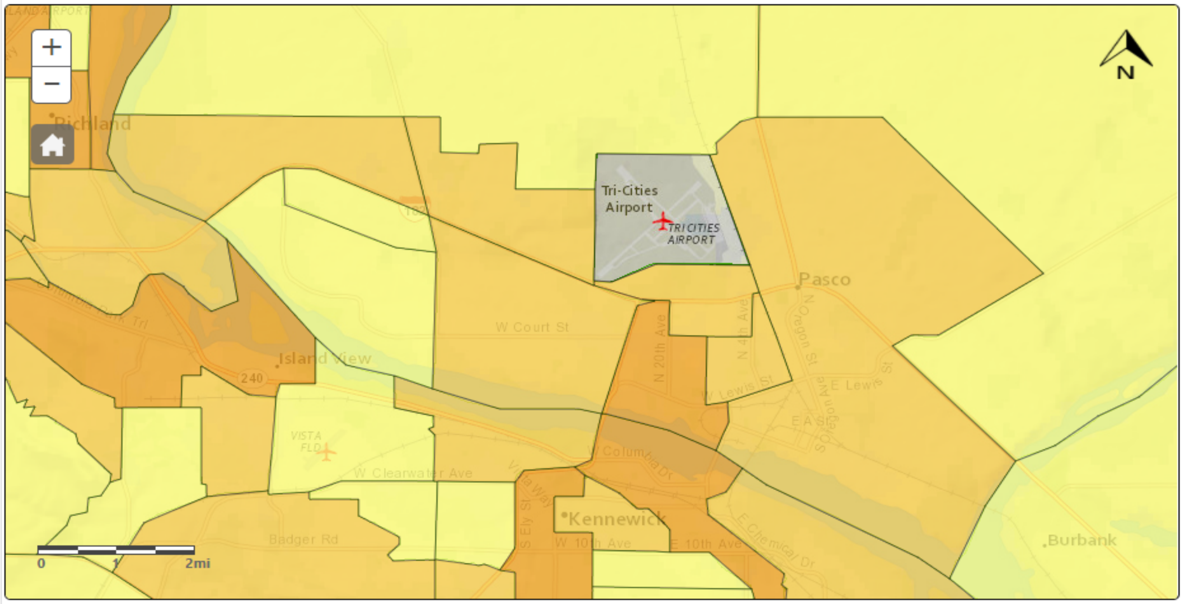
Selection Criteria & Filters

Notes | Table | Chart | Map

Measure 1

Fatal and Serious Crashes involving a Pedestrian or Bicyclist- Rate per 100,000

Geography: Census Tract, Year: 2013-2017



Legend (Measure 1)

Rates for Fatal and Serious Crashes- Bike and Pedestrians combined

- 0 - 0
- >0 - < 41.82
- 41.82 - 4166.67

Locate Address

Enter a County, Zip Code, or Address

Locate

Adjust Transparency

0% 50% 100%

Select Layers to Display

☐ County Boundaries

Washington State Greenhouse Gas Emissions Inventory: 1990-2015

Report to the Legislature

December 2018

Publication 18-02-043

Publication and Contact Information

This document is available on the Department of Ecology's website at: https://fortress.wa.gov/ecy/publications/summarypages/1802043.html

For more information contact:

Air Quality Program
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6800

Washington State Department of Ecology — www.ecology.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

To request ADA accommodation including materials in a format for the visually impaired, call Ecology at 360-407-6800 or visit https://ecology.wa.gov/accessibility. People with impaired hearing may call Washington Relay Service at 711. People with speech disability may call TTY at 877-833-6341.

Washington State Greenhouse Gas Emissions Inventory: 1990-2015

Report to the Legislature

Air Quality Program

Washington State Department of Ecology

Olympia, Washington

This page is purposely left blank

Table of Contents

List of Figures and Tables

Page

Figures

Tables

Executive Summary

As required in RCW 70.235.020 (2), this report provides a summary of Washington's greenhouse gas emissions from the 1990 baseline established in law through 2015, the most recent year the data necessary to create this inventory are available. The information in this report is used to evaluate Washington's greenhouse gas emissions, discuss where the emissions are coming from, and determine whether they are increasing or decreasing over time.

Key findings are:

- Washington's 2015 total greenhouse gas emissions were 97.4 million metric tons (MMT).
- Washington's 2015 total greenhouse gas emissions were 7.4 MMT higher than the 1990 baseline of 90.0 MMT.
- Washington's greenhouse gas emissions increased by about 6.1 percent from 2012 to 2015, primarily due to increased emissions from the electricity sector. During this time period Washington's economy also grew at a compound annual growth rate of 2.95% per year.[1]
- Compared to the nation, the electricity sector in Washington contributes significantly less greenhouse gas emissions due to the availability of hydropower.
- In 2015, Washington's largest contributors of greenhouse gases were the:
    - Transportation sector at 42.5 percent.
    - Residential, commercial, and industrial sector at 21.3 percent.
    - Electricity sector at 19.5 percent.

[1] https://www.deptofnumbers.com/gdp/washington/

Background Information

Greenhouse gases (GHGs) are substances that contribute to climate change by trapping heat in the atmosphere. The internationally-recognized greenhouse gases that contribute to human-caused climate change are:

- Carbon dioxide
- Hydrofluorocarbons
- Methane
- Nitrogen trifluoride
- Nitrous oxide
- Perfluorocarbons
- Sulfur hexafluoride.

Greenhouse gases are released during:

- *Stationary combustion*, which occurs at places that use equipment (such as boilers) to produce electricity, steam, heat, or power;
- *Mobile combustion*, which occurs when fuel is burned for transportation (such as in cars, trucks, ships, trains, and planes);
- *Industrial processes*, such as manufacturing cement, aluminum, ammonia, etc. where the process itself generates greenhouse gases; and
- *Fugitive releases* from the production, processing, transmission, storage, or use of fuels and other substances that do not pass through a stack, chimney, vent, or exhaust pipe (such as the release of sulfur hexafluoride from electrical equipment or nitrous oxide from fertilizers).

Washington's greenhouse gas legislation

In 2008, the Legislature established limits for reducing greenhouse gas emissions in Washington, and included specific requirements for reporting greenhouse gas emissions.

Washington state greenhouse gas emissions reductions are in RCW 70.235.020 (1)

> (i) By 2020, reduce overall emissions of greenhouse gases in the state to 1990 levels;
> (ii) By 2035, reduce overall emissions of greenhouse gases in the state to twenty-five percent below 1990 levels;
> (iii) By 2050, the state will do its part to reach global climate stabilization levels by reducing overall emissions to fifty percent below 1990 levels, or seventy percent below the state's expected emissions that year.

These reporting requirements are in RCW 70.235.020 (2):

*By December 31st of each even-numbered year beginning in 2010, the department and the *department of community, trade, and economic development[2] shall report to the governor and the appropriate committees of the senate and house of representatives the total emissions of greenhouse gases for the preceding two years, and totals in each major source sector. The department shall ensure the reporting rules adopted under RCW 70.94.151 allow it to develop a comprehensive inventory of emissions of greenhouse gases from all significant sectors of the Washington economy.*

Greenhouse gas emissions inventory

How the inventory was developed

To develop an inventory of Washington's greenhouse gas emissions, Ecology used a set of generally accepted principles and made adjustments as needed to apply them to Washington. The inventory is based on aggregated data for each sector, not facility-specific emissions.

The data to develop this inventory is provided by the U.S. Environmental Protection Agency's (EPA) State Inventory and Projection Tool (SIT). This greenhouse gas emissions tool has sector modules that are updated and released periodically throughout the year. The most complete annual greenhouse gas profile from these sector modules is from 2015.

In addition to U.S. EPA's SIT tool, the Washington State Department of Commerce annually provides greenhouse gas emissions for electricity calculated from fuel mix disclosure data. Each utility is required to report to the Department of Commerce the fuel mix that generates their electricity. Commerce then uses this information to determine an aggregated fuel mix for the entire state.

Greenhouse gas sectors

Ecology categorized greenhouse gas emissions into the following sectors:

- Transportation.
- Electricity consumption.[3]
- Residential, commercial, and industrial.[4]
- Fossil fuel industry.[5]
- Waste management.
- Industrial processes.[6]
- Agriculture.

[2] Renamed Department of Commerce
[3] Electricity consumption – greenhouse gas emissions associated with Washington's electricity demand
[4] Residential, commercial, and industrial - greenhouse gas emissions from fuels combusted to primarily produce space heating and/or process heating
[5] Fossil fuel industry – greenhouse gas emissions known as fugitive emissions from leaking or venting in processing or distribution systems
[6] Industrial processes - non-combustion sources of greenhouse gas emissions from industrial processes

How greenhouse gas emissions are shown

Carbon dioxide equivalent: The emission inventory shows greenhouse gas emissions in million metric tons (MMT) of carbon dioxide equivalent (CO_2e). Using carbon dioxide equivalent as a measurement allows us to capture the cumulative impacts of all greenhouse gases in one number.

Global Warming Potential: Greenhouse gas emissions in this report use the global warming potential values from the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report. A greenhouse gas global warming potential is the ratio of its heat-trapping ability to that of carbon dioxide. For example, the global warming potential of nitrous oxide is 298 because one metric ton of nitrous oxide has 298 times more ability to trap heat in the atmosphere than one metric ton of carbon dioxide.

In 1992, the United States signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC). Article 2 of the UNFCCC states:

…parties to the convention agreed to develop, periodically update, and publish, national inventories of anthropogenic emissions. The emissions are to be reported by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies.

The United States fulfills these commitments by submitting EPA's national greenhouse gas inventory report. Starting with 2013 greenhouse gas emission data, the United States and other developed countries have also agreed to submit to the UNFCCC annual inventories based on the use of Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) global warming potential values.[7] Washington follows this guidance and methodology to develop this annual greenhouse gas inventory.

[7] http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Chapter-Executive-Summary.pdf

Greenhouse gases included in the inventory

Washington's greenhouse gas emissions inventory includes the greenhouse gases also found in the U.S. Greenhouse Gas Emissions Inventory in Table 1. As stated previously, both inventories now use the global warming potential from the IPCC Fourth Assessment Report.[8]

Table 1: Global Warming Potential Factors for Greenhouse Gases

Greenhouse Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Hydrofluorocarbons (HFCs)	12 – 14,800
Perfluorocarbons (PFCs)	7,390 – 12,200
Sulfur hexafluoride (SF_6)	22,800
Nitrogen trifluoride (NF_3)	17,200

[8] This 2013 inventory is the first time that U.S. greenhouse gas emissions are reported using the Assessment Report 4 global warming potential values. https://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Annex-6-Additional-Information.pdf

Findings: Inventory Results

The 2015 estimate for total greenhouse gas emissions was 97.4 MMT CO_2e. This represents an approximate 6.1% increase from 2012 total greenhouse gas emissions.

As seen in Table 2, the original 1990 baseline data uses the global warming potential from IPCC's second assessment report (SAR). This was the established protocol at the time the original inventory data were created. However, given the recent mandate from the UNFCCC to use updated GWP estimates in all inventories going forward, all the data for all years is re-estimated using the recommended global warming potential from IPCC's Fourth Assessment Report (AR4) so that a consistent time series is available and accurate comparisons can be made across time.

The updated 1990 baseline using GWP AR4 and improved methodologies for Waste Management and Agriculture results in an increase of 1.6 MMT CO2e in the 1990 greenhouse gas baseline totals. Although the 1990 baseline has increased, it is important to note that this does not mean that achieving the 2020 greenhouse gas emissions limit (or the other future limits) has become easier. Rather, the change in the GWP factors has caused all emission estimates to rise across all years, so the level of effort necessary to achieve the greenhouse gas limits in the future is roughly the same.

Table 2: Washington State Total Annual GHG Emissions (MMT CO2e)

Million Metric Tons CO_2e	1990	1990	2000	2005	2012	2013	2014	2015
GWP	**SAR**	**AR4**	**ARA**	**AR4**	**AR4**	**AR4**	**AR4**	**AR4**
Electricity, Net Consumption-Based	**16.9**	**16.9**	**23.3**	**18.9**	**15.2**	**18.2**	**18.2**	**19.0**
Coal	16.8	16.80	17.4	15.20	12.10	13.34	13.96	14.03
Natural gas	0.1	0.10	5.28	3.60	3.00	4.81	4.16	4.91
Petroleum	0.0	0.00	0.60	0.00	0.10	0.07	0.06	0.07
Biomass and waste (CH_4 and N_2O)	0.0	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Residential/Commercial/Industrial (RCI)	**18.6**	**18.6**	**20.1**	**19.4**	**20.7**	**21.1**	**20.5**	**20.7**
Coal	0.6	0.61	0.00	0.10	0.20	0.19	0.25	0.18
Natural gas	8.6	8.62	11.37	10.32	11.57	12.07	11.77	11.21
Oil	9.1	9.16	8.51	8.75	8.68	8.51	8.16	9.05
Wood (CH_4 and N_2O)	0.2	0.26	0.25	0.21	0.26	0.31	0.31	0.27
Transportation	**37.5**	**37.9**	**44.9**	**42.3**	**40.4**	**38.8**	**39.3**	**41.4**
On-road gasoline	20.4	20.70	24.50	23.92	21.20	21.71	21.76	21.42
On-road diesel	4.1	4.22	7.72	7.06	7.38	7.01	7.46	8.15
Marine vessels	2.6	2.48	1.76	1.63	2.13	1.92	1.62	2.33
Jet fuel and aviation gasoline	9.1	9.10	10.05	7.70	8.02	6.57	6.95	7.77
Rail	0.8	0.80	0.30	1.26	0.97	0.86	0.82	0.80
Natural gas, LPG	0.6	0.60	0.60	0.74	0.68	0.77	0.71	0.92
Fossil Fuel Industry	**0.5**	**0.6**	**0.7**	**0.8**	**0.8**	**0.8**	**0.9**	**0.8**
Natural gas industry (CH_4)	0.5	0.58	0.73	0.80	0.82	0.83	0.86	0.84
Coal mining (CH_4)	0.0	0.0	0.00	.00	0.00	0.00	0.00	0.00
Oil industry (CH_4)	0.0	0.0	0.00	.00	0.00	0.00	0.00	0.00
Industrial Processes	**7.0**	**7.0**	**10.0**	**4.5**	**5.0**	**5.2**	**5.3**	**5.3**
Cement manufacture (CO_2)	0.2	0.20	0.44	0.44	0.26	0.33	0.38	0.32
Aluminum production (CO_2, PFC)	5.9	5.90	7.38	1.58	1.23	1.17	1.03	0.96
Limestone and dolomite use (CO_2)	0.0	0.00	0.02	0.03	0.01	0.01	0.02	0.02
Soda ash	0.1	0.10	0.10	0.05	0.05	0.05	0.05	0.05
ODS substitutes (HFC, PFC)	0.0	0.00	1.62	2.11	3.30	3.41	3.57	3.76
Semiconductor mfg (HFC, PFC, SF_6, NF_3)	0.0	0.00	0.09	0.09	0.07	0.07	0.08	0.08
Electric power T & D (SF_6)	0.8	0.80	0.36	0.19	0.12	0.11	0.12	0.10
Waste Management	**1.5**	**3.1**	**3.5**	**4.2**	**3.2**	**3.3**	**3.4**	**3.5**
Solid waste management	1.0	2.58	2.84	3.48	2.36	2.54	2.61	2.68
Wastewater management	0.5	0.55	0.68	0.71	0.79	0.80	0.81	0.82
Agriculture	**6.4**	**5.8**	**6.0**	**5.9**	**6.4**	**6.4**	**6.6**	**6.6**
Enteric fermentation	2.0	2.62	2.57	2.44	2.53	2.53	2.54	2.58
Manure management	0.7	0.86	1.24	1.27	1.52	1.55	1.62	1.65
Agriculture soils	3.7	2.32	2.24	2.22	2.38	2.33	2.43	2.40
Total Gross Emissions	**88.4**	**90.0**	**108.6**	**96.0**	**91.8**	**93.9**	**94.1**	**97.4**

Washington's Greenhouse Gas Emissions Trends

Trends by sector, 1990–2015

Figure 1 shows greenhouse gas emissions from 1990 to 2015 by sector.

There was a significant decrease in emissions between 2000 and 2002, mainly due to changes in the aluminum industry in Washington.[9]

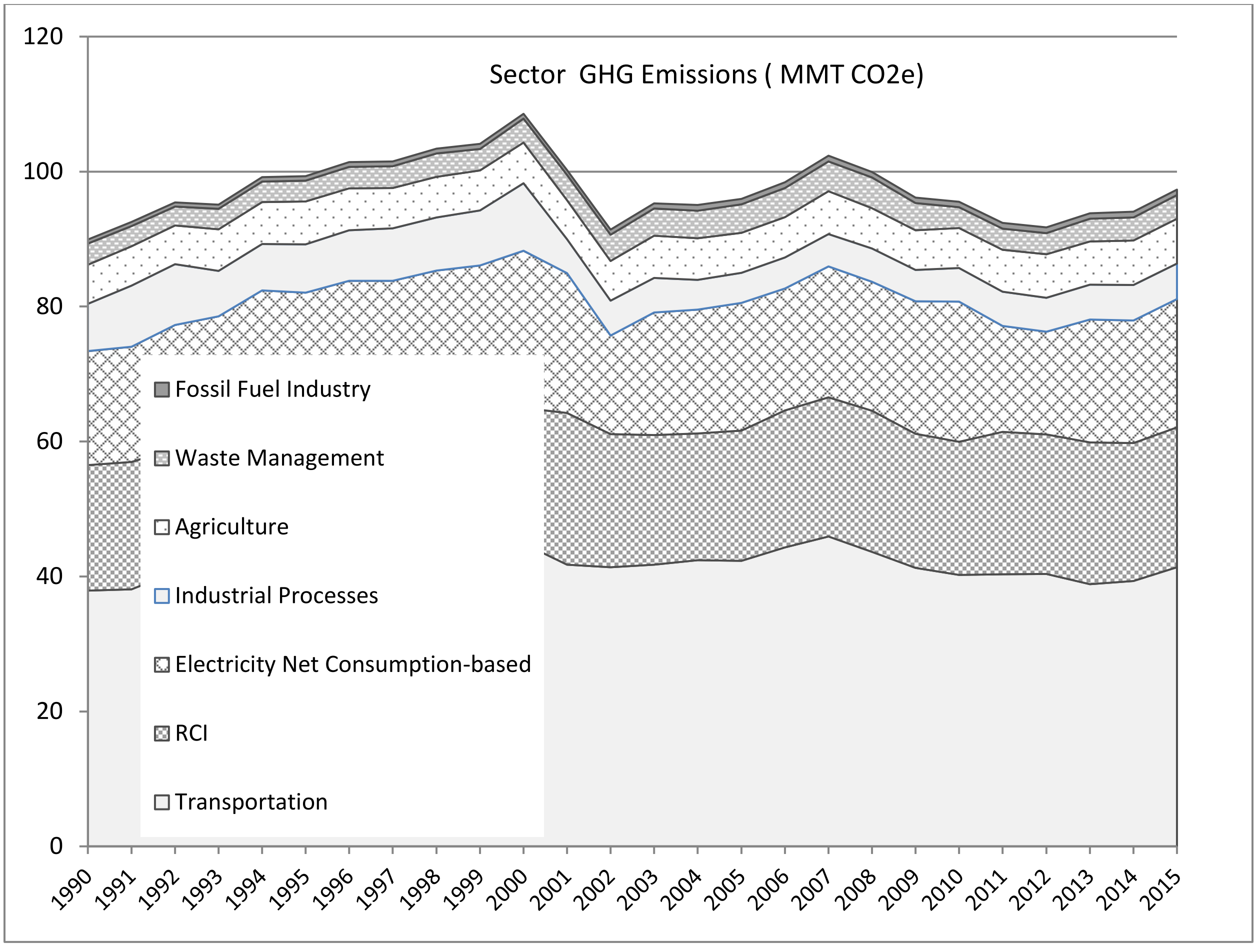


Figure 1: Total Annual Greenhouse Gas Emissions (MMT CO2e) by Sector from 1990 – 2015

[9] The SIT module develops an estimate of aluminum emissions that now includes process CO2 emissions.

Trends by sector, 2012–2015

Figure 2 compares total 2012–2015 greenhouse gas emissions from the electricity, residential, commercial, and industrial (RCI), and transportation sectors.

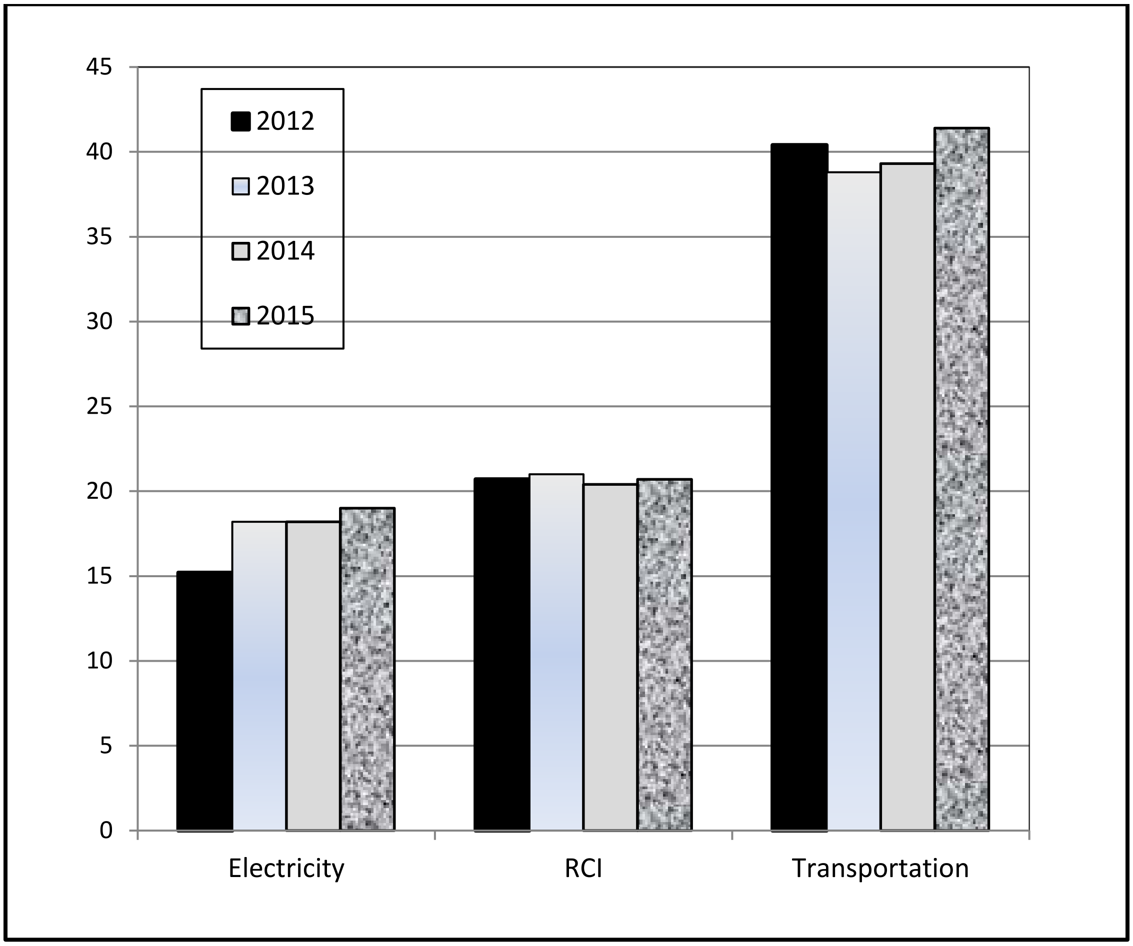


Figure 2: Total Greenhouse Gas Emissions (MMT CO2e) by Sector for 2012–2015

Trends by sector, Washington and U.S.

Nationally, in 2015 the electricity sector is the largest contributor of greenhouse gases (Figure 3). Since Washington State uses hydropower for much of its electricity, the electricity sector is a less significant greenhouse gas source. The transportation sector is Washington's most significant contributor of greenhouse gases.

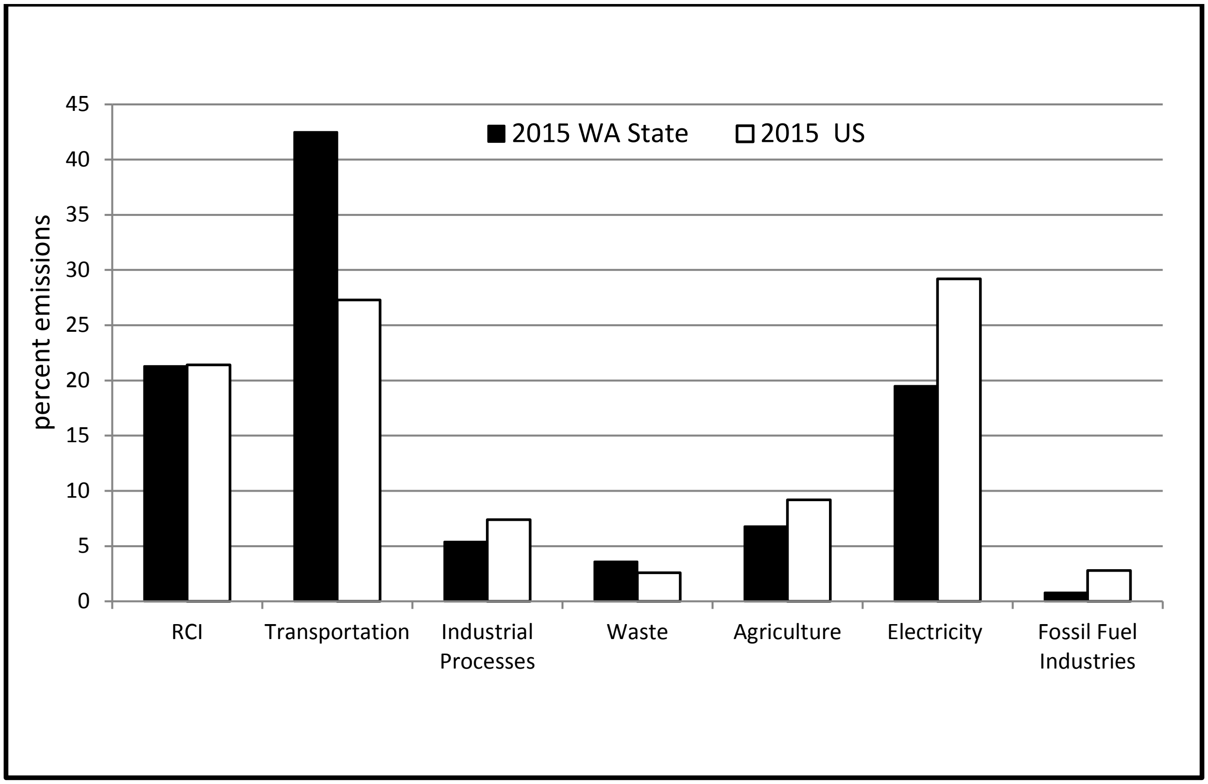


Figure 3: Percent Greenhouse Gas Emissions by Sector – 2015, Washington and U.S[10]

[10] Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015, Table ES-2 https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf

Summary of results by sector

Transportation sector

In 2015, transportation is Washington's largest greenhouse gas emissions contributor, while electricity is the largest contributor nationally.

Washington greenhouse gas emissions from the transportation sector have been fairly constant for several years, with on-road gasoline continuing to contribute over 50 percent of transportation sector emissions as indicated in Figure 4. Marine vessel emissions include emissions from recreational, commercial, and ocean-going vessels, but excludes marine bunker fuels consumed in international waters.

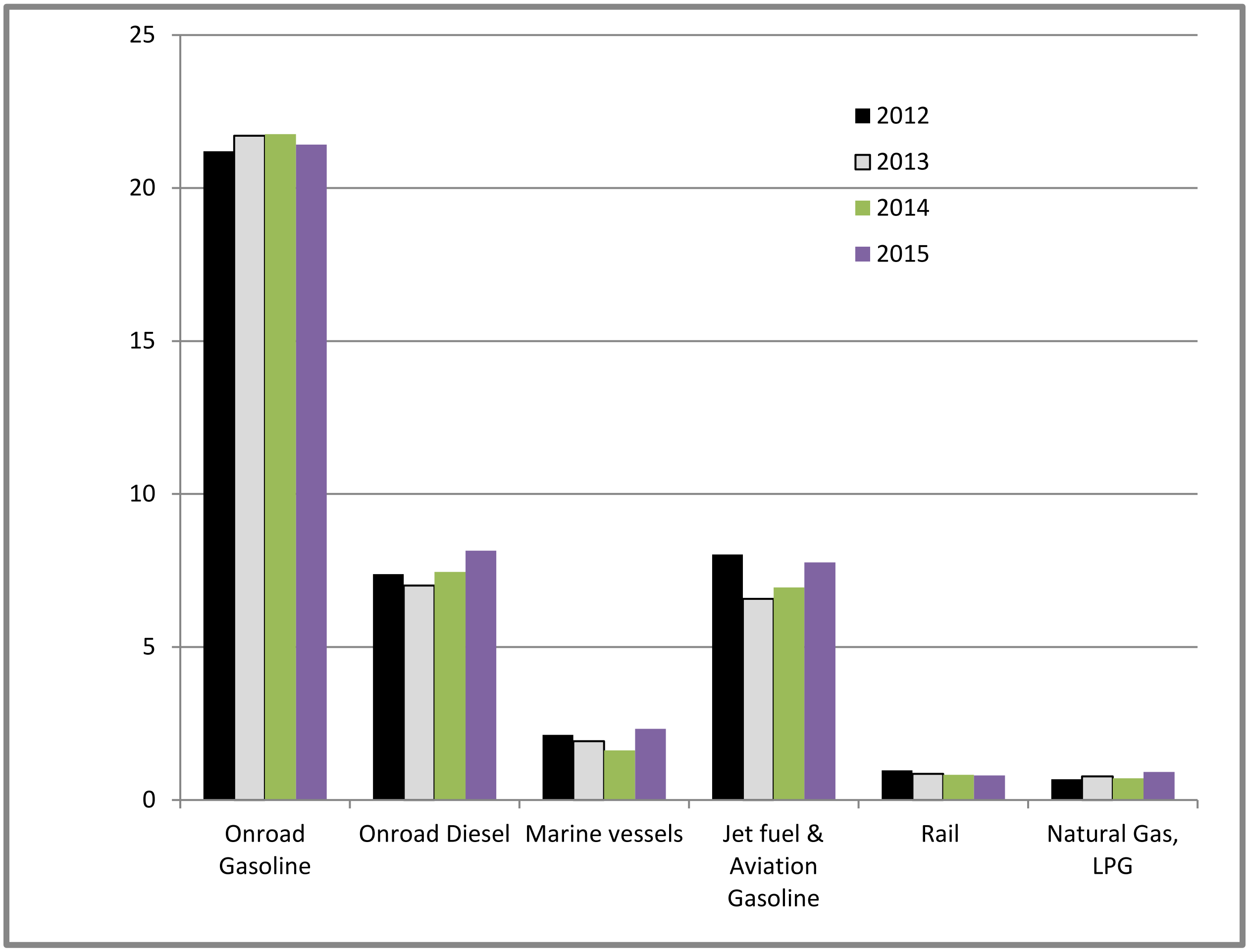


Figure 4: Greenhouse Gas Emissions by transportation sector

Electricity sector

Despite the large availability of clean hydroelectricity, Washington also uses electricity from coal and natural gas. Some of this electricity is produced in Washington and some is imported from other states. Washington's greenhouse gas emissions from electricity are estimated using a consumption-based (or "load-based") approach. In other words, emissions are calculated based on the emissions profile of the power sources that deliver electricity to Washington for use in the homes and businesses of Washington regardless of where those power sources are located. For example large coal plants in Montana and Wyoming provide a significant portion of the emissions associated with electricity use in Washington.

Electricity GHG emissions have increased from 2012 to 2015; however, historically electricity emissions have fluctuated up and down based on the amount of water available to supply the many dams that provide Washington with both water and power. The 2016 information was available to include in this bar chart since electricity greenhouse gas emissions are determined by Washington State's fuel mix disclosure data analysis.

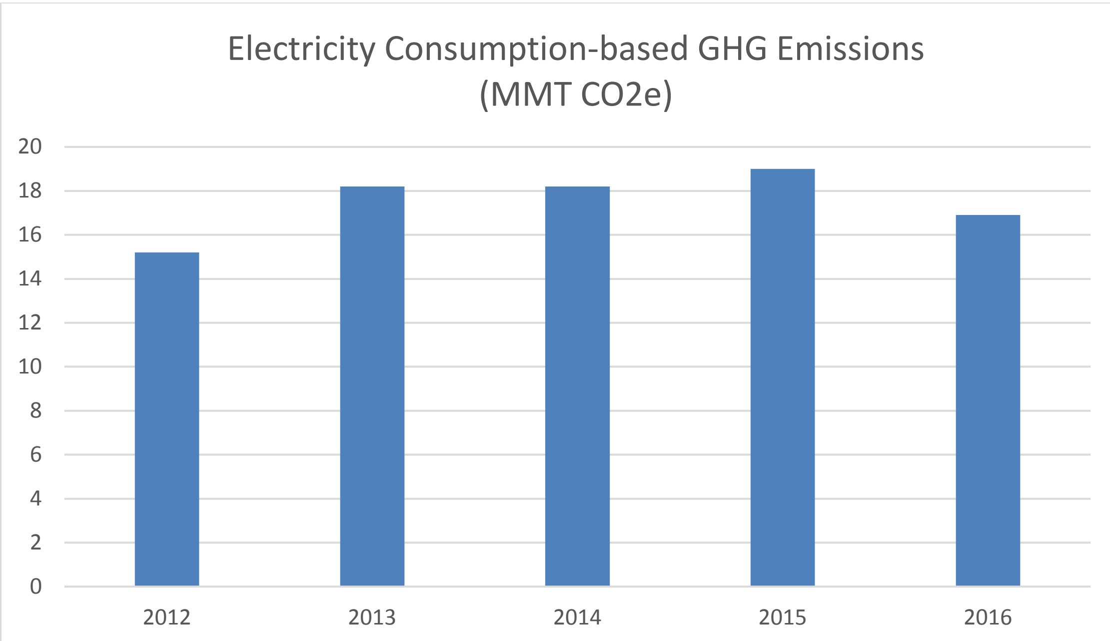


Figure 5: Annual GHG emissions from Electricity (Consumption-Based)

Residential, commercial, and industrial (RCI) sector

Greenhouse gas emissions in this sector occur from energy consumption when fuels are combusted to provide heat, including space heating and process heating (heating necessary for production processes or other applications). The data indicates a decrease in greenhouse gases from residential heating while the commercial and industrial sectors have remained fairly constant from 2012 to 2015.

The RCI sector is a relatively large source of greenhouse gas emissions in Washington. In 2015:

- 11.7 MMT CO_2e came from the industrial space and process heating.
- 4.8 MMT CO_2e came from the residential space heating.
- 4.1 MMT CO_2e came from the commercial space and process heating.

As Figure 6 indicates, the industrial sector continues to be the largest contributor of greenhouse gas emissions in the RCI sector.

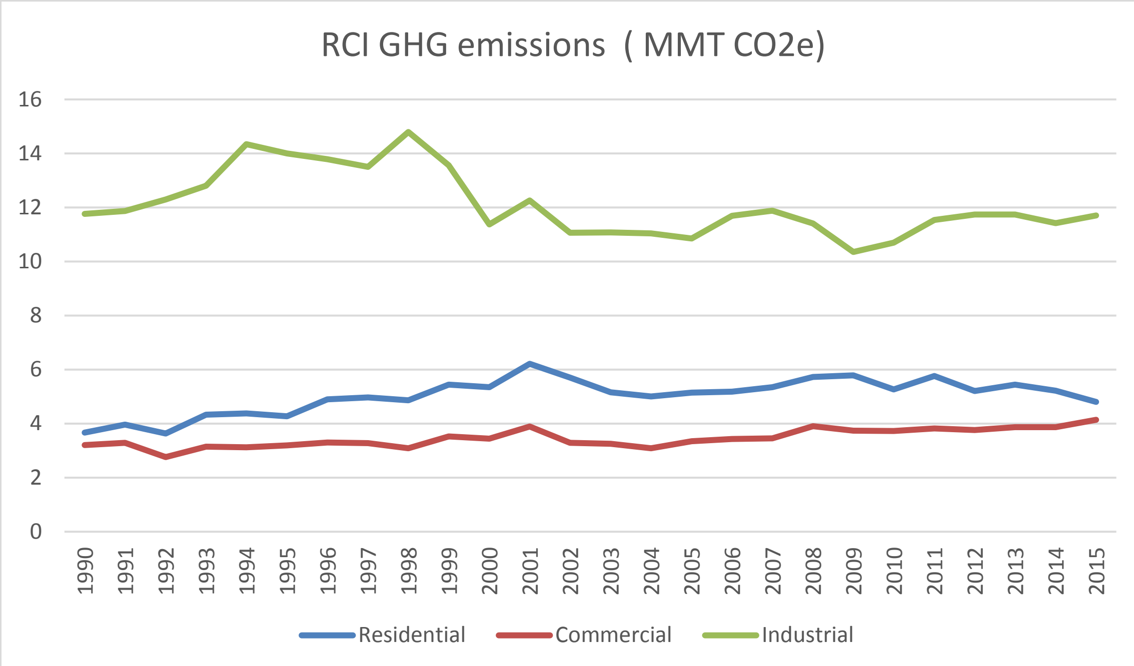


Figure 6: Annual RCI GHG emissions

Fossil fuel industry sector

This sector includes fugitive greenhouse gas emissions that are released during the production, processing, transmission, and distribution of fossil fuels. These emissions are typically fugitive methane due to leakage and venting from natural gas pipelines, and petroleum systems.

In 2015, these emissions were about 1.0 percent of Washington’s greenhouse gas emissions.

Waste management sector

This sector includes greenhouse gas emissions from landfills and wastewater treatment facilities. This inventory does not include waste exported from Washington to other states for disposal.

Washington’s 2015 greenhouse gas emissions from this sector are estimated at 2.8 percent of the total emissions. However, the 1990 baseline emissions from this sector are updated due to: 1) improved methodology in the U.S. EPA State Inventory Tool module, and 2) the use of Fourth Assessment Report global warming potentials.

Industrial processes sector

This sector includes greenhouse gas emissions from industry-specific processes such as aluminum or cement manufacturing, or fugitive emissions such as sulfur hexafluoride (SF_6) releases from electric power transmission and distribution systems.

In 2015, greenhouse gas emissions from this sector contributed ~ 5% of Washington's total greenhouse gas emissions.

The EPA State Inventory Tool module develops an estimate of aluminum emissions. This is calculated using a ratio of state capacity to total production. The state capacity was wrong because the capacity of a Washington facility had been left out. This was corrected starting in 2008.

Washington produces small amounts of lime and nitric acid. Although these processes emit greenhouse gases, they are expected to have relatively low emissions due to their low levels of production. This greenhouse gas inventory excludes estimates for these processes.

Agriculture sector

Agricultural activities such as manure management, fertilizer use, and livestock digestion process (enteric fermentation) result in methane and nitrous oxide emissions.

In 2015, these emissions accounted for about 6.8 percent of Washington's greenhouse gas emissions.

Next Steps

An annual Washington greenhouse gas inventory will be completed for 2016 and 2017 as EPA releases the State Inventory Tool modules for these years. This data will be provided in the next legislative report on Washington Greenhouse Gas Inventory issued in December 2020.

Because of the potential for significant annual data fluctuations in greenhouse gas emissions within sectors, it is useful to display the data display as multi-year averages.
Figure 7 presents a three year averaging of greenhouse gas emissions from each sector. The inner circle displays the percent distribution of the sectors; whereas, the outer ring provides the percent distribution from each source within each sector. As an example, under three year averaging, 42 percent of Washington State greenhouse gas emissions are from the Transportation sector with 22.7 percent of total Washington state emissions from on-road gasoline.

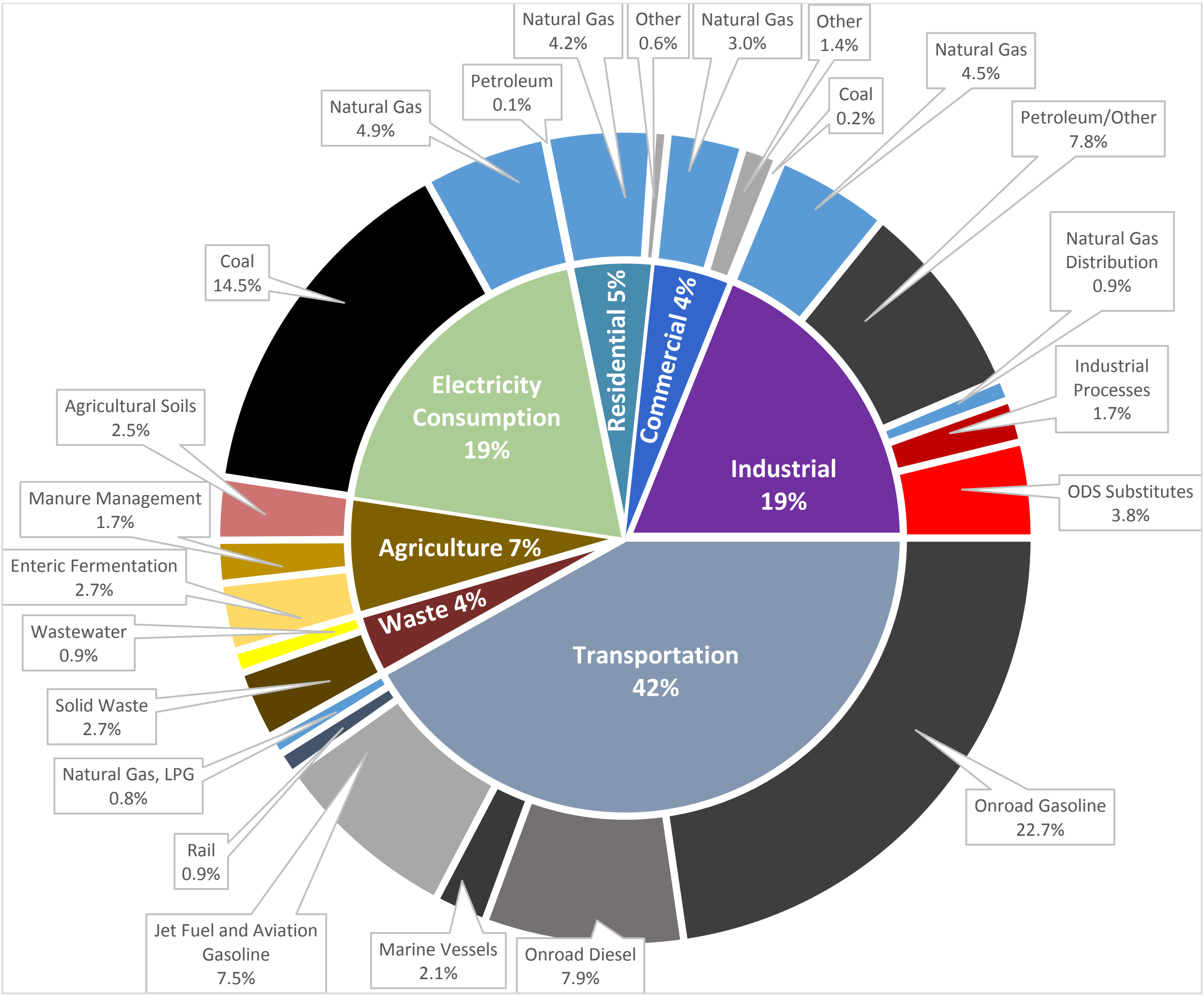


Figure 7: Washington Greenhouse Gas Emissions, 3 year average (2013-2015)

Conclusion

This inventory summarizes the greenhouse gas emissions from specific sectors in Washington from the 1990 baseline through 2015.

Key points are:

- Washington's 2015 total greenhouse gas emissions were 97.4 million metric tons (MMT).
- Washington's 2015 total greenhouse gas emissions were 7.4 MMT higher than the 1990 baseline of 90.0 MMT.
- Compared to the nation, the electricity sector in Washington contributes significantly less because of the availability of hydropower although emissions flux considerably from year to year.
- In 2015, Washington's largest contributors of greenhouse gases were:
  - Transportation sector at 42.5 percent.
  - Residential, commercial, and industrial sector at 21.3 percent.
  - Electricity sector at 19.5 percent.
- Washington's greenhouse gas emissions increased by about 6.1 percent from 2012 to 2015, primarily due to increased emissions from the electricity sector. During this time period Washington's economy also grew at a compound annual growth rate of 2.95% per year.[11]

[11] https://www.deptofnumbers.com/gdp/washington/

A REVIEW OF THE INTERNATIONAL MODELING LITERATURE: TRANSIT, LAND USE, AND AUTO PRICING STRATEGIES TO REDUCE VEHICLE MILES TRAVELED AND GREENHOUSE GAS EMISSIONS

A Report for the California Air Resources Board and the California Department of Transportation

Caroline Rodier, Ph.D. Senior Researcher
Transportation Sustainability Research Center
Institute of Transportation Studies
University of California, Berkeley
1301 S. 46th Street, Richmond Field Station (RFS), Bldg. 190, Richmond, CA 94804
(510) 665-3524 (O) (510) 665-2183 (F)
caroline@tsrc.berkeley.edu

October 1, 2009

ACKNOWLEDGEMENTS

The author would like to thank the California Air Resources Board (ARB), California Department of Transportation (Caltrans), California Energy Commission (CEC), and the Energy Efficiency Center at the University of California, Davis for their generous contributions to this research. In particular, we would like to acknowledge Jeff Weir, Lezlie Kimura, Kurt Karperos, and Lynn Terry of ARB; Reza Navai, Nancy Chinlund, and Larry Orcutt of Caltrans; and Panama Bartholomy of CEC. I would also like to thank Susan Shaheen, Bob Johnston, Gordon Garry, Dan Sperling, and for their support and advice. A special thanks to undergraduate researcher, Martin Brown, for his dedicated assistance to this project. The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein.

ABSTRACT

California led the nation by passing the first global warming legislation in the U.S. California is tasked with reducing green house gas (GHG) emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050. The California Air Resources Board estimates that significant GHG reductions from passenger vehicles can be achieved through improvements in vehicle technology and the low carbon fuel standard; however, these reductions will not be enough to achieve 1990 levels if current trends in vehicle miles traveled (VMT) continue. Currently, most operational regional models in California have limited ability to represent the effects of transit, land use, and auto pricing strategies; efforts are now underway to develop more advanced modeling tools, including activity-based travel and land use models. In the interim, this report reviews the international modeling literature on land use, transit, and auto pricing policies to suggest a range of VMT and GHG reduction that regions might achieve if such policies were implemented. The synthesis of the literature categorizes studies, by geographic area, policy strength, and model type, to provide insight into order of magnitude estimates for 10-, 20-, 30-, and 40-years time horizons. The analysis also highlights the effects of modeling tools of differing quality, policy implementation timeframes, and variations in urban form on the relative effectiveness of policy scenarios.

Key Words: Travel modeling; land use modeling; land use and transit measures; auto pricing; green house gas reductions

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

EXECUTIVE SUMMARY

California led the nation by passing the first global warming legislation in the U.S. California is tasked with reducing green house gas (GHG) emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050. The California Air Resources Board estimates that significant GHG reductions from passenger vehicles can be achieved through improvements in vehicle technology and the low carbon fuel standard; however, these reductions will not be enough to achieve 1990 levels if current trends in vehicle miles traveled (VMT) continue. Currently, most operational regional models in California have limited ability to represent the effects of transit, land use, and auto pricing strategies; efforts are now underway to develop more advanced modeling tools, including activity-based travel and land use models. In the interim, this report reviews the international modeling literature on land use, transit, and auto pricing policies to suggest a range of VMT and GHG reduction that regions might achieve if such policies were implemented. The synthesis of the literature categorizes studies, by geographic area, policy strength, and model type, to provide insight into order of magnitude estimates for 10-, 20-, 30-, and 40-year time horizons. The analysis also highlights the effects of modeling tools of differing quality, policy implementation timeframes, and variations in urban form on the relative effectiveness of policy scenarios.

The results of this report provide some order-of-magnitude estimates for policies that appear to have some promise of near term implementation. Employee parking pricing may result in approximately a 1% reduction in VMT over the 10-year time horizons. Pay-as-you-drive insurance policy may produce reductions ranging from 4% to 5% reduction over all time horizons. Moderate cordon pricing schemes are likely to reduce VMT by 2% to 3% over time. Increased transit investment may reduce VMT by 0.1% to 1% during a 10-year time horizon, and in future 10-year increments, this may increase by 1 percentage point at the higher reduction level. Land-use-only scenarios may reduce VMT by up to 2% in the 10-year time horizon, which may increase by approximately 2 to 3 percentage points at the higher reduction level at 10 year increments. Land use and transit scenarios may reduce VMT by 2% to 6% during a 10-year time horizon, and these figures may increase by approximately 2 to 5 percentage points at each future 10-year increment. Combined land use, transit, and pricing policy measures would bring significantly greater reductions both in the shorter and longer term time horizons.

In general, the results confirm that even improved calibrated travel models are likely to underestimate VMT reductions from land use, transit, and pricing policies. These models simply are not suited for the policy analysis demands in the era of global climate change. For example, when similar transit scenarios were simulated with the improved calibrated travel model and the integrated land use and transport model, the latter produced significantly larger results (6.0% versus 0.3%). Despite the very aggressive pricing measures simulated by the improved travel model in the San Francisco region, the results are significantly lower than weaker pricing policies simulated in the same region using an advanced travel model.

However, even the advanced models used in the reviewed studies exhibit limitations. Scenarios simulated with integrated land use and travel models of relatively moderate policy strength in regions with high quality transit tended to show very small reductions in VMT distributed widely above the median. These integrated models use relatively large zones and thus have coarse geographic resolutions, which may overestimate the share of vehicle trips relative to walk and bike trips from transit-oriented development policies. On the other hand, the advanced travel model used in the pricing studies may fail to identify possible consequences arising from land use and transport interactions. For example, pricing policies simulated with integrated land use and travel models showed that in some cities these policies may actually increase VMT by shifting housing and employment to outer areas of the regions and increasing average shopping trip lengths. Theoretically advanced land use and travel models are needed that have fine-grained geographic resolutions and represent greater variation in the socio-economic attributes of travelers.

The results of the extrapolation analysis in this study also illustrate the challenge of implementing land use and transit strategies in a regulatory framework that emphasizes near-term compliance. For example, the Sacramento Area Council of Government's blueprint land use and transport plan was simulated over a 50-year time horizon; the extrapolated results, which evenly distribute VMT reduction over time, show a 4.2% reduction in VMT in the 10-year time horizon. However, a much more aggressive scenario, simulated with the improved travel model in the region over a 10-year time horizon, only showed a 0.4% reduction in VMT.

The analysis of consistent policies across different regions also provides insight into how VMT reduction may vary given existing land use densities and transit infrastructure. For example, analyses of land-use only policies suggest that these policies may be less effective in various European regions and in Washington, D.C. relative to the more sprawling and rapidly growing regions (e.g., Sacramento) where trend land use patterns do not take full advantage of existing transit capacity. The results of the auto pricing policies tend to show greater reductions in VMT in European cities because of higher quality modal options to the auto. As a result, care should be taken in generalizing such results to U.S. cities without high quality alternatives.

CHAPTER 1: INTRODUCTION

California led the nation by passing the first global warming legislation in the U.S. The *Global Warming Solutions Act* (AB 32) requires California's green house gas (GHG) emissions be reduced to 1990 levels by 2020, and the Governor's Executive Order targets an additional 80% reduction below 1990 levels by 2050. Transportation accounts for 36% of total GHG emissions in California and 27% in the U.S. The California Air Resources Board (CARB) estimates that significant GHG reductions from passenger vehicles can be achieved through improvements in vehicle technology and the low carbon fuel standard; however, these reductions will not be enough to achieve 1990 levels if current trends in vehicle miles traveled (VMT) continue. As a result, land use and transport strategies to reduce growth in VMT are an important part of achieving California's GHG goals.

Currently most operational models used by state, regional, and local governments in California have limited ability to represent the effects of transit, land use, and auto pricing strategies. The major metropolitan planning organizations (MPOs) in California are in the process of developing more advanced modeling tools (activity-based travel and land use models); however, it is likely to be at least three years before such models are fully operational. In the interim, this report reviews the international modeling literature to suggest a range of VMT and GHG reductions that regions might achieve if such policies were implemented over 10-, 20-, 30-, and 40-year time horizons. The analysis also provides insights into the effects of varying modeling tools, policy types, regulatory timeframes, and urban form on the relative effectiveness of discrete and combined policy alternatives.

The report begins with a description of the methods used in the evaluation of the scenarios including the categorization of models, area type, and policy strength. Next, a general overview of the studies reviewed is provided, including the location, models, and scenarios by policy type. This is followed by a literature synthesis, which presents results separately for single- and combined-policy scenarios. Finally, key conclusions are drawn.

CHAPTER 2: METHODS

The literature reviewed in this study consists of studies conducted by regional or state government agencies, academic researchers, and community groups. To be included in this review, the study must report VMT and/or GHG effects of a policy alternative relative to a base case (typically a trend or business-as-usual) in the same horizon year. The results are presented as per capita percentage change in VMT and include both personal and commercial vehicle travel. GHG results from reduced vehicle travel are used from one study (Lautso et al., 2004) because VMT results were not available. Most studies provide simulation results for only one or two time horizons (most typically 20 or 30 years); however, the AB 32 legislation has an initial 10-year time horizon, and the Governor's Executive Order has a 40 year time horizon. Incremental progress toward GHG reduction goals will have to be monitored. As a result, compound annual growth rates were calculated using the current base case (e.g., year 2005) for each future policy scenario time horizon or horizons. The growth rates were then applied to estimate results for the time horizons of 10, 20, 30, and 40 years. However, if a pricing study included only one time horizon, then future overestimates were addressed by applying average extrapolation changes from studies of the same policies in similar regions (i.e., size and transit infrastructure). It is important to note that the timing of implementation could change the estimates for these time horizons and, in general, near term effects may be overestimated and outer-year effects may be underestimated. Study intervals (SI), free from distribution assumptions, are identified for a 68% and 95% range of study scenario results.

EVALUATION

In the evaluation of these studies, the type and quality of the model are categorized as described in Table 1. The model types include (1) travel and/or land use models of varying quality, calibrated to specific regions and used for regulatory compliance and planning; (2) experimental or research models typically of high quality but lacking more rigorous calibration of official models; and (3) sketch planning or visioning tools used by community-based groups to explore different development futures, but not to make official forecasts.

TABLE 1 Model Type and Quality Categories

Model Type	Quality
Poor Calibrated Travel	Limited sensitivity to changes in travel time and cost (zone-based without feedback to trip distribution) (4-step without feedback)
Typical Calibrated Travel	Some sensitivity to changes in travel time and cost (zone based with feedback to trip distribution) (4-step with feedback of uncertain quality)
Improved Calibrated Travel	Better sensitivity to changes in travel time and cost (smaller zones with feedback to trip distribution) and higher geographic resolutions (4-step with feedback and greater sensitivity to transit, walk, and bike variables)
Advanced Calibrated Models	More advanced representation of travel behavior, land use, and economic theories; good sensitivity to modal changes in travel time and costs; land use effects; and high geographic resolutions (Travel and land use models; activity-based models)
Experimental/research models	Similar to advanced models but without the rigorous calibration of official models
Visioning tools	Sketch planning for quick scenario analysis; exploratory analysis of alternative policies (unofficial 4-step model; UPLAN; PLACES; INDEX)

To address generalizability, study results are categorized by area type, defined by population size and transit commute mode share (in approximately 2000). A region with a population of seven million or more is categorized as large, between seven and one million is medium, and less than one million is small. Regions with transit commute mode share greater than or equal to 10% are categorized as having high quality transit, and those with mode share less than 10% have moderate to low quality transit.

Policy type and strength are also identified in this analysis in Table 2. Land use and auto pricing policies are widely considered to be effective policies to reduce VMT; however, historically, in California and the U.S., the adoption and implementation of these policies have been difficult for a variety of political and institutional reasons. Some of the literature included in this study attempts to "bookend" or represent extreme ends of the policy-implementation spectrum. For example, some assume all new development over a 20-year period would be accomplished through infill and redevelopment in areas near transit. Others include congestion pricing policies on all congested roadways or combine multiple auto pricing policies in one scenario (e.g., fuel pricing, VMT pricing, and parking pricing). In the near term, such aggressive implementation of land use and pricing policies seems unlikely.

TABLE 2 Policy Strength and Type Categories

Policy Strength	Policies Typically Included
Moderate	Improve transit service; reduce transit fares.
Aggressive	Land use and transport strategies in official planning documents and/or that represent moderate changes relative to historical development patterns; cordon pricing; pay-as-you-drive insurance; parking pricing in the urban core; widespread carsharing and telecommuting; traffic calming.
Very Aggressive	Land use and transport strategies that depart significantly from historical patterns and are not included in official planning documents; VMT pricing; congestion pricing on all roadways; fuel pricing; and region-wide parking pricing.

CHAPTER 3: SUMMARY OF STUDIES REVIEWED

In Table 3, the studies reviewed in this report are summarized by source, location, model, and number of scenarios by type.

TABLE 3 Summary of Studies Reviewed by Source, Location, Model, and Number of Scenario Types

Size/ Transit	Region	Studies	Models	Scenario #			
				TR	LU	LUTR	PR
Large/High	Chicago	Chicago Metropolis, 2003	LU (CRIEM/GIS)+TDM			4	
	Yorkshire	Simmonds et al., 2006	LU (DELTA)+ TDM	7			5
	Washington DC	Safirova, et al., 2007	LU (LUSTRE)		4		6
		Nelson et al., 2003	START TDM				1
	Philadelphia	DVRPC, 2003	DVPCP TDM		1		
	San Francisco	Deakin et al., 1996	STEP TDM				10
		MTC, 2007	MTC TDM	1	1	1	2
Large/ Moderate	San Diego	Deakin et al., 1996	STEP TDM				10
		SANDAG, 1998	SANDAG TDM			3	
		SANDAG, 2007		1		1	
	Los Angeles	Deakin et al., 1996	STEP TDM				10
		SCAG, 2004	SCAG TDM			1	
		SCAG, 2008		1		1	
Medium/High	Brussels, BEL	Lautso et al., 2004	LU/TDM (TRANUS)	1	1		9
	Naples, ITA	Lautso et al., 2004	LU/TDM (MEPLAN)		1		9
	Dortmund, GER	Lautso et al., 2004	LU/TDM (IRPUD)	1	1		13
		BCI et al., 2006	LU/TDM (Dortmund)				3
	Bilbao, ESP	Lautso et al., 2004	LU/TDM (MEPLAN)	1	1		9
Medium/ Moderate	Austin	ENVISION TX, 2003	NA			3	
	Salt Lake City	Envision Utah, 1998	NA			2	
		Governor's Office, 2000	LU (UrbanSim)+TDM			1	
	Sacramento	Deakin et al., 1996	STEP TDM				10
		Johnston et al., 1998	SACMET TDM	2		1	
		Johnston et al., 2000	LU/TDM (MEPLAN)				1
		Rodier, 2002		2		2	4
		Johnston et al., 2005		1	1	1	2
		SACOG, 2004	LU(MEPLAN)+ SACMET TDM			1	
		SACOG, 2008	SACSIM TDM			1	
	Twin Cities	CEE et al., 1999	GIS + TDM		3		
		Barnes, 2003			1	3	
	Portland	CSI, 1996	METRO TDM			2	
		METRO, 1998				1	
	Seattle	PSCOG, 1990	PSCOG TDM			2	
	Baltimore	BMC, 2002	BMC TDM			2	
	Orlando	HDR, 2003	LU (ULAM)+FSU TDM		1		
Small/High	Helsinki, FIN	Lautso et al., 2004	LU/TDM (MEPLAN	1	1		11
	Edinburgh, UK	BCI et al., 2006	LU (LUTI)+TDM				4
Small/ Moderate	Vicenza, ITA	Lautso et al., 2004	LU/TDM (MEPLAN)	1	1		10

Small/Poor	San Joaquin	Bai et al., 2007	LU (UPLAN)+TDM			1	
	Pee Dee	Pee Dee COG, 2003	TDM		1		

Scenarios: TR is transit; LU is pricing; and PR is auto pricing.
Models: TDM is travel model; LU is land use model; and LU/TDM is integrated.

CALIFORNIA

Special attention is paid to recent transport, land use, and/or pricing studies conducted by the four major MPOs in California because of their relevance to the GHG goals of AB 32 and the subsequent executive order. The Sacramento Area Council of Governments (SACOG) has pioneered "Blueprint" planning in California: an MPO-sponsored participatory planning process used to develop a common land use and transport vision for the region, which is ideally accompanied by high-quality modeling of travel, environmental, and economic impacts. The San Francisco Bay Area Metropolitan Transportation Commission (MTC), the San Diego Association of Governments (SANDAG), and the Los Angeles South Coast Association of Governments (SCAG) have also conducted blueprint planning processes that are more or less similar to SACOG's approach. The San Joaquin Valley region is currently conducting its blueprint planning process. In a dramatic departure from the past, four major MPOs have included their land use strategy in official regional transportation planning documents (SACOG, 2008; SANDAG, 2007; SCAG, 2008; MTC, 2007). SACOG was allowed by the U.S. Environmental Protection Agency to use its land use plan in its official regional transportation plan alternative as part of its air quality conformity process. The results of earlier visioning studies of land use and transport scenarios in these regions are also presented in this study (SACOG, 2004; SCAG, 2004**;** SANDAG, 1998). These studies typically simulate scenarios for a 30-year time horizon. However, the earlier SACOG Blueprint study (SACOG, 2004) simulated a 50-year time horizon.

Deakin et al. (Deakin, *et al.*, 1996) use an advanced calibrated travel model (the STEP model) to conduct analyses of a common set of pricing policies across the San Francisco, Los Angeles, Sacramento, and San Diego regions. The STEP model (separately calibrated to the four regions) is particularly well suited to evaluate pricing policies because of its disaggregate representation of the costs experienced by travelers. Policies are simulated for a current base year as well as a 20-year future time horizon.

Rodier and Johnston conduct a series of simulation studies using the Sacramento region's improved travel demand model (SACMET) (Johnston, *et al.,* 2000) as well as an experimental land use and transport model (the Sacramento MEPLAN model) (Rodier, 2002; Johnston, *et al.*, 2006) to explore transit, land use, and pricing policies for time horizons of 10, 20, and 50 years.

More recently, Bai et al. (Bai, *et al.*, 2007) use an experimental modeling framework that includes the UPLAN land use model and a TP+/Viper travel demand model to examine transit and land use scenarios in the San Joaquin Valley region for a 25-year time horizon.

OTHER STATES

Outside of California in the U.S., simulations have been conducted in three large regions in the U.S. with high quality transit. Safirova et al. (Safirova, *et al.*, 2007) and Nelson et al. (Nelson, *et al.*, 2003) use the experimental LUSTRE land use model and/or START travel model to simulate transit, pricing, and land use scenarios in the Washington, D.C., region for a 20-year time horizon. Thirty-year visioning studies of land use and transit scenarios are conducted for the Chicago region using an advanced land use and travel model. In the Philadelphia region, which is part of the states of Delaware, Pennsylvania, and New Jersey, a travel model of uncertain quality is used to evaluate alternative land use and transit scenarios for a 20-year time horizon.

Numerous studies have been conducted in medium-sized city regions with moderate quality transit. In Portland, Oregon, an improved travel demand model is used to simulate land use, transit, and pricing scenarios in the famous LUTRAQ study (20-year time horizon) (CSI, *et al.*, 1996). Later, in an official planning study, the improved travel model is used to simulate future land use scenarios for a 50-year time horizon (Metro, 1998). In Salt Lake City, Envision Utah explores land use and transit scenarios as part of a regional visioning planning process for a 20-year time horizon (Envision Utah, 1998). Later, an official regional planning document includes the results of a modified land use and transport plan, with roots in the Envision Utah process, and simulated with an advanced land use model (UrbanSim) and an improved calibrated travel model for a 20 year time horizon (Governor's Office of Planning and Budget, 2000). Visioning studies are also conducted in the Twin Cities (Barnes, 2003; CEE, 1999), Austin (ENVISION Central Texas, 2003), Baltimore (BMC, 2002), Seattle (PSCOG, 1990), and Orlando (HDR, 2003).

INTERNATIONAL

Several studies simulate consistent sets of policy scenarios across European regions. In the PROPOLIS study, advanced calibrated land use and travel models (MEPLAN, TRANUS, and/or IRPUD) are used to simulate the effects of common transit, land use, and auto pricing policies for 10- and 20-year time horizons in six European regions (Lautso, *et al.*, 2004). Dortmund, Naples, and Bilbao are medium-sized regions with high quality transit. Helsinki is small sized with high quality transit, and Vicenza is small with moderate transit quality.

In Europe, the STEPS study, also uses advanced land use and travel models to simulate the effect of common policies in Dortmund and Edinburgh for 20 year time horizons (BCI, *et al.,* 2006). The Dortmund and the Edinburgh SPM models are advanced calibrated land use and travel models. Edinburgh is categorized as a small sized city with relatively high quality transit.

Simmonds et al. (Simmonds, *et al.*, 2006) use an advanced land use and travel model calibrated to the Yorkshire region (SWYSM which includes the DELTA, START, and DTM sub-models) to evaluate a range of transit and pricing policies in an official planning document for a 25-year time horizons. The Yorkshire region is large with high quality transit.

CHAPTER 4: SYNTHESIS

SINGLE POLICY SCENARIOS

Transit

In the four major regions of California, scenarios are simulated that represent transit service improvements ranging from 2.9% to 475% (SANDAG, 2007; MTC, 2007; Johnston, *et al.,* 2000; Rodier, 2002; Johnston, *et al.,* 2006; SCAG, 2008). Scenarios simulated in six European cities (Lautso, *et al.*, 2004) reduce transit travel time by 10%. In Yorkshire, (Simmonds and Parkman, 2006) transit service is expanded incrementally over subareas with a 30% reduction in fares and a 20% increase in frequency. Percentage change in VMT for the four time horizons for these transit scenarios (N=9) is as follows (as illustrated in Figure 1).

- 10 years: median -0.3%; 68% SI -1.1% to -0.1%; 95% SI -3.7% to -0.0%
- 20 years: median -0.7%; 68% SI -2.1% to -0.2%; 95% SI -6.0% to -0.0%
- 30 years: median -0.9%; 68% SI -3.1% to -0.2%; 95% SI -8.9% to -0.0%
- 40 years: median -1.0%; 68% SI -3.5% to -0.3%; 95% SI -10.4% to -0.0%

Figure 2 illustrates the distribution of transit results for the most frequent time horizon represented in these studies, the 20-year horizon. Most scenarios were simulated with land use and travel models. Those simulated with travel models only, in San Diego, San Francisco, and Sacramento, tend to fall around the median within the 68% SI (SANDAG, 2007; MTC, 2007; Johnston, *et al.,* 2000). Scenarios with similar transit investment are simulated in both the Sacramento MEPLAN model (Rodier, 2002) and the official calibrated travel model (Johnston, *et al.,* 2000) but produce very different VMT reductions: 6.0% versus 0.3%. The extreme ends of the distribution are represented by a very aggressive transit investment scenario simulated with the Sacramento MEPLAN model (Johnston, *et al.*, 2006) and a transit and highway scenario simulated with a calibrated travel model in the Los Angeles region, which indicated a 0.5% increase in VMT (Johnston, *et al.,* 2000). The transit scenarios simulated with a land use and travel model in Yorkshire tend to rank with the level of transit service improvement, and most fall above the median within the 95% SI. Yorkshire is a large region with high quality transit, and thus the relative level of transit service improvement may be small compared to existing services (Simmonds and Parkman, 2006).

FIGURE 1 Box Plots of Single Policy VMT Reductions by Time Horizon.

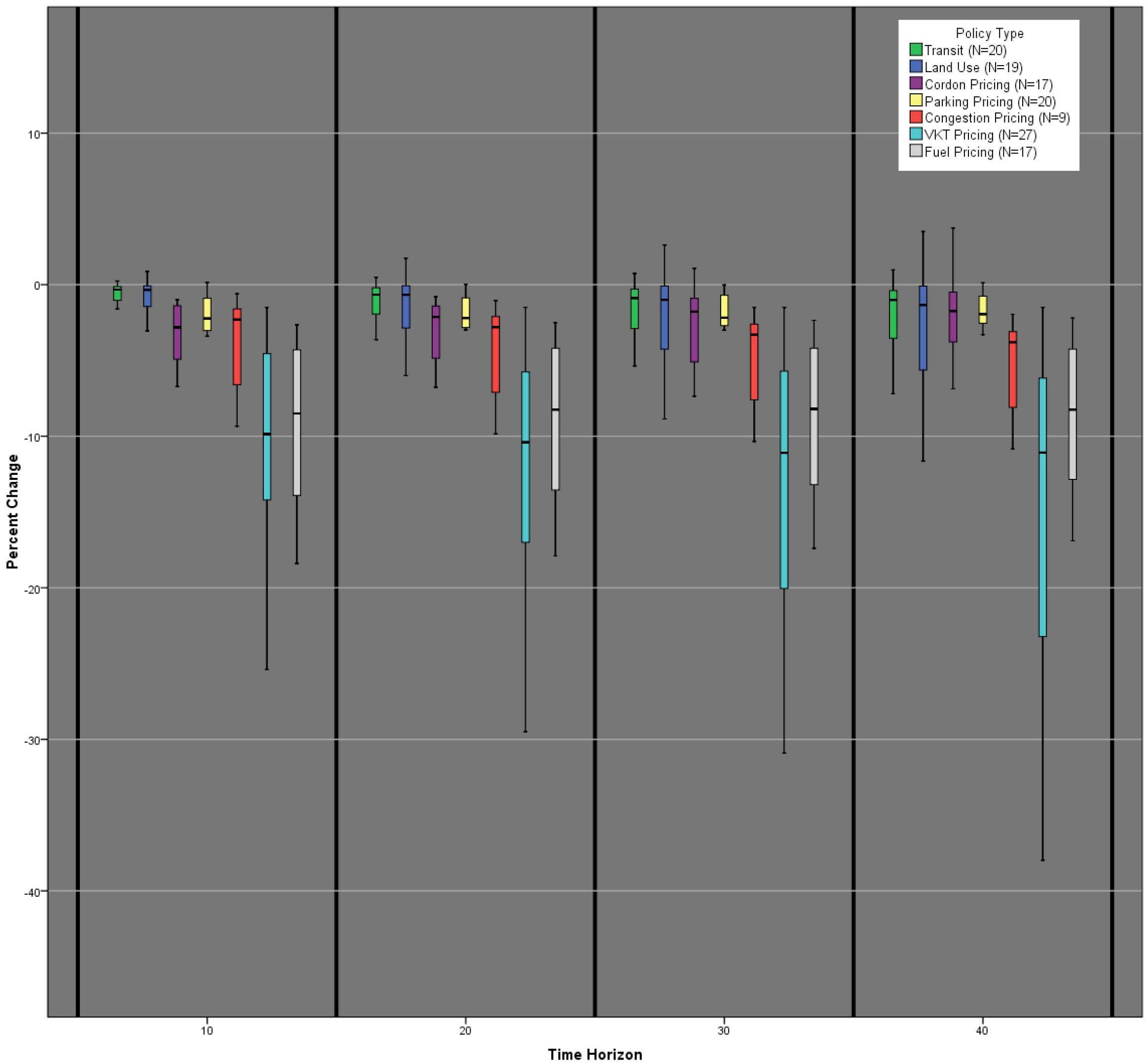
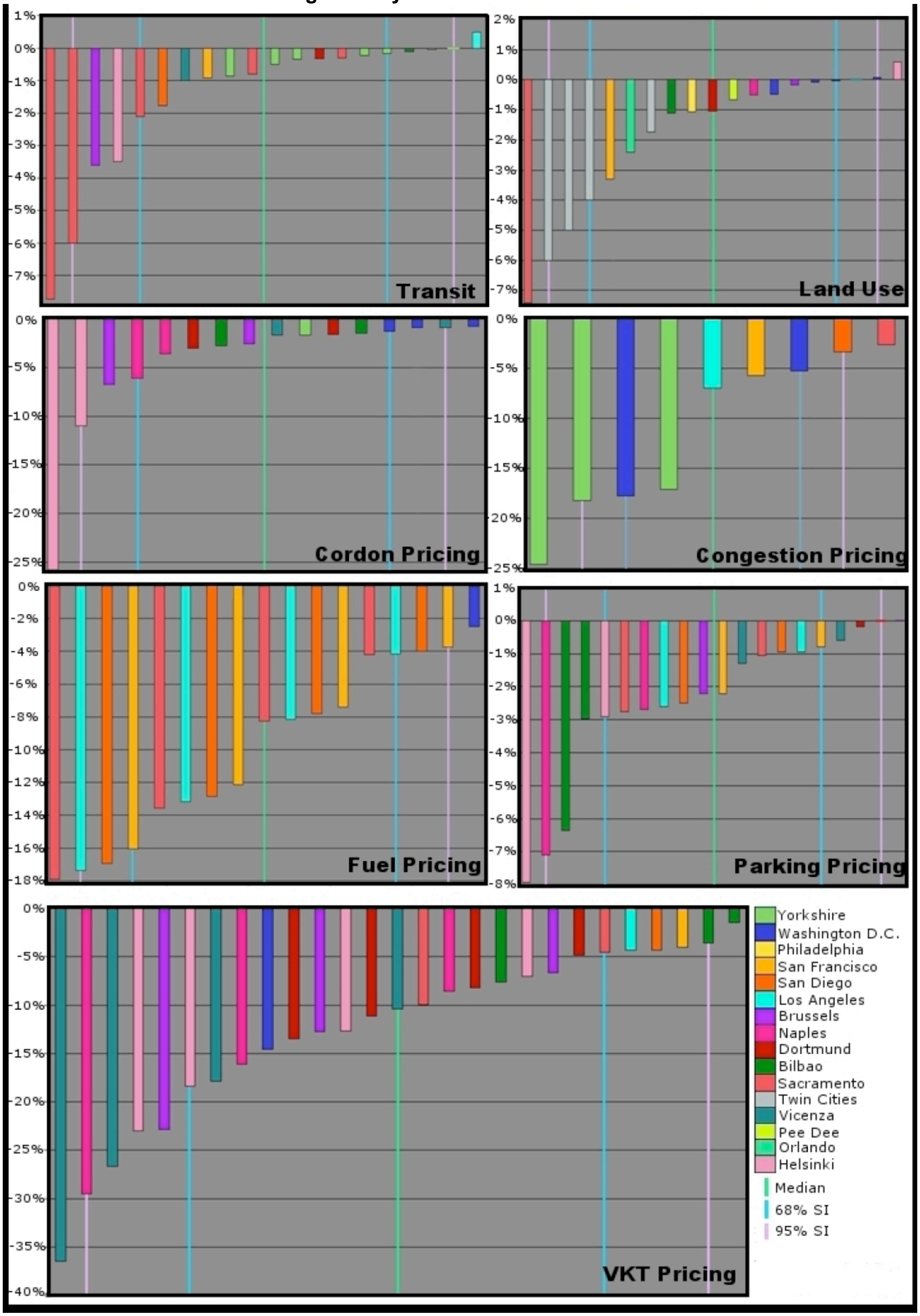


FIGURE 2 Distributions of Single Policy VMT Reductions for 20-Year Time Horizon.



Land Use

Aggressive to very aggressive land-use-only scenarios are simulated in regions of varying size and quality of transit. In Washington, D.C., Safirova (Safirova, *et al.*, 2007) simulates land use scenarios that include high preference for living inside the beltway (25% more attractive); increased residential housing density (20% more dense inside the beltway); live near your work program (closing cost assistance of $8,000 for first-time home buyers); and an inclusionary zoning program (increased stock of affordable housing). Elsewhere, simulations include a land use plan developed as part of the blueprint process in the San Francisco region (MTC, 2007); a recentralized land use scenario in an official Philadelphia region report (DVRPC, 2003); transit-oriented development policies in six European regions (Lautso, *et al.*, 2004); visioning scenarios in the Twin Cities (Barnes, 2003; CEE, 1999); and finally a very aggressive urban growth boundary policy in the Sacramento region (Johnston, *et al.,* 2006). Percentage change in VMT for these scenarios (N=19) is as follows:

- 10 years: median -0.5%; 68% SI -2.0% to -0.1%; 95% SI -3.1% to -0.0%
- 20 years: median -1.1%; 68% SI -4.0% to -0.0%; 95% SI -6% to 0.1%
- 30 years: median -1.4%; 68% SI -5.9% to -0.1%; 95% SI -7.5% to 0.1%
- 40 years: median -1.7%; 68% SI -7.7% to -0.1%; 95% SI -9.8% to 0.2%

Some interesting patterns develop in the ordering of scenarios around the median. See Figure 2. Scenarios simulated with integrated land use and travel models of relatively moderate policy strength in regions with high quality transit (Washington, D.C., Helsinki, Brussels, Vicenza, and Naples) tend to show very small reductions in VMT distributed above the median (Safirova, *et al.*, 2007; Lautso, *et al.*, 2004). VMT is actually increased in two scenarios, one in Washington D.C. and the other in Helsinki (Safirova, *et al.*, 2007; Lautso, *et al.*, 2004). These integrated models use relatively large zones and thus have coarse geographic resolutions, which may overestimate the share of vehicle trips relative to walk and bike trips from transit oriented development policies. The exception to this trend, however, is the very aggressive land use scenario simulated with the experimental land use and travel model in the Sacramento region, which has the greatest level of VMT reduction falling outside the 95% SI. This may be explained by the relative densities and transit quality of the regions: dense European and Washington D.C. regions with high quality transit may limit the relative effectiveness of the additional densification policies compared to the more sprawling and rapidly growing Sacramento region where trend land use patterns do not take full advantage of existing transit capacity. Results for Twin Cities, a region similar to Sacramento, also fall below median between the 68% SI and the 95% SI (Barnes, 2003; CEE, 1999). Scenarios simulated with travel models only tend to fall around the median in Philadelphia (DVRPC, 2003), Pee Dee (Pee Dee COG, 2003), San Francisco (MTC, 2007), and Orlando (HDR, 2003).

Cordon Pricing

Studies of a range of cordon pricing policies are conducted in Washington D.C. as well as in Yorkshire and in six other European cities. In Washington, D.C., Safirova el al. (Safirova, *et al.*, 2007) evaluate three cordon pricing scenarios: downtown cordon ($4.70); downtown cordon ($2.18) and a beltway cordon around the urban core ($3.43); and a broader beltway cordon ($2.84). Simmonds et al. (Simmonds and Parkman, 2006) simulate cordon charges around the towns and cities of the Yorkshire region. In the PROPOLIS study, cordon pricing is set at 20% and 60% of the value of commuters' travel time (Lautso, *et al.*, 2004). Percentage change in VMT for scenarios (N=16) is as follows:

- 10 years: median -2.8%; 68% SI -5.8% to -1.3%; 95% SI -14.5% to -1.1%
- 20 years: median -2.1%; 68% SI -6.1% to -1.3%; 95% SI -11.0% to -0.9%
- 30 years: median -1.8%; 68% SI -6.4% to -0.7%; 95% SI -7.4% to -0.6%
- 40 years: median -1.7%; 68% SI -4.0% to -0.5%; 95% SI -6.9% to -0.4%

All of the cordon pricing policy scenarios are simulated with integrated land use and transport models, which allow for land uses to reallocate in response to the cordon charge and thus the effect of a static policy may be reduced over time. Generally, policies rank with the magnitude of the cordon charge by region. See Figure 2. Below the median at the tail end of the distribution, the Helsinki scenario includes two cordons that appear to affect a significantly larger share of trips than in the other regional cordon pricing scenarios. This result is unlikely to be transferable to regions with multiple employment centers.

Parking Pricing

Parking pricing studies are available for the major California regions and six European cities. Deakin et al. (Deakin, *et al.*, 1996) simulate two employee parking pricing charges, representing a minimum daily price of $1.00 and another of $3.00 for drive alone work trips. In the PROPOLIS study, parking pricing is set at 20% and 60% of the value of commuters' travel time (Lautso, *et al.*, 2004). Percentage change in VMT for these parking pricing scenarios (N=16) is as follows:

- 10 years: median -2.2%; 68% SI -3.2% to -0.8%; 95% SI -6.9% to 0.1%
- 20 years: median -2.2%; 68% SI -2.9% to -0.8%; 95% SI -7.1% to 0.0%
- 30 years: median -2.2%; 68% SI -2.8% to -0.6%; 95% SI -7.0% to -0.2%
- 40 years: median -2.0%; 68% SI -2.6% to -0.7%; 95% SI -6.1% to -0.0%

The high parking pricing scenarios simulated with an advanced travel model in the California regions fall below the median within the 68% SI, and the low parking pricing scenarios fall above the median within the 68% SI (Deakin, *et al.*, 1996) with approximately 1% reductions across all time horizons. See Figure 2. In the PROPOLIS study, the scenarios simulated with the integrated land use and travel models tend to rank by policy strength for regions. The regions of Helsinki and Naples tend to be most responsive to the pricing policies, and Dortmund and Brussels tend to be least responsive. The small change in Dortmund is explained by the policy tendency to reduce the auto mode share and to increase average shopping trips lengths (Lautso, *et al.*, 2004). In Brussels, per capita VMT is increased by 0.02% in one scenario because of housing and employment shifts from the city center and inner urban areas to outer areas of the regions (Lautso, *et al.*, 2004). As households and employers are able to adjust to the parking pricing policies in scenarios simulated by the land use and transport models, some results are slightly dampened, and some are increased over-time.

Congestion Pricing

Congestion pricing charges are imposed on all regional roadways to reduce volume of capacity ratios to the 0.9 level in the major California regions (Deakin, *et al.*, 1996). In Washington, D.C., different congestion tolling schemes are simulated, including a variable comprehensive toll (similar to Deakin, *et al.*, 1996) and a variable freeway toll (a more limited application) (Safirova, *et al.*, 2007). In Yorkshire, the marginal external cost of pricing is imposed on roadways. Percentage change in VMT for these scenarios (N=9) is as follows:

- 10 years: median -2.3%; 68% SI -6.6% to -1.6%; 95% SI -6.8% to -1.0%
- 20 years: median -2.8%; 68% SI -7.1% to -2.1%; 95% SI -7.3% to -1.4%
- 30 years: median -3.3%; 68% SI -7.6% to -2.6%; 95% SI -7.8% to -1.7%
- 40 years: median -3.8%; 68% SI -8.1% to -3.1%; 95% SI -8.3% to -2.1%

As population grows over time, so does congestion, and thus these policies are more effective. In general, the stronger congestion pricing policies simulated in the California regions fall at or above the median, and congestion pricing of similar strength in Yorkshire and Washington, D.C., fall below. See Figure 2. This result is likely explained by relative congestion levels in these studies. The California region scenarios were simulated with 1990 and 2010 time horizons and thus tend to have lower relative congestion than latter studies with a 2020 time horizon. However, it is also possible that the interaction between land use and transport and greater modal alternatives to the auto contribute to the larger effects.

VMT Pricing

VMT pricing scenarios are evaluated in the California regions (Deakin, *et al.*, 1996; Rodier, 2002), Washington, D.C., (Safirova, *et al.*, 2007), and six European regions (Lautso, *et al.*, 2004). Deakin et al. (Deakin, *et al.*, 1996) simulate a VMT fee (two cents per mile/1.6 kilometer increase in auto operating costs) in the four major California regions, which may represent an aggressive but feasible policy strategy in the form of pay-as-you-drive insurance. Rodier (Rodier, 2002) simulates a higher VMT pricing fee (five cents per mile increase in auto operating costs) in the Sacramento region. Safirova et al. (Safirova, *et al.*, 2007) simulate an even more aggressive VMT fee (a 10 cent per mile increase in auto operating costs) in the Washington, D.C., area. The PROPOLIS study includes VMT pricing scenarios that increase per-mile auto operating cost by 25%, 50%, and 100% over existing levels (Lautso, *et al.*, 2004). Percentage change in VMT for these scenarios (N=27) is as follows:

- 10 years: median -9.9%; 68% SI -14.2% to -4.4%; 95% SI -22.7% to -2.2%
- 20 years: median -10.4%; 68% SI -18.4% to -4.6%; 95% SI -29.5% to -3.6%
- 30 years: median -11.2%; 68% SI -22.4% to -5.0%; 95% SI -43.2% to -3.9%
- 40 years: median -11.1%; 68% SI -24.4% to -5.0%; 95% SI -54.2% to -3.8%

Moderate VMT pricing falls above the median within the 68% SI, and higher VMT pricing in Sacramento and Washington D.C. falls below the median within the 68% SI. See Figure 2. In the PROPOLIS study, the scenarios simulated with the integrated land use and travel model tend to rank by region by policy strength. The regions of Vicenza and Naples tend to be most responsive to the pricing policies, and Dortmund and Bilbao tend to be least responsive. In the PROPOLIS study, over time, as the regional urban economies adjust to the policy, there is a slight dampening of the VMT reductions at the lower VMT price levels and a heightening of the reductions at the highest VMT price levels. The low VMT scenarios in Deakin et al. (Deakin, *et al.*, 1996) scenarios could represent a pay-as-you-drive insurance scenario in California, and these results suggest a 4% to 5% reduction over the four time horizons.

Fuel Tax

Fuel tax studies are examined in California (Deakin, *et al.*, 1996) and in Washington, D.C., (Nelson, *et al.*, 2003) for the 20-year time horizon. In California, the following scenarios are simulated: $0.50 per gallon/3.8 liters (-0.13 fuel elasticity); $2.00 per gallon/3.8 liters (-0.13 fuel elasticity); $2.00 per gallon/3.8 liters (-0.05 fuel elasticity); and $2.00 per gallon/3.8 liters (-0.22 fuel elasticity). In Washington, D.C., Nelson et al. (Nelson, *et al.*, 2003) simulate a lower fuel tax ($0.25 cents per gallon/3.8 liters). The results of these fuel tax studies show that policies rank above and below the median by policy strength. See Figure 2. Percentage change in VMT for these scenarios (N=17) is as follows:

- 10 years: median -8.4%; 68% SI -16.6% to -4.1%; 95% SI -17.6% to -3.9%
- 20 years: median -8.2%; 68% SI -16.1% to -4.2%; 95% SI -17.4% to -3.8%
- 30 years: median -8.2%; 68% SI -15.5% to -4.1%; 95% SI -17.1% to -3.6%
- 40 years: median -12.9%; 68% SI -14.9% to -4.0%; 95% SI -16.9% to -3.5%

COMBINED SCENARIOS

Land Use and Transit

Analyses of the VMT effects of land use and transit scenarios are available from a series of official planning and visioning studies in the U.S. Aggressive but feasible land use plans are included in official planning documents for the following regions: San Francisco (MTC, 2007), San Diego (SANDAG, 2007), Los Angeles (SCAG, 2004; SCAG, 2008), Sacramento (SANDAG, 2007; SACOG, 2004), Baltimore (BMC, 2002), Seattle (PSCOG, 1990), Portland (Metro, 1998), and Salt Lake City (Governor's Office of Planning and Budget, 2000). More aggressive visioning studies are conducted in Chicago (Chicago Metropolis 2020, 2003), Salt Lake City (Envision Utah, 1998), Portland (CSI, *et al.*, 1996), Austin (ENVISION Central Texas, 2003), San Diego (SANDAG, 1998), and the Twin Cities (Barnes, 2003). More aggressive studies are also included in experimental studies in Sacramento (Johnston, *et al.,* 2000; Rodier, 2002*,* Johnston, *et al.,* 2006) and the San Joaquin Valley (Bai, *et al.*, 2007). Percentage change in VMT for these scenarios (N=34) is as follows:

- 10 years: median -3.9%; 68% SI -5.7% to -1.5%; 95% SI -7.7% to -0.4%
- 20 years: median -8.1%; 68% SI -11.4% to -3.4%; 95% SI -14.9% to -1.4%
- 30 years: median -11.9%; 68% SI -16.5% to -5.1%; 95% SI -21.4% to -2.0%
- 40 years: median -15.8%; 68% SI -20.7% to -6.7%; 95% SI -27.5% to -2.7%

In general, the results of the very aggressive visioning studies (SANDAG, 1998; Envision Utah, 1998; ENVISION Central Texas, 2003) and the experimental academic studies (Rodier, 2002; Johnston, *et al.,* 2006; Bai, *et al.*, 2007) fall below the median. See Figure 4. These studies tend to rank by the relative aggressiveness of plan, and those that employ land use and travel models (i.e., Chicago, San Joaquin Valley, and Sacramento) are more likely to fall below the median at the tail end of the distribution. Most of the studies above the median are official planning documents or more conservative plans in visioning studies. The studies above the median and at the tail end of the distribution tend to be less aggressive and use weaker travel models (SCAG, 2004; CSI, *et al.*, 1996; PSCOG, 1990; SCAG, 2008).

FIGURE 3 Box Plots of Combined Policy VMT Reductions by Time Horizon.

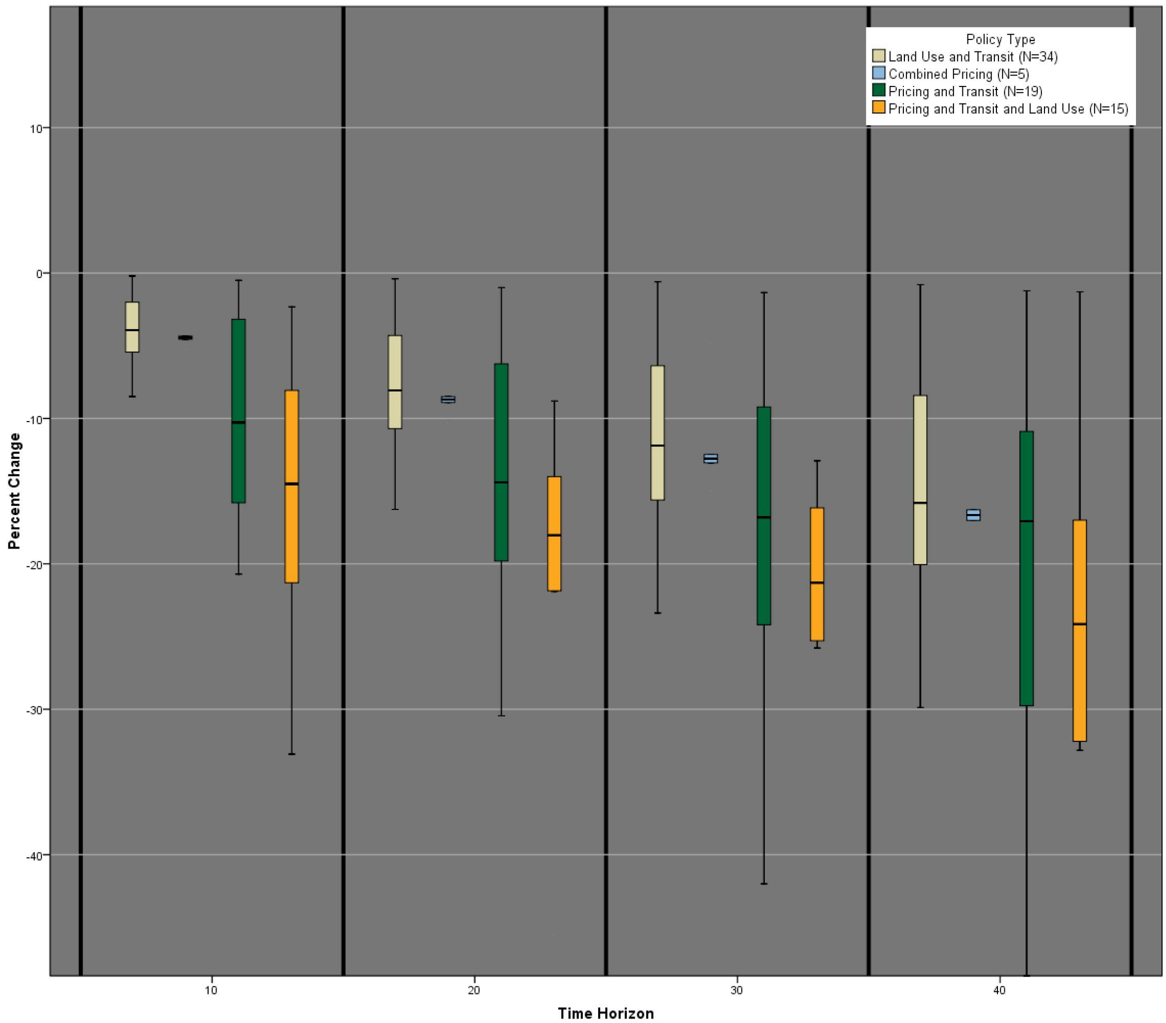
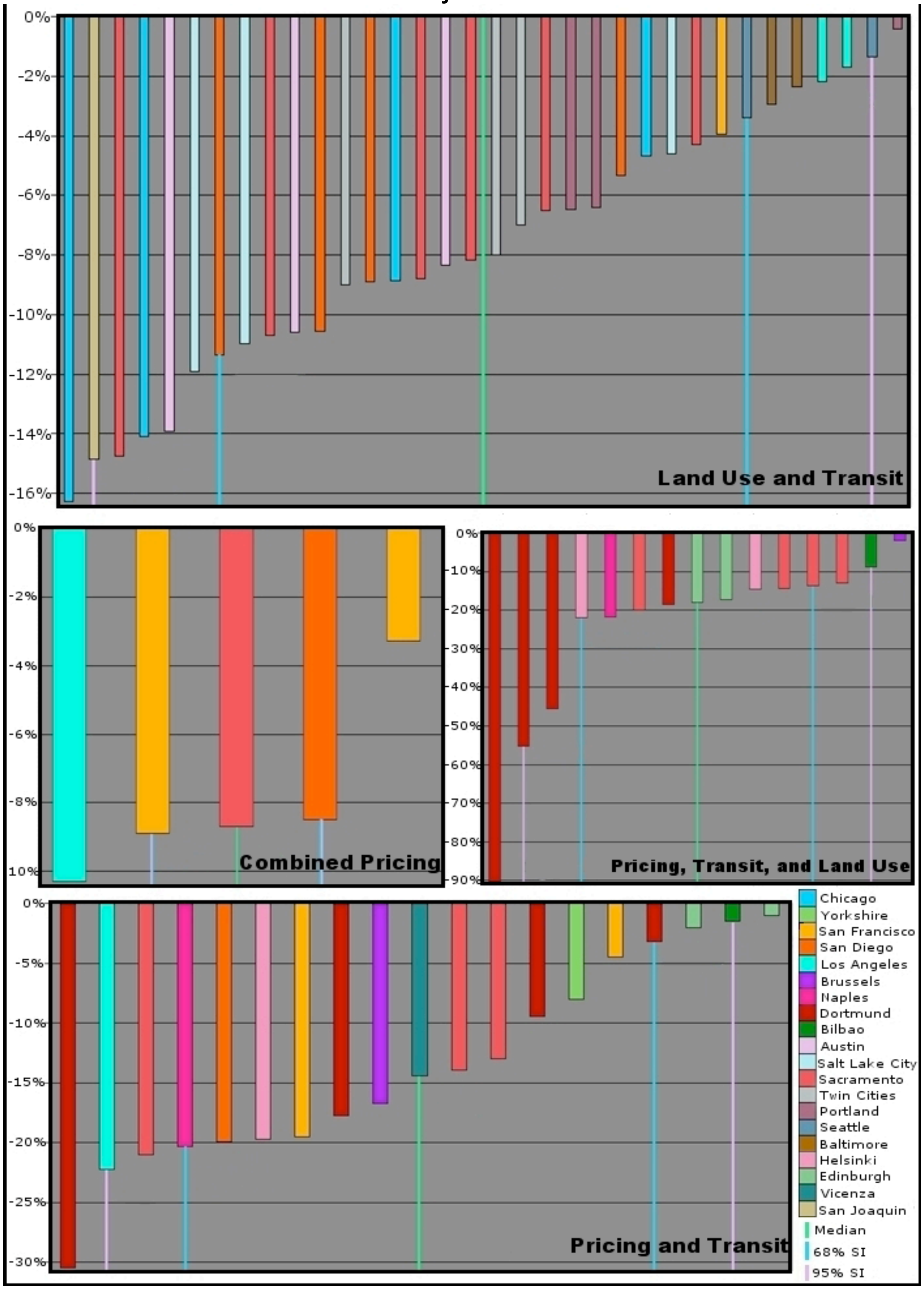


FIGURE 4 Distributions of Combined Policy VMT Reductions for 20-Year Time Horizon.



Combined Pricing

Combined pricing scenarios are available for the four major regions in California. A comprehensive auto pricing policy scenario is simulated by MTC (MTC, 2007) in the San Francisco region that includes a 100% increase in per-mile/1.6 kilometer auto operating costs, 4.9% increase in the average parking cost for work trips, and a congestion pricing charge of $0.25- per mile on all roads when volume to capacity ratios exceed 0.9. Deakin et al. (Deakin, *et al.*, 1996) also explore combined pricing policies, which include a region-wide congestion pricing policy with an average cost of $0.13 per mile; a region-wide employee parking pricing policy with a minimum charge of $1.00 per day; a fuel tax of $0.05 per gallon; and VMT/emissions-based fees of approximately $0.01 per mile. Despite the aggressive pricing measures included in the MTC scenario, the results are the lowest of all scenarios and low compared to the results of the single pricing policies, described above, which illustrates improved travel models lack of sensitivity to pricing policies relative advance models (i.e., STEP model). Percentage change in VMT for these scenarios (N=5) is as follows (SI is high to low because of sample size) (see Figures 3).

- 10 years: median -4.5%; 68% SI -4.6% to -4.3%
- 20 years: median -8.7%; 68% SI -8.9% to -8.5%
- 30 years: median -12.8%; 68% SI -13.1% to -12.5%
- 40 years: median -16.6%; SI -17.0% to -16.3%

Transit and Pricing

In California, the comprehensive auto pricing policy scenario (described above) is added to the transit scenario for the San Francisco region (MTC, 2007). Deakin et al. (Deakin, *et al.*, 1996) also add expanded transit to more aggressive pricing policies, including region-wide congestion pricing (mean $0.13 per mile); region-wide employee parking pricing (minimum $3.00 per day); fuel tax ($2.00 per gallon); and VMT/emissions based fees ($0.01 per mile). In Sacramento, experimental studies examine a $0.05 VMT pricing policy with an aggressive transit scenario (Rodier, 2002) and an even more aggressive transit scenario with a gas tax ($1.00 per gallon) and parking pricing ($6.00 downtown and $1.00 elsewhere) (Johnston, et al*., 2006*).

Outside the U.S. in Yorkshire, the congestion pricing policy (described above) is combined with increased transit frequencies and reduced transit fares (Simmonds, *et al.*, 2006). In Dortmund and Edinburgh (BCI, *et al.,* 2006), the combined pricing policy (fuel tax, VMT pricing, and congestion pricing), transit enhancements (increased speeds and reduced fares), and traffic auto calming are simulated with low, high, and/or extreme fuel price levels. In the PROPOLIS study, 75% increase in per mile/1.6 kilometers auto operating costs is added to a 5% reduction in transit travel times.

Percentage change in VMT for these scenarios (N=15) is as follows:

- 10 years: median -10.3%; 68% SI -16.6% to -1.6%; 95% SI -20.0% to -1.0%
- 20 years: median -14.4%; 68% SI -20.3% to -3.2%; 95% SI -22.2% to -1.5%
- 30 years: median -16.8%; 68% SI -28.3% to -4.7%; 95% SI -31.4% to -1.5%
- 40 years: median -17.1%; 68% SI -35.8% to -6.3%; 95% SI -39.5% to -2.0%

All the PROPOLIS and the Deakin et al. (Deakin, *et al.*, 1996) results fall below the median within the 95% SI. See Figure 4. Again, in Deakin et al. (Deakin, *et al.*, 1996) the regions with relatively fewer modal alternatives to the auto are more strongly affected by the auto pricing policies. The Sacramento scenarios simulated by Rodier (Rodier, 2002) and Johnston et al. (Johnston, *et al.,* 2006) tend to be less aggressive than the Deakin et al. (Deakin, *et al.*, 1996) scenarios and fall just above the median. In the STEPS study (BCI, *et al.,* 2006), the extremely high (Dortmund) and low (Edinburgh) fuel price scenarios fall at the ends of the distribution.

Land Use, Transit, and Pricing

Pricing, expanded transit, and land use studies are available from studies in Sacramento as well as European regions (Johnston, *et al.,* 2000; Rodier, 2002; Johnston, *et al.,* 2006; Lautso, *et al.*, 2004; BCI, *et al.,* 2006). Scenarios in Sacramento include very aggressive land use, transit, and pricing policies (VMT tax and parking) (Johnston, *et al.,* 2000); VMT pricing policy with an urban reserve, subsidy for infill development, and transit expansion (Rodier, 2002); a VMT pricing policy with an urban growth boundary and transit expansion scenario (Rodier, 2002); and a combined pricing and transit scenario (described above) with an urban growth boundary (Johnston, *et al.,* 2006). In the PROPOLIS study, the transit-oriented development policy is combined with a 75% increase in auto operating costs, a 50% reduction in transit fares, and a 5% increase in transit travel speeds. In Helsinki, the transit-oriented development scenario is also added to a 20% reduction in transit fares, a 5% increase in transit travel speeds, and a distance based congestion pricing charge (Lautso, *et al.*, 2004). In Dortmund and Edinburgh (BCI, *et al.,* 2006), the combined land use, carsharing, telecommuting, fuel tax, congestion pricing, and traffic calming policies scenario is simulated at the low, high, and/or very extreme fuel price levels. Percentage change in VMT for these scenarios (N=15) is as follows:

- 10 years: median -14.5%; 68% SI -22.5% to -7.1%; 95% SI -33.1% to -4.9%
- 20 years: median -18.0%; 68% SI -21.9% to -13.7%; 95% SI -55.2% to -8.8%
- 30 years: median -21.4%; 68% SI -25.8% to -14.6%; 95% SI -70.0% to -12.9%
- 40 years: median -24.1%; 68% SI -32.8% to -16.8%; 95% SI -79.9% to -12.7%

The results below the median at the tail end of the distribution include very extreme fuel price levels and a broader range of travel demand management measures (e.g., carsharing, telecommuting, and traffic calming). See Figure 4. These policies may be considered very aggressive in the U.S. context. In general, policies rank by strength given their geographic context.

CHAPTER 5: CONCLUSIONS

The results of this report provide some order-of-magnitude estimates for policies that appear to have some promise of near term implementation. Employee parking pricing may result in approximately a 1% reduction in VMT over the 10-year time horizons. Pay-as-you-drive insurance policy may produce reductions ranging from 4% to 5% reduction over all time horizons. Moderate cordon pricing schemes are likely to reduce VMT by 2% to 3% over time. Increased transit investment may reduce VMT by 0.1% to 1% during a 10-year time horizon, and in future 10-year increments, this may increase by 1 percentage point at the higher reduction level. Land-use-only scenarios may reduce VMT by up to 2% in the 10-year time horizon, which may increase by approximately 2 to 3 percentage points at the higher reduction level at 10 year increments. Land use and transit scenarios may reduce VMT by 2% to 6% during a 10-year time horizon, and these figures may increase by approximately 2 to 5 percentage points at each future 10-year increments. Combined land use, transit, and pricing policy measures would bring significantly greater reductions both in the shorter and longer term time horizons.

In general, the results confirm that even improved calibrated travel models are likely to underestimate VMT reductions from land use, transit, and pricing policies. These models simply are not suited for the policy analysis demands in the era of global climate change. For example, when similar transit scenarios were simulated with the improved calibrated travel model and the integrated land use and transport model, the latter produced significantly larger results (6.0% versus 0.3%). Despite the very aggressive pricing measures simulated by the improved travel model in the San Francisco region, the results are significantly lower than weaker pricing policies simulated in the same region using an advanced travel model.

However, even the advanced models used in the reviewed studies exhibit limitations. Scenarios simulated with integrated land use and travel models of relatively moderate policy strength in regions with high quality transit tended to show very small reductions in VMT distributed widely above the median. These integrated models use relatively large zones and thus have coarse geographic resolutions, which may overestimate the share of vehicle trips relative to walk and bike trips from transit-oriented development policies. On the other hand, the advanced travel model used in the pricing studies may fail to identify possible consequences arising from land use and transport interactions. For example, pricing policies simulated with integrated land use and travel models showed that in some cities these policies might actually increase VMT by shifting housing and employment to outer areas of the regions and increasing average shopping trip lengths. Theoretically advanced land use and travel models are needed that have fine-grained geographic resolutions and represent greater variation in the socio-economic attributes of travelers.

The results of the extrapolation analysis in this study also illustrate the challenge of implementing land use and transit strategies in regulatory framework that emphasizes near-term compliance demonstration. For example, SACOG's blueprint land use and transport plan was simulated over a 50-year time horizon; the extrapolated results, which evenly distribute VMT reduction over time, show a 4.2% reduction in VMT in the 10-year time horizon. However, a much more aggressive scenario, simulated with the improved travel model in the region over a 10-year time horizon, only showed a 0.4% reduction in VMT.

The analysis of consistent policies across different regions also provides insight into how VMT reduction may vary given existing land use densities and transit infrastructure. For example, the analysis of land-use-only policies suggest that these policies may be less effective in various European regions and Washington, D.C. relative to the more sprawling and rapidly growing regions (e.g., Sacramento) where trend land use patterns do not take full advantage existing transit capacity. The results of the auto pricing policies tended to show greater reductions in VMT in European cities because of higher quality modal options to the auto. As a result, care should be taken in generalizing such results to U.S. cities without high quality alternatives.

REFERENCES

Bai, S., Niemeier, D., Handy, S., Gao, S., Lund J., and Sullivan D. *Integrated Impacts of Regional Development, Land Use Strategies and Transportation Planning on Future Air Pollution Emissions.* Transportation Land-use Planning & Air Quality Conference, 2007.

Baltimore Metropolitan Council (BMC). *Baltimore Vision 2030. Transportation Indicators. Baltimore Regional Partnership.* Smart Mobility, Inc. et al., Baltimore, ML, November, 2002.

Barnes, G. *Transportation-Related Impacts of Different Regional Land-Use Scenarios. Final Report*. Humphrey Institute of Public Affairs, University of Minnesota. Minnesota Department of Transportation, September, 2003.

BCI, AUEB, ITS, JRC IPTS, KUL-SADL, LT, Novem, Speikermann und Wegener, Stratec, TIS, TRL, TRT, TTR, UPM. *Scenarios for the Transport system and Energy Supply and Their Potential Effects: STEPs. Work Package 4 Scenario Impacts: Deliverable 4.2,* 2006.

Cambridge Systematics Inc. (CSI) et al. *Analysis of Alternatives. Making the Land Use Transportation Air Quality Connections*. 1000 Friends of Oregon, Portland, Oregon, May, 1996.

Center for Energy and Environment (CEE), Minnesotans for an Energy-Efficient Economy, 1000 Friends of Minnesota. *Two Roads Diverge: Analyzing Growth Scenarios for the Twin Cities Region*. MN, June, 1999.

Chicago Metropolis 2020. *The Metropolis Plan: Choices for the Chicago Region*. Chicago, IL, 2003.

Deakin, Elizabeth, Greig Harvey, Randall Pozdenza, and Geoffrey Yarema. *Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy, and Equity Impacts*. California Air Resources Board, November, 1996.

Delaware Valley Regional Planning Commission (DVRPC). *Regional Analysis of What-If Transportation Scenarios: Final Report*. Philadelphia, PA, 2003.

ENVISION Central Texas. *Envision Central Texas Briefing Packet.* Austin, TX, 2003.

Envision Utah. *Scenario Analysis: Executive Summary.* Salt Lake City, UT, 1998.

Governor's Office of Planning and Budget. *Strategy Analysis: Quality Growth Efficiency Tools*. Salt Lake City, UT, 2000.

HDR. *Community Connections A Transportation Vision for the Next 25 Years: Land Use Experiment Technical Memorandum No. 8.* Orlando, FL, July, 2003.

Johnston, R. A., C. J. Rodier, M. Choy, and J. E. Abraham. *Air Quality Impacts of Transit and Supporting Land Use and Pricing Policies.* A Report for the U.S. Environmental Protection Agency, February, 2000.

Johnston, R. A., S. Gao, and M. J. Clay. Modeling Long-Range Transportation and Land Use Scenarios for the Sacramento Region, Using Citizen-Generated Policies. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1902,* Transportation Research Board of the National Academies, Washington D.C., 2005, pp. 99-106.

Lautso, Kari, Klaus Spiekermann, Michael Wegener, Ian Sheppard, Philip Steadman, Angelo Marino, Roberto Domingo, Sylvie Gayda. *PROPOLIS: Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability: Final Report*, European Commission, Energy, Environment, and Sustainable Development Thematic Programme. February, 2004.

Metro. *Region 2040: Concepts for Growth*. Portland, OR, 1998.

Metropolitan Planning Commission (MTC). *Transportation 2035 in Motion Forecasts for the San Francisco Bay Area 2009 Regional Transportation Plan*. Oakland, CA, November, 2007.

Nelson, Peter, Kenneth Gillingham, and Elena Safirova. *Revving up the Tax Engine: Gas Taxes and the DC Metro Area's Transportation Dilemma.* Resources for the Future. Washington, DC., 2003.

Pee Dee Regional Council of Governments (Pee Dee COG). *Planning Implications of Alternate Development Patterns on Infrastructure and Existing Planning Policies.* Florence, SC, 2003.

Puget Sound Council of Governments (PSCOG). *Summary and Comparison between Alternatives. Vision 2020. Growth Strategy and Transportation Plan for the Central Puget Sound Region. Final Environmental Impact Statement*. Seattle, WA, September, 1990.

Rodier, C. J. *Air Emissions Impacts of Regional Transportation and Land Development Policies*. A Report for the U.S. Environmental Protection Agency, June, 2002.

Sacramento Area Council of Governments (SACOG). *Tall Order Forum 2004: Regional Choices for Our Future.* Sacramento, CA, 2004.

Sacramento Area Council of Governments (SACOG). *Metropolitan Transportation Plan 2025*. Sacramento, CA, 2008.

Safirova, Elena, Sébastien Houde, and Winston Harrington. *Spatial Development and Energy Consumption.* Resources for the Future, Washington, DC., 2007.

San Diego Association of Governments (SANDAG). *2020 Cities/County Forecast Land Use Alternatives Summary*. San Diego, CA, 1998.

San Diego Association of Governments (SANDAG). *2030 Regional Transportation Plan: Pathways for the Future.* San Diego, CA, 2007.

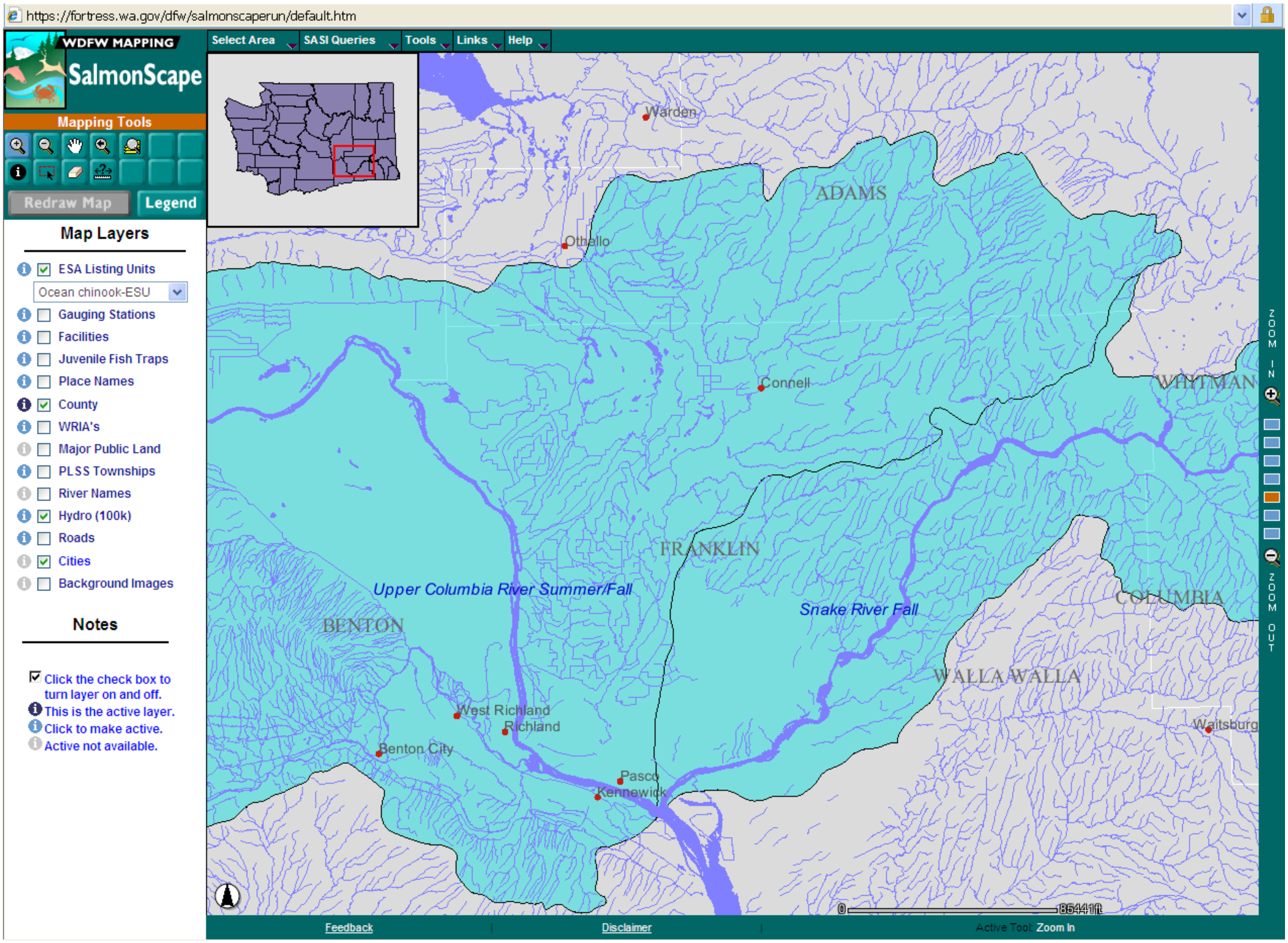
Simmonds, David, Andy Skinner, Olga Feldman, James Nicoll, and Caroline Sinclair. *Wider Economic Impacts of Transport Interventions: Final Report.* London, England, 2006.

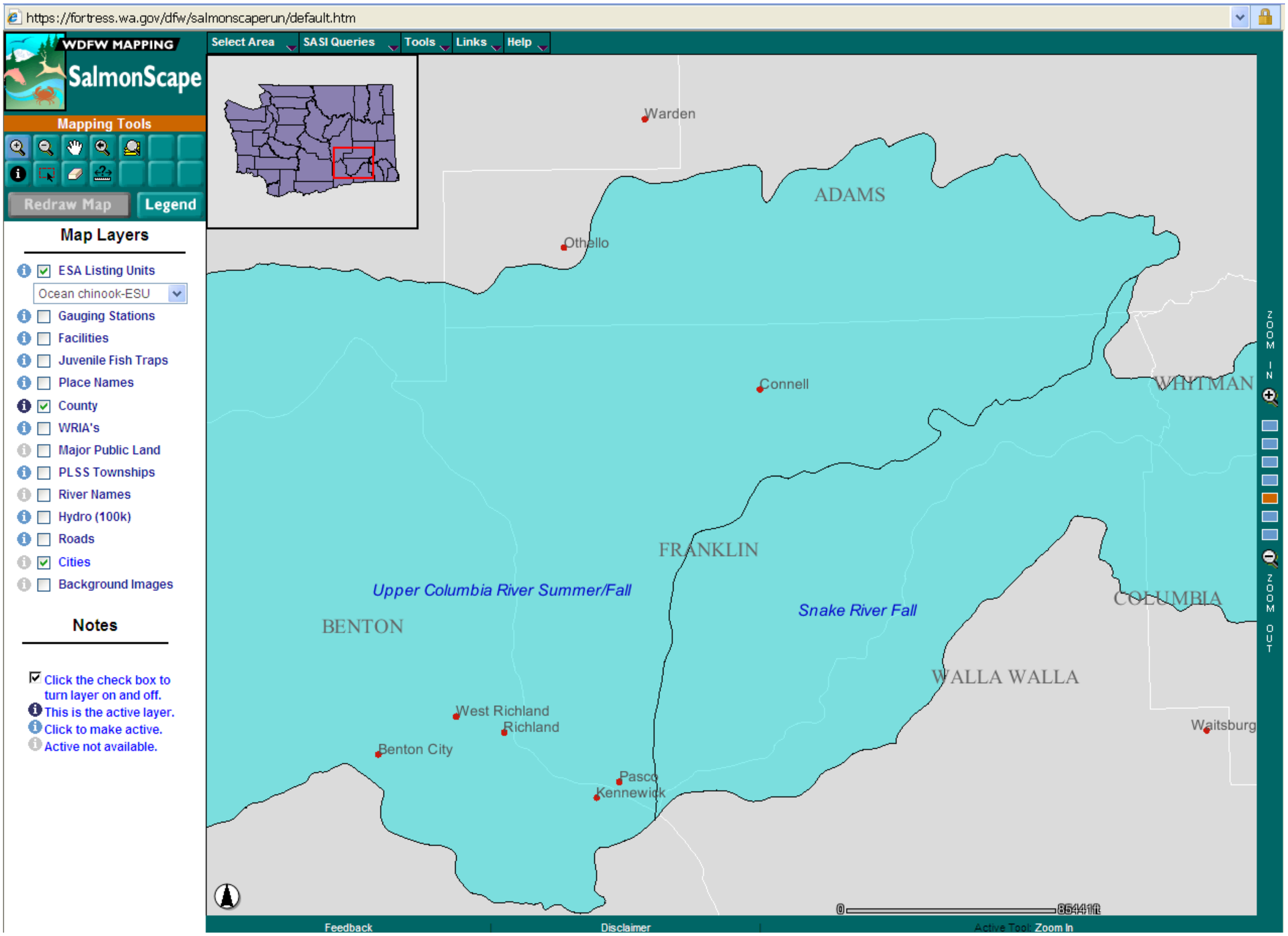
Simmonds, David and Mouchel Parkman, MVA Consultancies. *Wider Economic Impacts of Transport Interventions: Final Report.* London, England: Authors, 2006.

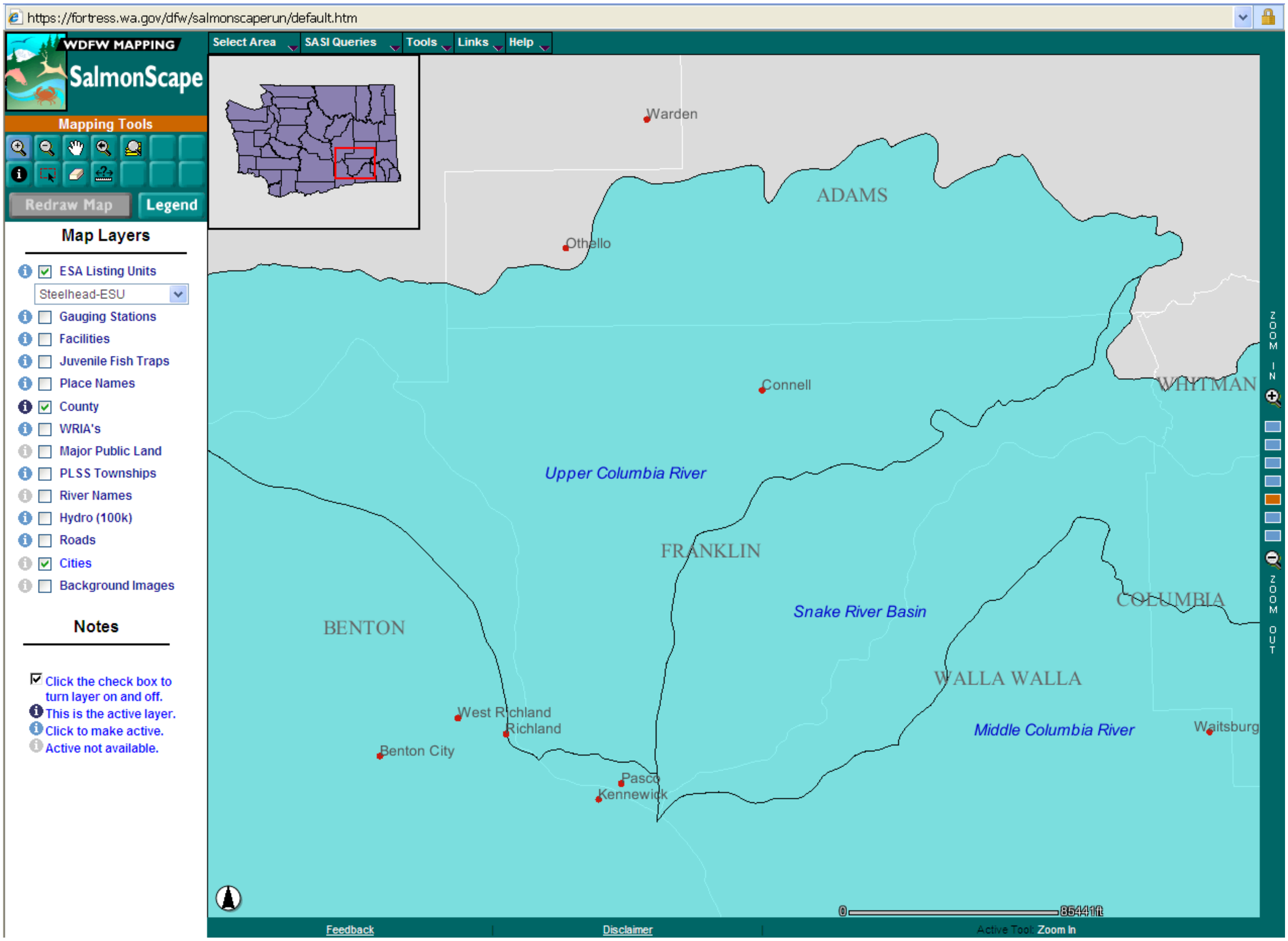
Southern California Association of Governments (SCAG). *Southern California Compass. Growth Vision Report.* Los Angeles, CA, 2004.

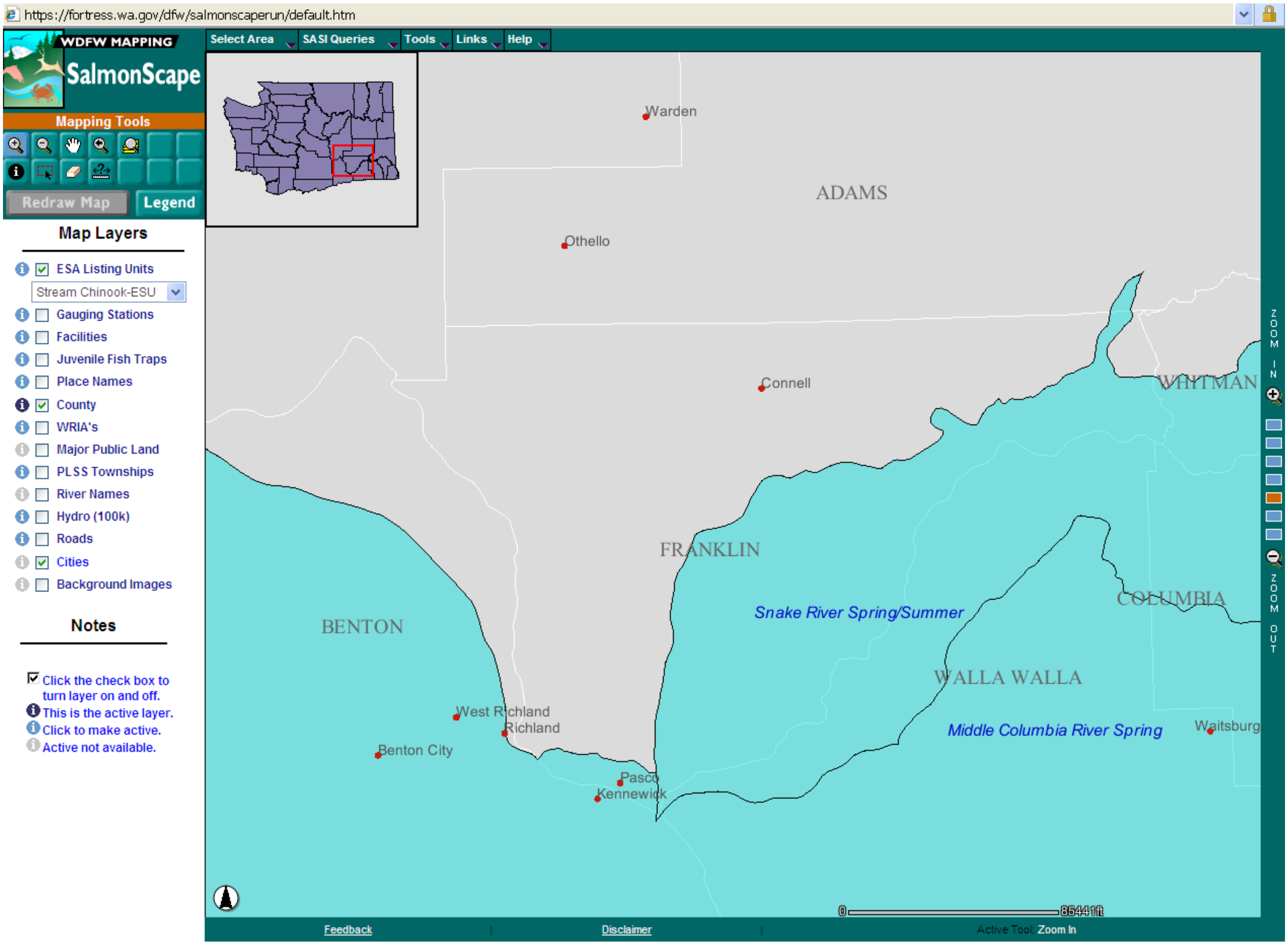
Southern California Association of Governments (SCAG). *Draft Regional Transportation Plan.* Los Angeles, CA, 2008.

Southern California Association of Governments (SCAG). *Regional Transportation Plan: Transportation Conformity Report.* Los Angeles, CA, 2008.


https://fortress.wa.gov/dfw/salmonscaperun/default.htm
WDFW MAPPING
SalmonScape
Select Area
SASI Queries
Tools
Links
Help
Mapping Tools
Redraw Map
Legend
Map Layers
ESA Listing Units
Ocean chinook-ESU
Gauging Stations
Facilities
Juvenile Fish Traps
Place Names
County
WRIA's
Major Public Land
PLSS Townships
River Names
Hydro (100k)
Roads
Cities
Background Images
Notes
Click the check box to turn layer on and off.
This is the active layer.
Click to make active.
Active not available.
Warden
Othello
ADAMS
Connell
WHITMAN
FRANKLIN
Upper Columbia River Summer/Fall
BENTON
Snake River Fall
COLUMBIA
WALLA WALLA
West Richland
Richland
Benton City
Pasco
Kennewick
Waitsburg
ZOOM IN
ZOOM OUT
0
85441ft
Feedback
Disclaimer
Active Tool: Zoom In


https://fortress.wa.gov/dfw/salmonscaperun/default.htm
WDFW MAPPING
SalmonScape
Mapping Tools
Redraw Map
Legend
Select Area
SASI Queries
Tools
Links
Help
Map Layers
ESA Listing Units
Ocean chinook-ESU
Gauging Stations
Facilities
Juvenile Fish Traps
Place Names
County
WRIA's
Major Public Land
PLSS Townships
River Names
Hydro (100k)
Roads
Cities
Background Images
Notes
Click the check box to turn layer on and off.
This is the active layer.
Click to make active.
Active not available.
Warden
ADAMS
Othello
Connell
WHITMAN
FRANKLIN
Upper Columbia River Summer/Fall
Snake River Fall
COLUMBIA
BENTON
WALLA WALLA
West Richland
Richland
Benton City
Pasco
Kennewick
Waitsburg
ZOOM IN
ZOOM OUT
0
85441ft
Feedback
Disclaimer
Active Tool: Zoom In


https://fortress.wa.gov/dfw/salmonscaperun/default.htm
WDFW MAPPING
SalmonScape
Mapping Tools
Redraw Map
Legend
Map Layers
ESA Listing Units
Steelhead-ESU
Gauging Stations
Facilities
Juvenile Fish Traps
Place Names
County
WRIA's
Major Public Land
PLSS Townships
River Names
Hydro (100k)
Roads
Cities
Background Images
Notes
Click the check box to turn layer on and off.
This is the active layer.
Click to make active.
Active not available.
Select Area
SASI Queries
Tools
Links
Help
Warden
ADAMS
Othello
Connell
WHITMAN
Upper Columbia River
FRANKLIN
Snake River Basin
COLUMBIA
BENTON
WALLA WALLA
West Richland
Richland
Benton City
Middle Columbia River
Waitsburg
Pasco
Kennewick
ZOOM IN
ZOOM OUT
0
85441 ft
Feedback
Disclaimer
Active Tool: Zoom In


https://fortress.wa.gov/dfw/salmonscaperun/default.htm
WDFW MAPPING
SalmonScape
Select Area
SASI Queries
Tools
Links
Help
Mapping Tools
Redraw Map
Legend
Map Layers
ESA Listing Units
Stream Chinook-ESU
Gauging Stations
Facilities
Juvenile Fish Traps
Place Names
County
WRIA's
Major Public Land
PLSS Townships
River Names
Hydro (100k)
Roads
Cities
Background Images
Notes
Click the check box to turn layer on and off.
This is the active layer.
Click to make active.
Active not available.
Warden
ADAMS
Othello
Connell
WHITMAN
FRANKLIN
Snake River Spring/Summer
COLUMBIA
BENTON
WALLA WALLA
West Richland
Richland
Benton City
Middle Columbia River Spring
Waitsburg
Pasco
Kennewick
ZOOM IN
ZOOM OUT
0
85441ft
Feedback
Disclaimer
Active Tool: Zoom In

United States Census Bureau

Rent by monthly housing costs

Search

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey TableID: DP04 Product: 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
HOUSING OCCUPANCY				
Total housing units	28,659	28,659	22,053	22,053
Occupied housing units	27,067	94.4%	20,988	95.2%
Vacant housing units	1,592	5.6%	1,065	4.8%
Homeowner vacancy rate	1.9	(X)	2.5	(X)
Rental vacancy rate	0.8	(X)	0.0	(X)
UNITS IN STRUCTURE				
Total housing units	28,659	28,659	22,053	22,053
1-unit, detached	20,501	71.5%	16,036	72.7%
1-unit, attached	1,386	4.8%	1,386	6.3%
2 units	602	2.1%	591	2.7%
3 or 4 units	867	3.0%	561	2.5%
5 to 9 units	499	1.7%	428	1.9%
10 to 19 units	810	2.8%	810	3.7%
20 or more units	1,345	4.7%	1,240	5.6%
Mobile home	2,499	8.7%	1,001	4.5%
Boat, RV, van, etc.	150	0.5%	0	0.0%
YEAR STRUCTURE BUILT				
Total housing units	28,659	28,659	22,053	22,053
Built 2014 or later	1,769	6.2%	1,356	6.1%

Rent by monthly housing costs

Search

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
HOUSING OCCUPANCY				
Total housing units	28,659	28,659	22,053	22,053
UNITS IN STRUCTURE				
YEAR STRUCTURE BUILT				
Total housing units	28,659	28,659	22,053	22,053
Built 2014 or later	1,769	6.2%	1,356	6.1%
Built 2010 to 2013	2,674	9.3%	2,082	9.4%
Built 2000 to 2009	6,637	23.2%	6,150	27.9%
Built 1990 to 1999	4,014	14.0%	2,862	13.0%
Built 1980 to 1989	1,814	6.3%	1,093	5.0%
Built 1970 to 1979	4,204	14.7%	2,605	11.8%
Built 1960 to 1969	1,505	5.3%	1,343	6.1%
Built 1950 to 1959	2,755	9.6%	2,173	9.9%
Built 1940 to 1949	1,371	4.8%	1,019	4.6%
Built 1939 or earlier	1,916	6.7%	1,370	6.2%
ROOMS				
Total housing units	28,659	28,659	22,053	22,053
1 room	509	1.8%	509	2.3%
2 rooms	819	2.9%	723	3.3%
3 rooms	1,786	6.2%	1,495	6.8%

United States Census Bureau

Rent by monthly housing costs

Search

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
HOUSING OCCUPANCY				
Total housing units	28,659	28,659	22,053	22,053
UNITS IN STRUCTURE				
YEAR STRUCTURE BUILT				
ROOMS				
Total housing units	28,659	28,659	22,053	22,053
1 room	509	1.8%	509	2.3%
2 rooms	819	2.9%	723	3.3%
3 rooms	1,786	6.2%	1,495	6.8%
4 rooms	4,809	16.8%	3,927	17.8%
5 rooms	6,693	23.4%	5,172	23.5%
6 rooms	4,627	16.1%	3,612	16.4%
7 rooms	2,248	7.8%	1,292	5.9%
8 rooms	2,985	10.4%	2,056	9.3%
9 rooms or more	4,183	14.6%	3,267	14.8%
Median rooms	5.5	(X)	5.3	(X)
BEDROOMS				
Total housing units	28,659	28,659	22,053	22,053
No bedroom	663	2.3%	663	3.0%
1 bedroom	1,474	5.1%	1,102	5.0%

United States Census Bureau

Rent by monthly housing costs

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
HOUSING OCCUPANCY				
Total housing units	28,659	28,659	22,053	22,053
UNITS IN STRUCTURE				
YEAR STRUCTURE BUILT				
ROOMS				
BEDROOMS				
Total housing units	28,659	28,659	22,053	22,053
No bedroom	663	2.3%	663	3.0%
1 bedroom	1,474	5.1%	1,102	5.0%
2 bedrooms	6,315	22.0%	5,213	23.6%
3 bedrooms	12,851	44.8%	9,347	42.4%
4 bedrooms	5,790	20.2%	4,465	20.2%
5 or more bedrooms	1,566	5.5%	1,263	5.7%
HOUSING TENURE				
Occupied housing units	27,067	27,067	20,988	20,988
Owner-occupied	17,833	65.9%	13,576	64.7%
Renter-occupied	9,234	34.1%	7,412	35.3%
Average household size of owner-occupied unit	3.30	(X)	3.28	(X)
Average household size of renter-occupied unit	3.60	(X)	3.60	(X)
YEAR HOUSEHOLDER MOVED INTO UNIT				

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
HOUSING TENURE				
YEAR HOUSEHOLDER MOVED INTO UNIT				
Occupied housing units	27,067	27,067	20,988	20,988
Moved in 2017 or later	5,977	22.1%	4,790	22.8%
Moved in 2015 to 2016	5,153	19.0%	4,286	20.4%
Moved in 2010 to 2014	4,506	16.6%	3,570	17.0%
Moved in 2000 to 2009	7,391	27.3%	5,860	27.9%
Moved in 1990 to 1999	2,667	9.9%	1,581	7.5%
Moved in 1989 and earlier	1,373	5.1%	901	4.3%
VEHICLES AVAILABLE				
Occupied housing units	27,067	27,067	20,988	20,988
No vehicles available	689	2.5%	639	3.0%
1 vehicle available	6,487	24.0%	5,657	27.0%
2 vehicles available	10,516	38.9%	8,238	39.3%
3 or more vehicles available	9,375	34.6%	6,454	30.8%
HOUSE HEATING FUEL				
Occupied housing units	N	N	N	N
Utility gas	N	N	N	N
Bottled, tank, or LP gas	N	N	N	N
Electricity	N	N	N	N

United States Census Bureau | Rent by monthly housing costs

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
HOUSE HEATING FUEL				
Occupied housing units	N	N	N	N
Utility gas	N	N	N	N
Bottled, tank, or LP gas	N	N	N	N
Electricity	N	N	N	N
Fuel oil, kerosene, etc.	N	N	N	N
Coal or coke	N	N	N	N
Wood	N	N	N	N
Solar energy	N	N	N	N
Other fuel	N	N	N	N
No fuel used	N	N	N	N
SELECTED CHARACTERISTICS				
Occupied housing units	27,067	27,067	20,988	20,988
Lacking complete plumbing facilities	201	0.7%	201	1.0%
Lacking complete kitchen facilities	258	1.0%	163	0.8%
No telephone service available	N	N	N	N
OCCUPANTS PER ROOM				
Occupied housing units	27,067	27,067	20,988	20,988
1.00 or less	24,231	89.5%	18,406	87.7%
1.01 to 1.50	2,024	7.5%	1,770	8.4%

United States Census Bureau

Rent by monthly housing costs

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
Occupied housing units	N	N	N	N
SELECTED CHARACTERISTICS				
Occupied housing units	27,067	27,067	20,988	20,988
Lacking complete plumbing facilities	201	0.7%	201	1.0%
Lacking complete kitchen facilities	258	1.0%	163	0.8%
No telephone service available	N	N	N	N
OCCUPANTS PER ROOM				
Occupied housing units	27,067	27,067	20,988	20,988
1.00 or less	24,231	89.5%	18,406	87.7%
1.01 to 1.50	2,024	7.5%	1,770	8.4%
1.51 or more	812	3.0%	812	3.9%
VALUE				
Owner-occupied units	17,833	17,833	13,576	13,576
Less than $50,000	1,418	8.0%	847	6.2%
$50,000 to $99,999	753	4.2%	690	5.1%
$100,000 to $149,999	3,005	16.9%	2,378	17.5%
$150,000 to $199,999	2,351	13.2%	2,099	15.5%
$200,000 to $299,999	5,769	32.4%	5,040	37.1%
$300,000 to $499,999	3,672	20.6%	2,262	16.7%
$500,000 to $999,999	802	4.5%	260	1.9%

United States Census Bureau

Rent by monthly housing costs

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
Occupied housing units	N	N	N	N
SELECTED CHARACTERISTICS				
Occupied housing units	27,067	27,067	20,988	20,988
OCCUPANTS PER ROOM				
VALUE				
Owner-occupied units	17,833	17,833	13,576	13,576
Less than $50,000	1,418	8.0%	847	6.2%
$50,000 to $99,999	753	4.2%	690	5.1%
$100,000 to $149,999	3,005	16.9%	2,378	17.5%
$150,000 to $199,999	2,351	13.2%	2,099	15.5%
$200,000 to $299,999	5,769	32.4%	5,040	37.1%
$300,000 to $499,999	3,672	20.6%	2,262	16.7%
$500,000 to $999,999	802	4.5%	260	1.9%
$1,000,000 or more	63	0.4%	0	0.0%
Median (dollars)	222,100	(X)	213,700	(X)
MORTGAGE STATUS				
Owner-occupied units	17,833	17,833	13,576	13,576
Housing units with a mortgage	N	N	N	N
Housing units without a mortgage	N	N	N	N
SELECTED MONTHLY OWNER COSTS (SMOC)				

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey TableID: DP04 Product: 2018: ACS 1-Year Estimates Data Profiles

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
SELECTED MONTHLY OWNER COSTS (SMOC)				
Housing units with a mortgage	N	N	N	N
Less than $500	N	N	N	N
$500 to $999	N	N	N	N
$1,000 to $1,499	N	N	N	N
$1,500 to $1,999	N	N	N	N
$2,000 to $2,499	N	N	N	N
$2,500 to $2,999	N	N	N	N
$3,000 or more	N	N	N	N
Median (dollars)	1,320	(X)	1,230	(X)
Housing units without a mortgage	N	N	N	N
Less than $250	N	N	N	N
$250 to $399	N	N	N	N
$400 to $599	N	N	N	N
$600 to $799	N	N	N	N
$800 to $999	N	N	N	N
$1,000 or more	N	N	N	N
Median (dollars)	459	(X)	467	(X)
SELECTED MONTHLY OWNER COSTS AS A PERCENTAGE OF HOUSEHOLD INCOME (SMOCAPI)				

United States Census Bureau

Rent by monthly housing costs

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
SELECTED MONTHLY OWNER COSTS AS A PERCENTAGE OF HOUSEHOLD INCOME (SMOCAPI)				
Housing units with a mortgage (excluding units where SMOCAPI cannot be computed)	12,493	12,493	9,955	9,955
Less than 20.0 percent	5,998	48.0%	4,478	45.0%
20.0 to 24.9 percent	1,955	15.6%	1,846	18.5%
25.0 to 29.9 percent	1,714	13.7%	1,133	11.4%
30.0 to 34.9 percent	719	5.8%	520	5.2%
35.0 percent or more	2,107	16.9%	1,978	19.9%
Not computed	0	(X)	0	(X)
Housing unit without a mortgage (excluding units where SMOCAPI cannot be computed)	5,222	5,222	3,503	3,503
Less than 10.0 percent	3,061	58.6%	1,901	54.3%
10.0 to 14.9 percent	1,174	22.5%	782	22.3%
15.0 to 19.9 percent	223	4.3%	223	6.4%
20.0 to 24.9 percent	487	9.3%	487	13.9%
25.0 to 29.9 percent	55	1.1%	55	1.6%
30.0 to 34.9 percent	0	0.0%	0	0.0%
35.0 percent or more	222	4.3%	55	1.6%
Not computed	118	(X)	118	(X)
GROSS RENT				

United States Census Bureau

Rent by monthly housing costs

Search

// Search / Tables / DP04

SELECTED HOUSING CHARACTERISTICS

Survey/Program: American Community Survey **TableID:** DP04 **Product:** 2018: ACS 1-Year Estimates Data Profiles

Data Notes | Selections | 2 Geographies | Years | 1 Topic | Survey | Code | Hide | Filter | Sort | Transpose Table | Margin of Error | Restore Layout | Download | Print | Share | More Data | Map

	Franklin County, Washington		Pasco city, Washington	
	Estimate	Percent	Estimate	Percent
SELECTED MONTHLY OWNER COSTS AS A PERCENTAGE OF HOUSEHOLD INCOME (SMOCAPI)				
GROSS RENT				
Occupied units paying rent	N	N	N	N
Less than $500	N	N	N	N
$500 to $999	N	N	N	N
$1,000 to $1,499	N	N	N	N
$1,500 to $1,999	N	N	N	N
$2,000 to $2,499	N	N	N	N
$2,500 to $2,999	N	N	N	N
$3,000 or more	N	N	N	N
Median (dollars)	902	(X)	911	(X)
No rent paid	N	N	N	N
GROSS RENT AS A PERCENTAGE OF HOUSEHOLD INCOME (GRAPI)				
Occupied units paying rent (excluding units where GRAPI cannot be computed)	8,282	8,282	6,999	6,999
Less than 15.0 percent	1,041	12.6%	808	11.5%
15.0 to 19.9 percent	1,328	16.0%	832	11.9%
20.0 to 24.9 percent	1,465	17.7%	1,455	20.8%
25.0 to 29.9 percent	1,205	14.5%	1,019	14.6%
30.0 to 34.9 percent	1,016	12.3%	814	11.6%
35.0 percent or more	2,227	26.9%	2,071	29.6%
Not computed	952	(X)	413	(X)

UN environment programme

Emissions Gap Report 2019

ISBN: 978-92-807-3766-0
Job number: DEW/2263/NA

Disclaimers

Suggested citation
United Nations Environment Programme (2019). *Emissions Gap Report 2019*. UNEP, Nairobi.

http://www.unenvironment.org/emissionsgap

Supported by:

ClimateWorks FOUNDATION

SITRA

ROYAL NORWEGIAN MINISTRY OF CLIMATE AND ENVIRONMENT

UDENRIGSMINISTERIET
Ministry of Foreign Affairs of Denmark

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Government of the Netherlands

Sweden Sverige

Emissions Gap Report 2019

November 2019

Acknowledgements

The United Nations Environment Programme (UNEP) would like to thank the members of the steering committee, the lead and contributing authors, reviewers and the secretariat for their contribution to the preparation of this assessment report. Authors and reviewers have contributed to the report in their individual capacities. Their affiliations are only mentioned for identification purposes.

Project steering committee

Juliane Berger (German Environment Agency), John Christensen (UNEP DTU Partnership), Navroz K. Dubash (Centre for Policy Research, India), Jian Liu (UNEP), Simon Maxwell (Independent), Surabi Menon (ClimateWorks Foundation), Bert Metz (European Climate Foundation), Katia Simeonova (UNFCCC), Priyadarshi Shukla (Ahmedabad University), Oksana Tarasova (World Meteorological Organization), Merlyn van Voore (UNEP)

Chapter 1

Lead authors: Anne Olhoff (UNEP DTU Partnership), John Christensen (UNEP DTU Partnership)

Chapter 2

Lead authors: Takeshi Kuramochi (NewClimate Institute, Germany), Michel den Elzen (PBL Netherlands Environmental Assessment Agency), Glen Peters (CICERO, Norway)

Contributing authors: Andrzej Ancyger (Climate Analytics, Germany), Ankit Bhardwaj (Centre for Policy Research, India), Gabriel Blanco (National University of the Center of the Buenos Aires Province, Argentina), Taryn Fransen (World Resources Institute, USA), Andreas Geiges (Climate Analytics, Germany), Frederic Hans (NewClimate Institute, Germany), Christopher Henderson (World Resources Institute, USA), Niklas Höhne (NewClimate Institute, Germany), Kejun Jiang (Energy Research Institute, China), Maria Jose de Villafranca (NewClimate Institute, Germany), Kimon Keramidas (Joint Research Centre/European Commissions), Joojin Kim (Solutions For Our Climate, Republic of Korea), Akihisa Kuriyama (Institute for Global Environmental Strategies, Japan), Leonardo Nascimento (NewClimate Institute, Germany), Jos Olivier (PBL Netherlands Environmental Assessment Agency), Deger Saygin (SHURA, Turkey), Ranping Song (World Resources Institute, China), Claire Stockwell (Climate Analytics, Germany), Kentaro Tamura (Institute for Global Environmental Strategies, Japan), Paola Tanguy (NewClimate Institute, Germany), Heleen van Soest (PBL Netherlands Environmental Assessment Agency), Jorge Villarreal Padilla (Iniciativa Climática de México), Ryan Wilson (Climate Analytics, Germany), William Wills (Centro Clima, Brazil), Paola Yanguas Parra (Climate Analytics, Germany)

Chapter 3

Lead authors: Joeri Rogelj (Grantham Institute, Imperial College London, UK; International Institute for Applied Systems Analysis, Austria), Michel den Elzen (PBL Netherlands Environmental Assessment Agency)

Contributing authors: Daniel Huppmann (International Institute for Applied Systems Analysis, Austria), Gunnar Luderer (Potsdam Institute for Climate Impact Research, Germany)

Chapter 4

Lead authors: Niklas Höhne (NewClimate Institute, Germany), Taryn Fransen (World Resources Institute, USA), Frederic Hans (NewClimate Institute, Germany)

Contributing authors: Ankit Bhardwaj (Centre for Policy Research, India), Gabriel Blanco (National University of the Center of the Buenos Aires Province, Argentina), Jesse Burton (University of Cape Town, South Africa), Michel den Elzen (PBL Netherlands Environmental Assessment Agency), Markus Hagemann (NewClimate Institute, Germany), Christopher Henderson (World Resources Institute, USA), Maria Daniela Keesler (National University of the Center of the Buenos Aires Province, Argentina), Jiang Kejun (Energy Research Institute, China), Akihisa Kuriyama (Institute for Global Environmental Strategies (IGES), Japan), Fu Sha (National Centre for Climate Change Strategy, China), Ranping Song (World Resources Institute, China), Kentaro Tamura (Institute for Global Environmental Strategies, Japan), Jorge Villarreal (Iniciativa Climática de México), William Wills (Centro Clima, Brazil)

Chapter 5

Lead authors: Nebojsa Nakićenović (International Institute for Applied Systems Analysis and Vienna University of Technology, Austria), Charlie Wilson (Tyndall Centre for Climate Change Research, UK)

Contributing authors: Bill Colglazier (American Association for Advancement of Science), Owen Gaffney (Potsdam Institute for Climate Impact Research, Germany), Dirk Messner (United Nations University), Narasimha Rao (Yale School of Forestry & Environmental Studies, USA), Caroline Zimm (International Institute for Applied Systems Analysis, Austria)

Chapter 6

Lead Authors: Yacob Mulugetta (Department of Science, Technology, Engineering & Public Policy, University College London, UK), Pablo E. Carvajal (International Renewable

Energy Agency, Germany), James Haselip (UNEP DTU Partnership), Thomas Spencer (The Energy and Resources Institute, India)

Contributing Authors: Edo Abraham (Delft University of Technology, the Netherlands,), Simon Batchelor (Gamos Ltd, UK), Brigitte Knopf (Mercator Research Institute on Global Commons and Climate Change, Germany)

Chapter 7

Lead authors: Edgar Hertwich (Norwegian University of Science and Technology), Reid Lifset (Yale School of Forestry & Environmental Studies, USA), Stefan Pauliuk (Faculty of Environment and Natural Resources, University of Freiburg, Germany), Niko Heeren (Yale School of Forestry & Environmental Studies, USA)

Contributing Authors: Saleem Ali (University of Delaware, USA), Peter Berrill (Yale School of Forestry & Environmental Studies USA), Tomer Fishman (Interdisciplinary Center Herzliya, Israel), Qingshi Tu (Yale School of Forestry & Environmental Studies USA), Paul Wolfram (Yale School of Forestry & Environmental Studies, USA)

Reviewers

Lawrence Agbemabiese (University of Delaware), Juan Carlos Altamirano (World Resources Institute /New Climate Economy), Birgit Aru (European Commission DG CLIMA), Mohammed Awojobi (University of Delaware), Christoph Bertram (Potsdam Institute for Climate Impact Research), Kathryn Jennifer Bowen (Australian National University), Sylvain Cail (Enerdata), Rachel Chi Kiu Mok (World Bank), Filippo Civitelli (UK Department for Business, Energy and Industrial Strategy), Robert Ddamulira (University of Delaware), Maya De Souza (Resource Efficiency, DEFRA), Riyanti Djalante (United Nations University – Institute for the Advanced Study of Sustainability), Eric Fee (German Environment Agency), Steve Forden (UK Department for Business, Energy and Industrial Strategy), James Foster (UK Department for Business, Energy and Industrial Strategy), Sabine Fuß (Mercator Research Institute on Global Commons and Climate Change), Harikumar Gadde (World Bank), Manuela Galan (UK Department for Business, Energy and Industrial Strategy), Mengpin Ge (World Resources Institute), Olivia Grippner (European Commission DG CLIMA), Christoph Helbig (Augsburg University), Fintan Hurley (Institute of Occupational Medicine), Yasuko Kameyama (National Institute for Environmental Studies, Japan), Rakhyun E. Kim (Utrecht University), Peter King (Institute for Global Environmental Strategies), Almbana Kona (European Commission DG CLIMA), Xavier Labandeira (University of Vigo), Gerd Leipold (Humboldt-Viadrina Governance Platform), Kelly Levin (World Resources Institute), Shannon McDaniel (Global Covenant of Mayors), Apurba Mitra (World Resources Institute), Miles Perry (European Commission DG CLIMA), John Quinn (UK Department for Business, Energy and Industrial Strategy), Chandra Shekhar Sinha (World Bank), Leena Srivastava (The Energy Resource Institute), Joel N. Swisher (Western Washington University), Saara Tamminen (SITRA), Oras Tynkkynen (SITRA), Tom Van-Ierland (European Commission DG CLIMA), Marion Vieweg (Current Future), Kenichi Wada (Research Institute of Innovative Technology for the Earth), Jim Watson (UK Energy Research Centre), Zhao Xiusheng (Tsinghua University)

Chief scientific editors

Anne Olhoff (UNEP DTU Partnership), John Christensen (UNEP DTU Partnership)

Editorial support

Olivier Bois von Kursk (UNEP DTU Partnership)

Secretariat and project coordination

Ivana Audia (UNEP DTU Partnership), Olivier Bois von Kursk (UNEP DTU Partnership), Anne Olhoff (UNEP DTU Partnership), John Christensen (UNEP DTU Partnership), Pinya Sarasas (UNEP), Maarten Kappelle (UNEP)

Media and launch support

Keishamaza Rukikaire, Nancy Groves, Michael Logan, Josie Raine, Sajni Shah, Moses Osani, Despina Kannaourou, David Cole, Pooja Munshi, Gregory Mwaura, Richard Waiguchu, Salome Mbeyu Chamanje, Florian Fussstetter, Joyce Sang, Viola Kup, Alejandro Laguna, Mark Grassi, Charlotte De kruijk (UNEP), Mette Annelie Rasmussen, Lasse Hemmingsen (UNEP DTU Partnership)

Design, layout and printing

Joseph & Sebastian (Layout and cover), Caren Weeks (Figures), Cuartalinea (Printing), Despina Kannaourou (UNEP)

Language editing and translation of the executive summary

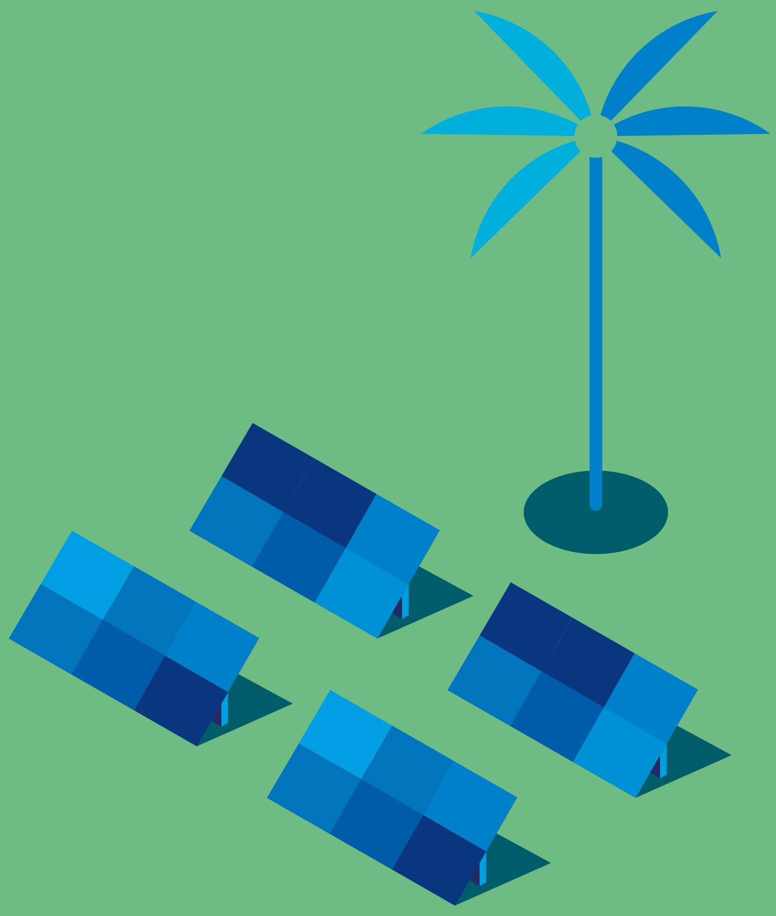
Strategic Agenda

Thanks also to:

Climate Transparency, Oras Tynkkynen (Sitra), Sandra Aparcana, Jacob Ipsen Hansen, Pia Riis Kofoed-Hansen, Susanne Konrad, Thomas Kragh Laursen, Daniel Puig, Fatima-Zahra Taibi, Xianli Zhu (UNEP DTU Partnership), David Berman, Yunting Duan, Angeline Djampou, Lu Liu, Daria Vasilevskaia, Ying Wang and Edoardo Zandri (UNEP)

Finally, the United Nations Environment Programme would like to thank the ClimateWorks Foundation, the Danish Ministry of Foreign Affairs, the Dutch Ministry of Economic Affairs and Climate Policy, the Finnish Innovation Fund (Sitra), the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Norwegian Ministry of Climate and Environment, and the Swedish International Development Authority (SIDA) for their support to the work of the Emissions Gap Report.

Contents



Glossary

This glossary is compiled according to the Lead Authors of the Report drawing on glossaries and other resources available on the websites of the following organizations, networks and projects: Intergovernmental Panel on Climate Change, Non-State Actor Zone for Climate Action, United Nations Environment Programme, United Nations Framework Convention on Climate Change and World Resources Institute.

Baseline/reference: The state against which change is measured. In the context of transformation pathways, the term 'baseline scenarios' refers to scenarios that are based on the assumption that no mitigation policies or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions that can serve to highlight the level of emissions that would occur without further policy effort. Typically, baseline scenarios are then compared to mitigation scenarios that are constructed to meet different goals for greenhouse gas emissions, atmospheric concentrations or temperature change. The term 'baseline scenario' is used interchangeably with 'reference scenario' and 'no policy scenario'. In much of the literature the term is also synonymous with the term 'business as usual (BAU) scenario', although the term 'BAU' has fallen out of favour because the idea of 'business as usual' in century-long socioeconomic projections is hard to fathom.

Bioenergy: Energy derived from any form of biomass such as recently living organisms or their metabolic by-products

Cancun pledge: During 2010, many countries submitted their existing plans for controlling greenhouse gas emissions to the Climate Change Secretariat and these proposals were formally acknowledged under the United Nations Framework Convention on Climate Change (UNFCCC). Developed countries presented their plans in the shape of economy-wide targets to reduce emissions, mainly up to 2020, while developing countries proposed ways to limit their growth of emissions in the shape of plans of action.

Carbon dioxide emission budget (or carbon budget): For a given temperature rise limit, for example a 1.5°C or 2°C long-term limit, the corresponding carbon budget reflects the total amount of carbon emissions that can be emitted for temperatures to stay below that limit. Stated differently, a carbon budget is the area under a carbon dioxide (CO_2) emission trajectory that satisfies assumptions about limits on cumulative emissions estimated to avoid a certain level of global mean surface temperature rise.

Carbon dioxide equivalent (CO_2e): A way to place emissions of various radiative forcing agents on a common footing by accounting for their effect on climate. It describes, for a given mixture and amount of greenhouse gases, the amount of CO_2 that would have the same global warming ability, when measured over a specified time period. For the purpose of this report, greenhouse gas emissions (unless otherwise specified) are the sum of the basket of greenhouse gases listed in Annex A to the Kyoto Protocol, expressed as CO_2e assuming a 100-year global warming potential.

Carbon intensity: The amount of emissions of CO_2 released per unit of another variable such as gross domestic product, output energy use, transport or agricultural/forestry products.

Carbon offset: See Offset.

Carbon price: The price for avoided or released CO_2 or CO_2e emissions. This may refer to the rate of a carbon tax or the price of emission permits. In many models that are used to assess the economic costs of mitigation, carbon prices are used as a proxy to represent the level of effort in mitigation policies.

Carbon tax: A levy on the carbon content of fossil fuels. Because virtually all of the carbon in fossil fuels is ultimately emitted as CO_2, a carbon tax is equivalent to an emission tax on CO_2 emissions.

Co-benefits: The positive effects that a policy or measure aimed at one objective might have on other objectives, without yet evaluating the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on, among others, local circumstances and implementation practices. Co-benefits are often referred to as ancillary benefits.

Conditional NDC: NDC proposed by some countries that are contingent on a range of possible conditions, such as the ability of national legislatures to enact the necessary laws, ambitious action from other countries, realization of finance and technical support, or other factors.

Conference of the Parties (COP): The supreme body of the United Nations Framework Convention on Climate Change. It currently meets once a year to review the Convention's progress.

Current policy trajectory: This trajectory is based on estimates of 2020 emissions considering projected economic trends and current policy approaches including policies at least through 2015. Estimates may be based on either official data or independent analysis.

Deforestation: Conversion of forest to non-forest.

Economic mitigation potential: The mitigation potential, which takes into account social costs and benefits and social discount rates, assuming that market efficiency is improved by policies and measures and barriers are removed.

Downcycling: A form of recycling that involves reusing materials in less demanding applications, accepting reduced performance of the material in terms of specifications such as hardness, tensile strength, or ductility. In its new application, the downcycled material replaces a material of lower economic value than the original application.

Emissions gap: The difference between the greenhouse gas emission levels consistent with a specific probability of limiting the mean global temperature rise to below 2°C or 1.5°C in 2100 above pre-industrial levels and the GHG emission levels consistent with the global effect of the NDCs, assuming full implementation from 2020.

Emission pathway: The trajectory of annual greenhouse gas emissions over time.

Global warming potential: An index representing the combined effect of the differing times greenhouse gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation.

Greenhouse gases: The atmospheric gases responsible for causing global warming and climatic change. The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent, but very powerful, GHGs are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6).

Integrated assessment models: Models that seek to combine knowledge from multiple disciplines in the form of equations and/or algorithms in order to explore complex environmental problems. As such, they describe the full chain of climate change, from production of greenhouse gases to atmospheric responses. This necessarily includes relevant links and feedbacks between socio-economic and biophysical processes.

Intended Nationally Determined Contribution (INDC): INDCs are submissions from countries describing the national actions that they intend to take to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. Once a country has ratified the Paris Agreement, its INDC is automatically converted to its NDC (see below), unless it chooses to further update it. INDCs are thus only used in this publication in reference to countries that have not yet ratified the Paris Agreement.

Kigali Amendment: The Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer aims for the phase-down of hydrofluorocarbons (HFCs) by cutting their production and consumption.

Kyoto Protocol: An international agreement, standing on its own, and requiring separate ratification by governments, but linked to the UNFCCC. The Kyoto Protocol, among other things, sets binding targets for the reduction of greenhouse gas emissions by industrialized countries.

Land Use, Land-Use Change and Forestry (LULUCF): A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land use change and forestry activities.

Likely chance: A likelihood greater than 66 percent chance. Used in this assessment to convey the probabilities of meeting temperature limits.

Last-mile solution: A solution designed for the movement of people and goods to the final destination of a multi-staged journey. In a public transportation system, this refers to the last leg of the journey.

Lock-in: Lock-in occurs when a market is stuck with a standard even though participants would be better off with an alternative.

Mitigation: In the context of climate change, a human intervention to reduce the sources, or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings and expanding forests and other 'sinks' to remove greater amounts of CO_2 from the atmosphere.

Monitoring, reporting and verification: A process/concept that potentially supports greater transparency in the climate change regime.

Nationally Determined Contribution (NDC): Submissions by countries that have ratified the Paris Agreement which presents their national efforts to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. New or updated NDCs are to be submitted in 2020 and every five years thereafter. NDCs thus represent a country's current ambition/target for reducing emissions nationally.

Non-state and subnational actors: 'Non-state and subnational actors' includes companies, cities, subnational regions and investors that take or commit to climate action.

Offset (in climate policy): A unit of CO_2e emissions that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere.

Product lightweighting: A process of creating lighter products through designs that require less material or substitute heavier material with lighter and/or less energy-intensive materials. Lighter material alternatives, both in weight or volume, can generate substantial energy savings in the transport and building sectors.

Ride sharing/car sharing: Two forms of arrangements in which two or more people share a vehicle for transportation. In ride sharing, also known as carpooling, the driver takes a passenger along for a ride that the driver gains utility from as well, often for commutes or long distance trips. This arrangement is distinguishable from ride hailing or ride sourcing, both of which are a form of taxi service. In car sharing, a person hires a car from another for a limited duration of time without the owner to undertake the desired trip.

Scenario: A description of how the future may unfold based on 'if-then' propositions. Scenarios typically include an initial socio-economic situation and a description of the key driving forces and future changes in emissions, temperature or other climate change-related variables.

Shared Socioeconomic Pathways (SSP): Scenarios of projected socioeconomic global changes up to 2100. They are used to derive greenhouse gas emissions scenarios associated with different climate policies scenarios.

Source: Any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol into the atmosphere.

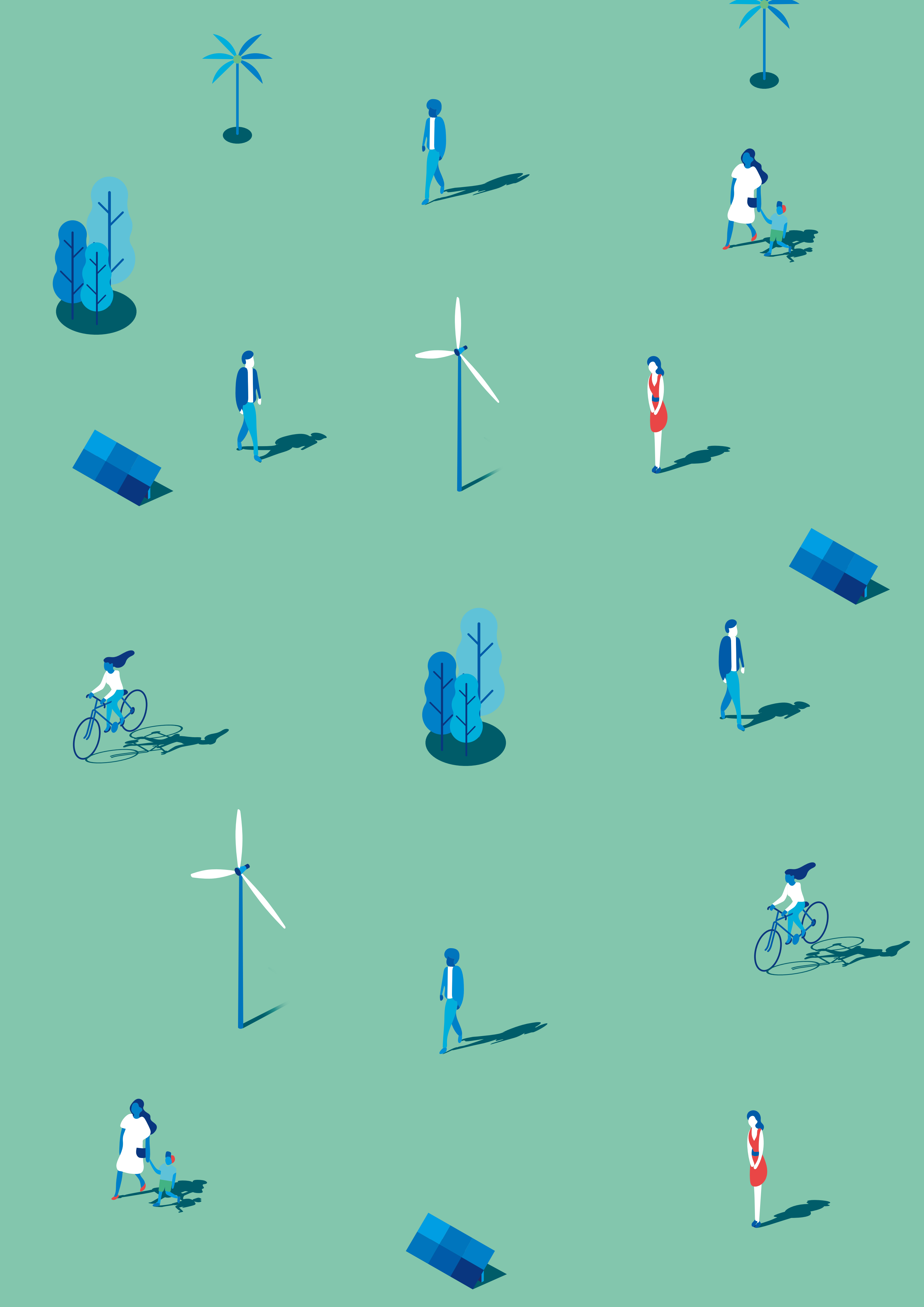
Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Technical mitigation potential: Such potential is estimated for given scenarios assuming full implementation of the best available pollutant reduction technology, as it exists today, by 2030 independent of their costs but considering the technical lifetime of technologies and other key constraints (e.g., cultural acceptance) that could limit applicability of certain measures in specific regions.

Uncertainty: A cognitive state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (for example a probability density function) or by qualitative statements (for example reflecting the judgement of a team of experts).

Unconditional NDCs: NDCs proposed by countries without conditions attached.

2020 pledge: See Cancun pledge.



Foreword

Each year for the last decade, the UN Environment Programme's Emissions Gap Report has compared where greenhouse gas emissions are headed, against where they should be to avoid the worst impacts of climate change. Each year, the report has found that the world is not doing enough. Emissions have only risen, hitting a new high of 55.3 gigatonnes of CO_2 equivalent in 2018. The UNEP Emissions Gap Report 2019 finds that even if all unconditional Nationally Determined Contributions (NDCs) under the Paris Agreement are implemented, we are still on course for a 3.2°C temperature rise.

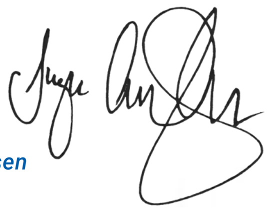
Our collective failure to act strongly and early means that we must now implement deep and urgent cuts. This report tells us that to get in line with the Paris Agreement, emissions must drop 7.6 per cent per year from 2020 to 2030 for the 1.5°C goal and 2.7 per cent per year for the 2°C goal. The size of these annual cuts may seem shocking, particularly for 1.5°C. They may also seem impossible, at least for next year. But we have to try.

We have to learn from our procrastination. Any further delay brings the need for larger, more expensive and unlikely cuts. We need quick wins, or the 1.5°C goal of the Paris Agreement will slip out of reach. The Intergovernmental Panel on Climate Change (IPCC) has warned us that going beyond 1.5°C will increase the frequency and intensity of climate impacts, such as the heatwaves and storms witnessed across the globe in the last few years. We cannot afford to fail.

The Climate Action Summit has increased momentum to address this global challenge. Now, in this critical period, the world must deliver concrete, stepped-up action. To deliver the cuts we need, nations have to raise the ambition of their current pledges over fivefold for the 1.5°C goal when they revise their NDCs in 2020. To reach the 2°C goal, they must triple ambition. They must then immediately follow up with policies and strategies to implement their promises.

The report tells us that the major transformation of our societies and economies we need can still happen. Political and societal focus on the climate crisis is at an all-time high, with youth movements holding us to account. There are many ambitious efforts from governments, cities, businesses and investors. There are plentiful options for rapid and cost-effective emission reductions. A shift to renewable energy and energy efficiency in the power, buildings and transport sectors, for example, could deliver reductions of over 16 gigatonnes of CO_2 equivalent each year by 2050. Using materials such as iron, steel and cement more efficiently also offers opportunities.

This report gives us a stark choice: set in motion the radical transformations we need now, or face the consequences of a planet radically altered by climate change. I hope that its findings inspire governments to step forward with the increased climate ambition the world so desperately needs.



Inger Andersen

Executive Director
United Nations Environment Programme

Executive summary – Emissions Gap Report 2019

Introduction

This is the tenth edition of the United Nations Environment Programme (UNEP) Emissions Gap Report. It provides the latest assessment of scientific studies on current and estimated future greenhouse gas (GHG) emissions and compares these with the emission levels permissible for the world to progress on a least-cost pathway to achieve the goals of the Paris Agreement. This difference between "where we are likely to be and where we need to be" has become known as the 'emissions gap'.

Reflecting on the ten-year anniversary, a summary report, entitled Lessons from a decade of emissions gap assessments, was published in September for the Secretary-General's Climate Action Summit.

The summary findings are bleak. Countries collectively failed to stop the growth in global GHG emissions, meaning that deeper and faster cuts are now required. However, behind the grim headlines, a more differentiated message emerges from the ten-year summary. A number of encouraging developments have taken place and the political focus on the climate crisis is growing in several countries, with voters and protestors, particularly youth, making it clear that it is their number one issue. In addition, the technologies for rapid and cost-effective emission reductions have improved significantly.

As in previous years, this report explores some of the most promising and applicable options available for countries to bridge the gap, with a focus on how to create transformational change and just transitions. Reflecting on the report's overall conclusions, it is evident that incremental changes will not be enough and there is a need for rapid and transformational action.

The political context in 2019 has been dominated by the United Nations Secretary-General's Global Climate Action Summit, which was held in September and brought together governments, the private sector, civil society, local authorities and international organizations.

The aim of the Summit was to stimulate action and in particular to secure countries' commitment to enhance their nationally determined contributions (NDCs) by 2020 and aim for net zero emissions by 2050.

According to the press release at the end of the Summit, around 70 countries announced their intention to submit enhanced NDCs in 2020, with 65 countries and major subnational economies committing to work towards achieving net zero emissions by 2050. In addition, several private companies, finance institutions and major cities announced concrete steps to reduce emissions and shift investments into low-carbon technologies. A key aim of the Summit was to secure commitment from countries to enhance their NDCs, which was met to some extent, but largely by smaller economies. With most of the G20 members visibly absent, the likely impact on the emissions gap will be limited.

As regards the scientific perspective, the Intergovernmental Panel on Climate Change (IPCC) issued two special reports in 2019: the Climate Change and Land report on climate change, desertification, land degradation, sustainable land management, food security and greenhouse gas fluxes in terrestrial ecosystems, and the Ocean and Cryosphere in a Changing Climate report. Both reports voice strong concerns about observed and predicted changes resulting from climate change and provide an even stronger scientific foundation that supports the importance of the temperature goals of the Paris Agreement and the need to ensure emissions are on track to achieve these goals.

This Emissions Gap Report has been prepared by an international team of leading scientists, assessing all available information, including that published in the context of the IPCC special reports, as well as in other recent scientific studies. The assessment production process has been transparent and participatory. The assessment methodology and preliminary findings were made available to the governments of the countries specifically mentioned in the report to provide them with the opportunity to comment on the findings.

1. GHG emissions continue to rise, despite scientific warnings and political commitments.

- GHG emissions have risen at a rate of 1.5 per cent per year in the last decade, stabilizing only briefly between 2014 and 2016. Total GHG emissions, including from land-use change, reached a record high of 55.3 $GtCO_2e$ in 2018.
- Fossil CO_2 emissions from energy use and industry, which dominate total GHG emissions, grew 2.0 per cent in 2018, reaching a record 37.5 $GtCO_2$ per year.

- There is no sign of GHG emissions peaking in the next few years; every year of postponed peaking means that deeper and faster cuts will be required. By 2030, emissions would need to be 25 per cent and 55 per cent lower than in 2018 to put the world on the least-cost pathway to limiting global warming to below 2˚C and 1.5°C respectively.

- Figure ES.1 shows a decomposition of the average annual growth rates of economic activity (gross domestic product – GDP), primary energy use, energy use per unit of GDP, CO_2 emissions per unit of energy and GHG emissions from all sources for Organisation for Economic Co-operation and Development (OECD) and non-OECD members.

- Economic growth has been much stronger in non-OECD members, growing at over 4.5 per cent per year in the last decade compared with 2 per cent per year in OECD members. Since OECD and non-OECD members have had similar declines in the amount of energy used per unit of economic activity, stronger economic growth means that primary energy use has increased much faster in non-OECD members (2.8 per cent per year) than in OECD members (0.3 per cent per year).

- OECD members already use less energy per unit of economic activity, which suggests that non-OECD members have the potential to accelerate improvements even as they grow, industrialize and urbanize their economies in order to meet development objectives.

- While the global data provide valuable insight for understanding the continued growth in emissions, it is necessary to examine the trends of major emitters to gain a clearer picture of the underlying trends (figure ES.2). Country rankings change dramatically when comparing total and per capita emissions: for example, it is evident that China now has per capita emissions in the same range as the European Union (EU) and is almost at a similar level to Japan.

- Consumption-based emission estimates, also known as a carbon footprint, that adjust the standard territorial emissions for imports and exports, provide policymakers with a deeper insight into the role of consumption, trade and the interconnectedness of countries. Figure ES.3 shows that the net flow of embodied carbon is from developing to developed countries, even as developed countries reduce their territorial emissions this effect is being partially offset by importing embodied carbon, implying for example that EU per capita emissions are higher than Chinese when consumption-based emissions are included. It should be noted that consumption-based emissions are not used within the context of the United Nations Framework Convention on Climate Change (UNFCCC).

Figure ES.1. Average annual growth rates of key drivers of global CO_2 emissions (left of dotted line) and components of greenhouse gas emissions (right of dotted line) for OECD and non-OECD members

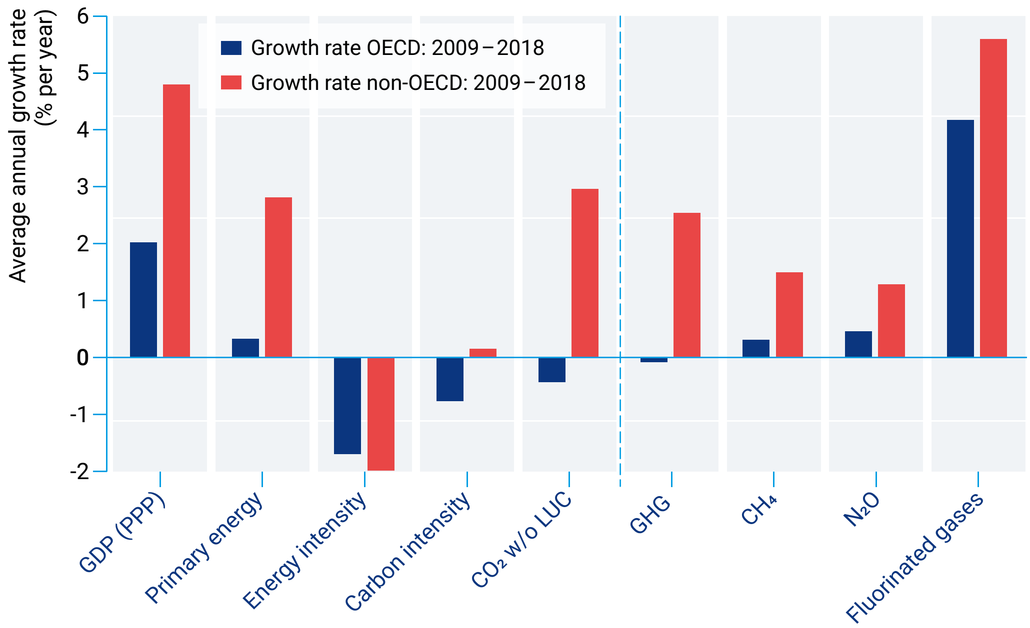
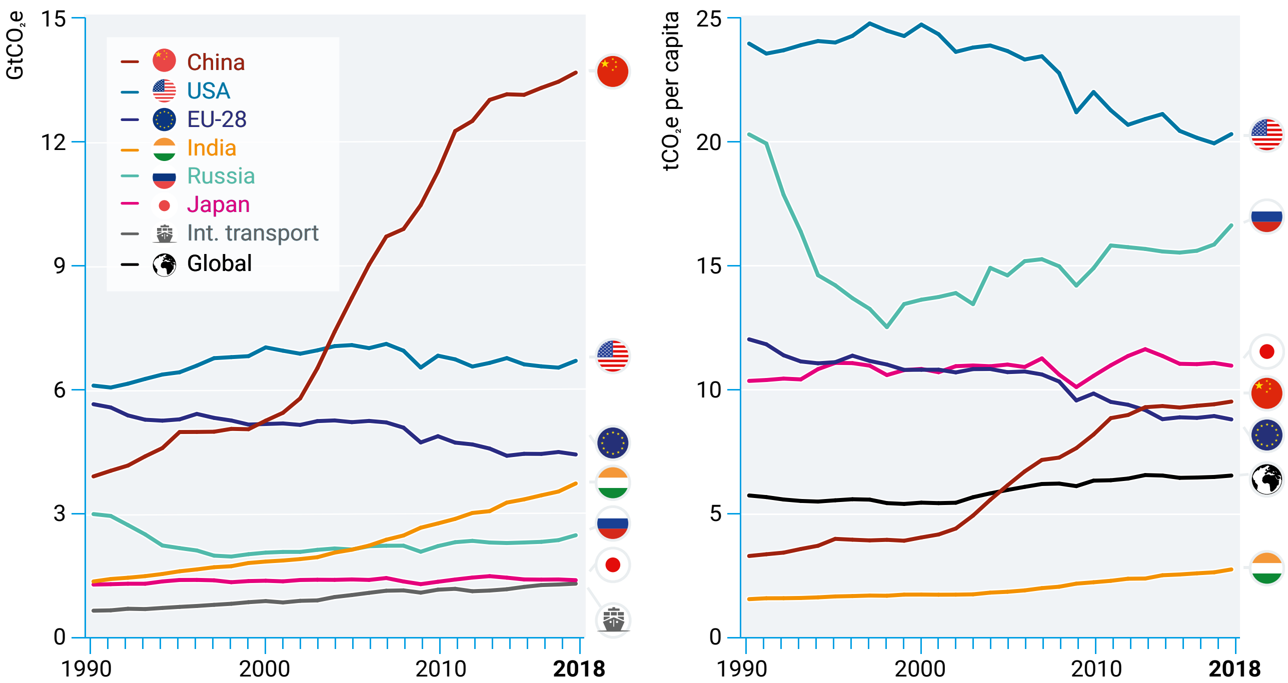


Figure ES.2. Top greenhouse gas emitters, excluding land-use change emissions due to lack of reliable country-level data, on an absolute basis (left) and per capita basis (right)



2. G20 members account for 78 per cent of global GHG emissions. Collectively, they are on track to meet their limited 2020 Cancun Pledges, but seven countries are currently not on track to meet 2030 NDC commitments, and for a further three, it is not possible to say.

- As G20 members account for around 78 per cent of global GHG emissions (including land use), they largely determine global emission trends and the extent to which the 2030 emissions gap will be closed. This report therefore pays close attention to G20 members.

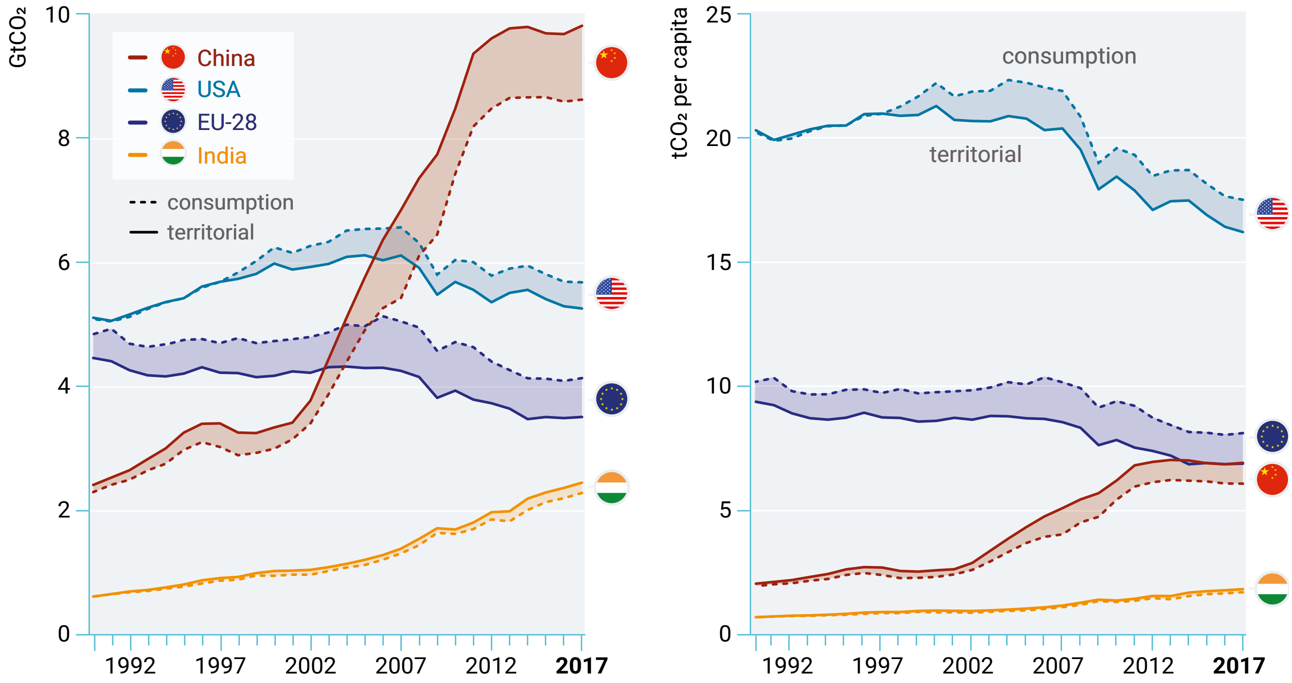
- G20 members with 2020 Cancun Pledges are collectively projected to overachieve these by about 1 $GtCO_2e$ per year. However, several individual G20 members (Canada, Indonesia, Mexico, the Republic of Korea, South Africa, the United States of America) are currently projected to miss their Cancun Pledges or will not achieve them with great certainty. Argentina, Saudi Arabia and Turkey have not made 2020 pledges and pledges from several countries that meet their targets are rather unambitious.

- Australia is carrying forward their overachievement from the Kyoto period to meet their 2020 Cancun Pledge and counts cumulative emissions between 2013 and 2020. With this method, the Australian Government projects that the country will overachieve its 2020 pledge. However, if this 'carry-forward' approach is not taken, Australia will not achieve its 2020 pledge.

- On the progress of G20 economies towards their NDC targets, six members (China, the EU28, India, Mexico, Russia and Turkey) are projected to meet their unconditional NDC targets with current policies. Among them, three countries (India, Russia and Turkey) are projected to be more than 15 per cent lower than their NDC target emission levels. These results suggest that the three countries have room to raise their NDC ambition significantly. The EU28 has introduced climate legislation that achieves at least a 40 per cent reduction in GHG emissions, which the European Commission projects could be overachieved if domestic legislation is fully implemented in member states.

- In contrast, seven G20 members require further action of varying degree to achieve their NDC: Australia, Brazil, Canada, Japan, the Republic of Korea, South Africa and the United States of

Figure ES.3. CO_2 emissions allocated to the point of emissions (territorial) and the point of consumption, for absolute emissions (left) and per capita (right)



America. For Brazil, the emissions projections from three annually updated publications were all revised upward, reflecting the recent trend towards increased deforestation, among others. In Japan, however, current policy projections have been close to achieving its NDC target for the last few years.

- Studies do not agree on whether Argentina, Indonesia and Saudi Arabia are on track to meet their unconditional NDCs. For Argentina, recent domestic analysis that reflects the most recent GHG inventory data up to 2016 projects that the country will achieve its unconditional NDC target, while two international studies project that it will fall short of its target. For Indonesia, this is mainly due to uncertainty concerning the country's land use, land-use change and forestry (LULUCF) emissions. For Saudi Arabia, the limited amount of information on the country's climate policies has not allowed for further assessments beyond the two studies reviewed.

- Some G20 members are continuously strengthening their mitigation policy packages, leading to a downward revision of current policy scenario projections for total emissions over time. One example is the EU, where a noticeable downward shift has been observed in current policy scenario projections for 2030 since the 2015 edition of the Emissions Gap Report.

3. Although the number of countries announcing net zero GHG emission targets for 2050 is increasing, only a few countries have so far formally submitted long-term strategies to the UNFCCC.

- An increasing number of countries have set net zero emission targets domestically and 65 countries and major subnational economies, such as the region of California and major cities worldwide, have committed to net zero emissions by 2050. However, only a few long-term strategies submitted to the UNFCCC have so far committed to a timeline for net zero emissions, none of which are from a G20 member.

- Five G20 members (the EU and four individual members) have committed to long-term zero emission targets, of which three are currently in the process of passing legislation and two have recently passed legislation. The remaining 15 G20 members have not yet committed to zero emission targets.

Table ES.1. Global total GHG emissions by 2030 under different scenarios (median and 10th to 90th percentile range), temperature implications and the resulting emissions gap

Scenario (rounded to the nearest gigaton)	Number of scenarios in set	Global total emissions in 2030 [$GtCO_2e$]	Estimated temperature outcomes			Closest corresponding IPCC SR1.5 scenario class	Emissions Gap in 2030 [$GtCO_2e$]		
			50% probability	66% probability	90% probability		Below 2.0°C	Below 1.8°C	Below 1.5°C in 2100
2005-policies	6	**64** (60–68)							
Current policy	8	**60** (58–64)					**18** (17–23)	**24** (23–29)	**35** (34–39)
Unconditional NDCs	11	**56** (54–60)					**15** (12–18)	**21** (18–24)	**32** (29–35)
Conditional NDCs	12	**54** (51–56)					**12** (9–14)	**18** (15–21)	**29** (26–31)
Below 2.0°C (66% probability)	29	**41** (39–46)	Peak: 1.7-1.8°C In 2100: 1.6-1.7°C	**Peak: 1.9-2.0°C In 2100: 1.8-1.9°C**	Peak: 2.4-2.6°C In 2100: 2.3-2.5°C	Higher-2°C pathways			
Below 1.8°C (66% probability)	43	**35** (31–41)	Peak: 1.6-1.7°C In 2100: 1.3-1.6°C	**Peak: 1.7-1.8°C In 2100: 1.5-1.7°C**	Peak: 2.1-2.3°C In 2100: 1.9-2.2°C	Lower-2°C pathways			
Below 1.5°C in 2100 and peak below 1.7°C (both with 66% probability)	13	**25** (22–31)	Peak: 1.5-1.6°C In 2100: 1.2-1-3°C	**Peak: 1.6-1.7°C In 2100: 1.4-1.5°C**	Peak: 2.0-2.1°C In 2100: 1.8-1.9°C	1.5°C with no or limited overshoot			

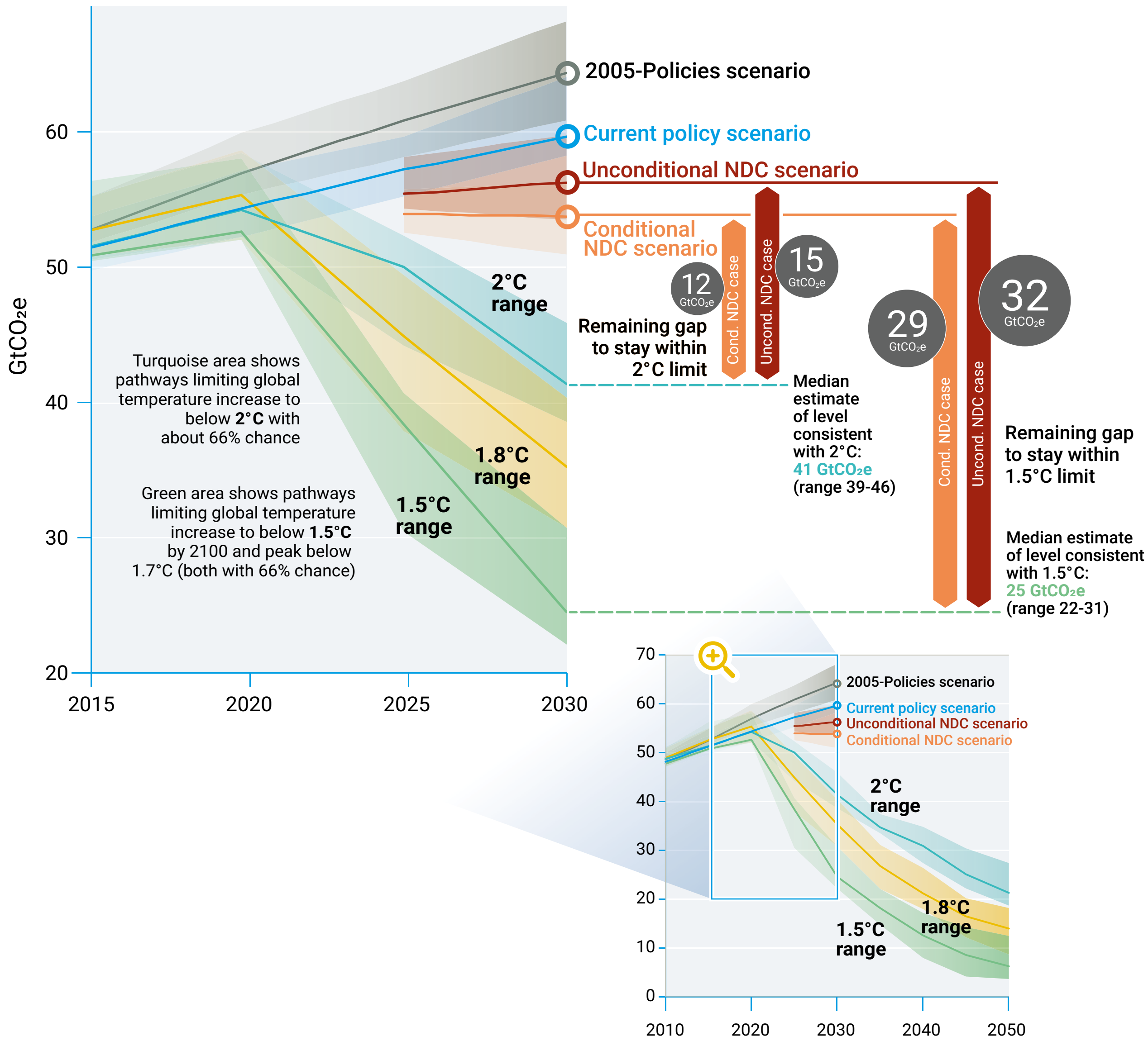
4. The emissions gap is large. In 2030, annual emissions need to be 15 $GtCO_2e$ lower than current unconditional NDCs imply for the 2°C goal, and 32 $GtCO_2e$ lower for the 1.5°C goal.

- Estimates of where GHG emissions should be in 2030 in order to be consistent with a least-cost pathway towards limiting global warming to the specific temperature goals have been calculated from the scenarios that were compiled as part of the mitigation pathway assessment of the IPCC Special Report on Global Warming of 1.5°C report.

- This report presents an assessment of global emissions pathways relative to those consistent with limiting warming to 2°C, 1.8°C and 1.5°C, in order to provide a clear picture of the pathways that will keep warming in the range of 2°C to 1.5°C. The report also includes an overview of the peak and 2100 temperature outcomes associated with different likelihoods. The inclusion of the 1.8°C level allows for a more nuanced interpretation and discussion of the implication of the Paris Agreement's temperature targets for near-term emissions.

- The NDC scenarios of this year's report are based on updated data from the same sources used for the current policies scenario and is provided by 12 modelling groups. Projected NDC levels for some countries, in particular China and India, depend on recent emission trends or GDP growth projections that are easily outdated in older studies. Thus, studies that were published in 2015, before the adoption of the Paris Agreement, have been excluded in this year's update. Excluding such studies has had little impact

Figure ES.4. Global GHG emissions under different scenarios and the emissions gap by 2030



on the projected global emission levels of the NDC scenarios, which are very similar to those presented in the UNEP Emissions Gap Report 2018.

- With only current policies, GHG emissions are estimated to be 60 $GtCO_2e$ in 2030. On a least-cost pathway towards the Paris Agreement goals in 2030, median estimates are 41 $GtCO_2e$ for 2°C, 35 $GtCO_2e$ for 1.8°C, and 25 $GtCO_2e$ for 1.5°C.

- If unconditional and conditional NDCs are fully implemented, global emissions are estimated to reduce by around 4 $GtCO_2e$ and 6 $GtCO_2e$ respectively by 2030, compared with the current policy scenario.

- The emissions gap between estimated total global emissions by 2030 under the NDC scenarios and under pathways limiting warming to below 2°C and 1.5°C is large (see Figure ES.4). Full implementation of the unconditional NDCs is estimated to result in a gap of 15 $GtCO_2e$ (range: 12–18 $GtCO_2e$) by 2030, compared with the 2°C scenario. The emissions gap between implementing the unconditional NDCs and the 1.5°C pathway is about 32 $GtCO_2e$ (range: 29–35 $GtCO_2e$).

- The full implementation of both unconditional and conditional NDCs would reduce this gap by around 2–3 $GtCO_2e$.

- If current unconditional NDCs are fully implemented, there is a 66 per cent chance that warming will be limited to 3.2°C by the end of the century. If conditional NDCs are also effectively implemented, warming will likely reduce by about 0.2°C.

5. Dramatic strengthening of the NDCs is needed in 2020. Countries must increase their NDC ambitions threefold to achieve the well below 2°C goal and more than fivefold to achieve the 1.5°C goal.

- The ratchet mechanism of the Paris Agreement foresees strengthening of NDCs every five years. Parties to the Paris Agreement identified 2020 as a critical next step in this process, inviting countries to communicate or update their NDCs by this time. Given the time lag between policy decisions and associated emission reductions, waiting until 2025 to strengthen NDCs will be too late to close the large 2030 emissions gap.
- The challenge is clear. The recent IPCC special reports clearly describe the dire consequences of inaction and are backed by record temperatures worldwide along with enhanced extreme events.
- Had serious climate action begun in 2010, the cuts required per year to meet the projected emissions levels for 2°C and 1.5°C would only have been 0.7 per cent and 3.3 per cent per year on average. However, since this did not happen, the required cuts in emissions are now 2.7 per cent per year from 2020 for the 2°C goal and 7.6 per cent per year on average for the 1.5°C goal. Evidently, greater cuts will be required the longer that action is delayed.
- Further delaying the reductions needed to meet the goals would imply future emission reductions and removal of CO_2 from the atmosphere at such a magnitude that it would result in a serious deviation from current available pathways. This, together with necessary adaptation actions, risks seriously damaging the global economy and undermining food security and biodiversity.

6. Enhanced action by G20 members will be essential for the global mitigation effort.

- This report has a particular focus on the G20 members, reflecting on their importance for global mitigation efforts. Chapter 4 in particular focuses on progress and opportunities for enhancing mitigation ambition of seven selected G20 members – Argentina, Brazil, China, the EU, India, Japan and the United States of America – which represented around 56 per cent of global GHG emissions in 2017. The chapter, which was pre-released for the Climate Action Summit, presents a detailed assessment of action or inaction in key sectors, demonstrating that even though there are a few frontrunners, the general picture is rather bleak.
- In 2009, the G20 members adopted a decision to gradually phase out fossil-fuel subsidies, though no country has committed to fully phasing these out by a specific year as yet.
- Although many countries, including most G20 members, have committed to net zero deforestation targets in the last few decades, these commitments are often not supported by action on the ground.
- Based on the assessment of mitigation potential in the seven previously mentioned countries, a number of areas have been identified for urgent and impactful action (see table ES.2). The purpose of the recommendations is to show potential, stimulate engagement and facilitate political discussion of what is required to implement the necessary action. Each country will be responsible for designing their own policies and actions.

7. Decarbonizing the global economy will require fundamental structural changes, which should be designed to bring multiple co-benefits for humanity and planetary support systems.

- If the multiple co-benefits associated with closing the emissions gap are fully realized, the required transition will contribute in an essential way to achieving the United Nations 2030 Agenda with its 17 Sustainable Development Goals (SDGs).
- Climate protection and adaptation investments will become a precondition for peace and stability, and will require unprecedented efforts to transform societies, economies, infrastructures and governance institutions. At the same time, deep and rapid decarbonization processes imply fundamental structural changes are needed within economic sectors, firms, labour markets and trade patterns.
- By necessity, this will see profound change in how energy, food and other material-intensive services are demanded and provided by governments, businesses and markets. These systems of provision are entwined with the preferences, actions and demands of people as consumers, citizens and communities. Deep-rooted shifts in values, norms, consumer culture and world views are inescapably part of the great sustainability transformation.
- Legitimacy for decarbonization therefore requires massive social mobilization and investments in social cohesion to avoid exclusion and resistance to change. Just and timely transitions towards sustainability need to be developed, taking into account the interests and rights of people vulnerable to the impacts of climate change, of people and regions where decarbonization requires structural adjustments, and of future generations.
- Fortunately, deep transformation to close the emissions gap between trends based on current

Table ES.2. Selected current opportunities to enhance ambition in seven G20 members in line with ambitious climate actions and targets

Argentina

- Refrain from extracting new, alternative fossil-fuel resources
- Reallocate fossil-fuel subsidies to support distributed renewable electricity-generation
- Shift towards widespread use of public transport in large metropolitan areas
- Redirect subsidies granted to companies for the extraction of alternative fossil fuels to building-sector measures

Brazil

- Commit to the full decarbonization of the energy supply by 2050
- Develop a national strategy for ambitious electric vehicle (EV) uptake aimed at complementing biofuels and at 100-per cent CO_2-free new vehicles
- Promote the 'urban agenda' by increasing the use of public transport and other low-carbon alternatives

China

- Ban all new coal-fired power plants
- Continue governmental support for renewables, taking into account cost reductions, and accelerate development towards a 100 per cent carbon-free electricity system
- Further support the shift towards public modes of transport
- Support the uptake of electric mobility, aiming for 100 per cent CO_2-free new vehicles
- Promote near-zero emission building development and integrate it into Government planning

European Union

- Adopt an EU regulation to refrain from investment in fossil-fuel infrastructure, including new natural gas pipelines
- Define a clear endpoint for the EU emissions trading system (ETS) in the form of a cap that must lead to zero emissions
- Adjust the framework and policies to enable 100 per cent carbon-free electricity supply by between 2040 and 2050
- Step up efforts to phase out coal-fired plants
- Define a strategy for zero-emission industrial processes
- Reform the EU ETS to more effectively reduce emissions in industrial applications
- Ban the sale of internal combustion engine cars and buses and/or set targets to move towards 100 per cent of new car and bus sales being zero-carbon vehicles in the coming decades
- Shift towards increased use of public transport in line with the most ambitious Member States
- Increase the renovation rate for intensive retrofits of existing buildings

India

- Plan the transition from coal-fired power plants
- Develop an economy-wide green industrialization strategy towards zero-emission technologies
- Expand mass public transit systems
- Develop domestic electric vehicle targets working towards 100 per cent new sales of zero-emission cars

Japan

- Develop a strategic energy plan that includes halting the construction of new freely emitting coal-fired power plants, as well as a phase-out schedule of existing plants and a 100 per cent carbon-free electricity supply
- Increase the current level of carbon pricing with high priority given to the energy and building sector
- Develop a plan to phase out the use of fossil fuels through promoting passenger cars that use electricity from renewable energy
- Implement a road map as part of efforts towards net-zero energy buildings and net-zero energy houses

USA

- Introduce regulations on power plants, clean energy standards and carbon pricing to achieve an electricity supply that is 100 per cent carbon-free
- Implement carbon pricing on industrial emissions
- Strengthen vehicle and fuel economy standards to be in line with zero emissions for new cars in 2030
- Implement clean building standards so that all new buildings are 100 per cent electrified by 2030

policies and achieving the Paris Agreement can be designed to bring multiple co-benefits for humanity and planetary support systems. These range, for example, from reducing air pollution, improving human health, establishing sustainable energy systems and industrial production processes, making consumption and services more efficient and sufficient, employing less-intensive agricultural practices and mitigating biodiversity loss to liveable cities.

- This year's report explores six entry points for progressing towards closing the emissions gap through transformational change in the following areas: (a) air pollution, air quality, health; (b) urbanization; (c) governance, education, employment; (d) digitalization; (e) energy- and material-efficient services for raising living standards; and (f) land use, food security, bioenergy. Building on this overview, a more detailed discussion of transitions in the energy sector is presented in chapter 6.

8. Renewables and energy efficiency, in combination with electrification of end uses, are key to a successful energy transition and to driving down energy-related CO_2 emissions.

- The necessary transition of the global energy sector will require significant investments compared with a business-as-usual scenario. Climate policies that are consistent with the 1.5°C goal will require upscaling energy system supply-side investments to between US$1.6 trillion and US$3.8 trillion per year globally on average over the 2020–2050 time frame, depending on how rapid energy efficiency and conservation efforts can be ramped up.

- Given the important role that energy and especially the electricity sector will have to play in any low-carbon transformation, chapter 6 examines five transition options, taking into account their relevance for a wide range of countries, clear co-benefit opportunities and potential to deliver significant emissions reductions. Each of the following transitions correspond to a particular policy rationale or motivation, which is discussed in more detail in the chapter:

  - Expanding Renewable Energy for electrification.
  - Phasing out coal for rapid decarbonization of the energy system.
  - Decarbonizing transport with a focus on electric mobility.
  - Decarbonizing energy-intensive industry.
  - Avoiding future emissions while improving energy access.

- Implementing such major transitions in a number of areas will require increased interdependency between energy and other infrastructure sectors, where changes in one sector can impact another. Similarly, there will be a strong need to connect demand and supply-side policies and include wider synergies and co-benefits, such as job losses and creation, rehabilitation of ecosystem services, avoidance of resettlements and reduced health and environmental costs as a result of reduced emissions. The same applies for decarbonizing transport, where there will be a need for complementarity and coordination of policies, driven by technological, environmental and land-use pressures. Policies will need to be harmonized wherever possible to take advantage of interdependencies and prevent undesirable outcomes such as CO_2 leakage from one sector to another.

- Any transition at this scale is likely to be extremely challenging and will meet a number of economic, political and technical barriers and challenges. However, many drivers of climate action have changed in the last years, with several options for ambitious climate action becoming less costly, more numerous and better understood. First, technological and economic developments present opportunities to decarbonize the economy, especially the energy sector, at a cost that is lower than ever. Second, the synergies between climate action and economic growth and development objectives, including options for addressing distributional impacts, are better understood. Finally, policy momentum across various levels of government, as well as a surge in climate action commitments by non-state actors, are creating opportunities for countries to engage in real transitions.

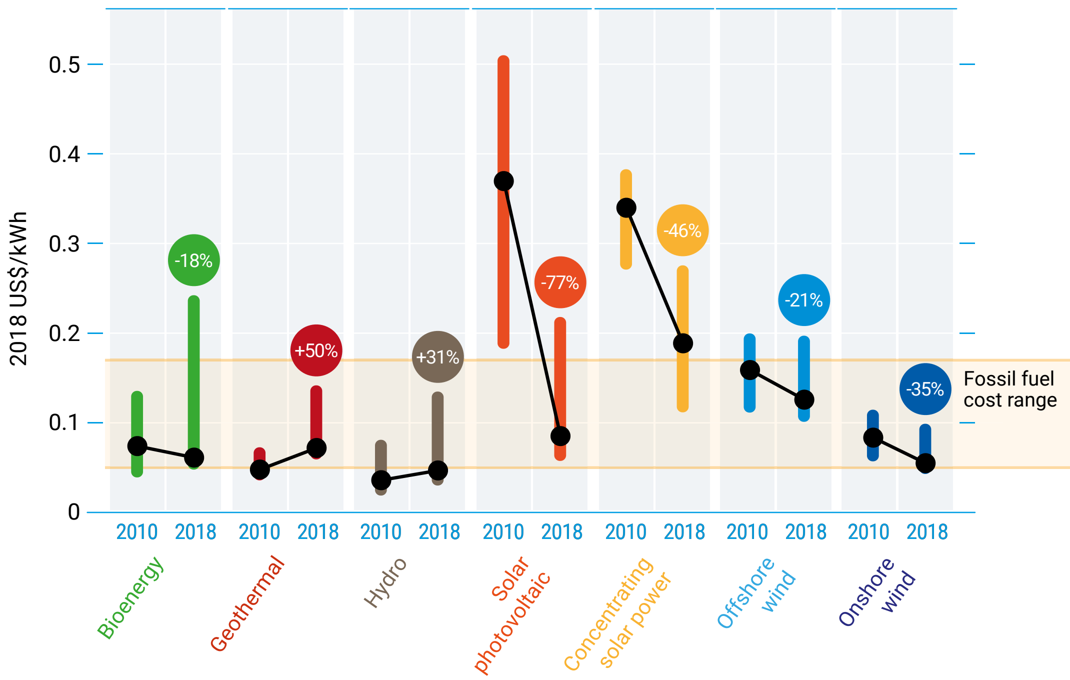
- A key example of technological and economic trends is the cost of renewable energy, which is declining more rapidly than was predicted just a few years ago (see figure ES.5). Renewables are currently the cheapest source of new power generation in most of the world, with the global weighted average purchase or auction price for new utility-scale solar power photovoltaic systems and utility-scale onshore wind turbines projected to compete with the marginal operating cost of existing coal plants by 2020. These trends are increasingly manifesting in a decline in new coal plant construction, including the cancellation of planned plants, as well as the early retirement of existing plants. Moreover, real-life cost declines are outpacing projections.

A short summary of the main aspects of each transition is presented in table ES.3.

Table ES.3. Summary of five energy transition options

Option	Major components	Instruments	Co-benefits	Annual GHG emissions reduction potential of renewables, electrification, energy efficiency and other measures by 2050
Renewable energy electricity expansion	• Plan for large shares of variable renewable energy • Electricity becomes the main energy source by 2050, supplying at least 50 per cent of total final energy consumption (TFEC) • Share of renewable energy in electricity up to 85 per cent by 2050 • Transition	• Flexibility measures to take on larger shares of variable renewable energy • Support for deployment of distributed energy • Innovative measures: cost reflective tariff structures, targeted subsidies, reverse auctions, net metering	• Greater efficiency in end-use energy demand • Health benefits • Energy access and security • Employment	• Power sector: 8.1 $GtCO_2$ • Building sector: 2.1 $GtCO_2$ • District heat and others: 1.9 $GtCO_2$
Coal phase-out	• Plan and implement phase-out of coal • Coal to renewable energy transition • Expand carbon capture usage and storage systems • Improve system-wide efficiency	• Regional support programmes • Tax breaks, subsidies • Carbon pricing • Moratorium policies • De-risking of clean energy investments • Relocation of coal workers (mines and power plants)	• Lower health hazards (air, water, land pollution) • Future skills and job creation	Share of the power emissions reduction from a coal phase-out: 4 $GtCO_2$ (range: 3.6– 4.4 $GtCO_2$), with 1 $GtCO_2$ from the OECD and 3 $GtCO_2$ from the rest of the world
Decarbonize transport	• Reduce energy for transport • Electrify transport • Fuels substitution (bioenergy, hydrogen) • Modal shift	• Pathways for non-motorized transport • Standards for vehicle emissions • Establishing of charging stations • Eliminating of fossil-fuel subsidies • Investments in public transport	• Increased public health from more physical activity, less air pollution • Energy security • Reduced fuel spending • Less congestion	Electrification of transport: 6.1 $GtCO_2$
Decarbonize industry	• Demand reduction (circular economy, modal shifts and logistics) • Electrify heat processes • Improve energy efficiency • Direct use of biomass/ biofuels	• Carbon pricing • Standards and regulations, especially on materials demand reduction	• Energy security • Savings and competitiveness	• Industry: 4.8 $GtCO_2$
Avoid future emissions and energy access	• Link energy access with emission reductions for 3.5 billion energy-poor people	• Fit and auctions • Standards and regulations • Targeted subsidies • Support for entrepreneurs	• Better access • Meet basic needs and SDGs	• N/A

Figure ES.5. Changes in global levelized cost of energy for key renewable energy technologies, 2010-2018



9. Demand-side material efficiency offers substantial GHG mitigation opportunities that are complementary to those obtained through an energy system transformation.

- While demand-side material efficiency widens the spectrum of emission mitigation strategies, it has largely been overlooked in climate policymaking until now and will be important for the cross-sectoral transitions.

- In 2015, the production of materials caused GHG emissions of approximately 11.5 $GtCO_2e$, up from 5 $GtCO_2e$ in 1995. The largest contribution stems from bulk materials production, such as iron and steel, cement, lime and plaster, other minerals mostly used as construction products, as well as plastics and rubber. Two thirds of the materials are used to make capital goods, with buildings and vehicles among the most important. While the production of materials consumed in industrialized countries remained within the range of 2–3 $GtCO_2e$, in the 1995–2015 period, those of developing and emerging economies have largely been behind the growth. In this context, it is important to keep in mind the discussion about the point of production and points of consumption (see figure ES.6).

- Material efficiency and substitution strategies affect not only energy demand and emissions during material production, but also potentially the operational energy use of the material products. Analysis of such strategies therefore requires a systems or life cycle perspective. Several investigations of material efficiency have focused on strategies that have little impact on operations, meaning that trade-offs and synergies have been ignored. Many energy efficiency strategies have implications for the materials used, such as increased insulation demand for buildings or a shift to more energy-intensive materials in the lightweighting of vehicles. While these additional, material-related emissions are well understood from technology studies, they are often not fully captured in the integrated assessment models that produce scenario results, such as those discussed in this report.

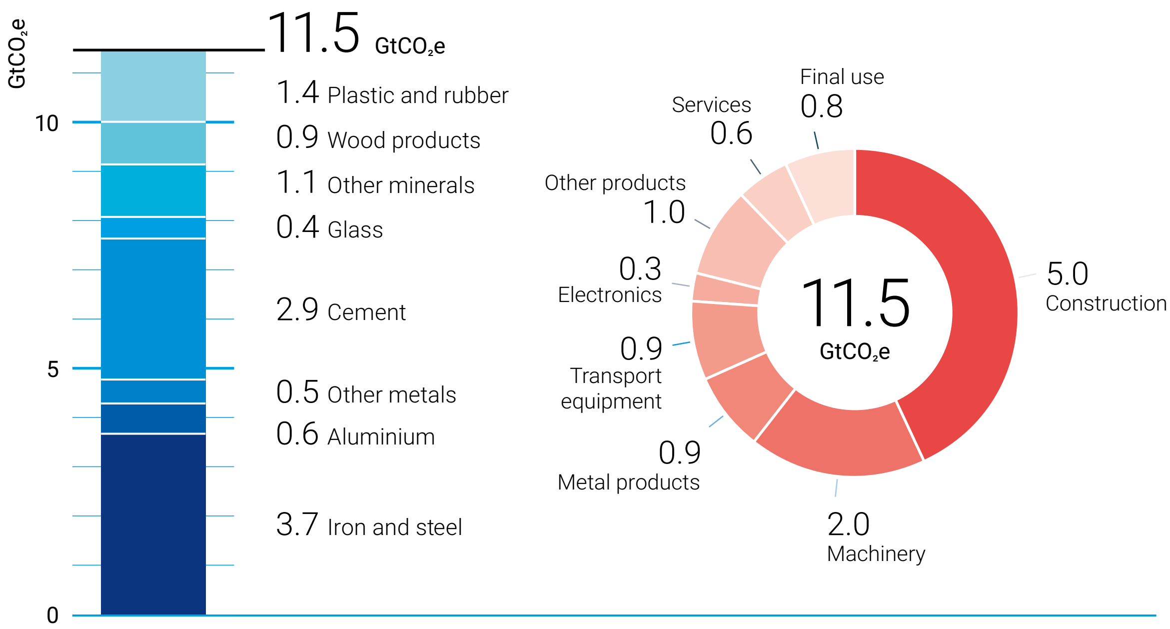
- In chapter 7, the mitigation potential from demand-side material efficiency improvements is discussed in the context of the following categories of action:

  - Product lightweighting and substitution of high-carbon materials with low-carbon materials to reduce material-related GHG emissions associated with product production, as well as operational energy consumption of vehicles.

  - Improvements in the yield of material production and product manufacture.

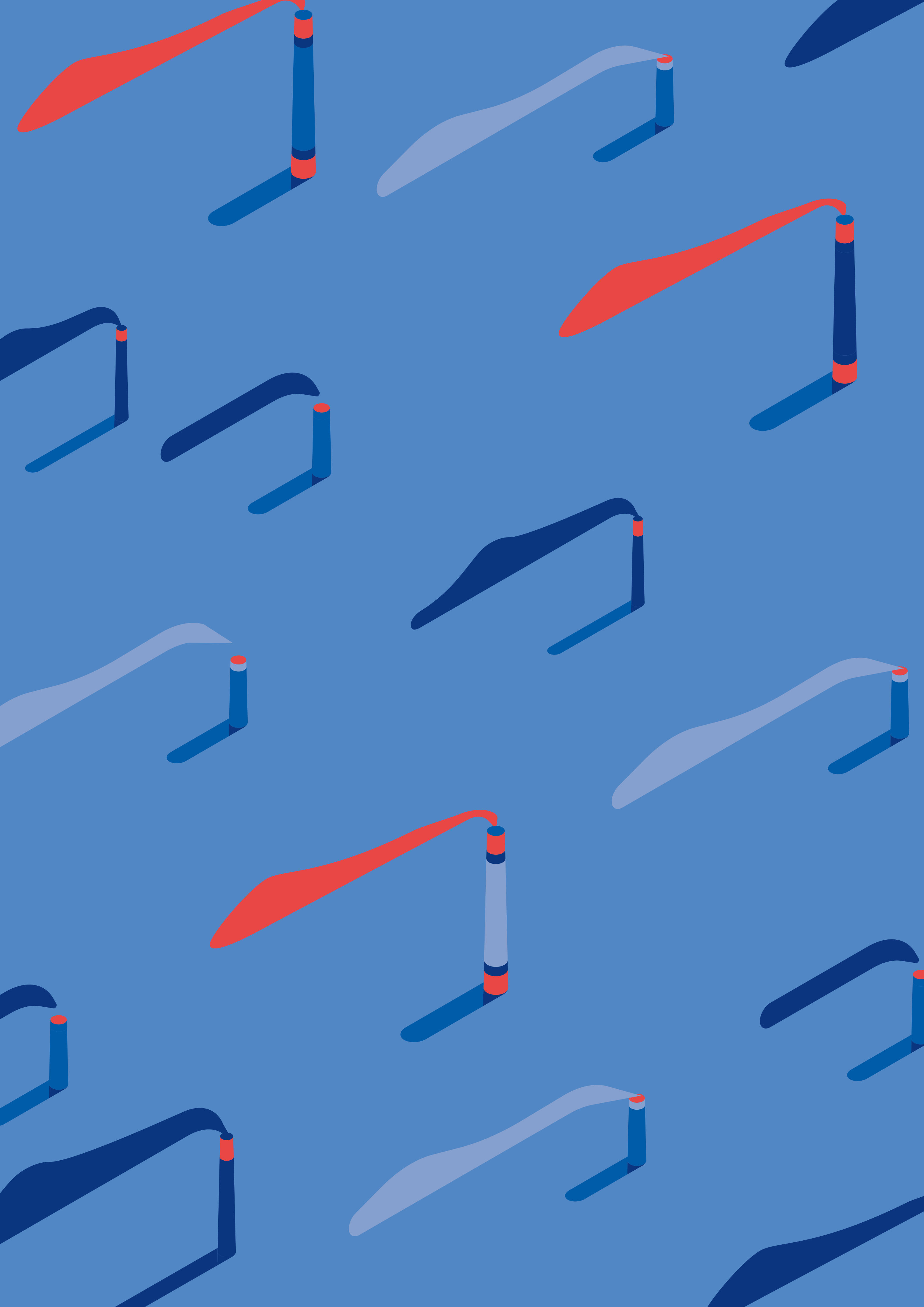
  - More intensive use, longer life, component reuse, remanufacturing and repair as strategies to obtain more service from material-based products.

Figure ES.6. GHG emissions in $GtCO_2e$ associated with materials production by material (left) and by the first use of materials in subsequent production processes or final consumption (right)



- Enhanced recycling so that secondary materials reduce the need to produce more emission-intensive primary materials.

► These categories are elaborated for housing and cars, showing that increased material efficiency can reduce annual emissions from the construction and operations of buildings and the manufacturing and use of passenger vehicles, thus contributing a couple of gigatons of carbon dioxide equivalent in emission reductions to the global mitigation effort by 2030.



1 Introduction

Authors:
Anne Olhoff (UNEP DTU Partnership) and John Christensen (UNEP DTU Partnership)

This tenth edition of the United Nations Environment Programme (UNEP) Emissions Gap Report provides an independent scientific assessment of how countries' climate pledges and actions are affecting the global greenhouse gas emissions (GHG) trend, comparing it with the emission reductions necessary to limit global warming to well below 2°C and 1.5°C in accordance with the Paris Agreement. This difference between where we are likely to be by 2030 and where we need to be has become known as the 'emissions gap'.

To mark the 10-year anniversary, a publication summarizing the lessons from a decade of emissions gap assessments (Christensen and Olhoff 2019) was published to support the United Nations Secretary-General's Climate Action Summit in September 2019. This publication shows that despite a decade of increased focus on climate change, global GHG emissions have not been curbed and the emissions gap is now larger than ever. It is clear that the world cannot afford another decade lost. Unless mitigation action and ambition are increased immediately and profoundly through enhanced nationally determined contributions (NDCs) and supported by ambitious long-term mitigation strategies, it will not be possible to avoid exceeding the 1.5°C goal, and it will become increasingly challenging to achieve the well below 2°C goal.

At the Climate Action Summit, countries and regions announced their intention to improve national and subnational action. For example, 70 countries agreed to submit enhanced NDCs by 2020, with the number of commitments to zero GHG and carbon emission targets at some point during the second half of this century increasing from around 20 countries and eight regions before the Summit to 71 countries and 11 regions after the Summit. However, these countries and regions account for just 15 per cent of global emissions, indicating that the scale and pace of climate commitments and action is still far from what is required to keep the Paris Agreement goals within reach.

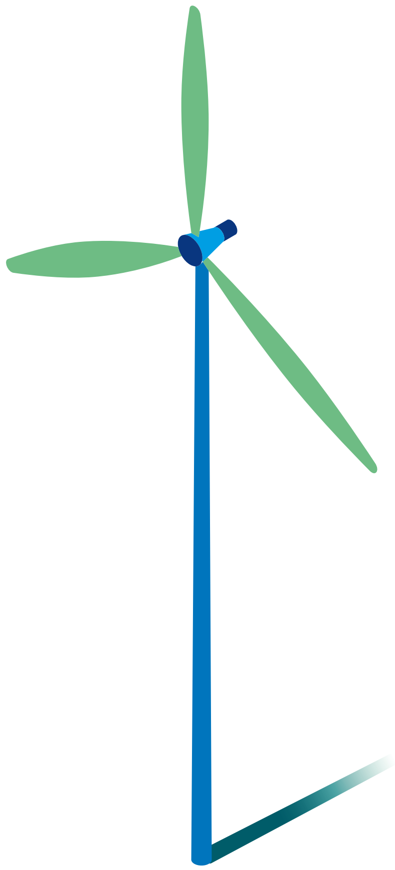
The challenge for the twenty-fifth session of the Conference of the Parties (COP 25) to the United Nations Framework Convention on Climate Change (UNFCCC) and the year to follow is thus to bring about the necessary move from incremental to transformational climate ambition and action. The year 2020, which is when countries are requested to submit new or updated NDCs and invited to communicate long-term mitigation strategies as part of the UNFCCC process, will be defining in this regard.

As in previous years, this Emissions Gap Report has been prepared by an international team comprising 57 leading scientists from 33 expert institutions across 25 countries, assessing all available information, including that published in the context of the Intergovernmental Panel on Climate Change (IPCC) special reports. The assessment process has been overseen by a distinguished steering committee and has been transparent and participatory. The assessment methodology and preliminary findings were made available to the governments of the countries specifically mentioned in the report to provide them with the opportunity to comment on the findings.

The report is organized into seven chapters, including this introduction, and is structured on the questions that guided the 2018 Talanoa Dialogue: Where are we? Where do we want to go? How do we get there? In this way, chapter 2 focuses on where we are, providing an updated assessment of the status and trends of current and projected global GHG emissions, and the progress of G20 members towards their Cancun Pledges for 2020 and their NDC targets for 2030.

Addressing the issue of where we want to go and comparing it with where we are likely to be, chapter 3 assesses what the gap between estimated global emissions will be by 2030 if NDCs are fully implemented, as well as the range consistent with the well below 2°C and 1.5°C temperature goals. The chapter also considers what the temperature implications will be at the end of the century if current policies are continued, and whether global emissions by 2030 will be permissible if the current level of ambition of NDCs is not increased.

Finally, the second part of the report examines how the gap can be bridged. Chapter 4 provides a comprehensive overview of recent ambitious climate actions by national and subnational governments as well as non-state actors, and



a detailed overview of policy progress and opportunities for enhanced mitigation ambition for selected G20 members. With the aim of informing the Climate Action Summit and the preparation of new and updated NDCs, a special pre-release version of chapter 4 was published in time for the Summit. The chapter illustrates that collectively, the G20 members have not yet taken on transformative commitments at the breadth and scale necessary, highlighting that despite many positive developments, commitments are still far from what is required. Chapter 5 details the key transformations that are needed to align global trends with the Paris Agreement goals and how such transformational pathways in many cases can be synergistic with achieving other development priorities, including the Sustainable Development Goals (SDGs). Global transformation of energy systems is crucial for bridging the emissions gap. Chapter 6 reviews five transition options that are relevant for many countries, can be designed to achieve development and mitigation goals simultaneously and are associated with significant emission reduction potentials. Finally, chapter 7 assesses how material efficiency strategies for residential buildings and cars can contribute to bridging the gap.

2 Global emissions trends and G20 status and outlook

Lead authors:

Takeshi Kuramochi (NewClimate Institute, Germany), Michel den Elzen (PBL Netherlands Environmental Assessment Agency), Glen Peters (CICERO, Norway)

Contributing authors:

Andrzej Ancyger (Climate Analytics, Germany), Ankit Bhardwaj (Centre for Policy Research, India), Gabriel Blanco (National University of the Center of the Buenos Aires Province, Argentina), Taryn Fransen (World Resources Institute, USA), Andreas Geiges (Climate Analytics, Germany), Frederic Hans (NewClimate Institute, Germany), Christopher Henderson (World Resources Institute, USA), Niklas Höhne (NewClimate Institute, Germany), Kejun Jiang (Energy Research Institute, China), Maria Jose de Villafranca (NewClimate Institute, Germany), Kimon Keramidas (Joint Research Centre/European Commissions), HYPERLINK "mailto:joojin.kim@forourclimate" Joojin Kim (Solutions For Our Climate, Republic of Korea), Akihisa Kuriyama (Institute for Global Environmental Strategies, Japan), Leonardo Nascimento (NewClimate Institute, Germany), Jos Olivier (PBL Netherlands Environmental Assessment Agency), Deger Saygin (SHURA, Turkey), Ranping Song (World Resources Institute, China), Claire Stockwell (Climate Analytics, Germany), Kentaro Tamura (Institute for Global Environmental Strategies, Japan), Paola Tanguy (NewClimate Institute, Germany), Heleen van Soest (PBL Netherlands Environmental Assessment Agency), Jorge Villarreal Padilla (Iniciativa Climática de México), Ryan Wilson (Climate Analytics), William Wills (Centro Clima, Brazil), Paola Yanguas Parra (Climate Analytics, Germany)

2.1 Introduction

This chapter assesses the latest trends in greenhouse gas (GHG) emissions as well as progress of G20 economies towards both the Cancun pledges for 2020 and Nationally Determined Contributions (NDCs) for 2025 and 2030. The chapter is organized as follows: section 2.2 takes stock of the current global GHG emissions status and trends. Section 2.3 provides an assessment of whether G20 members are on track to meet their Cancun pledges and NDC targets, while section 2.4 summarizes recent policy developments of individual G20 economies. This section also serves as a basis for chapter 4, which explores opportunities for additional GHG emissions reductions that could be considered in the NDC update process by 2020 and beyond. Section 2.5 provides an overview of submitted long-term low emissions development strategies to date.

In the 2019 report, all GHG emission figures are expressed using the 100-year global warming potentials (GWPs) from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report[1], unless otherwise noted, whereas United Nations Environment Programme (UNEP) Emissions Gap Report 2018 used Global Warming Potential (GWP) values of IPCC Second Assessment Report.

2.2 Current global emissions: status and trends

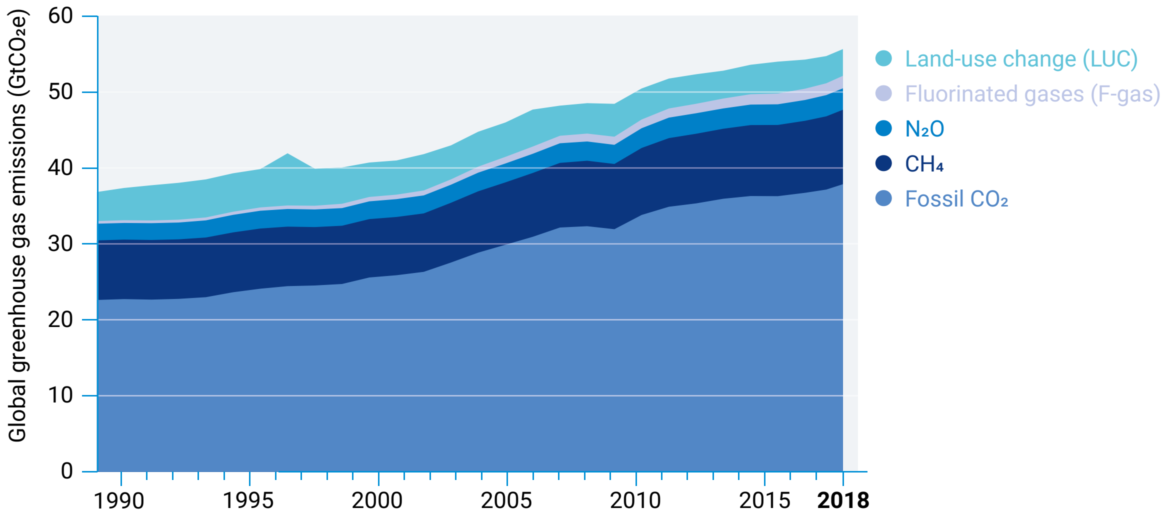
Total GHG emissions grew 1.5 per cent per year in the last decade (2009 to 2018) without land-use change (LUC) and 1.3 per cent per year with LUC, to reach a record high of 51.8 $GtCO_2e$ in 2018 without LUC emissions and 55.3 $GtCO_2e$[2] in 2018 with LUC. GHG emissions growth was 2.0 per cent in 2018 and there is no sign of a peak in any of the GHG emissions[3] (figure 2.1). GHG emissions have grown every year since the global financial crisis in 2009, with only slightly lower growth in 2015 due to big declines in coal use in both the United States of America and China. Fossil CO_2 emissions, from both energy use and industry, dominate total GHG emissions and reached a record 37.5 $GtCO_2$ per year in 2018, after growing 1.5

1 This change was made to be more in line with the decisions made at the COP in Katowice. Parties agreed on the Fifth Assessment Report (AR5) for reporting reasons at COP 24 in Katowice. A full switch to AR5 GWP was not yet possible because the literature is still not up to date on this decision.

2 GHG emissions are 1.8 $GtCO_2e$ higher than the emissions estimate in 2017 presented in recent UNEP Emissions Gap Reports. This is mainly due to the impact of GWPs (1.5 $GtCO_2e$) and the change in LUC emissions (-0.7 $GtCO_2e$), whereas the yearly change in 2018 contributes 1.0 $GtCO_2e$.

3 GHG emissions are based on EDGARv5 (Olivier and Peters 2019) and LUC emissions are from Houghton and Nassikas (2017). In this report, GWPs from the IPCC Fourth Assessment Report are used (25 for CH_4 and 298 for N_2O). This yields total GHG emissions that are 1 $GtCO_2e$ higher in 1970 and 1.5 $GtCO_2e$ higher in 2018.

Figure 2.1. Global greenhouse gas emissions from all sources



Source: Olivier and Peters (2019), Houghton and Nassikas (2017) for land-use change emissions, and Friedlingstein *et al.* (2019) for updates from 2016 to 2018

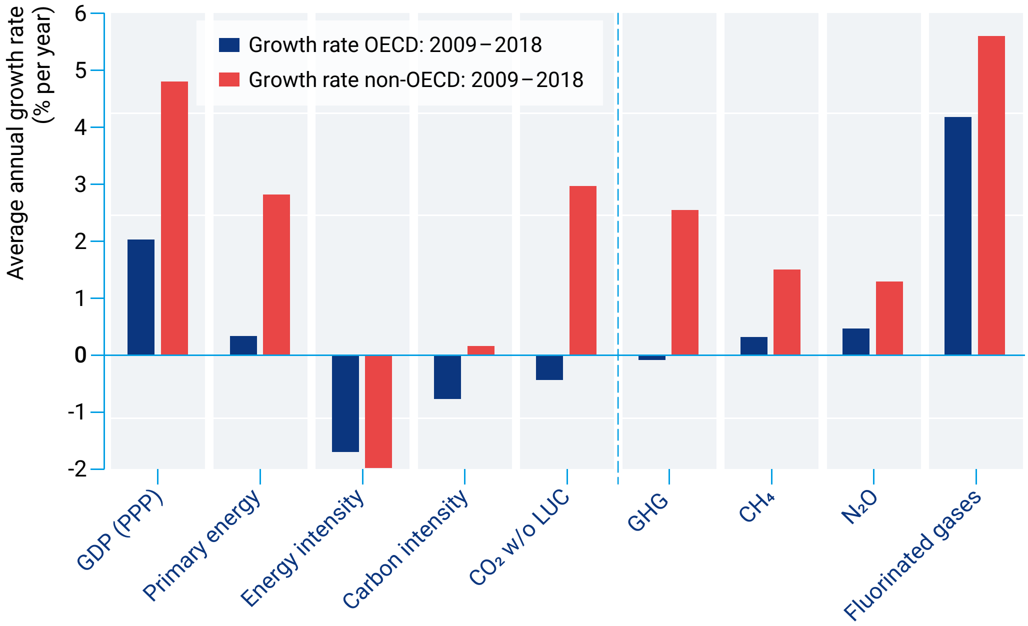
per cent per year in the last decade and 2.0 per cent in 2018[4]. The growth in fossil CO_2 emissions was due to robust growth in energy use (2.9 per cent in 2018). CO_2 emissions from LUC are about 7 per cent of total GHGs and have large uncertainty and inter-annual variability, remaining relatively flat over the last decade (IPCC 2019). Methane (CH_4) emissions, the next most important GHG, grew at 1.3 per cent per year in the last decade and 1.7 per cent in 2018. Nitrous oxide (N_2O) emissions are growing steadily, at 1.0 per cent per year in the last decade and 0.8 per cent in 2018. Fluorinated gases (SF6, HFCs, PFCs) are growing the fastest, at 4.6 per cent per year in the last decade and 6.1 per cent in 2018.

GHG emissions are growing globally, despite progress in climate policy, as the countries where emissions are declining are not able to offset the growth in emissions in other countries. A recent study found that there are 18 developed economies where CO_2 emissions are declining (Le Quéré *et al.* 2019), the United States of America and some European countries. We extend several aspects of that analysis to compare Organisation for Economic Co-operation and Development (OECD) and non-OECD economies. Figure 2.2 shows a decomposition of the growth in economic activity (Gross Domestic Product, GDP), primary energy use, the energy use per unit of GDP, the CO_2 emissions per unit of energy, and GHG emissions from all sources, for OECD (blue) and non-OECD (orange) economies. Economic activity has been much stronger in non-OECD economies, growing at over 4.5 per cent per year in the last decade compared to just 2 per cent per year in OECD economies. Since the OECD (1.7 per cent per year) and non-OECD (2 per cent per year) economies have had similar declines in the amount of energy used per unit of economic activity, economic growth means that that energy use has grown much faster in non-OECD economies (2.8 per cent per year) than OECD economies (0.3 per cent per year). OECD economies already use less energy per unit economic activity, suggesting that non-OECD economies have the potential to accelerate improvements.

Declining or flat energy use makes it easier for non-fossil energy sources, like wind and solar, to displace fossil fuels in the energy system. The flat energy use in OECD economies is one key reason that emissions have decreased in those regions (Le Quéré *et al.* 2019), with the declines accelerated due to a declining amount of CO_2 emitted per unit of energy use (-0.8 per cent per year). In non-OECD economies, slightly more CO_2 is emitted per unit of energy in the last decade (0.2 per cent per year growth), meaning that CO_2 emissions have grown slightly faster than energy use. In non-OECD economies, the rapid deployment of solar and wind power has not been strong enough to displace fossil fuels, particularly in countries with growing energy use and

4 In this report, CO_2 emissions from fossil-fuels and industry grew 2.0 per cent in 2018, using EDGARv5 (Olivier and Peters 2019). The Global Carbon Budget estimates 2018 fossil-fuel and industry emissions to grow 2.1 per cent (Friedlingstein *et al.* 2019), while for combustion-related emissions only, the Institute of Economic Affairs estimated growth of 1.7 per cent (IEA 2019) and BP estimated growth of 2.0 per cent (BP 2019).

Figure 2.2. Average annual growth rates of key drivers of global CO_2 emissions (left of dotted line) and components of greenhouse gas emissions (right of dotted line) for OECD and non-OECD economies



Source: Olivier and Peters (2019) and Global Carbon Project (Friedlingstein *et al.* 2019) for energy and economic data

globally. In total, OECD economies have seen CO_2 emissions decline by -0.4 per cent per year in the last decade, while non-OECD economies have seen emissions growing at nearly 3 per cent per year. In the near term, it is expected that energy use will continue to grow in non-OECD economies, but more rapid improvements in energy intensity, together with deployment of low-carbon energy sources, could lead to an earlier peak and then decline in CO_2 emissions.

GHG emissions are dominated by CO_2, but the non-CO_2 emissions represent over 34 per cent of total GHG emissions including LUC. OECD economies have only seen very limited growth in CH_4 and N_2O, but rapid growth in fluorinated gases, leading to an overall slight decline in GHG emissions. Non-OECD economies have seen strong growth in all non-CO_2 GHGs, leading to an overall increase in GHG emissions of 2.5 per cent per year in the last decade. While CO_2 dominates GHG emissions, reductions in other components can help achieve an earlier peak in GHG emissions.

While global emissions statistics provide important information on collective progress, they mask the dynamics at the country level (figure 2.3). The top four emitters (China, EU28, India and the United States of America) contribute to over 55 per cent of the total GHG emissions over the last decade excluding LUC, the top seven (including Japan, Russia and international transport) account for 65 per cent, while G20 members contribute 78 per cent. China emits more than one-quarter (26 per cent) of global emissions (excluding LUC), and despite contributing significantly to the slowdown in global emissions from 2014 to 2016, emissions in the country are now rising again, growing 2.5 per cent in the last decade and 1.6 per cent in 2018 to reach a record high 13.7 $GtCO_2e$ in 2018. The United States of America emits 13 per cent of global GHG emissions, with a gradual decline in GHG emissions of 0.1 per cent per year in the last decade, but an increase of 2.5 per cent in 2018 due to increased energy demand from an unusually warm summer and cold winter. The European Union emits 8.5 per cent of global GHG emissions and has had a steady decline of 1 per cent per year in the last decade and a decline of 1.3 per cent in 2018. India, accounting for 7 per cent of global emissions, continues to have rapid growth in emissions of 3.7 per cent per year in the last decade and 5.5 per cent in 2018. The Russian Federation (4.8 per cent) and Japan (2.7 per cent) are the next largest emitters, with international transport (aviation and shipping) representing around 2.5 per cent of GHG emissions. If LUC emissions were included, the rankings would change, with Brazil likely to be the largest emitter.

The ranking of countries changes dramatically when considering per capita emissions (figure 2.3, right), but less so when allocating emissions to consumption (figure 2.4). Consumption-based emissions, also known as a carbon footprint, adjusts the standard territorial emissions. As figure 2.4 shows, developed countries import more emissions than they export, with the opposite holding true in developing countries. In the 2000s, there was a growing gap between consumption-based emissions in developed countries and their territorial emissions. This gap was larger than the reductions made under the Kyoto Protocol (Peters *et al.* 2011). Since the global financial crisis in 2008, the

Figure 2.3. The top emitters of greenhouse gases, excluding land-use change emissions due to lack of reliable country-level data, on an absolute basis (left) and per capita basis (right)

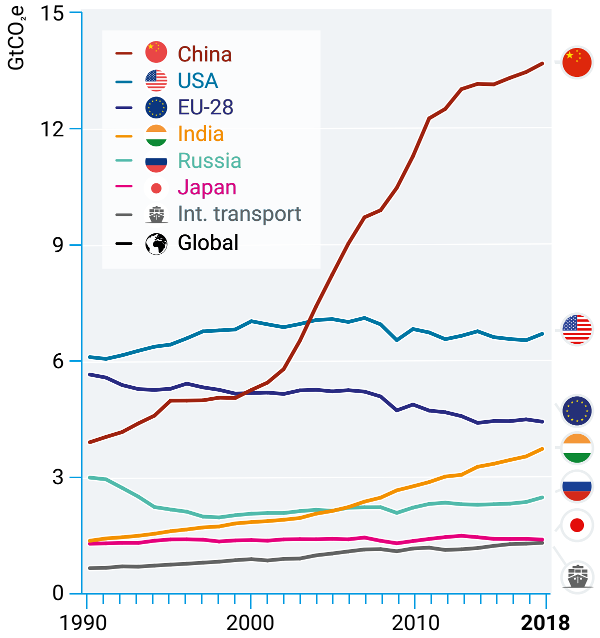
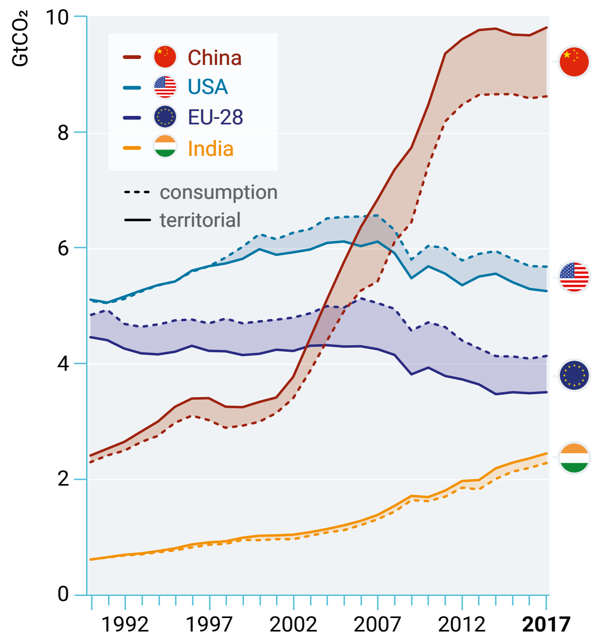


Figure 2.4. CO_2 emissions allocated to the point of emissions (territorial) and the point of consumption, for absolute emissions (left) and per capita (right)



Source: Olivier and Peters (2019), Houghton and Nassikas (2017) for land-use change emissions, and Friedlingstein *et al.* (2019) for updates from 2016 to 2018 gap has stabilized, and even declined. China contributed to most of the growth in the 2000s, but also the stabilization in the 2010s (Pan *et al.* 2017). Consumption-based emission estimates allow policymakers to focus on different policy levers and may help deal with carbon leakage under stringent climate policies.

2.3 Assessment of G20 Member progress towards Cancun pledges and NDC targets

GHG emissions projections were compiled and reviewed to assess the emission levels expected for G20 members under existing policies ("Current policies scenario") and whether they would meet their respective emissions reduction targets for 2020 and 2030. We followed the methodology of den Elzen *et al.* (2019) to enable a fair comparison of projections from different data sources, including both official data sources published by the G20 governments as well as sources published by independent research institutions.

Up-to-date emissions projections published since November 2018 were collected from countries' recently published National Communications, the third biennial reports of seven G20 members, several other new national studies and the independent global studies Climate Action Tracker (Climate Action Tracker 2019d), the Joint Research Centre (JRC) of the European Commission (Keramidas *et al.* 2018) and PBL Netherlands Environmental Assessment Agency (Kuramochi *et al.* 2018) for the current policies scenario and NDC scenario projections (see appendix A, available online, for scenario definitions). Several studies on current policies scenario projections from the UNEP Emissions Gap Report 2018 data set were excluded, as these were concluded not to be representative of the policies implemented to date (mostly those published before 2017, depending on the G20 Member). All data sources are presented in appendix A. Current policies scenario projections from studies without NDC quantification were compared to official NDC emission values in absolute terms or – when official NDC emission values are not available – to the median estimates of NDC emission levels across independent studies.

This section should be read with some important caveats in mind (den Elzen *et al.* 2019). First, whether a country is projected to achieve or miss its emissions reduction targets with existing policies depends on both the ambition level of the targets, which this study does not assess, and the strength or stringency of existing policy packages. Therefore, countries projected to achieve their NDCs with existing policies are not necessarily undertaking more mitigation action than countries that are projected to miss them. Chapter 3 of this report and the literature (Rogelj *et al.* 2010; 2016) are clear that the NDCs are collectively far from sufficient to keep warming to 2°C, let alone 1.5°C, and thus all countries have to raise the ambition of their current NDCs significantly. According to the Paris Agreement, countries are obligated to regularly update and strengthen their NDCs. The assessment conducted in this section is based on current NDCs, recognizing that they are to be revised and should be strengthened considerably by 2020 to meet the climate goal of the Paris Agreement. Second, current policies scenario projections are subject to the uncertainty associated with macroeconomic trends, such as GDP and population growth and technology developments, as well as with the impact of policies. Some Cancun pledges and NDCs are also subject to uncertainty of future GDP growth and other underlying assumptions.

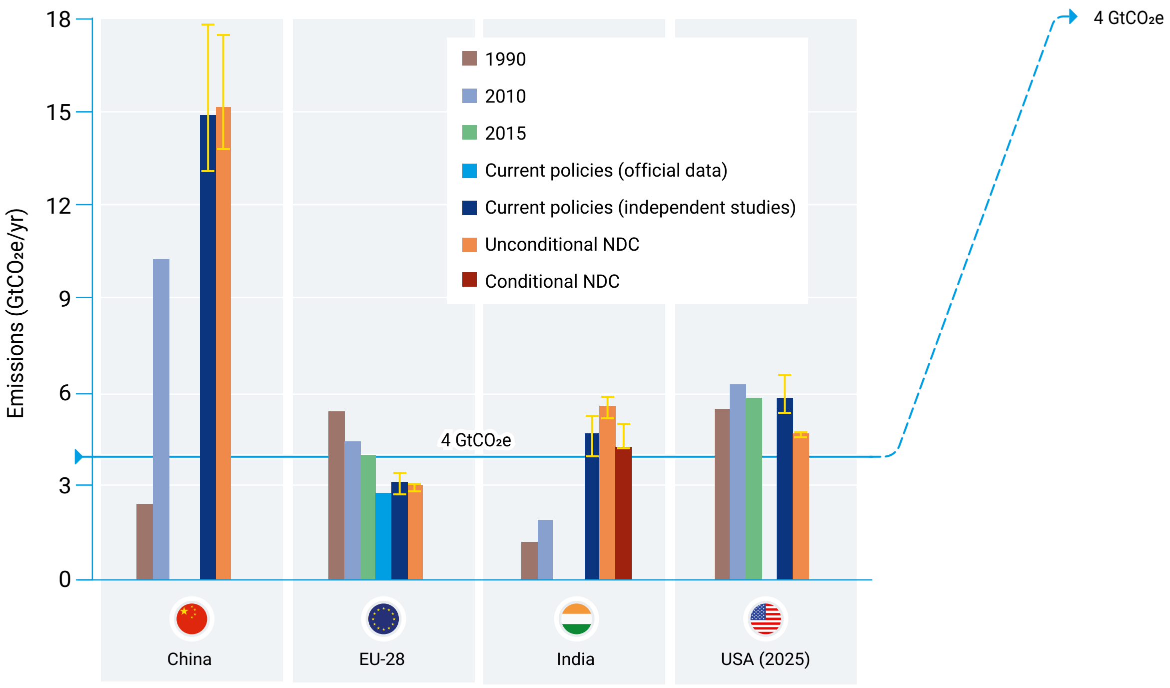
It is also worth noting that the current policies scenario projections do not reflect the likely impact of all policies implemented to date for a number of reasons. First, there is always a time lag between the date a new policy measure was implemented and the date a scenario study that considered this new policy was published. Second, it often takes time for research institutions to assess whether a new policy measure would be effectively implemented to achieve its intended objective, resulting in an even larger time lag. Third, GHG emissions projection models have limitations on the types of policies they can incorporate, which may result in an under- or overestimation of projected emissions.

On the progress of G20 economies towards their 2020 pledges, they are collectively (those who have Cancun pledges) projected to overachieve their Cancun pledges by about 1 $GtCO_2e$ per year based on the assessments from the Climate Action Tracker (Climate Action Tracker 2019d) and PBL (Kuramochi *et al.* 2018), the two studies that annually update both the 2020 pledge emission levels and current policies scenario projections. However, several individual G20 members (Canada, Indonesia, Mexico, Republic of Korea, South Africa, the United States of America) are currently projected to miss their Cancun pledges or will not achieve them with great certainty. In Australia, the Government projects that they would overachieve their 2020 pledge based on their carbon budget approach that accounts for cumulative emissions between 2013 and 2020 (Australia, Department of the Environment and Energy 2018). Argentina, Saudi Arabia and Turkey have not made 2020 pledges.

On the progress of G20 economies towards their NDC targets, six members: China, the EU28, India, Mexico, Russia and Turkey, are projected to meet their unconditional NDC targets with current policies (table 2.1). Among them, the current policies scenario emissions projections for three countries (India, Russia and Turkey) are projected to be 15+ per cent lower than the NDC target emission levels. These results suggest that the three countries have room for raising their NDC ambitions significantly. The EU28 has introduced climate legislation that achieves at least 40 per cent GHG reductions and is projected by the European Commission (European Commission 2018b) to overachieve these, if domestic legislation is fully implemented (figure 2.5).

Figure 2.5. Greenhouse gas emissions (all gases and sectors) of the G20 and its individual members by 2030 under different scenarios and compared with historical emissions

Figure 2.5a.



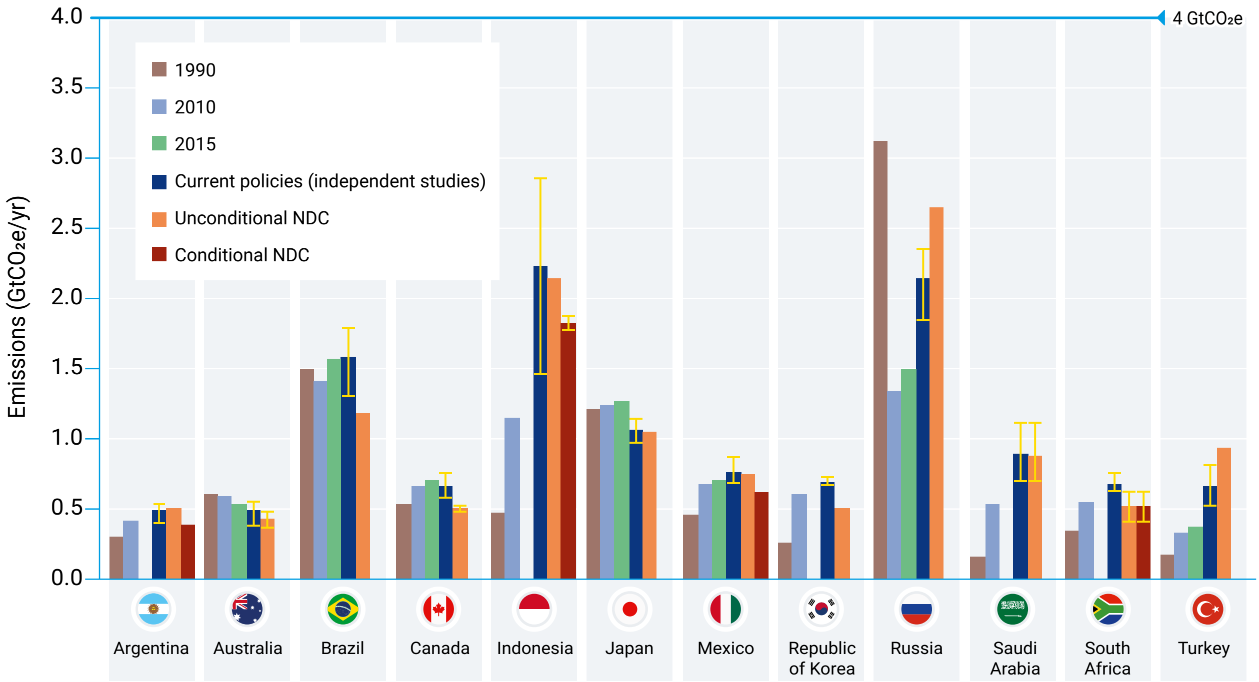
The change in assessment results for the EU28 from our 2018 report is partially due to the differences in whether and how the new policy packages adopted in recent months were considered in GHG emissions projections (see also the EU28 section and an earlier paragraph in this section). All three independent studies (Climate Action Tracker, JRC and PBL) do not take the recently adopted policy packages into account. Also, along with official publications, the European Environment Agency (EEA 2018) projects emissions based on Member state-level policies[5] and the third Biennial Report of 2017 ("With Current Measures" scenario), which projects that the EU28 would remain short of achieving its NDC target, and does not cover policies implemented in last two years. By contrast, the reference scenario in the 2018 analysis produced by the European Commission supporting the long-term vision document, which reflects recent European Union (EU)-level policies and assumes their full implementation, projects that the EU28 could reduce its GHG emissions by 48 per cent from 1990 levels including LULUCF. For this reason, the EU28 has been classified as projected to overachieve its NDC target in table 2.1, even though the independent studies do not project the EU28 to achieve its NDC target (figures 2.5 and 2.6), as they are not fully updated.

Seven G20 members require further action of varying degree to achieve their NDC targets: Australia, Brazil (new, changed compared to UNEP (2018)), Canada, Japan (new), Republic of Korea, South Africa and the United States of America. For Brazil, the projections from three annually updated publications were all revised upward, reflecting, among others, the recent turn of trends on deforestation. Japan's current policies projections have been on the borderline of achieving the NDC target for the last few years.

Studies do not agree on whether Argentina, Indonesia and Saudi Arabia (new) are on track to meet their unconditional NDCs. For Argentina, a recent domestic analysis that reflects the most recent GHG inventory data up to 2016 (Keesler, Orifici and Blanco 2019) projects that the unconditional NDC target – which was revised in 2016 with a more ambitious one – will be achieved including scenarios that are less optimistic (see annex B for details), while two other international studies project that the country will fall short of achieving its unconditional NDC with existing policies. For Indonesia, the lack of agreement is mainly due to the uncertainty on land-use, LUC and forestry (LULUCF) emissions. For Saudi Arabia, the limited amount

5 Member States who are at different stages when it comes to implementing domestic measures to meet EU legislation. It is logical that progression is achieved in these projections over time as Member States take additional actions.

Figure 2.5b.



Notes: For reporting reasons, the emission projections for China, the EU28, India and the United States of America are shown in figure 2.5a and the other countries shown in figure 2.5b, using two different vertical axes.
The current policies and NDC scenario estimates are based on average GHG emission projections. The findings regarding whether countries are projected to over- or underachieve their NDC targets under current policies may therefore differ from the assessment in table 2.1, which is based solely on the number of independent studies.

As a conservative assumption, South Africa is not considered as having a firm commitment to peak, since there is no guarantee that the conditions upon which they made the pledge will be met.
* For the United States of America, the unconditional NDC is for 2025. For Brazil, we refer to the indicative target for 2030.
** South Africa's NDC is based on an emissions trajectory with an emissions range of 398–614 $MtCO_2e$ including LULUCF over the 2025–2030 period.

of information on the country's climate policies did not allow for further assessments beyond the two studies reviewed.

Some G20 members are continuously strengthening their mitigation policy packages, leading to a downward revision of current policies scenario projections over time. One example is the EU, where a noticeable downward shift in current policies scenario projections for 2030 has taken place since the 2015 edition of the UNEP Emissions Gap Report (see section on the EU28 below for recent policy developments).

Figure 2.5 provides a detailed comparison of estimated emissions under current policies scenarios as estimated by official and independent sources and the NDC scenario for all G20 members except for the EU Member States, mapping these against 1990, 2010 and 2015 emissions. For each of the G20 members, average (median when more than five studies) GHG emission projections have been calculated for current policies and full implementation of the NDC, following the approach of den Elzen *et al.* (2019), the results of which were presented in the UNEP Emissions Gap Report 2018 (UNEP 2018) including climate change. Countries will meet again at the United Nations Framework Convention on Climate Change (UNFCCC).

As mentioned, average GHG emission projections are presented for the current policies scenarios in figure 2.5 and 2.6, whereas the assessment in table 2.1 is based solely on the number of independent studies that support a given country finding. As a result, some countries may be classified as projected to meet their NDC target according to the number of studies available (table 2.1), while they may be projected to miss their NDC

Table 2.1. Assessment of progress towards achieving the unconditional NDC targets for the G20 under current policies based on independent studies

Projected to meet the unconditional NDC target with currently implemented policies		**Expected to meet the unconditional NDC target with additional policy measures and/or stricter enforcement of existing policies**		**Uncertain or insufficient information**
Overachievement of the target by more than 15 per cent, suggesting a weak target	**Overachievement of the target by less than 15 per cent**	**Projected emissions 0–15 per cent above the NDC target**	**Projected emissions 15 per cent or more above the NDC target**	
• **India** (6 of 6 studies) • **Russia** (3 of 3 studies) [1] • **Turkey** (3 of 3 studies)	• **China** (3 of 5 studies, one uncertain) [2] • **EU28** (1 of 3 studies, one uncertain) [1,2,3] • **Mexico** (2 of 3 studies)	• **Australia** (3 of 4 studies) [1] • **Japan** (2 of 3 studies) • **South Africa** (3 of 3 studies) [1,4]	• **Brazil** (4 of 4 studies) • **Canada** (3 of 3 studies) [1] • **Republic of Korea** (3 of 3 studies) • **United States of America** (2025) (5 of 5 studies) [1]	• **Argentina** (1 of 3 studies projected to meet the unconditional NDC; updated NDC in 2016) • **Indonesia** (3 studies disagree) • **Saudi Arabia** (2 studies disagree)

Notes: The assessment is based on the number of independent studies that support the findings (except for the EU28, see the note below and the section analysis). These are compared to the available studies, as indicated in brackets.

1. We also examined current policies scenario projections from official publications. The number of publications that support the above findings based on independent studies are Australia: 1 of 1; Canada: 2 of 2; Russia: 1 of 1; South Africa: 1 of 1; the United States of America: 1 of 1. For the EU28, three official publications disagree (see footnote 3).
2. The Climate Action Tracker indicates that upper-end projections would miss the NDC target range.
3. The EU assessment result is based on projections fully implementing adopted EU climate and energy legislation (European Commission 2018b). For the EU28, among the three independent studies and three official studies, the evaluation was made based on a study by PBL that took into account the best recently adopted policy packages (Kuramochi *et al.* 2018) and projections from the most recent official analysis by the European Commission (European Commission 2018b).
4. South Africa's current policies scenario projections were compared to the upper-bound estimate of the NDC range.

target based on the average emission projections under the current policies scenario (and vice versa).

To supplement the findings presented above, table 2.2 presents projected per capita GHG emissions under current policies and NDC targets based on independent studies in both absolute and relative terms (compared to 2010 levels) for all G20 members excluding the four EU Member States. We find that nine G20 members, including China, are projected to emit more than 10 tCO_2e per capita annually (approximately the levels in 2010 for EU28 and Japan) in 2030 under current policies and seven members could even achieve levels under unconditional NDC targets. Among OECD members[6], the EU28 performs well in both absolute and per capita emission levels in 2030 and in their change rates compared to 2010 levels, even though the consumption-based emissions are considerably higher, as shown in figure 2.4. Mexico also performs well in terms of the projected development of per capita emissions under both current policies and NDC scenarios. As table 2.2 shows, emissions per capita annually in 2030 under the unconditional NDC targets are projected to decline between 2010 and 2030 in all G20 economies except China, India, Indonesia, the Russian Federation, Saudi Arabia and Turkey. There are also large differences in per capita emission levels. The per capita emissions of India are about half the G20 average, whereas Saudi Arabia reaches three times the G20 average.

6 Australia, Canada, the EU, Japan, Mexico, Republic of Korea, Turkey, the United States.

Table 2.2. – Overview of G20 Member status and progress, including on Cancun pledges and NDC targets*

Country	Share in global GHG emissions in 2017 excluding LULUCF and including LULUCF (in brackets) [1]	Projected per capita GHG emissions including LULUCF in 2030 (tCO_2e/cap) and change rates from 2010 levels (in brackets) [2) 3) 4)]	
		Current policies scenario (central estimates [5)] of independent studies)	Unconditional NDC (official values whenever available, otherwise central estimates of independent studies)
Argentina	**0.8%** (0.9%)	**10.6** (+4%)	**10.2** (-1%)
Australia	**1.2%** (1.1%)	**17.5** (-34%)	**15.1** (-43%)
Brazil	**2.3%** (2.9%)	**7.1** (-1%)	**5.3** (-26%)
Canada	**1.6%** (1.8%)	**16.0** (-17%)	**12.6** (-35%)
China	**26.8%** (25%)	**10.2** (+35%)	**10.3** (+37%)
EU28	**9.0%** (7.9%)	**6.1** (-31%)	**5.9** (-33%)
India	**7.0%** (7.1%)	**3.1** (+100%)	**3.7** (+138%)
Indonesia	**1.7%** (4.9%)	**7.4** (+56%)	**7.1** (+50%)
Japan	**3.0%** (2.9%)	**8.8** (-8%)	**8.6** (-10%)
Mexico	**1.5%** (1.5%)	**5.4** (-9%)	**5.3** (-10%)
Republic of Korea	**1.6%** (1.3%)	**13.4** (+10%)	**9.7** (-20%)
Russia	**4.6%** (4.3%)	**15.0** (+61%)	**18.5** (+99%)
Saudi Arabia	**1.5%** (1.4%)	**22.7** (+16%)	**22.2** (+14%)
South Africa	**1.1%** (1.1%)	**10.2** (-3%)	**7.8** (-26%)
Turkey	**1.2%** (1.0%)	**7.3** (+63%)	**10.4** (+132%)
USA	**13.1%** (12.5%)	**16.5** (-14%)	**11.5** (-40%)

*Emission figures include LULUCF, unless otherwise noted.

Notes:
1. Olivier and Peters (2018), excluding LULUCF/including LULUCF. LULUCF emissions based on the Food and Agriculture Organization of the United Nations (FAO) data (Food and Agriculture Organization Corporate Statistical Database [FAOSTAT] 2018).
2. The population projections are based on the medium fertility variant of the United Nations Population Prospects 2019 edition (United Nations Department of Economics and Social Affairs [UN DESA] 2019).
3. For comparison, the G20 average per capita emissions in 2010 was 7.2 tCO_2e/cap based on national GHG inventory reports submitted to the United Nations Framework Convention on Climate Change (UNFCCC) (supplemented by EDGAR and FAO (Kuramochi *et al.* 2018)). Assumptions on LULUCF emissions presented in appendix A, table A - 2.
4. Median estimates are used when more than five studies are available, otherwise average estimates.
5. Historical data based on the second Biennial Report.

Box 2.1. Comparing emission values across chapters

To compare these G20 estimates with the G20 shares of the global greenhouse gas emissions estimates of the current policies scenarios and 1.5- and 2°C-consistent global emission levels, as presented in chapter 3, we need to discuss the LULUCF CO_2 emissions. Given the difference in estimating the "anthropogenic sink" between countries and the global integrated assessment modelling community (Grassi *et al.* 2017), the LULUCF CO_2 estimates included here based on inventory data are not necessarily directly comparable with countries' land-use CO_2 emissions estimates at the global level used by the global model community. Grassi *et al.* (2017) find a current ±3 $GtCO_2e$/year difference in global LULUCF net emissions between country reports (such as greenhouse gas inventories and National Communications) and scenarios studies (as reflected in IPCC reports). Among the many possible reasons for these differences, Grassi *et al.* (2017) suggest that a key factor – which deserves further analysis – relates to what is considered "anthropogenic forest sink". At least two-thirds of the difference of 3 $GtCO_2e$, about 2 $GtCO_2e$, could be attributed to the G20 members.

The G20 total emissions projections for 2030 alone would be about 43 $GtCO_2e$/year, after correcting for the anthropogenic sink, which would exceed the 2°C-consistent global emission levels of the integrated assessment models presented in chapter 3. This G20 projected emissions level in 2030 is about 72 per cent of global emissions of the current policies (60 $GtCO_2e$) in 2030 seen in chapter 3, which is close to the 78 per cent share of G20 in the global emissions in 2018. It is lower in 2030, which was to be expected, given the increasing share of non-G20 and in-time international aviation and shipping emissions until 2030.

Figure 2.6 presents the additional effort needed according to estimates based on independent studies and shows that the main contributions would need to come in particular from the United States of America. If we assume a linear interpolation between the NDC target year (2025) and the 2050 United States of America long-term target (80 per cent reduction below 2005 levels indicated in the longterm low-carbon development strategy (LTS) document – see section 2.5) to estimate an indicative 2030 target, the required additional emissions reductions would halve if the 2030 target remained at the same level as for 2025, instead of progressing linearly towards its 2050 target as assumed in our analysis. The three countries that are projected to significantly overachieve their unconditional NDC targets (by more than 15 per cent), i.e. India, Russia and Turkey, are expected to together exceed their NDC targets by about 1.5 $GtCO_2e$ in 2030 with current policies (compared to about 1 $GtCO_2e$ in the UNEP Emissions Gap Report 2018). By contrast, the emission gaps are noticeably larger than in the 2018 assessment for the two large LULUCF emitters, i.e. Brazil and Indonesia, reflecting the recent increase of historical emissions and the political uncertainties in the two countries.

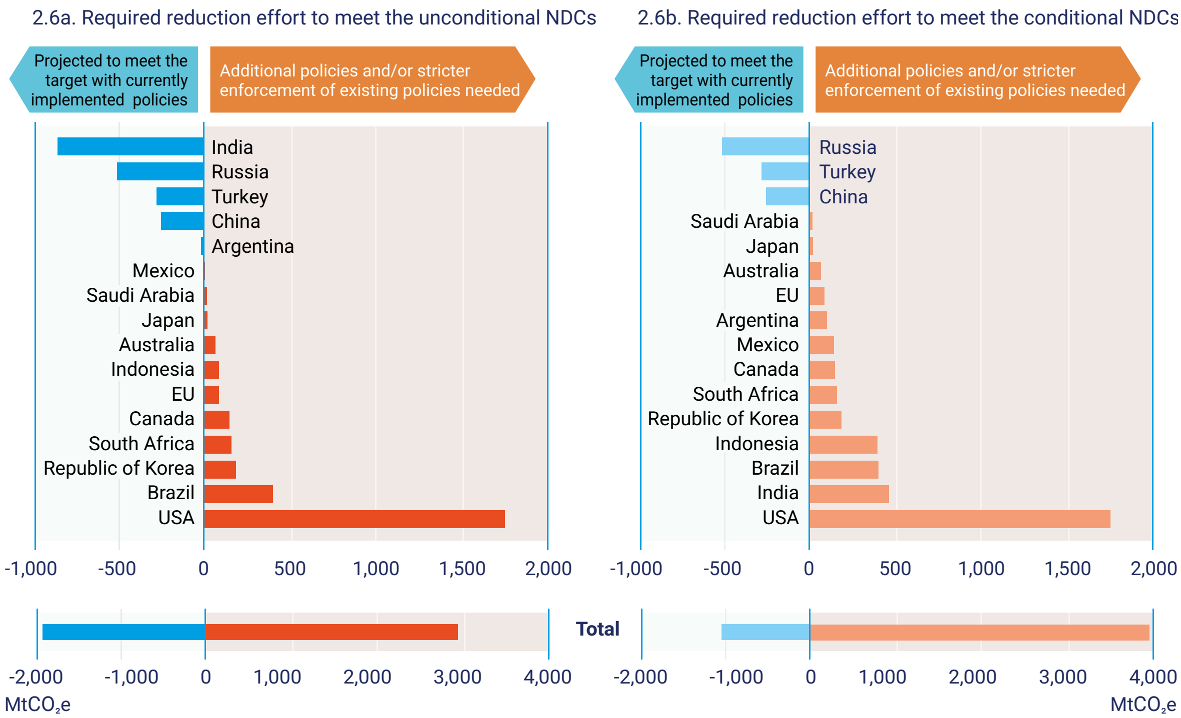
Overall, this study indicates that current policies of G20 members collectively fall short of achieving the unconditional NDCs. The total GHG emissions for G20 members are projected to be 41.0 $GtCO_2e$/year (range: 35.1 to 47.6 $GtCO_2e$/year), which is slightly lower than the projections by den Elzen *et al.* (2019) after correcting for different GWPs.

G20 members as a whole will need to reduce their GHG emissions further by about 1.1 $GtCO_2e$/year by 2030 to achieve unconditional NDC target emission levels and by about 2.9 $GtCO_2e$/year to achieve conditional NDC target emission levels. If we exclude the 1.6 $GtCO_2e$/year overachievement of unconditional NDCs by India, Russia and Turkey and assume that these countries will follow their current policies trajectory rather than that implied by their unconditional NDCs (as done in many NDC scenario projections from global models presented in chapter 3), then the G20 economies are collectively short of the unconditional NDCs by about 2.7 $GtCO_2e$/year against unconditional NDCs and by about 3.7 $GtCO_2e$/year against conditional NDCs in 2030. The estimated difference between the current policies scenario and NDC scenario projections for G20 members remains similar to that in the UNEP Emissions Gap Report 2018, but some G20 members (i.e. the EU and South Africa) have lower current policies projections than in the 2018 report (UNEP 2018), whereas others have higher projections (i.e. Brazil, and to a lesser extent, China).

2.4 Recent policy developments of G20 members

This section presents selected policy developments observed recently in individual G20 members and their potential implications on GHG emissions, where information is available. Information on main sector-level policies in selected G20 members is presented in chapter 4 and in appendix B, which is available online.

Figure 2.6. Additional emissions reduction effort required in 2030 per G20 Member to achieve NDC targets, based on current policies scenario projections of independent studies



Note: The NDC scenario projections from global models presented in chapter 3 assume that the countries that overachieve their NDCs follow their current policies trajectory. The calculations for the United States of America are based on an interpolation between its 2025 NDC and the 2050 long-term target (80 per cent reduction from 2005 levels) and for Brazil, they are based on its indicative 2030 target. As the current policies estimates of the independent studies are based on average GHG emission projections, the findings regarding whether countries are projected to over- or underachieve their unconditional NDC targets may therefore differ from the assessment in table 2.1, which is based solely on the number of independent studies.

Argentina

Unconditional NDC target projection: Uncertain or insufficient information

Argentina submitted its first NDC in 2015 and a revised version in 2016 where the country unconditionally committed to emit no more than 483 $MtCO_2e$/year in 2030. Since then, the country has established a National Climate Change Cabinet integrated by most of the ministries to design a low-carbon strategy and ensure the coherence of policies and measures. Under this institutional framework, the ministries have prepared a set of sectoral plans describing the mitigation policies and measures to be implemented to reach the NDC goals (Argentina, National Climate Change Cabinet 2019).

Policies and measures in the energy sector include the construction of several large-scale hydropower plants, three new nuclear power plants[7], various types of large-scale renewable energy power plants such as wind, solar PV and biomass, smaller renewable energy systems for distributed generation and residential solar water heaters. Implementation of these actions is behind schedule (Compañía Administradora del Mercado Mayorista Eléctrico S.A. [CAMMESA] 2019), mainly due to difficulties accessing financial resources (Gubinelli 2018). The weak infrastructure for electricity transportation is also a major barrier for the expansion of renewable, grid-connected power plants (Mercado Eléctrico 2019; Singh 2019). At the same time, the heavily subsidized exploitation of non-conventional fossil fuels from the Vaca Muerta reservoir is adding GHG emissions in a magnitude similar to the estimated emissions reductions of the renewable energy plan (Iguacel 2018). The initial exploration and future exploitation of offshore oil and natural gas is adding to the burden (Baruj and Drucaroff 2018; Boletín Oficial de la República Argentina 2019).

7 One of these three nuclear power plants, Atucha II, is already operational. The other two are currently under development.

Policies and measures have been developed for the industry and transport sectors such as energy efficiency, recycling and reuse of waste, renewable energy generation for self-consumption, promotion of low-emission urban mobility and public transport, intercity railroad restoration and efficiency improvements in road and railway freight transportation. Some of these actions are being implemented (for example, the initial implementation of hybrid and electric buses in large cities and the use of alternative fuels in cement kilns), while some other actions are behind schedule. In relation to agriculture, forestry and land-use, the key sectors for Argentina in relation to their contribution to GDP and to GHG emissions, sectoral plans have been presented with policies and measures such as conservation and restoration of native forests, sustainable forest management and fire prevention, increasing the forested area and promoting bioenergy from different biomasses. In addition to the measures proposed, Argentina urgently needs to revise the technologies and practices it has been using for decades in agricultural production to avoid further soil degradation and the impact on health of rural and suburban populations caused by using agrochemicals (Instituto National de Tecnología Agropecuaria (n.d).; Panigatti 2010). It also needs to provide the due amount of funding to finance the law that protects native forests and keep under control the rate of deforestation that increased in 2017 after several years of declination (Argentina, Ministerio de Ambiente y Desarrollo Sustentable 2018).

Australia

Unconditional NDC target projection: Emissions 0–15 per cent above target

With the re-election of Australia's conservative Government in May, there has been no recent material change in Australian climate policy. This will make achieving its NDC of a 26 per cent to 28 per cent emissions reduction below 2005 levels by 2030 challenging. However, it appears that the Australian Government intends to use carry-over permits from the Kyoto Protocol to do so, and uses a carbon budget approach that accounts for cumulative emissions between 2021 and 2030 in order to assess progress against its NDC (Australia, Department of the Environment and Energy 2018). The dropping of the proposed National Energy Guarantee in 2018 and that the renewable energy target will not be raised for years after 2020 up to 2030 (Clean Energy Regulator 2018) leaves Australia with no major policy tool to encourage emission reductions from the electricity sector in the short to medium term. There has been a 1.4 billion Australian dollar commitment to a 2 GW expansion of the Snowy Mountains hydroelectric project; however, the emission reductions stemming from this project are not expected to occur until well after 2030 (Marsden Jacob Associates 2018). In 2017, the Government's advisory body, the Climate Change Authority, concluded that other policies would be needed to deliver the structural changes necessary for Australia to decarbonize (Climate Change Authority 2017).

The latest projection published by the Government shows that emissions would remain largely unchanged up to 2030 (Australia, Department of the Environment and Energy 2018; Climate Action Tracker, 2019a). To date, much of the support from the Government's signature climate policy, the recently renamed "Climate Solutions Fund", has gone to LUC projects (Clean Energy Regulator 2017). The current Government decided earlier in 2019 to provide an additional 2 billion Australian dollars to the Climate Solutions Fund. The Australian Government estimates that these measures will contribute to an additional 100 $MtCO_2e$ of emissions reductions by 2030 (Australia, Department of the Environment and Energy 2019).

Brazil

Unconditional NDC target projection: Emissions at least 15 per cent above target

After the strong reduction in deforestation rates from 2004 (18,900 km²) to 2012 (4,656 km²), the deforestation rate grew again to 7,900 km² in 2018 (+70 per cent). Preliminary numbers indicate that in the first semester of 2019 deforestation rates continued to grow relative to the same period of 2018. President Bolsonaro significantly reduced the Ministry of Environment's budget for climate-change related activities; transferred the body responsible for identifying, defining, and registering Indigenous Territory to the Ministry of Agriculture; relaxed the rules for converting environmental fines into alternative compensations; extended deadlines for adequacy to registries that supported enforcement measures; and abolished most committees and commissions for civil participation and social control in the Federal Government (Climate Action Tracker 2019b).

Given the key role of the LULUCF sector in Brazil's NDC, which aims to reduce the country's GHG emissions by 37 per cent below 2005 levels by 2025 and to an indicative level of 43 per cent below 2005 levels by 2030, and given the huge global importance of its forests for environmental services, biodiversity and carbon sequestration, the Brazilian Government urgently needs to strengthen mitigation action in this sector. Official projections still show a decreasing trend (Programa Despoluição de Bacias Hidrográficas [PRODES] 2019), which is contrary to the observed trend. If environmental regulations and deforestation control policies are reversed or suspended, net emissions from deforestation could increase by 850-1,500 $MtCO_2e$/year by 2030 (Rochedo *et al.* 2018).

Despite the negative developments in climate policy and emissions regarding the forestry sector, Brazil has made progress in the energy sector. Market developments between 2015 and September 2019 seem to favour renewable energy over fossil fuels. Although fossil capacity was eligible in the latest auctions, no coal and only 4 GW of gas-fired power generation have been contracted since 2015 in comparison to 10 GW of renewables per cent. Wind has been the most competitive technology with concessions of 4 GW, followed by solar (3.3 GW), hydro (1.6 GW), and biomass (1.0 GW) (Brazil, Brazilian Electricity Regulatory Agency [ANEEL] 2019).

In the transport sector, the Government has launched the RenovaBio programme (Decree No. 9.308) that aims to increase the amount of biofuel in the national energy mix and has already led to an additional production of 31.9 million m^3 in 2016 and 2017 (Brazil, Ministry of Science, Technology, Innovation and Communications 2019); therefore the biofuel production in the country will probably meet the indicative targets mentioned in Brazil's NDC. President Bolsonaro also signed the first concession for the rail transport sector in 10 years. The project allows cargo to be transported from the Midwest and flow through both the Port of Itaqui (in the north) and the Port of Santos (in the southeast) (Brazil, Investment Partnerships Program 2019). The Federal Government plans to significantly increase the share that railway transport constitutes in the next eight years (from 15 per cent to 29 per cent).

Canada

Unconditional NDC target projection: Emissions at least 15 per cent above target

In its NDC, Canada pledged to reduce its GHG emissions by 30 per cent below 2005 levels by 2030. With Royal Assent of the Greenhouse Gas Pollution Pricing Act in December 2018, carbon pricing will be in place across all Canadian provinces and territories by September 2019, except the Province of Alberta, but is facing court challenges from a number of provinces (Climate Action Tracker 2019c). Alberta repealed its carbon tax in May 2019, however the federal carbon price will be applied to that Province in January 2020 (Province of Alberta Queen's Printer 2019; Vigliotti 2019). The adoption of performance standards on coal and gas-fired power stations at the end of 2018 means Canada is on track to meet its 2030 coal phase-out commitment, although it is expected that many coal-fired plants will be replaced with natural gas variants, creating a risk of future stranded assets (Climate Action Tracker 2017; Government of Canada, 2018b; 2018a). The 2019 federal budget included a 300 million Canadian dollar investment in zero-emission vehicles, while the Government has set sales targets of 10 per cent by 2025, 30 per cent by 2030, and 100 per cent by 2040 (Canada, Transport Canada 2019). According to Canada's Greenhouse Gas and Air Pollutant Emissions Projections (2018), when taking into account currently announced federal, provincial and territorial policies and measures, Canada's emissions in 2030 are projected at 592 Mt – or 223 Mt lower than what was projected before the adoption of the Pan-Canadian Framework for Clean Growth and Climate Change.

China

Unconditional NDC target projection: Overachievement of the target by less than 15 per cent

China's NDC targets include capping CO_2 emissions around 2030 and making an effort to cap them earlier, as well as a 20 per cent share of non-fossil fuels in the total primary energy demand (based on the conversion factor of the Chinese National Bureau of Statistics for renewable energy and nuclear power generation). Further targets include reducing the carbon intensity of its GDP by 60 per cent to 65 per cent below 2005 by 2030 and increasing forestry stock by 4.5 billion m^3 by 2030 compared to the 2005 level.

Since 2017, China's National Energy Administration (NEA) has developed a warning system for investment in coal power plants, which evaluates the risks of new coal power projects based on investment returns, electricity demand and environmental concerns. The system rates the feasibility of coal power projects in 38 regions as bad, moderate or good. New coal investment is banned, in principle, in regions with a bad rating. In April 2019, the NEA published the latest risk rating, which reduces the number of regions that ban new coal investment from 24 to 21 (NEA of China 2019). The change may encourage coal power development and slow down power sector decarbonization.

China's renewable energy and new energy vehicle (NEV) has experienced exponential growth in the past decade, in part thanks to generous subsidies. As the costs of the technologies fall and markets mature, China has started to phase down relevant subsidies. The Government suspended the approval of all new subsidized solar PV projects in May 2018 (NEA, National Development and Reform Commission [NDRC]; Ministry of Finance [MOF] of China 2019) and issued new regulations to reduce subsidies for solar and wind projects in 2019 (NDRC of China 2019a; 2019b.). The country also slashed the subsidy standard of 50 per cent for new energy cars in 2019 and plans to stop subsidies by the end of 2020 (He and Cui 2019). In the short-term, the efforts would result in a rush to develop renewable power projects or purchase new energy cars before phase-out of subsidies. In the midterm, utility-scale solar PV and onshore wind power can reach grid-parity by 2021 (Hang 2019; Tu *et al.* 2019). In fact, China has already approved 21 GW of wind and solar projects without subsidy (Hill 2019). The new policy will also accelerate the marketization of the NEV industry in China (Xiao 2019). In summary, the recent subsidy reform is a necessary step for the large-scale adoption of renewable energy and NEV in China.

EU28

Unconditional NDC target projection: Overachievement of the target by less than 15 per cent

The EU has adopted climate legislation to implement its NDC target of a 40 per cent reduction below 1990 levels by 2030. It has reviewed its EU emission trading system and increased its annual reduction of the cap. It has set national emission reduction targets for Member States for the sectors not covered in the EU emissions trading system. It has put in place legislation that ensures accounted LULUCF emissions are not resulting in a decrease of the EU's sink. Combined, these legislations meets the at least

40 per cent greenhouse gas reduction target of the NDC. In recent months, the EU has implemented a number of important accompanying measures that would lead to an overachievement of its NDC target. The adoption of the new renewable energy directive (Directive 2018/2002; RED II) and the new energy efficiency directive (Directive 2018/2002) (European Commission 2018c) with the respective goals of increasing the share of renewables in the energy mix and improving energy efficiency – if effectively implemented – would lead to emissions reductions of at least 45 per cent by 2030 relative to 1990 (European Commission 2018a). These two directives were parts of the package of measures called Clean Energy for all Europeans presented by the European Commission in November 2016. With the adoption of the Electricity Regulation and Electricity Directive by the Council in May 2019, European institutions finalized the work on this package, which also included a directive focusing on energy efficiency in the building sector (adopted in May 2018), and a Governance Regulation which obligates Member States to present National Energy and Climate Plans (NECPs) describing measures they are going to implement to contribute to meeting the EU's energy and climate goals. Collectively, the current draft NECPs are projected to fall short of both renewable and energy efficiency targets (European Commission 2019b). Final NECPs, taking on-board recommendations by the European Commission and featuring greater ambition where necessary, are due by the end of 2019.

Significant progress has also been made in the transport sector in which the adoption of CO_2 emissions standards for passenger cars and vans in December 2018 was followed by standards for new heavy-duty vehicles in early 2019. According to the legislation, average emissions from passenger vehicles sold by each manufacturer in 2030 will have to be 37.5 per cent lower for new cars and 31 per cent lower for new vans compared to 2021 levels (European Council 2019). Emissions from new heavy-duty vehicles should decrease by 15 per cent in the second half of the next decade and by 30 per cent in 2030 and beyond – in both cases in comparison to 2019 (European Commission 2019a). These regulations, however, may need to be strengthened after 2030 if net zero GHG emissions by 2050 as proposed by the European Commission (European Commission 2018a) are to be achieved.

Furthermore, an increasing number of countries are committing to the phase-out of coal-fired power plants; Finland has agreed on a phase-out of coal-fired power plants by 2029 (Europe Beyond Coal 2019) and Germany is discussing a phase-out (a commission advised it to do so by 2038) (Germany, Federal Ministry for Economic Affairs and Energy [BMWi] 2019). Other Member States that committed to, or announced coal phase-outs, include Austria (2025), Denmark (2030), France (2021), Ireland (2025), Italy (2025), the Netherlands (2030), Portugal (2030), Sweden (2022) and the United Kingdom (2025) (Europe Beyond Coal 2019).

India

Unconditional NDC target projection: Overachievement of the target by more than 15 per cent, suggesting a weak target

India's NDC has three numeric targets for 2030: reduce emissions intensity by 33 per cent to 35 per cent from 2005 levels, achieve an installed power capacity of 40 per cent from non-fossil fuel sources and create an additional carbon sink of 2.5–3.0 $GtCO_2e$ from forest and tree cover. India has continued its efforts towards achieving its renewable and intensity targets, though the previous year saw no substantial course change. In 2018, renewable deployment exceeded conventional fuels (Buckley and Shah 2019), though is projected to remain short of the 175 GW target by 2022 (Vembadi, Das and Gambhir 2018; Buckley and Shah 2019). The deployment of renewables has been let down by unclear, inconsistent taxation and import duty norms (Buckley and Garg 2019; Buckley and Shah 2019). Interrelated factors have stymied India's uptake of fossil fuel infrastructure, including a financial crisis that has led multiple coal power plants to be deemed as non-performing or stressed assets (India, Parliamentary Standing Committee on Energy 2018). In addition, the National Clean Air Programme released in 2019 aims to reduce $PM_{2.5}$ and PM_{10} concentrations by 25 per cent to 30 per cent, and provides additional motivation to shut down old coal power plants (India, Ministry of Environment, Forest and Climate Change [MoEFCC] 2019b).

India has simultaneously continued its efforts to broaden energy access. India reported the 100 per cent electrification of households in early 2019 (India, Ministry of Power 2019), with likely implications for the future of India's energy demand. The Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM) scheme launched in early 2019 is aimed at promoting solar energy in rural areas with the target to install 26 GW of solar agricultural pumps by 2022 (India, Cabinet Committee on Economic Affairs 2018). India also released an India Cooling Action Plan in 2019 to provide cooling services while keeping their GWP minimal by reducing energy and refrigerant demand (MoEFCC 2019a).

India has also begun deliberating policies to electrify public and private modes of transport. The second phase of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) was launched in 2019, aiming to support the uptake of electric two-wheelers, three-wheelers, four-wheelers and buses, with projected cumulative savings of 7.2 $MtCO_2e$ (India, Cabinet on Economic Affairs 2018). India is also deliberating upon targets to ban sales of all fossil fuel powered two-, three- and four-wheeler vehicles in the next decade. India also aims to electrify all its broad gauge railway routes by 2021–2022 (India, Cabinet Committee on Economic Affairs 2018).

Indonesia

Unconditional NDC target projection: Uncertain or insufficient information

Indonesia's NDC sets an unconditional 29 per cent and a conditional 41 per cent (with sufficient international support) reduction target on the country's GHG emissions below business-as-usual by 2030. The National Energy Policy referred to in Indonesia's NDC aims to increase the share of renewable energy in the total primary energy supply to 23 per cent by 2025 from the current 6.5 per cent (Republic of Indonesia, Ministry of Energy and Mineral Resources [MEMR] 2017), but this target will likely not be met and the country's heavy reliance on coal-fired power will likely continue under current policy measures (Climate Action Tracker 2019e). The new Electricity Supply Business Plan (RUPTL) 2019–2028 adopted in January 2019 (Republic of Indonesia 2019) also envisages the installation of almost 40 GW of fossil-fired power plants, about 27 GW of which being coal-fired, in the next 10 years. It is estimated that this 27 GW of coal-fired power alone would annually emit up to 200 $MtCO_2e$ over the next 40 years, unless they are decommissioned before the end of their lifetime.

In the land-use sector, Presential Instruction No 8 of 2018 (President of the Republic of Indonesia 2018) presents a three-year moratorium on the entire licensing process for palm oil plantations and an order for the relevant central Government ministries and regional governments to conduct a massive review of oil palm licensing data (Mongabay 2018). A recent Presidential Instruction also made the temporary moratorium on forest-clearing permits for logging and plantations issued in 2011 permanent, but the historical development of land-use GHG emissions casts doubt on the effectiveness of these measures (Jong 2019). Although the Global Forest Watch (2018) reported in 2017 that Indonesia was one of the few tropical nations to reduce its deforestation rates in 2017, this was likely due, in part, to the national peat drainage moratorium (Norway, Ministry of Climate and Environment 2016), in effect since 2016.

Japan

Unconditional NDC target projection: Emissions 0–15 per cent above target

Under its NDC, Japan aims to reduce its GHG emissions by 26 per cent by 2030 from 2013 levels. Japan's total GHG emissions seem to have peaked in the fiscal year (FY) of 2013 before decreasing for four consecutive years. In the power sector, decarbonization efforts are being strengthened only incrementally. In March 2019, the Ministry of the Environment (MOE) announced three new actions to accelerate decarbonization progress in the power sector (MOE 2019), among which is stricter enforcement of environmental impact assessments on planned coal-fired power plants. However, the downsides are the overall limited effectiveness of the measures, as the MOE cannot veto the plans, and that coal-fired power plants already under construction will be unaffected by this action.

As for renewables, the Environmental Impact Assessment Act will apply from April 2020 and will also be applicable to large-scale solar PV projects with capacities greater than 40 MW (or greater than 30 MW following a screening process based on the current status of land-use on the project site) (Ministry of Economy, Trade and Industry [METI] 2019b). The Government has also started reviewing the scope of renewable projects to be supported under the feed-in tariff (FIT) scheme, which contributed to the large increase of solar PV capacity in the last years, to control the increasing surcharge (METI 2019c). These new rules are likely to secure proper business disciplines for solar PV in Japan, despite curbing the speed at which large-scale solar projects can be deployed after the full installation of capacity with FIT approval. For wind power, the new law put into effect on 1 April 2019 (METI 2019a) allows offshore wind power developers to occupy a registered area up to 30 years after consultation with relevant ministries and local stakeholders. This will promote the development of offshore wind farms.

For the transport sector, a panel under the METI published an interim report on the long-term strategy for car manufacturing (METI 2018), which establishes a long-term goal to reduce tank-to-wheel CO_2 emissions by 80 per cent below 2010 levels by 2050 for all new vehicles produced by Japanese car manufacturers and by 90 per cent by 2050 for new passenger vehicles. The goal for new passenger vehicles assumes a near 100 per cent share of electrified vehicles (including hybrids, plug-in hybrids, battery electric vehicles and fuel cell electric vehicles). With CEOs of major car manufacturers such as Toyota, Nissan and Honda all being members of the panel, the development of these long-term goals can be considered an important step towards decarbonization of Japan's transport sector.

Mexico

Unconditional NDC target projection: Overachievement of the target by less than 15 per cent

Mexico's NDC makes an unconditional commitment to reduce GHG emissions by 22 per cent below business-as-usual in 2030, implying a net emissions peak from 2026, and a conditional commitment to reduce emissions by 36 per cent below business-as-usual in 2030. Mexico's new Administration has stalled years of progress in the energy sector with decisions that threaten to reverse progress made towards enhanced climate action through, for example, Mexico's General Climate Change law of 2012 (Mexico, Cámara de Diputados del H. Congreso de la Unión 2012) or its Energy Transition law of 2015 (Mexico, Cámara de Diputados del H. Congreso de la Unión 2015). The National Electricity Outlook (PRODESEN) 2019–2033 adopted in June 2019 (Mexico, Ministry of Energy 2019) limits deeper deployment of clean energy (including efficient cogeneration) beyond the 35.1 per cent by 2024 target (24.12 per cent in June 2018) by increasing fossil fuel-fired generation, reducing wind power and not increasing solar power growth rates. Furthermore, the Ministry has cancelled the 2018 long-term power auction and cut-off the transmission lines to evacuate renewable energy. There have been no announcements of further auctions. Despite the recognition of the importance of reducing GHG emissions and increasing renewable energy deployment, the National Development Plan adopted in June 2019 (Mexico, Diario Oficial de la Federación 2019) adds a new additional refinery with the aim to increase gasoline, diesel and fuel oil production.

After postponing Mexico's 2018 long-term energy auction round – a policy scheme introduced in 2015 after the country's energy reform that aimed to increase its clean energy share – President Lopez Obrador cancelled the fourth auction round in January 2019 Mexico, Centro Nacional de Control de Energía 2018). Although the first three rounds of electricity auctions had led to a substantial amount of new renewable energy projects (Notimex 2019), President Lopez Obrador's plans for the power sector include the modernization of gas and coal-fired power plants previously planned for retirement and the construction of a 700 MW coal-fired plant in the short and midterm (Solís 2018a, 2018b).

President Obrador has also presented a National Refining Plan aimed at "rescuing" Mexico's oil industry and achieving energy independence through the rehabilitation of six oil refineries and the construction of a new one in Dos Bocas, Tabasco, and a plan for constructing a railroad in the Yucatan peninsula (known as the Maya Train project) (Government of Mexico 2019). These three infrastructure projects have faced national and international criticism (see, for example, Gurría (2019)).

Republic of Korea

Unconditional NDC target projection: Emissions at least 15 per cent above target

Dynamic discussions are taking place in the Republic of Korea in relation to the adequacy of its 2030 power sector emissions target. In its NDC, the Republic of Korea has committed to reducing its GHG emissions to 37 per cent below business-as-usual or to 536 $MtCO_2e$ per year by 2030 (UNFCCC 2018), and initially set up a road map in 2016 to achieve this target. However, the plan in the initial road map to procure 96 $MtCO_2e$ per year of international credits was subject to environmental integrity and economic feasibility-related criticism. In July 2018, the road map was amended, stating that 16 $MtCO_2e$ per year will be reduced by international credits rather than 96 $MtCO_2e$ per year (Republic of Korea, Ministry of Environment 2018).

Another important change to the road map was that contemplated emission reductions from the power sector were reduced from 64.5 $MtCO_2e$ per year to 23.7 $MtCO_2e$ per year (Republic of Korea, Ministry of Environment 2018), which is mainly attributable to the Moon Jae-In Administration's nuclear policy, under which 8.8 GW of new nuclear power plant construction projects were cancelled. The amended GHG road map stated that an additional emission reduction requirement of 34.1 $MtCO_2e$ per year may be imposed on the power sector depending on further discussions, which mostly relates to how ambitiously the country will decommission its operational coal power plant fleet by 2030. The additional 34.1 $MtCO_2e$ per year reduction issue has become the centre of national climate and energy policy discussions and was one of most contentious topics when establishing the Third Energy Framework Plan, under which the country aims to increase its renewables share in total electricity generation from 7.6 per cent in 2017 to 35 per cent by 2040 and to phase down coal and nuclear power (KBS 2019).

Air pollution concerns, originating from the South Chungcheong Province, where approximately 18 GW of coal power plants (half of the Republic of Korea's coal power fleet) are located, may expedite the speed of coal power plant retirements and lead to more ambitious reductions from the country's power sector. In early 2019, opposition from this Province led to the suspension of retrofits of 4.5 GW of coal power plants (Chosunilbo 2019; Chung 2019). If the retrofits were implemented, the life period of these power plants would have extended to until around 2040. The Governor of South Chungcheong Province has also committed to decommissioning coal power plants that are older than 25 years, which, if successful, will result in 14 units being decommissioned by 2026 (Powering Past Coal Alliance 2018).

Russia

Unconditional NDC target projection: Overachievement of the target by more than 15 per cent, suggesting a weak target

Russia pledged to limit GHG emissions by 15–25 per cent below 1990 levels by 2020 and by 25–30 per cent below 1990 levels by 2030, and recently announced that it will ratify the Paris Agreement (United Nations 2019). While the ratification date is uncertain, a draft Decree of the President on a new 2030 emission reduction target is to be prepared by December 2019, with a draft implementation plan to achieve the 2030 target expected in the first half of 2020 (UNFCCC 2019b). The Russian Action Plan mandates the drafting of a "low-carbon strategy until 2050" by the end of 2019 (Sauer and Collett-White 2019). However, no mention of the preparation of this draft has yet been made. The fact that only draft documents are expected provides a weak basis for tracking and assessing progress, as they may just contain principles and approaches without concrete mitigation measures and GHG targets. In December 2018, the Government introduced new draft legislation that would establish a cap-and-trade system for major carbon emitters by 2025 (Sauer and Collett-White 2019).

Saudi Arabia

Unconditional NDC target projection: Uncertain or insufficient information

In its NDC, Saudi Arabia commits to reducing emissions by up to 130 $MtCO_2e$ per year below business-as-usual by 2030 through actions that contribute to economic diversification and adaptation. The country's actions to mitigate climate change are driven by its motive to diversify its economy (Al-Sarihi 2019). In 2016, Saudi Arabia published its Vision 2030, which included a renewable energy target of 9.5 GW by 2023 and a phase-out of fossil fuel subsidies (Kingdom of Saudi Arabia 2016). However, the implementation of this vision has been delayed for both renewable energy and the fossil fuel price reform (Nereim 2017; Krane 2019). Most recently, in March 2018, Saudi Arabia and the SoftBank Group signed a memorandum of understanding to build a 200 GW solar plant, the largest single solar project worldwide, as part of Vision 2030 (Nereim and Cunningham 2018). However, the expected tenders to implement the plan have been delayed since January 2019 (Bellini 2019). Outside the power sector, the Public Investment Fund announced in October 2018 its intention to locate an electric vehicle industry in Saudi Arabia, following an agreement to invest more than US$1 billion in an United States of America-based electric vehicle manufacturer (Torchia *et al.* 2018).

South Africa

Unconditional NDC target projection: Emissions 0–15 per cent above target

In its Cancun Pledge, South Africa aims to reduce its GHG emissions by 34 per cent below business-as-usual in 2020, and commits to achieving a peak, plateau and decline of GHG emissions in its NDC, with emissions peaking between 2020 and 2025, before plateauing at 398–614 $MtCO_2e$ per year between 2025 and 2030.

The South African Government released the long-awaited draft of its Integrated Resource Plan (Republic of South Africa, Department of Energy 2018) in August 2018. The revised plan aims to decommission 35 GW of Eskom's currently operational coal generation capacity (42 GW) by 2050, with 12 GW of this decommissioned by 2030, another 16 GW by 2040, and a further 7 GW by 2050 (Republic of South Africa, Department of Energy 2018). The 5.7 GW of coal capacity currently under construction would be completed and another 1 GW of new coal capacity would be commissioned by 2030. The significant volume of coal capacity to be decommissioned by 2030 and beyond marks a significant shift away from previous planning. The Government has not yet communicated a timeline for the Integrated Resource Plan (IRP) update's final adoption as of September 2019.

South Africa approved a carbon tax in February 2019, which covers fossil fuel combustion emissions, industrial processes and product-use emissions, and fugitive emissions (Reuters 2019). The tax has been implemented since June 2019, but a basic tax-free threshold for around 60 per cent of emissions and additional allowances for specific sectors means that tax exemptions will apply for up to 95 per cent of emissions during the first phase until 2022 (KPMG 2019).

In addition, South Africa released a draft climate change bill in June 2018 for public comment (Republic of South Africa, Department of Environmental Affairs 2018), but the Government has not yet communicated a timeline for the law's final adoption as of July 2019. The draft law aims to establish a Ministerial Committee on Climate Change to oversee and coordinate activities across all sector departments. Under the proposed legislation, the Minister of Environmental Affairs together with the Ministerial Committee on Climate Change would have to set sectoral emission targets for each GHG emitting sector in line with the national emission target every five years.

Turkey

Unconditional NDC target projection: Overachievement of the target by more than 15 per cent, suggesting a weak target

In its Intended Nationally Determined Contribution (INDC), Turkey aims to limit its GHG emissions to 21 per cent below business-as-usual or to 959 $MtCO_2e$ per year in 2030 (excluding LULUCF). Turkey's current emissions are on this trajectory. The energy sector is at the centre of the country's low-carbon transition debate, representing more than 85 per cent of its total GHG emissions in 2017, with 40 per cent of all energy sectors emissions resulting from electricity generation.

At the start of 2018, Turkey put in place an ambitious National Energy Efficiency Action Plan (NEEAP) for the 2017–2023 period, which aims to reduce the its total energy demand (in primary terms) by 14 per cent compared with the 2017 level. The six-year plan includes the six sectors that supply and demand energy, covering a comprehensive list of 55 actions. The renewable energy FIT mechanism that will still be available for new projects until the end of 2020 was successful in raising the wind and solar PV share in total electricity demand to 10 per cent (and around a third of the total demand supplied from renewables). Following the global trend, Turkey is diversifying its policy portfolio. Since 2017, three rounds of auctions have taken place for onshore wind (twice) and solar PV with favourable prices and local content requirements. The Government has indicated that auctions will be the key mechanism for renewable energy investments in the coming decade.

The Government has set an ambitious plan for new coal-fired power plants, with purchase guarantees and subsidies to investors. Among the G20 members, Turkey ranks third for new coal-fired power plant capacity being planned (37 GW), following China and India (as at January 2019). This is twice as much as Turkey's current operational capacity. However, planned capacities are not being constructed due to a lack of financing, with around only 1 GW currently under construction. More than 40 GW in planned coal-fired power plant capacity was cancelled over the 2010–2018 period. Nuclear energy has been on Turkey's agenda as an alternative source for many years. The country's first nuclear power plant is planned to have four 1.2 GW reactors, with the first reactor planned to start operation by 2023.

United States of America

Unconditional NDC target projection: Emissions at least 15 per cent above target

The current NDC target for the United States of America is to reduce emissions by 26–28 per cent from 2005 levels by 2025. However, President Trump's Government is taking actions to move the country's emissions trajectory in the opposite direction, cutting environmental regulations in favour of giving more freedom to industry. The Trump Administration recently issued the final Affordable Clean Energy (ACE) rule, its replacement for the Obama Administration's Clean Power Plan, which was meant to reduce emissions from power plants in order to achieve the country's NDC target. While the Clean Power Plan would have reduced power sector emissions by roughly 32 per cent, the ACE rule is expected to reduce them by roughly 1 per cent (Natural Resources Defense Council [NRDC] 2018).

The Trump Administration has also frozen the vehicle emissions and fuel economy standards for cars and light trucks until 2026, meaning that the average fuel economy will remain at 35 miles per gallon (mpg), rather than rising to 54 mpg. According to analysis by the Rhodium Group, this will increase emissions from the transportation sector by 28–83 $MtCO_2e$ per year by 2030, with the ultimate amount dependent upon the effect of oil prices on consumption (Larsen *et al.* 2019). However, a group of automakers recently struck a deal with the state of California to strengthen standards for gas mileage and emissions from their vehicles (Van Sant 2019).

However, despite the Trump Administration's actions, market trends have resulted in a significant drop in emissions over the past decade. The country's energy-related CO_2 emissions fell by 14 per cent between 2005 and 2017, while the economy grew by 20 per cent (U.S. Energy Information Administration [EIA] 2018). Action at state and local levels has also grown significantly since President Trump's announcement that the United States of America would leave the Paris Agreement. A group of 25 governors representing over half of the country's population and US$11.7 trillion in GDP have joined the U.S. Climate Alliance, a coalition committed to reducing GHG emissions in line with the goals of the Paris Agreement (U.S. Climate Alliance 2019).

2.5 Preparation of long-term strategies and the way forward

Another important ongoing policy process is the preparation of long-term low emissions development strategies under the Paris Agreement. As of October 2019, only seven G20 members (Canada, France, Germany, Japan, Mexico, the United Kingdom and the United States of America) had submitted their strategies to the UNFCCC and another two (the EU28 and South Africa) had published their draft strategies (UNFCCC 2019a). Of the seven long-term strategies submitted by G20 members to the UNFCCC, only Japan committed to achieving long-term net zero GHG emissions as early as possible in the second half of this century, though France and the United Kingdom have passed bills that commit to net zero GHG emissions by 2050. A few other members, including the EU28, are in the process of revising their domestic and international long-term goals. For non-annex I G20 members, there have been some indications to suggest that they would establish long-term strategies that contain timelines for achieving net zero GHG emissions. For comparison, to keep warming below 1.5°C in 2100 with a 66 per cent chance, global total net CO_2 emissions would need to be reduced to zero by around 2050 (IPCC 2018). There is an increasing number of countries that have set or are in the process of setting net zero emissions targets domestically (Energy & Climate Intelligence Unit 2019).

More long-term strategies are expected to be submitted to the UNFCCC in the coming months, which will provide a better understanding of the level of collective long-term ambition and how it will affect the pathways towards achieving the Paris Agreement's long-term temperature goals. It will also be important to scrutinize the consistency between the (revised) NDCs and long-term strategies to ensure that countries' long-term low-carbon development pathways are feasible.

3 The emissions gap

Lead authors:

Joeri Rogelj (Grantham Institute Imperial College London, UK; International Institute for Applied Systems Analysis, Austria), Michel den Elzen (PBL Netherlands Environmental Assessment Agency)

Contributing authors:

Daniel Huppmann (International Institute for Applied Systems Analysis, Austria), Gunnar Luderer (Potsdam Institute for Climate Impact Research, Germany)

3.1 Introduction

This chapter updates the annual assessment of the emissions gap in the year 2030. Consistent with previous reports, the emissions gap in 2030 is defined as the difference between projected emissions under full implementation of the nationally determined contributions (NDCs) and emissions under least-cost pathways that are in line with the Paris Agreement goals of limiting global average temperature increase to well below 2°C and pursuing to limiting it to 1.5°C. The chapter first presents the various scenarios used for the assessment of the emissions gap (section 3.2), that is, reference scenarios, NDC scenarios and scenarios consistent with limiting global warming to a specific temperature limit. The next section updates the 2030 emissions gap (section 3.3). This is followed by a discussion of the temperature implications of the emissions gap (section 3.4) and the potential impact of non-state actions on the gap (section 3.5).

3.2 Scenarios considered for the 2030 gap assessment

This section will provide an update on the scenarios considered for the year-2030 gap assessment which comprise reference scenarios, NDC scenarios and least-cost mitigation scenarios consistent with specific temperature targets.

3.2.1 Reference scenarios and updates

Reference scenarios are used as benchmarks against which progress in emission reductions can be tracked. Two reference scenarios are considered: the 2005 policies scenario and the current policy scenario.

The **2005 policies scenario** projects global greenhouse gas (GHG) emissions assuming no new climate policies are put in place from around 2005 onwards1. For 2019, the data for this scenario are updated and based on projections from six modelling studies that are also used for the current policy scenario projections from the same data source (the CD-LINKS Scenario Database, version 1.0) to maintain consistency (McCollum *et al.* 2018). Data for this scenario was available from the following international modelling groups: International Institute for Applied Systems Analysis (IIASA using the MESSAGE–GLOBIOM model), Joint Research Centre (JRC using the POLES model), National Institute for Environmental Studies (NIES using the Asia-Pacific Integrated [AIM] model), PBL Netherlands Environmental Assessment Agency (PBL using the IMAGE model), Potsdam Institute for Climate Impact Research (PIK using the REMIND–MAgPIE model) and RFF–CMCC European Institute on Economics and the Environment (RFF–CMCC using the WITCH model).

The **current policy scenario** projects GHG emissions assuming all currently adopted and implemented policies (defined as legislative decisions, executive orders, or equivalent) are realized and that no additional measures are undertaken. Updated data from eight modelling groups were available for this scenario. These include updated estimates from four modelling groups also considered in the UNEP Emissions Gap Report 2018 (United Nations Environment Programme [UNEP] 2018): Climate Action Tracker (CAT) (CAT 2019), JRC (Tchung-Ming *et al.* 2018), PBL (CD-LINKS Scenario Database) (McCollum *et al.* 2018), and the International Energy Agency (IEA) (2018). In addition, four new modelling groups (IIASA, NIES, PIK and RFF–CMCC) provided data for this scenario, available in the CD-LINKS Scenario Database (McCollum *et al.* 2018).

1 This scenario is the same as the “no policy scenario” of previous reports.

3.2.2 NDC scenarios and updates

The NDC scenarios estimate the levels of global total GHG emissions that are projected as a result of the implementation of the mitigation actions pledged by countries in their NDCs. In line with previous gap reports, two NDC scenarios are considered: the unconditional and the conditional NDC scenario. The **unconditional NDC scenario** assumes countries only implement the mitigation actions specified in their NDCs that have no conditions attached. Parties that do not have an NDC or solely have a conditional target in their NDC are assumed to follow their current policy scenario. The **conditional NDC scenario** assumes full achievement of Parties' mitigation pledges (both the conditional and unconditional actions listed as part of the mitigation contribution in their NDCs). Parties that do not have conditional mitigation targets in their NDC follow their unconditional target. Appendix A.1 (available online) provides a full overview of the studies considered for the reference and NDC scenarios.

The NDC scenario of the 2019 report is based on updated data from the same data sources as the current policies scenario and is provided by 12 modelling groups. Projected NDC levels for some countries, in particular China and India, depend on recent emission trends or gross domestic product (GDP) growth projections that quickly become outdated. Therefore, studies that were published in 2015, before the adoption of the Paris Agreement, have been omitted from the 2019 update. The emission projections of China and India for the current policies and NDC scenarios have been lowered in most studies that have updated projections of current policies on an annual basis, such as IEA, Climate Action Tracker, PBL and JRC. For China in particular, the projected peak level of CO_2 emissions has also decreased in the most recent studies compared to projections published in 2015. Nevertheless, the impact of excluding studies published before 2015 is small. The projected global emissions levels of the NDC scenarios are very similar to the levels assessed in the 2018 UNEP Emissions Gap Report[2].

3.2.3 Least-cost mitigation scenarios consistent with the Paris Agreement's temperature limits and updates in light of the IPCC Special Report on Global Warming of 1.5°C

Estimates of where GHG emissions should be in the year 2030 in order to be consistent with a least-cost pathway towards limiting global warming to specific temperature limits are calculated from the scenarios that were compiled as part of the mitigation pathway assessment of the Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C (IPCC SR1.5) (Rogelj *et al.* 2018), and are available online (Huppmann *et al.* 2018a; Huppmann *et al.* 2018b). Similar to the UNEP Emissions Gap Report 2018, least-cost mitigation pathways – or pathways that aim at limiting warming to specific temperature limits at the lowest overall cost[3] – are selected and grouped into **three temperature scenario groups** according to their maximum cumulative CO_2 emissions from 2018 onwards. This approach ensures that all scenarios in a specific temperature scenario group result in similar maximum warming and that there is limited overlap between the various groups. Moreover, this approach is consistent with the approach of the IPCC SR1.5 that groups scenarios in different categories based on their maximum temperature outcome (IPCC 2018; Rogelj *et al.* 2018).

Peak warming is achieved around the time of net-zero CO_2 emissions (Ricke and Caldeira 2014; Joos *et al.* 2013; Zickfeld and Herrington 2015) and current technical assessments of mitigation pathways show that some degree of carbon-dioxide removal (CDR) is required to compensate for ongoing emissions in sectors that are hard to decarbonize (IPCC 2018; Rogelj *et al.* 2018). After peak warming, global temperature rise could potentially be slowly reversed through the continued deployment of global CDR to achieve net negative CO_2 emissions (Allen *et al.* 2018; Zickfeld, MacDougall and Matthews 2016; Tokarska and Zickfeld 2015). However, CDR deployment at such scales is associated with important risks, as highlighted in earlier UNEP Emissions Gap Reports (for example, UNEP (2010)) and other assessment (de Coninck *et al.* 2018; Roy *et al.* 2018; Fuss *et al.* 2018).

The three temperature scenario groups describe a range of pathways that keep warming in the range of below 2°C–1.5°C and allow the identification of the consequences of strengthened or weakened action at various degrees of ambition, from limiting warming to roughly around 2°C over potential interpretations of "well below 2°C", to pursuing to limit warming to 1.5°C, and their corresponding emission reductions (see table 3.1). Each scenario considers a least-cost climate change mitigation pathway that starts reductions from 2020. The temperature outcomes of these scenarios are estimated using the climate model set up used in the IPCC Fifth Assessment Report (Meinshausen *et al.* 2009; Meinshausen, Raper and Wigley 2011; Rogelj *et al.* 2014; Clarke *et al.* 2014).

- **Below 2.0°C scenario:** This scenario limits maximum cumulative CO_2 emissions from 2018 until the time net-zero CO_2 emissions are reached

2 Assuming 100-year global warming potential (GWP) values of the IPCC's Fourth Assessment Report (AR4) for both datasets.

3 More specifically, least-cost pathways are calculated with integrated assessment models (that is, models that combine representations of the energy, economic, land and environment systems), and distribute the emission reductions across regions, sectors and gases in such a way that the global discounted reduction costs are minimized over time and the climate target is achieved with varying probability (see also box 3.1 in the UNEP Emissions Gap Report 2017).

(or until 2100 if net-zero is not reached before[4]) to between 900 and 1300 $GtCO_2$, and cumulative 2018–2100 emissions to at most 1200 $GtCO_2$. It is consistent with limiting end-of-century warming to below about 2.0°C with about 66 per cent or greater probability, while limiting peak global warming during the twenty-first century to below 2.0°C with about 66 per cent or greater probability. The median estimate of 2030 GHG emissions for this scenario is 41 $GtCO_2e$, which is consistent with the median 40 $GtCO_2e$ estimated for the "lower 2°C" scenario category of the IPCC SR1.5 (see table 2.4 in (Rogelj *et al.* 2018)).

- **Below 1.8°C scenario:** This scenario limits maximum cumulative CO_2 emissions from 2018 until the time net-zero CO_2 emissions are reached (or until 2100 if net-zero is not reached before) to between 600 and 900 $GtCO_2$, and cumulative 2018-2100 emissions to at most 900 $GtCO_2$. It is consistent with limiting peak and end-of-century warming to below about 1.8°C with about 66 per cent or greater probability. This scenario is included to provide additional, more granular information about how emissions reduction requirements in 2030 change with gradually increasing stringency of global mitigation action.

- **Below 1.5°C in 2100 scenario:** This scenario limits maximum cumulative CO_2 emissions from 2018 until the time net-zero CO_2 emissions are reached (all model realizations in this scenario reach net-zero before 2100) to below 600 $GtCO_2$, and cumulative 2018–2100 emissions to at most 380 $GtCO_2$, when net negative CO_2 emissions in the second half of the century are included. It is consistent with limiting global warming to below 1.5°C in 2100 with about 66 per cent probability, while limiting peak global warming during the twenty-first century to 1.6–1.7°C with about 66 per cent or greater probability. This class of scenarios is consistent with the scenarios in the IPCC 1.5°C Special Report that limit warming to 1.5°C with no or limited overshoot (as explained in box 3.2, UNEP Emissions Gap Report 2018; see also characteristics in table 3.1). The median estimate of 2030 emissions of 25 $GtCO_2e$ is well within the median estimate range of 22–28 $GtCO_2e$ of the IPCC SR1.5 for the 1.5°C with no or limited overshoot (see table 3.1).

Table 3.1 shows the 2030 global GHG emission levels for the three scenarios.

3.3 The 2030 emissions gap

In line with previous reports, the emissions gap for 2030 is defined as the difference between global total GHG emissions from least-cost scenarios that keep global warming to 2°C and 1.5°C with varying levels of likelihood and the estimated global total GHG emissions resulting from a full implementation of the NDCs. To allow for a more nuanced interpretation of the Paris Agreement's temperature targets, this assessment includes a below 1.8°C scenario. This section updates the gap based on estimated levels of GHG emissions in 2030 for the scenarios described in section 3.2. Table 3.1 provides a full overview of 2030 emission levels for the seven scenarios considered in this assessment, as well as the resulting emissions gap. A change compared to 2018 is that all emission projections have been aggregated with the 100-year global warming potential (GWP) values of the IPCC AR4[5], whereas UNEP Emissions Gap Report 2018 used the GWP values of the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC SAR). The difference between SAR and AR4 GWPs leads to a difference in both scenarios for 2°C, 1.8 °C and 1.5°C and current policy and NDC levels (typically 1–2 $GtCO_2e$), so that the effect on the size of the emissions gap will be limited.

Table 3.1 indicates that in the absence of further climate action since 2005 – that is, under a **2005-policies scenario** – the global total GHG emissions in 2030 would be 64 $GtCO_2e$ (range of 60–68 $GtCO_2e$). **Current policies** are estimated to reduce global emissions in 2030 to around 60 $GtCO_2e$, which is 4 $GtCO_2e$ lower compared to the **2005-policies scenario**.

The estimates of global emissions in 2030 under the **current policy scenario** have decreased slightly since 2015, when the UNEP Emissions Gap Report first introduced the current policies emission projection until 2030. The UNEP Emissions Gap Report 2015 estimated global emissions under a **current policy scenario** projection of about 62 $GtCO_2e$[6] (range of 59.5–63.5 $GtCO_2e$) in 2030 (UNEP 2015), which has been lowered to 60 $GtCO_2e$ (range of 58–64 $GtCO_2e$) in 2019, indicating that studies show slight progress of about 2 $GtCO_2e$ (range of 0.5–2 $GtCO_2e$) in policy implementation since the adoption of the Paris Agreement. The emissions projections of the current policies scenario of the Climate Action Tracker and PBL show a similar decrease over time. The **current policy scenario** estimate for 2030 is around 0.5 $GtCO_2e$ lower than the 2018 report estimate, when the implications of switching to the GWP values of the IPCC AR4 are taken into account, which is similar to the updated estimates of individual studies from the Climate Action Tracker and PBL. Overall, this implies that countries are still not on track to deliver their NDCs (see chapter 2 and chapter 4 for a discussion of G20 members'

4 If a scenario does not achieve net-zero CO_2 emissions before 2100 while still holding warming to below a specific temperature threshold, it is assumed that global CO_2 emissions will reach net-zero emissions immediately or shortly after 2100.

5 This change was made to be more in line with the decisions made at COP24 in Katowice, where the Parties agreed on AR5 for reporting reasons. A full switch to AR5 GWP was not yet possible because the literature is not yet up-to-date regarding this decision.

6 The numbers are based on the estimates of UNEP (2015) of 60 $GtCO_2e$ (range of 58–62 $GtCO_2e$), assuming 100-year GWP values of the IPCC SAR. Here, these estimates are converted using 100-year GWP values of the IPCC AR4, leading to an adjustment of 1.5 $GtCO_2e$.

Table 3.1. Global total greenhouse gas emissions in 2030 under different scenarios (median and 10th to 90th percentile range), temperature implications and the resulting emissions gap.

Scenario (rounded to the nearest gigaton)	Number of scenarios in set	Global total emissions in 2030 [$GtCO_2e$]	Estimated temperature outcomes			Closest corresponding IPCC SR1.5 scenario class	Emissions Gap in 2030 [$GtCO_2e$]		
			50% probability	66% probability	90% probability		Below 2.0°C	Below 1.8°C	Below 1.5°C in 2100
2005-policies	6	**64** (60–68)							
Current policy	8	**60** (58–64)					**18** (17–23)	**24** (23–29)	**35** (34–39)
Unconditional NDCs	11	**56** (54–60)					**15** (12–18)	**21** (18–24)	**32** (29–35)
Conditional NDCs	12	**54** (51–56)					**12** (9–14)	**18** (15–21)	**29** (26–31)
Below 2.0°C (66% probability)	29	**41** (39–46)	Peak: 1.7-1.8°C In 2100: 1.6-1.7°C	**Peak:** **1.9-2.0°C** **In 2100:** **1.8-1.9°C**	Peak: 2.4-2.6°C In 2100: 2.3-2.5°C	Higher-2°C pathways			
Below 1.8°C (66% probability)	43	**35** (31–41)	Peak: 1.6-1.7°C In 2100: 1.3-1.6°C	**Peak:** **1.7-1.8°C** **In 2100:** **1.5-1.7°C**	Peak: 2.1-2.3°C In 2100: 1.9-2.2°C	Lower-2°C pathways			
Below 1.5°C in 2100 and peak below 1.7°C (both with 66% probability)	13	**25** (22–31)	Peak: 1.5-1.6°C In 2100: 1.2-1-3°C	**Peak:** **1.6-1.7°C** **In 2100:** **1.4-1.5°C**	Peak: 2.0-2.1°C In 2100: 1.8-1.9°C	1.5°C with no or limited overshoot			

Note: The gap numbers and ranges are calculated based on the original numbers (without rounding), and these may differ from the rounded numbers (third column) in the table. Numbers are rounded to full $GtCO_2e$. GHG emissions have been aggregated with 100-year GWP values of the IPCC AR4 (to be consistent with Table 2.4 of IPCC Special Report on Global Warming of 1.5°C, whereas UNEP Emissions Gap Report 2018 used GWP values of IPCC SAR). The NDC and current policy emission projections are updated from the presented numbers in cross-chapter Box 11 of IPCC Special Report on Global Warming of 1.5°C (Bertoldi *et al.* 2018), with new studies that were published after the literature cut-off date of IPCC. Pathways were grouped into three categories depending on whether their maximum cumulative CO_2 emissions were less than 600, 600–900 or 900–1300 $GtCO_2$, respectively, from 2018 onwards until net-zero CO_2 emissions are reached, or until the end of the century if the net-zero point is not reached before. The estimated temperature outcomes represent estimates of global average surface air temperature (GSAT), most consistent with the impact assessment of the IPCC Fifth Assessment Report. Pathways assume limited action until 2020 and cost-optimal mitigation thereafter. Estimated temperature outcomes are based on the IPCC AR5 method (Meinshausen, Raper and Wigley 2011; Clarke *et al.* 2014).

Box 3.1. The remaining carbon budget as a tool for scenario classification

The IPCC SR1.5 provided an updated assessment of the remaining carbon budget, that is, the total amount of carbon dioxide that can be emitted if global warming is to be kept to a specific level relative to pre-industrial levels (Rogelj *et al.* 2018). Owing to advances and improvements in methods to estimate remaining carbon budgets, the IPCC SR1.5 reported median estimates that were larger than those reported five years earlier by the IPCC Fifth Assessment Report (Stocker *et al.* 2013; IPCC 2014). Despite these larger estimates of the remaining carbon budget by the IPCC, the emission pathways corresponding to the Paris Agreement limits used in the UNEP Emissions Gap Reports did not require a strong adjustment. How can this be the case?

The updates of the remaining carbon budget estimates in the IPCC SR1.5 were based on three main methodological advancements (Rogelj *et al.* 2018; Rogelj *et al.* 2019): (i) accounting for the latest estimates of anthropogenic global warming to date (Allen *et al.* 2018); (ii) a more formal description of the uncertainty in the ratio of global warming projected per cumulative ton of CO_2 (Stocker *et al.* 2013); and (iii) a more precise estimate of the warming due to emissions other than CO_2 at the time of peak warming (Rogelj *et al.* 2018; Huppmann *et al.* 2018a).

However, each of these methodological improvements were to some degree already taken into account in the emission pathways of the UNEP Emissions Gap Reports, which previously used a reduced-complexity climate model set up (Meinshausen *et al.* 2009; Meinshausen, Raper and Wigley 2011; Rogelj *et al.* 2014; Clarke *et al.* 2014). This model set up applied the methodological improvements that formed the basis for updating the IPCC SR1.5 carbon budgets. Specifically, it (i) accounted for recent estimates of warming to date by expressing temperature projections relative to a recent reference period (the 1986–2005 period) (Clarke *et al.* 2014); (ii) had a better coverage of the uncertainty in the ratio of global warming to cumulative CO_2 emissions by using an observationally constrained probabilistic climate model set up (Meinshausen *et al.* 2009); and (iii) used integrated assessment mitigation scenarios with internally consistent evolutions of all GHGs, also at the time of peak warming (Clarke *et al.* 2014). Previous UNEP Emissions Gap Reports were thus based on assumptions regarding temperature projections that were to some degree consistent with the methodological improvements implemented for the SR1.5 remaining carbon budget assessment, explaining why the emission pathways of the UNEP Emissions Gap Reports have not changed so much.

status and progress). Full implementation of the unconditional and conditional NDCs is estimated to reduce global emissions in 2030 by about 4 and 6 $GtCO_2e$, respectively, compared to the **current policy scenario** (table 3.1).

The emissions gap between estimated total global emissions in 2030 under the NDC scenarios and under pathways limiting warming to below 2°C and 1.5°C is illustrated in Figure 3.1. The full implementation of the unconditional NDCs is estimated to result in a gap in 2030 of 15 $GtCO_2e$ (range of 12–18) compared to the below 2°C scenario with a 66 per cent probability that warming stays below 2°C. The emissions gap between unconditional NDCs and below 1.5°C pathways is about 32 $GtCO_2e$ (range of 29–35). Taking into consideration the full implementation of both unconditional and conditional NDCs would reduce this gap by about 3 $GtCO_2e$. The estimates are similar to the gap assessed in the 2018 UNEP Emissions Gap Report. The only change compared to the 2018 report is that the gap between the conditional NDCs and the 2°C scenario is 1 $GtCO_2e$ lower in 2019.

In summary, the updated analysis and review of the progress set against national commitments under the Paris Agreement makes clear that the current pace of national action is insufficient for achieving the Paris Long-term Temperature Goal or even for achieving the emissions reductions implied by the NDC pledges. Increased emissions and lagging action mean that the gap figure for the 2019 report remains very large, and similar to the 2018 report. Translated into climate action, the analysis reconfirms that nations must triple their current efforts, – as reflected in the difference in projected emissions between current policies and conditional NDCs – to limit warming to 2°C and multiply their current efforts by at least five times to align global climate action and emissions with limiting warming close to 1.5°C[7].

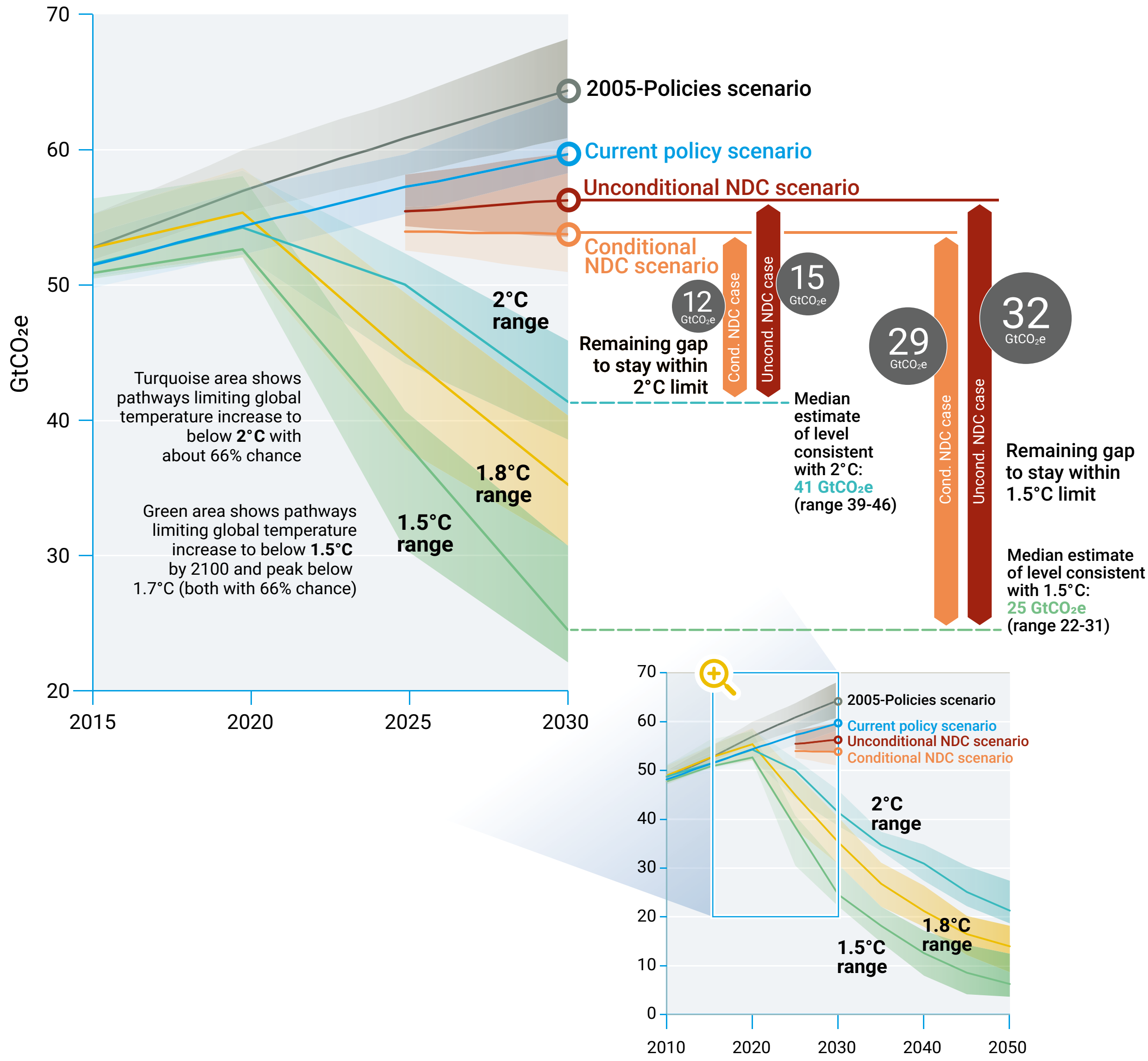
3.4 Implications of the emissions gap

3.4.1 Implications of postponing action

There are several implications of the projected 2030 GHG emissions under the current policies scenario and the

7 This statement is based on the quantitative evidence that conditional NDCs would reduce global GHG emissions relative to projections of current policies by 6 $GtCO_2e$, while the gap between current policies and the 2°C and 1.5°C scenarios amounts to 18 and more than 30 $GtCO_2e$, respectively (see table 3.1). This translates in the efforts that are currently being made to move from current policies to the conditional NDCs having to be multiplied by a factor of three and greater than five for global GHG emissions to be in line with a pathway towards limiting warming to around 2°C and 1.5°C, respectively.

Figure 3.1. Global greenhouse gas emissions under different scenarios and the emissions gap in 2030 (median estimate and 10th to 90th percentile range).



NDC scenarios. The high GHG emissions until 2030 result in a higher reliance on CDR, stronger potential trade-offs with sustainable development goals and lock-in of carbon-intensive infrastructure, which will make subsequent emissions reductions harder and more costly. Section 3.5 of the UNEP Emissions Gap Report 2018 provides an overview of these issues.

The long-term implications and the inadequacy of the current policies and NDCs are also apparent if viewed from a slightly broader perspective and when considering the required global emissions reductions until mid-century. The lower ("zoom-out") part of figure 3.1 indicates how a failure to reduce GHG emissions adequately in the next decade will frustrate and undermine the possibility of achieving the deep emissions reductions that are required by 2050 in order to keep emissions in line with the temperature goal of the Paris Agreement.

The implications of postponing adequate climate action are clear from the past decade of UNEP Emissions Gap Reports. The data underlying the gap assessment indicate that had serious climate action begun in 2010, the emissions reductions required per year to meet the emissions levels in 2030 consistent with the 2°C and 1.5°C scenarios would only have been 0.7 per cent and 3.3 per cent per year on average. However, since this did not happen, the required cuts in emissions are now 2.7 per cent per year from 2020 to year-2030 for the 2°C goal and 7.6 per cent per year on average for the 1.5°C goal.

Box 3.2. Comparing emission estimates across chapters - Part II

Under the current policies scenario used for the assessment of the emissions gap, global GHG emissions in 2018 are estimated to be about 53.2 $GtCO_2e$. This is lower than the 2018 estimate of global GHG emissions of 55.3 $GtCO_2e$ provided in chapter 2 (see also box 2.1). Although this difference is relatively small and well within the uncertainty range surrounding the emissions estimates, it is worth exploring. Both estimates show a similar increase of about 10–15 per cent compared with 2010 levels.

There could be multiple reasons why the median emissions projections of the models are lower than the estimates of the historical emissions database. Some models may be calibrated to an earlier base-year. For example, for 2010, the calibration may be based on other emissions databases (such as IEA or PRIMAP), or the models may not include all emissions sources, or use the latest emissions factors. The six global models used for the current policies scenario of the UNEP Emissions Gap Report show a wide range in global GHG emissions in 2010 of [46;50] $GtCO_2e$, whereas the historical emissions database has an estimate of 50 $GtCO_2e$.

3.4.2 Temperature implications

Emissions until 2030 do not fully determine the warming until the end of the century, but the trend until 2030 can be used to project the warming, assuming this trend would continue until 2100. As in previous UNEP Emissions Gap Reports, this report uses internally consistent long-term emissions projections and relates the GHG emissions in the year 2030 to outcomes over the entire century (Rogelj *et al.* 2016). This approach provides temperature estimates for a wide range of 2030 GHG emissions levels (Jeffery *et al.* 2018) that are consistent with the wider integrated scenario literature.

Assuming that climate action continues consistently throughout the twenty-first century, a continuation of current policies would lead to a global mean temperature rise of 3.5°C by 2100 (range of 3.4–3.9°C, 66 per cent probability). This corresponds roughly to a tripling of the current level of warming as assessed by the IPCC (2018). The current unconditional NDCs as assessed in this report are consistent with limiting warming likely to 3.2°C (range 3.0–3.5°C) by the end of the century (66 per cent probability). These values are reduced by about 0.2°C if both conditional and unconditional NDCs are implemented. It is clear that neither current policies nor NDCs are adequate to limit warming to the temperature limits included in the Paris Agreement.

Temperature implications of the current NDCs can also be looked at from the perspective of the carbon budget that would be emitted until 2030 under the current NDCs. The IPCC SR1.5 reported that for limiting warming to 1.5°C with 50 per cent probability, the remaining carbon budget from 2018 onward amounts to 580 $GtCO_2$. This would be further reduced to 420 $GtCO_2$ for having a 66 per cent probability of success of limiting warming to 1.5°C. Further taking into account reinforcing Earth-system components, such as permafrost thawing, could reduce these estimates by a further 100 $GtCO_2$[8]. Starting from a current level of global CO_2 emissions of 41.6 $GtCO_2$ in 2018 (Le Quéré *et al.* 2018) and assuming a straight trajectory to 2030, the current unconditional NDC scenario implies cumulative emissions of about 510 $GtCO_2$ (range of 495–528 $GtCO_2$) until 2030. Therefore, current unconditional NDCs until 2030 already go beyond the carbon budget limits set for 1.5°C. Together with the knowledge that the current status of policies and measures that are being implemented by countries would lead to even more emissions, this leaves no doubt that the current NDCs are blatantly inadequate to achieve the climate goals of the Paris Agreement.

8 Note that the "below 1.5°C in 2100" scenario category applies a peak carbon budget limit of 600 $GtCO_2$, which in itself is not sufficient to limit warming to 1.5°C with a high likelihood, but it limits peak warming with greater than 66 per cent probability to no more than 1.7°C (see table 3.1). In addition, the "below 1.5°C in 2100" scenario category applies an end-of-century carbon budget limit of 380 $GtCO_2$ to limit warming to 1.5°C with a high likelihood. This reflects the 420 $GtCO_2$ remaining carbon budget for limiting warming to 1.5°C with 66 per cent probability, which is further reduced by specific Earth system feedbacks. A value of about 40 $GtCO_2$ is applied for this correction because the stringency of these scenarios suggest a lower impact of these processes than the 100 $GtCO_2$ that was assessed for warming up to 2°C.

4 Bridging the Gap – Enhancing mitigation ambition and action at G20 level and globally

Lead authors:

Niklas Höhne (NewClimate Institute, Germany), Taryn Fransen (World Resources Institute, USA), Frederic Hans (NewClimate Institute, Germany)

Contributing authors:

Ankit Bhardwaj (Centre for Policy Research, India), Gabriel Blanco (National University of the Center of the Buenos Aires Province, Argentina), Jesse Burton (University of Cape Town, South Africa), Michel den Elzen (PBL Netherlands Environmental Assessment Agency, the Netherlands), Markus Hagemann (NewClimate Institute, Germany), Christopher Henderson (World Resources Institute, USA), Maria Daniela Keesler (National University of the Center of the Buenos Aires Province, Argentina), Jiang Kejun (Energy Research Institute (ERI), National Development and Reform Commission, China), Akihisa Kuriyama (Institute for Global Environmental Strategies (IGES), Japan), Fu Sha (National Centre for ClimateChange Strategy, China), Ranping Song (World Resources Institute, China), Kentaro Tamura (IGES, Japan), Jorge Villarreal (Iniciativa Climática de México, Mexico), William Wills (EOS Estratégia e Sustentabilidade, Brazil).

4.1 Introduction

In the lead-up to the 2019 Climate Action Summit, United Nations Secretary-General António Guterres called on leaders to "announce the plans that they will set next year to reduce greenhouse gas emissions for 2030 and to achieve net zero emissions by 2050" (Farand 2019). The Secretary-General's message echoed the growing popular movement for transformative, ambitious climate action.

The focus on ambition and action is well founded, as illustrated by the gap assessment in Chapter 3. This chapter provides a comprehensive overview of recent ambitious climate actions by national and subnational governments as well as non-state actors, and a detailed overview of policy progress and opportunities for enhanced mitigation ambition for selected G20 members. The objective is to inform the preparation of new and updated nationally determined contributions (NDCs) that countries are requested to submit by 2020. The chapter addresses the following questions:

- How has the global situation changed since the Paris Agreement was adopted and how does this affect opportunities to increase ambition?
- How many and what type of ambitious climate commitments have been adopted by national governments, as well as by cities, states, regions, companies and investors to date?
- Among selected G20 members, what progress has been made recently towards ambitious climate action and what are the key opportunities for additional action?

The primary focus of this chapter is on ambitious climate targets and actions, which are defined as those that unambiguously contribute towards the transformations required to align global greenhouse gas (GHG) emissions pathways with the Paris Agreement goals. Section 4.2 summarizes the global opportunity to enhance ambition and action and provides an overview of the status of ambitious climate mitigation commitments made by G20 members as well as countries and non-state actors globally.

As G20 members account for 78 per cent of global GHG emissions, they largely determine global emission trends and the extent to which the 2030 emissions gap will be closed. This chapter therefore also pays particular attention to G20 members, with section 4.3 focusing on progress and opportunities for enhancing mitigation ambition of nine selected G20 members: Argentina, Brazil, China, the European Union, India, Japan, Mexico, South Africa and the United States of America, which represented around 56 per cent of global GHG emissions in 2017.[1] The selection of the G20 members was based entirely on the availability of expertise in the author team. Supplementing this chapter, annex B provides a detailed overview of the status of ambitious climate mitigation commitments made by G20 members as

1 Using the latest inventory data for all G20 members in the Electronic Data Gathering, Analysis, and Retrieval (EDGAR) (Olivier and Peters 2018) and latest reported national inventory data for each country for LULUCF emissions.

well as countries and non-state actors globally, while annex C provides a detailed update of recent policy developments of the nine selected G20 members, considering ambitious climate actions, as well as actions that are incremental. Both annexes are available online.

4.2 The global opportunity to enhance ambition and action

4.2.1 The scale and type of transformation needed to enhance climate ambition and action are clear

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C (Intergovernmental Panel on Climate Change [IPCC] 2018) concluded that limiting the temperature increase to 1.5°C with no or limited overshoot would mean reducing global CO_2 emissions by about 45 per cent from 2010 levels by 2030 and reaching net zero around 2050. To align with the 2°C limit, global CO_2 emissions would need to decline by about 25 per cent from 2010 levels by 2030 and reach net zero around 2070.

Under the Paris Agreement, countries are invited to submit long-term low GHG emission development strategies by 2020 and are requested to submit updated or new NDCs also by 2020. Considering the update of NDCs in the context of the development of long-term mitigation strategies is an important means to ensure consistency between short-term mitigation policies and targets and long-term goals. The IPCC Special Report on Global Warming of 1.5°C provides clear guidance on the economy-wide and sector transformations that are needed to limit the temperature increase to 1.5°C by the end of the century (see also Chapter 5).

Although the time frame for global emission reductions consistent with the 2°C limit is slightly longer, the major long-term sectoral transformations needed to reach net zero GHG emissions globally are essentially the same and can be summarized under the following headings:

- Full decarbonization of the energy sector, based on renewable energy and electrification across sectors – this includes phasing out coal-fired power plants.
- Decarbonization of the transport sector in parallel with modal shifts to public transportation, cycling and walking.
- Shifts in industry processes towards electricity and zero carbon and substitution of carbon-intensive products.
- Decarbonization of the building sector, including electrification and greater efficiency.
- Enhanced agricultural management as well as demand-side measures such as dietary shifts to more sustainable, plant-based diets and measures to reduce food waste.
- Zero net deforestation and the adoption of policies to conserve and restore land carbon stocks and protect natural ecosystems, aiming for significant net CO_2 uptake in this sector (IPCC 2018; UNEP 2017).

Transformations in these areas will require major shifts in investment patterns and financial flows, as well as several sectoral and economy-wide policy targets. The ambitious climate targets considered in section 4.2.3 are based on these overall areas of transformation and important sub-targets. A full overview is provided in annex B.

4.2.2 Drivers of ambition have evolved since the Paris Agreement

Compared with the run-up to the Paris Agreement in 2015, when countries prepared their intended NDCs, many drivers of climate action have changed, with several options for ambitious climate action becoming less costly, more numerous and better understood. Changes within three main categories in particular could facilitate greater NDC ambition today (UNEP 2018) including climate change. Countries will meet again at the United Nations Framework Convention on Climate Change (UNFCCC). First, technological and economic developments present opportunities to decarbonize the economy, especially the energy sector, at a cost that is lower than ever. Second, the synergies between climate action and economic growth and development objectives, including options for addressing distributional impacts, are better understood. Finally, policy momentum across various levels of government, as well as a surge in climate action commitments by non-state actors, is creating opportunities for countries to enhance the ambition of their NDCs.

The cost of renewable energy is declining more rapidly than was predicted just a few years ago. Renewables are currently the cheapest source of new power generation in most of the world, with the global weighted average purchase or auction price for new utility-scale solar power photovoltaic (PV) systems and utility-scale onshore wind turbines projected to compete with the marginal operating cost of existing coal plants by next year (International Renewable Energy Agency [IRENA] 2019. See also Chapter 6). These trends are increasingly manifesting in a decline in coal plant construction, including the cancellation of planned plants, as well as the early retirement of existing plants (Jewell *et al.* 2019; Smouse *et al.* 2018). Moreover, real-life cost declines are outpacing projections. The 2019 costs of onshore wind and solar PV power are 8 and 13 per cent lower respectively than IRENA predictions from just one year ago in 2018 (IRENA 2019). These cost declines, along with those of battery storage, are opening possibilities for utility-scale solar power.

Although technological progress has been uneven across sectors, with the industry and buildings sectors in particular lagging behind (International Energy Agency [IEA] 2019), the benefits extend beyond power generation. For example, as a result of falling battery costs, predictions forecast that electric vehicles will achieve price parity with internal combustion engine vehicles by the mid-2020s and lead global sales between 2035 and 2040 (Bloomberg NEF 2018).

Aside from advancements in technology, a growing body of research has documented that ambitious climate action, economic growth and sustainable development can go hand-in-hand when well managed. Analysis by the Global Commission on the Economy and Climate estimates that ambitious climate action could generate US$26 trillion in economic benefits between now and 2030 and create 65 million jobs by 2030, while avoiding 700,000 premature deaths from air pollution (The New Climate Economy 2018). Similarly, the IPCC (2018) found that, if managed responsibly, most mitigation options consistent with limiting warming to 1.5°C could have strong synergies with the Sustainable Development Goals (SDGs), especially those related to health, clean energy, cities and communities, responsible consumption and production, and oceans (IPCC 2018. See also chapter 5).

Momentum at all levels of government and parts of the business sector increases the potential to reflect greater ambition in the NDCs. At the subnational level, for example, over 70 large cities housing 425 million people have committed to go carbon-neutral by 2050 or sooner (see table B-1). At the national level, 13 countries have communicated long-term, low GHG emissions development strategies to the UNFCCC (UNFCCC 2019), with many more under development or developed at the national level but not communicated internationally (WRI 2019). At the international level, the Kigali Amendment to the Montreal Protocol outlines phase-down schedules for production and consumption of hydrofluorocarbons (HFCs). Businesses are increasingly moving towards zero emissions, 100 per cent renewables and 100 per cent emission-free transport (see annex B).

Taken together, cost-competitive technologies, potential synergies with development and economic growth, and strong action from the subnational to international levels provide a strong basis for more ambitious NDCs by 2020.

4.2.3 An increasing number of countries and regions are adopting ambitious goals in line with the transformation needed, but the scale and pace are far from sufficient

Several national and subnational governments and non-state actors have embarked on ambitious climate action in different policy areas that can help initiate the transformational change required to meet the long-term goals of the Paris Agreement. Although recent developments send promising signals, the adoption of ambitious climate targets is far from the scale and rate urgently required.

This section presents an overview of the extent to which G20 members, as well as and countries and regions worldwide, have committed or are in the process of committing to ambitious climate targets and actions. These targets and actions are defined as unambiguously supporting a move towards the major long-term sectoral transformations required to meet the well-below 2°C and 1.5°C temperature limits of the Paris Agreement, as outlined in section 4.2.1. Expanding on the key types of policy targets and actions that would support such major transformations, this section provides an overview of the status of commitments to the following ambitious climate targets organized in six main categories (table 4.1). A detailed overview of commitments made as of October 2019 for the above targets by individual countries, regions, businesses and investors is provided in annex B.

It should be noted that the overview of targets and commitments provided in this section and in the annex is not exhaustive. Rather, it builds on a broad range of literature to identify ambitious climate action in the different categories (Kuramochi *et al.* 2018), but given the scope of existing policies and rapid changes in policymaking, the overview may not be completely up-to-date. The list of targets is also incomplete. Notably, it is beyond the scope of this chapter to provide an overview of ambitious climate targets and commitments for agriculture. Finally, no attempt has been made to assess whether individual commitments are aligned with global least cost-effective emissions pathways to the 1.5°C or 2°C targets. Commitments differ in various respects, including the extent to which they are legally binding, the percentages and target years adopted, whether they refer to GHG or CO_2 emissions and whether they are net targets.[2] These specifications are important for a detailed picture of the individual commitments and are provided in annex B.

Ambitious climate targets and actions adopted by countries and regions to date are prime examples of climate action that others can follow. Dynamics to adopt legally binding targets differ between target categories and sectors. Most of the recent increase in national and subnational commitments is related to the adoption of economy-wide zero emission targets by 2050 or sooner (see figure 4.1), 100 per cent renewable energy or electricity targets (see figure 4.2) and a 100 per cent share of new zero-emission motorbikes, cars and/or buses (see figure 4.3). To date, countries, regions and subnational actors have mostly refrained from adopting legally binding ambitious targets in other sectors, such as industry, buildings or heavy transport, except for a few first movers.

Overall, the number of countries and states that are committing to zero emission targets is increasing fast, though it is still far from the scale and pace required, as

2 For this reason, reference is made to 'zero emissions targets' and the reader is referred to annex B, table B-1 for further detail.

Table 4.1. Overview of the number of ambitious climate actions and targets by countries, regions, cities and businesses

Overarching economy-wide climate actions	Countries	Regions	Cities	Businesses
Achieve zero emissions by year x	**71**	**11**	**>100**	**>500**
Implement ambitious comprehensive CO_2 pricing in all sectors by year x	(32 but not comprehensive)	(25 but not comprehensive)		
Phase out all fossil-fuel subsidies by year x	(Decision by G20 in 2009 yet to be implemented)			
Make all finance flows consistent with the Paris Agreement goals by year x	(>1 initial steps)			**>10**
Electricity production				
Reach 100 per cent renewable electricity or 100 per cent carbon-free electricity by year x	**53**	**33**	**>120**	**>180**
Phase out coal-fired power plants by year x with just a transition plan	**13**	**16**	**6**	**28**
Stop financing and insuring coal-fired power plants elsewhere as of year x	**-**			**>20**
Other energy industry				
Stop new fossil-fuel explorations and production as of year x	**6**			**>5**
Commit to zero fugitive emissions target for year x	(32 support zero routine flaring)			**>14**
Industry				
Ensure all new installations are low- carbon/ zero-emission and maximize material efficiency as of year x	-			**>3**
Implement ambitious carbon pricing for industry by year x	**1**	-		
Transport				
Shift to x per cent public transport by year x	**4**	-	**>5**	
Shift to 100 per cent share of new zero-emission motorbikes, cars and/or buses as of year x	**21**	**5**	**>52**	**>50**
Shift to 100 per cent carbon-free heavy goods transport and ships as of year x	-	-		**>10**
Shift to 100 per cent carbon-free aviation as of year x	(1 short haul)	(1 domestic)		-
Buildings				
Shift to 100 per cent (near-) zero energy buildings for new buildings as of year x	**3**	**7**	**>23**	**>23**
Fully decarbonize the building sector by year x	**1**	**6**	**>23**	**>23**
Phase out fossil fuels (for example, gas) for residential heating by year x	**1**	-	**>3**	
Increase the rate of zero-energy renovations to x per cent per year	(1 public building)	-		
Agriculture and forestry				
Zero net deforestation by year x	**>67**	**21**		**>12**

Note: Greyed cells indicate that no (relevant) data is available. For full details, see annex B. Given the scope of existing policies and rapid change in policymaking, the table makes no claim to be exhaustive.

Figure 4.1. Overview of ambitious overarching economy-wide climate actions and targets by G20 members, countries and regions (for full details, see annex B)

OVERARCHING

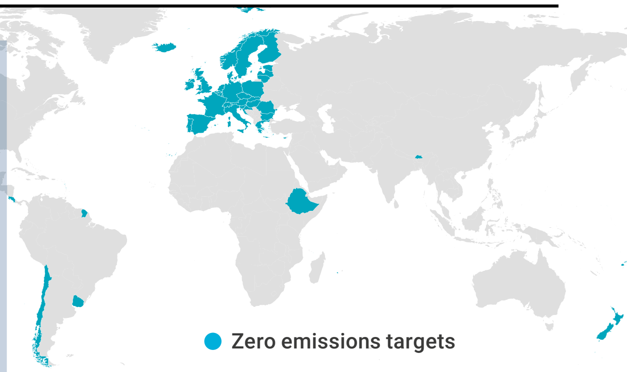
An increasing number of countries and regions are commiting to zero carbon dioxide or greenhouse gas emission targets, but not at the scale and pace required. Other economy-wide climate action such as completely phasing out fossil fuel subsidies, introducing comprehensive and ambitious carbon pricing and making all finance flows consistent with the Paris Agreement remains inadequate.

Target categories	G20 countries	Country level	Regional level
Zero emissions by year x	**2 G20** members (France, UK) have passed legislation **3 G20** members (EU and Germany and Italy as part of EU[1]) currently in process of passing legislation **15 G20** members have no binding (net-) zero-emission targets	71 countries	11 regions
Ambitious comprehensive CO_2 pricing in all sectors by year x [2]	**No G20** member has implemented ambitious comprehensive CO_2 pricing in all sectors, but 9 G20 members have implemented carbon pricing as ETS or carbon tax with partial coverage and/or lower CO_2 prices (as at August 2019)	No country ✖	No regions ✖
Phase out all fossil fuel subsidies by year x	**No G20** member has existing reform plans to fully phase out all fossil fuel subsidies, but the G20 took a decision in 2009 to gradually phase out fossil fuel subsides with an annual peer-review among G20 members	No country ✖	No regions ✖
Make all finance flows consistent with the Paris Agreement goals by year x *	**No G20** member has made all finance flows fully aligned with the Paris Agreement goals, but the UK has published a Green Finance Strategy in 2019 as an example of intermediate action	No country ✖	No regions ✖

* Non-state actor example

10 Multilateral Development Banks (MDBs) are currently working towards aligning their financing activities with the Paris Agreement goals. The MDBs will develop relevant methods and tools with the objective of presenting a joint Paris alignment approach and individual MDB progress towards alignment at COP 25 in 2019.

More information:
http://pubdocs.worldbank.org/en/784141543806348331/Joint-Declaration-MDBs-Alignment-Approach-to-Paris-Agreement-COP24-Final.pdf



The zero emissions targets include legally binding targets, legally binding targets that are currently under consideration, and non-legally binding targets.

Note: [1] Italy is not currently pursuing a process to pass national legislation on a zero-emissions target, but will be covered under the European Union target, if adopted.
[2] The Report of the High-Level Commission on Carbon Prices of 2018 recommends an average economy-wide price of at least US$40–80/t$CO_2$ by 2020 and US$50–100/t$CO_2$ by 2030 to close the emissions gap in order to meet the 2°C target (High-Level Commission on Carbon Prices 2017; UNEP 2018). For this reason, economy-wide carbon prices would need to be higher in the respective years to close the emissions gap in order to meet the Paris Agreement's temperature goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels".

illustrated in figure 4.1. To date, 71 countries and 11 regions, accounting for about 15 per cent of global GHG emissions in total[3], have long-term objectives to achieve net-zero emissions, differing in scope, timing and the degree to which they are legally binding. Before the 2019 Climate Action Summit, the number of countries and states committing to zero emission targets was 21 and 8 respectively. Five G20 members have committed to long-term net-zero emissions targets, of which three (the European Union, and Germany and Italy, as part of the European Union) are currently in the process of passing legislation, with two G20 members (France and the United Kingdom) having recently passed legislation. The remaining 15 G20 members have not yet committed to net-zero emission targets.

Economy-wide climate action remains extremely limited in other areas, such as a complete phase-out of fossil-fuel subsidies, comprehensive and ambitious carbon pricing and making finance flows consistent with the Paris Agreement. In 2009, the G20 members adopted a decision to gradually phase out fossil-fuel subsidies, though no country has yet committed to fully phasing these out by a specific year. Similarly, while carbon pricing is expanding, no country has established a comprehensive and ambitious system for this. At present, carbon tax and emissions trading system initiatives at the national and regional levels represent about 20 per cent of global GHG emissions (World Bank 2019). However, only 10 per cent of global emissions from fossil fuels are estimated to be priced at a level consistent with limiting global warming to 2°C (UNEP 2018). Furthermore, no country has explicitly committed to making their finance flows consistent with the Paris Agreement, though several multilateral development banks are currently working towards aligning their financing activities with the Paris Agreement goals (World Bank 2018).

In terms of electricity production (figure 4.2), 53 countries have committed or are in the process of committing to a 100 per cent renewables target. The number of countries increased from 10 countries before the 2019 Climate Action Summit. However, these countries accounted for less than 1 per cent of global CO_2 emissions from electricity generation in 2016.[4] Five G20 members have also committed to long-term net-zero emissions targets and, in turn, to fully decarbonizing their electricity sectors. In addition, 33 states and regions, including California (by 2045), and accounting for around 1 per cent of global from electricity generation[5], as well as an increasing number of cities and companies, have committed to 100 per cent renewable electricity targets.

The 13 countries that have currently committed or are in the process of committing to a full phase-out of coal accounted for around 5 per cent of global CO_2 emissions from coal-based electricity generation in 2016.[6] Five G20 members are among these 13 countries: Canada, France and Italy have already passed legislation, while Germany and the United Kingdom are in the process of passing legislation. A few non-state actors show high ambition, including 22 banks that have stopped direct financing to new coal mine projects and 23 banks that have stopped direct financing to new coal plant projects worldwide.

An increasing number of countries, states and cities are pledging to phase out combustion engines for vehicles and initiate substantial modal shifts towards public transport, though to date, no such commitments have been made for aviation, shipping and freight transport (figure 4.3). However, there are several interesting examples of non-state actors committing to ambitious climate action for these transport modes, as the figure shows. For example, Norway is aiming to make domestic flights carbon-free by 2040 and several companies are working on zero-emission tanker and port infrastructure.

At present, countries and states are largely refraining from ambitious target-setting in the heavy and extractive industry sector (see annex B). Six countries, including one G20 member (France), are currently committed to stopping new fossil-fuel explorations and production. In addition, a few European (re-) insurance companies have recently implemented policies to stop investments, insurance cover and underwriting for new and ongoing fossil-fuel projects. No countries have committed to zero fugitive emissions targets or to ensuring that all new installations are low-carbon or zero emissions and maximize material efficiency. Only Sweden has set a target for ambitious carbon pricing in the industry sector. Some major steel and cement producers have recently pledged to zero emissions by 2050 for their operations. Such commitments and technology road maps could serve as a starting point to define targets in the entire industry sector, following the frontrunners.

The buildings sector shows only scattered policy action at high levels of mitigation ambition, mainly centred on policymaking in the European Union (see annex B). In addition, six states and more than 23 cities have recently committed to zero targets for the buildings sector as part of the World Green Building Council's Net Zero Carbon Buildings Commitment by 2050. In general, there is a lack of targets for phasing out fossil fuels in heating, zero emissions in the sector and deep retrofits of existing buildings.

3 The zero emission targets considered cover legally binding, legally binding but under consideration, and non-legally binding pledges and participation in respective alliances. The share of these countries has been calculated on latest available EDGAR data and FAO data for LULUCF emissions (FAOSTAT 2018; Olivier and Peters 2018). For regions, their self-reported were used.

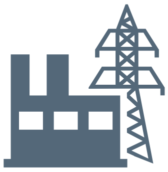
4 The share of these countries has been calculated on emissions data for CO_2 emission from electricity generation provided by IEA's CO_2 emission form fuel combustion dataset (IEA 2018).

5 The share of these regions has been calculated based on self-reported values.

6 The share of these countries has been calculated on emissions data for CO_2 emission from coal-based electricity generation provided by IEA's CO_2 emission from fuel combustion dataset (IEA 2018).

Figure 4.2. Overview of climate actions and targets in the electricity generation sector by G20 members, countries and regions (for full details, see annex B)

ELECTRICITY PRODUCTION



Several countries and regions have communicated 100% renewable electricity targets to fully decarbonize their electricity supply sector. Several are phasing out coal-fired power plants, but these are predominantly countries with already low shares of coal.

Target categories	G20 countries	Country level	Regional level
100% renewable electricity or 100% carbon free electricity by year x	**No G20** member has committed to a 100% renewable electricity or 100% carbon-free electricity target, but some regions within G20 members such as California (by 2045) or Fukushima (by 2040) have done so.	53 countries	33 regions
Phase out coal-fired power plants by year x with just transition plan	**3 G20** members (Canada, France, Italy) have passed legislation **2 G20** members (Germany, UK) currently in process of passing legislation **15 G20** members have no binding phase-out plan, but some have initiated action to limit coal use (e.g. China and India)	13 countries	16 regions
Stop financing and insuring of coal-fired power plants elsewhere as of year x	**No G20** member with legally binding legislation to fully stop financing and insuring of coal-fired power plants elsewhere	No country ✖	No regions ✖

* Non-state actor example

22 banks have stopped providing direct financing to new coal mine projects worldwide and 23 banks have stopped directly financing new coal plant projects worldwide as at August 2019. Some more banks and (national) development banks are currently in the process of making such commitments.

More information: https://www.banktrack.org/page/list_of_banks_which_have_ended_direct_finance_for_new_coal_minesplants#_

Figure 4.3. Overview of ambitious overarching economy-wide climate actions and targets by G20 members, countries and regions (for full details, see annex B)

TRANSPORT

While an increasing number of countries, regions, and cities pledge to phase out combustion engines and initiate substantial modal shifts towards public transport, no such commitments have been made for aviation, shipping, and freight transport to date.

Target categories	G20 countries	Country level	Regional level
100% share of new zero-emission motorbikes, cars and/or buses as of year x	**5 G20** members (Canada, France, Japan, Mexico, UK) have announced target **2 G20** members (India, Indonesia) have announced target but confirmation is pending **13 G20** members have not announced target for 100% new zero-emission motorbikes, cars and/or buses	21 countries	5 regions
Shift to x% public transport by year x *	**3 G20** members (China, India, Indonesia) with distinct modal shift targets No conclusion possible for all other G20 members	4 countries	No regions
100% carbon-free heavy transport and ships as of year x **	**No G20** member with legally binding target for 100% carbon-free heavy transport and ships	No country	No regions
100% carbon-free aviation as of year x ***	**No G20** member with legally binding target for 100% carbon free aviation	No country	No regions

* Non-state actor example

52 cities have targets for 100% electric cars and/or busses, e.g. Shenzen has already electrified all busses and taxis, Paris aims for 100% fossil free cars and busses in the city by 2025. 49 companies have pledged to accelerate their transition to electric vehicles under the EV100 initiative.

More information: https://www.theguardian.com/cities/2018/dec/12/silence-shenzhen-world-first-electric-bus-fleet
https://www.theclimategroup.org/ev100-members

** Non-state actor example

Several companies have recently announced their plans to develop zero emission container ships, for example by entirely powering tankers by hydrogen produced from renewable energy sources. For example, Maersk, the world's largest container shipping company, has committed to making carbon-neutral vessels commercially viable by 2030 by using energy sources such as biofuels and will cut its net carbon emissions to zero by 2050.

More information: https://www.maersk.com/news/articles/2019/06/26/towards-a-zero-carbon-future

*** Non-state actor example

Norway and Scotland both aim to decarbonize their domestic aviation sector by 2040. Avinor, Norway's airport operator, has announced a switch to electric air transport for all domestic flights as well as those to neighbouring Scandinavian capitals. Scotland plans to becoming the world's first net-zero aviation region by 2040, with trials of low or zero emission flights to begin in 2021.

More information: http://www.airport-business.com/2019/06/avinor-domestic-air-transport-norway-electrified-2040/
https://www.bbc.com/news/uk-scotland-scotland-politics-49556793?utm_source=CP+Daily&utm_campaign=66d62ab006-CPdaily03092019&utm_medium=email&utm_term=0_a9d8834f72-66d62ab006-110247033

Many countries, including most G20 members, have committed to zero net deforestation targets in the last decades (see annex B), though these commitments are often not supported by action on the ground. Countries, states, business and investors urgently need to ensure that they implement their various commitments, including those under the New York Declaration on Forests, the World Wide Fund for Nature's (WWF) call for zero net deforestation by 2020 and the Soft Commodities Compact.

To summarize, G20 members urgently need to step up their commitments on ambitious climate action. As this section shows, there are many opportunities to adopt economy-wide and sector-specific climate action targets as called for by the United Nations Climate Summit in September 2019, and to reflect such targets in the upcoming ambition-raising cycle and submission of long-term strategies under the Paris Agreement by 2020.

The G20 members could follow other national and subnational frontrunners driving ambitious climate action in several areas. Only a few G20 members, including France and the United Kingdom, have recently adopted legally binding legislation in multiple sectors, such as energy, transport and buildings, in addition to an economy-wide net-zero emissions target by 2050. The national and subnational actors already committed to ambitious climate action should inform policymakers in G20 member nations to accelerate their target-setting in different sectors of the economy. This is particularly true for sectors that are difficult to decarbonize, where subnational actors are showing promising frontrunner action aimed at long-term decarbonization in line with the Paris Agreement.

4.3 Opportunities to enhance ambition in selected G20 members

This section provides a summary of country-specific opportunities for enhanced climate ambition and action of nine selected G20 members: Argentina, Brazil, China, the European Union, India, Japan, Mexico, South Africa and the United States of America. The selection of G20 members is based entirely on the availability of data and expertise of the author team. The country-specific opportunities represent possible next steps in the policymaking process based on the current situation. The list of actions is not exhaustive and other actions, including those identified in the previous section and in annex B, would also need to be implemented to achieve global emission reductions at the scale required to maintain progress towards achieving the targets set out in the Paris Agreement.

Several steps were followed to identify the opportunities. First, an overview of the main policies affecting GHG emissions was generated for each country. Annex C, available online, provides a detailed update for each G20 member covered in this chapter. To the extent possible,

Table 4.2. Selected current opportunities to enhance ambition in seven G20 members in line with ambitious climate actions and targets as identified in annex B. For details, see annex C.

Argentina
• Refrain from extracting new, alternative fossil-fuel resources • Reallocate fossil-fuel subsidies to support distributed renewable electricity-generation • Shift towards widespread use of public transport in large metropolitan areas • Redirect subsidies granted to companies for the extraction of alternative fossil fuels to building-sector measures
Brazil
• Commit to the full decarbonization of the energy supply by 2050 • Develop a national strategy for ambitious electric vehicle (EV) uptake aimed at complementing biofuels and at 100 per cent CO_2-free new vehicles • Promote the 'urban agenda' by increasing the use of public transport and other low-carbon alternatives
China
• Ban all new coal-fired power plants • Continue governmental support for renewables, taking into account cost reductions and accelerate development towards a 100 per cent carbon-free electricity system • Further support the shift towards public modes of transport • Support the uptake of electric mobility, aiming at 100 per cent CO_2-free new vehicles • Promote near-zero emission building development and integrate it into Government planning

European Union[8]

- Adopt an EU regulation to refrain from investment in fossil-fuel infrastructure, including new natural gas pipelines
- Define a clear endpoint for the EU emissions trading system (ETS) in the form of a cap that must lead to zero emissions
- Adjust the framework and policies to enable 100-per cent carbon-free electricity supply by between 2040 and 2050
- Step up efforts to phase out coal-fired plants
- Define a strategy for zero-emission industrial processes
- Reform the EU ETS to more effectively reduce emissions in industrial applications
- Ban the sale of Internal Combustion Engine (ICE) cars and buses and/or set targets to move towards 100-per cent of new car and bus sales being zero-carbon vehicles in the coming decades
- Shift towards increased use of public transport in line with the most ambitious Member States
- Increase the renovation rate for intensive retrofits of existing buildings

India

- Plan the transition from coal-fired power plants
- Develop an economy-wide green industrialization strategy towards zero-emission technologies
- Expand mass public transit systems
- Develop domestic electric vehicle targets working towards 100 per cent new sales of zero-emission cars

Japan

- Develop a strategic energy plan that includes halting the construction of new freely emitting coal-fired power plants, as well as a phase-out schedule of existing plants and a 100 per cent carbon-free electricity supply
- Increase the current level of carbon pricing with high priority given to the energy and building sector
- Develop a plan to phase out the use of fossil fuels through promoting passenger cars that use electricity from renewable energy
- Implement a road map as part of efforts towards net-zero energy buildings and net-zero energy houses

Mexico

- Increase the share of clean energy power generation in the electricity mix up to 48 per cent by 2027, 53 per cent by 2030 and 60 per cent by 2050, which will require the reactivation of the electricity market and the expansion of the interconnection grid infrastructure
- Phase out coal-based power generation by 2030
- Expand sustainable mass public transport and non-motorized options, as well as a transportation demand management policy to reduce the motorization rate
- Reach the 0 per cent deforestation target by 2030

South Africa

- Halt new proposed coal-fired power plants contained in the draft Integrated Resource Plan (IRP) for electricity
- Commit to a 2040 target for the phase-out of coal in the power sector
- Develop a climate-compatible industrial development plan for the long-term decarbonization of industry
- Accelerate the shift of freight transport from road to rail and to low-carbon road transportation such as hydrogen and electricity-powered options
- Continue to tighten standards to reach zero-emission buildings by 2030 and enforce existing and future standards

USA

- Introduce regulations on power plants, clean energy standards and carbon pricing to achieve an electricity supply that is 100 per cent carbon-free
- Implement carbon pricing on industrial emissions
- Strengthen vehicle and fuel economy standards to be in line with zero emissions for new cars in 2030
- Implement clean building standards so that all new buildings are 100 per cent electrified by 2030

8 As policies in the European Union are already quite advanced, many of the opportunities to enhance ambition are evidently ambitious.

changes in policies since the adoption of the Paris Agreement that are expected to be associated with the highest emissions impacts are highlighted in annex C, supported by quantitative estimates from the literature reviewed to give a sense of the magnitude of the actions. No attempt has been made to provide mitigation potential per G20 member, as it is difficult to provide values that are comparable across members.

Using the current policy situation in each country as a starting point, political areas that would be obvious to pursue for development of the next steps were identified. For example, consideration was given to whether policy proposals had already been put forward by relevant actors. Subsequently, the opportunities were checked against the major actions that must be taken to put the world on a path that is compatible with the Paris Agreement long-term temperature goal as summarized in section 4.2.3 and listed in annex B. Finally, the opportunities were cross-checked with several country experts.

Table 4.2 provides an overview of selected opportunities for enhancing mitigation ambition identified for the seven G20 members considered in this publication. The selection is based on expert judgements regarding the extent to which these opportunities are in line with ambitious climate actions and targets as defined and outlined in section 2.3. The country sections provide additional examples of country-specific opportunities.

We find that the G20 members have ample opportunity to increase the ambition of their climate and energy policies, considering where they are today. There are some common features. For almost all analysed countries, a logical next step would be to plan for a 100 per cent emission-free electricity sector and an associated phase-out of coal-fired power plants. All the analysed countries could also work on incentivizing modal shift in transport, supporting electric vehicles or working towards zero-emission buildings. In other areas, the logical next steps are very country-specific, for example, prohibiting new fossil fuel extractions, eliminating fossil fuel subsidies, enhancing action in industry or taking action to reduce deforestation.

5 Transformations towards zero-carbon development pathways

Lead authors:

Nebojsa Nakićenović (International Institute for Applied Systems Analysis and Vienna University of Technology), Charlie Wilson (Tyndall Centre for Climate Change Research, UK)

Contributing authors:

Bill Colglazier (American Association for Advancement of Science), Owen Gaffney (Potsdam Institute for Climate Impact Research, Germany), Dirk Messner (United Nations University), Narasimha Rao (Yale School of Forestry & Environmental Studies, USA), Caroline Zimm (International Institute for Applied Systems Analysis, Austria)

5.1 The great transformation towards net zero greenhouse gas emissions

The previous chapters and the underlying studies of development pathways aligned with the goals of the Paris Agreement indicate alarming inconsistencies between current nationally determined contributions (NDCs) and the long-term goal of reaching net zero emissions by mid-century.

Closing the emissions gap in 2030 and reaching net zero greenhouse gas (GHG) emissions by 2050 will require unprecedented efforts to transform our societies, economies, infrastructures and governance institutions. By necessity, this will require profound change in how energy, food and other material-intensive services are supplied. These systems of provision are entwined with the preferences, actions and demands of people as consumers, citizens and communities. Deep-rooted shifts in values, norms, consumer culture and underlying worldviews are inescapably part of the necessary sustainability transformation.

Such transformations are disruptive and cannot be achieved through an accumulation of incremental and gradual improvements, as Schumpeter indicates in his vivid example “add as many mail-coaches as you please, you will never get a railroad by so doing” (Schumpeter 1935).

Past and current mitigation efforts have been insufficient to slow the global growth of emissions. Chapter 2 showed that global GHG emissions increased by 2 per cent in 2018, which is almost exactly aligned with the long-term exponential growth rate since the beginning of the Industrial Revolution. For many decades, science has made it clear that stabilizing temperatures at any level requires net zero emissions, as the global mean temperature is in the first approximation proportional to cumulative emissions (see chapter 3).

Countries are exceedingly late for achieving pathways to close the emissions gap, with most policies and measures so far having been incremental and gradual. As a result, deep transformations are now needed to peak global emissions immediately and commence the rapid decline towards net zero emissions by 2050. This has been termed the ‘carbon law’ (Rockström *et al.* 2017) for halving emissions every decade, starting with a 50 per cent decline by 2030 (Intergovernmental Panel on Climate Change [IPCC] 2018).

Closing the gap in this way could, with proper policy design, also enhance the United Nations 2030 Agenda with its 17 Sustainable Development Goals (SDGs), which provides a holistic vision of a sustainable future for all humanity within planetary boundaries, and thus acts as a new social contract for the world.

5.2. Multiple co-benefits of closing the emissions gap for sustainable development

There are thousands of pathways in the literature reviewed that show which strategies, policies and measures would enable fundamental transformations towards complete decarbonization. Constructing alternative pathways is an important way to understand inherent complexities and uncertainties of transformations and to develop robust strategies to navigate them. Multiple pathways could therefore be taken to achieve global decarbonization across spatial and temporal scales.

Pathways can be generated by narrative storytelling, model-based quantification or a combination of both. Integrated modelling is particularly useful for characterizing and quantifying interlinkages between options for meeting SDGs (IPCC 2018; Nakićenović *et al.* 2000; Riahi *et al.* 2017; The World in 2050 [TWI2050] 2018; TWI2050 2019; van Vuuren *et al.* 2017).

The Intergovernmental Panel on Climate Change (IPCC) recently synthesized evidence on the sustainable development impacts of pathways which limit warming to 1.5°C (Rogelj *et al.* 2018). Figure 5.1 distinguishes interactions between SDGs and three sectoral climate change mitigation strategies: (a) energy supply (e.g. biomass and non-biomass renewables, carbon capture and storage with bioenergy or fossil fuels); (b) energy demand (e.g. fuel switching and efficiency in transport, industry, and buildings); and (c) land use (e.g. sustainable diets and reduced food waste, soil sequestration, livestock and manure management, reduced deforestation).

Despite remaining uncertainty about the magnitude and likelihood of interactions in some areas, figure 5.1 provides two important insights. First, there are multiple benefits from achieving climate change goals for other SDGs, with these synergies being more pronounced than trade-offs, especially if implementation is holistic and concurrent (McCollum *et al.* 2018). Second, energy demand-related mitigation strategies are most consistently and strongly associated with broader sustainability benefits. The World in 2050 (TWI2050) reports demonstrate in more detail the synergies between achieving deep decarbonization and SDGs in unison (Sachs *et al.* 2019; TWI2050 2018; TWI2050 2019).

The basic strategies for closing the emissions gap are clear. In the case of energy supply, a rapid 'exponential' transformation is required towards zero-emission energy resources, particularly renewables (Global Energy Assessment [GEA] 2012; Rockström *et al.* 2017). In the case of energy demand, a rapid shift is required towards more energy and materially-efficient services that raise or maintain living standards (Grubler *et al.* 2018) (See also chapter 6 and chapter 7). In terms of land, sustainable agriculture and the 'return' of land to nature are important measures that can also result in net negative emissions.

In all cases, advanced technologies and sustainable behaviours are essential for delivering the transformational change required. The digital revolution could become an important enabler of this transformation if it proves amenable to 'social steering' towards decarbonization (TWI2050 2019).

The remainder of this chapter explores six exemplary entry points for closing the emissions gap through transformational change. These entry points are derived from the six major transformations developed in TWI2050 (2018): (a) air pollution, air quality, health; (b) urbanization; (c) governance, education, employment; (d) digitalization; (e) energy- and material-efficient services for raising living standards; (f) land use, food security, bioenergy.

5.3. Entry points for achieving SDGs with climate co-benefits

5.3.1 Air pollution, air quality, health

Indoor air pollution is responsible for around 4 million premature deaths each year, with outdoor air pollution accounting for a similar number according to the World Health Organization (WHO) (2019). Clean cooking and universal access to electricity improves health and also reduces GHG emissions if traditional fuels are replaced by renewables, electricity, liquefied petroleum gas (LPG) or natural gas (see chapter 6).

Fossil fuel-related emissions account for two thirds of the excess mortality rate attributable to outdoor air pollution. A global fossil fuel phase-out could avoid over 3 million premature deaths each year from outdoor air pollution, or well over 5 million premature deaths per year if other anthropogenic GHGs, including non-fossil emissions from agriculture and industry, are also controlled (Lelieveld *et al.* 2019).

Transformational pathways show huge synergies between eliminating air pollution and limiting climate change, as well as improving energy security. One study found that the annual policy costs of achieving these three energy-related challenges together would be about 40 per cent lower than the sum of the policy costs for each challenge pursued independently (GEA 2012; McCollum *et al.* 2011).

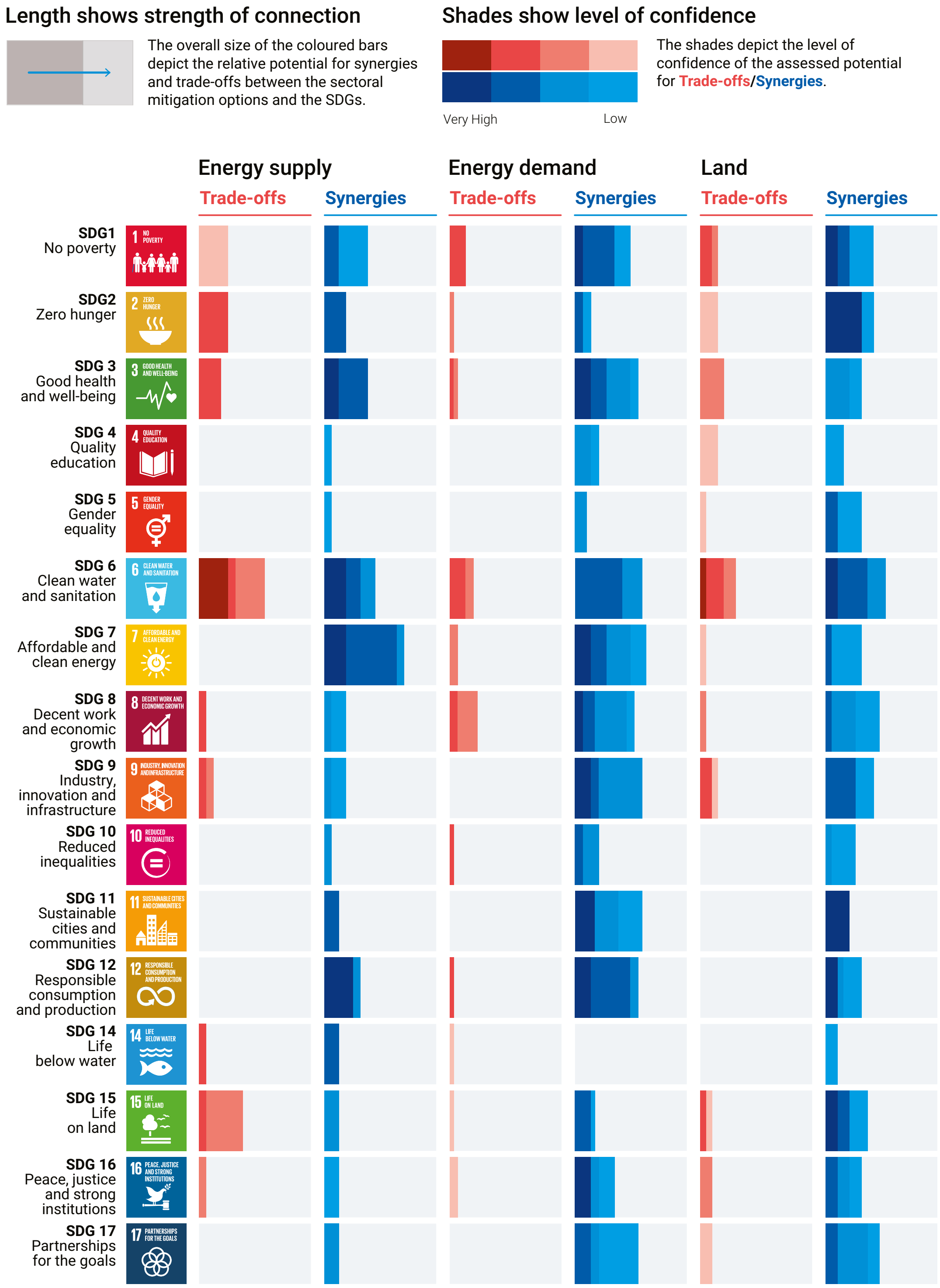
However, policy has to be done right as there are also significant trade-offs. Reducing air pollution from end-of-pipe particulate matter, sulfur and nitrous oxides can increase CO_2 emissions. Small particles and sulfur aerosols also mask anthropogenic temperature rise. Removing all pollution particles could result in an increase of warming by around 0.7°C globally, reaching around 2°C regionally over North America and North-East Asia, according to one estimate (Lelieveld *et al.* 2019). However, a reduction in tropospheric ozone and methane will significantly moderate this rise by around 0.35°C.

5.3.2. Urbanization and settlements

Urban areas are currently home to around 55 per cent of the world's population and 70 per cent of global economic output, though these figures are projected to grow to 70 per cent and up to 85 per cent respectively by 2050, particularly in small to medium-sized cities in the developing world (United Nations, Department of Economic and Social Affairs, Population Division 2018). Cities are hotspots of the global carbon cycle, with considerable fossil fuel and cement-related emissions from the provision (9.2 $GtCO_2e$) and use (9.6 $GtCO_2e$) of urban infrastructure equivalent to around half of current GHG emissions (Creutzig *et al.* 2015). What happens in existing and emerging cities, towns and municipal regions will therefore determine the prospects for sustainable development and closing the emissions gap.

Many rapidly growing urban areas are following the least sustainable model of all: urban sprawl (Grubler *et al.* 2012; Seto *et al.* 2014). Sustainable transformation is needed across all settlements, not merely in mega-conurbations, such as the Tokyo-Osaka corridor, Pearl River Delta or the Boston-Washington corridor. Many cities lack the basic urban infrastructure needed for economic productivity,

Figure 5.1. Potential synergies and trade-offs between the sectoral climate change mitigation options and the SDGs



Note: The strength of positive connections (synergies) and negative connections (trade-offs) across all individual options within a sector are aggregated into sectoral potentials for the whole mitigation portfolio. The (white) areas outside the bars, which indicate no interactions, have low confidence due to the uncertainty and limited number of studies exploring indirect effects. The bars denote the strength of the connection and do not consider the strength of the impact on the SDGs.

Source: Figure SPM4 in IPCC (2018)

social inclusion and the promise of basic services, such as sanitation, electricity, clean heating and cooking fuels, education, mobility, security and health care. Informal cities and slums account for a quarter of the urban population.

The transformation to sustainable cities and communities requires an integrated set of actions in urban areas around the world. Transport, buildings and industry are the key sources of energy demand and emissions within city boundaries. Certain characteristics of urban transformation are likely to be shared widely.

First, more compact urban form tends to reduce energy consumption and increase opportunities for more efficient district heating and cooling systems (Lucon 2014), transportation infrastructure and energy supply networks, and integrated management across different vectors (mobility, electricity, gas, heat).

Second, low-carbon infrastructure, including emissions-free electricity, public transportation, broadband connectivity and efficient road networks, is essential for delivering high-quality, affordable and universally accessible public services from health care and education to security and utilities (power, water, connectivity).

Third, short journeys account for two thirds of transport emissions in urban areas and could be replaced by active modes (Preston *et al.* 2013). Electrification of the vehicle fleet alongside mass transit and micromobility can replace diesel and petrol cars, making cities more liveable with lower pollution levels.

These examples of urban transformations demonstrate that there are many opportunities for integrating climate protection with initiatives to improve human well-being.

5.3.3. Governance, equity and social mobilization for change

Governance for sustainable development needs to build alliances for change, overcome vested interests, invest in new governance capacities, create visions of attractive futures, ensure justice and promote equity, and adopt a range of economic policy instruments to steer the economy and society towards the SDGs (TWI2050 2018). Transformative governance includes three critical elements.

First, economic instruments and political innovations are the tools or means of government. Road maps linking means to desired ends help create clear and stable expectations for the private sector and citizens alike, and therefore serve as coordination mechanisms within government to leverage systemic changes.

Second, the legitimacy of sustainable transformation depends on equity, justice and fairness in the distribution of costs and benefits at an individual, sectoral or regional level (Sachs *et al.* 2019). A particular challenge for transformative governance is how to respond to disruptive changes in technologies, economic sectors and labour markets (TWI2050 2019). Disruption creates uncertainties, instabilities and losers as well as winners, who – if organized and powerful – can act as strong barriers to change. In other cases, safety nets are needed to manage adverse distributional effects until the transformation towards sustainability can be achieved for all.

Third, new constellations of actors, partnerships and opportunities for citizens, cities, businesses and science are needed to drive proactive change and overcome inertias and path dependencies in incumbent systems. Large-scale transformation depends on social movements to build and reflect widespread public acceptance. This, in turn, depends on compelling visions of the multiple benefits of sustainable lifestyles, an area where research to-date has fallen short (Creutzig *et al.* 2016).

These elements of transformative governance can create a virtuous cycle: social movements depend on a widening arc of public awareness and understanding in which effective science communication can play an important role. Widespread social and moral commitment to sustainable development challenges interests vested in the unsustainable status quo. Civic engagement and popular support underpin the strong national alliances needed for sustainable development. Likeminded cooperation-oriented actors – governments, city alliances, civil society organizations, scientific institutions – can scale up coordinated action, embed joint learning processes and support vulnerable populations impacted by climate change.

Global governance beyond the local and national levels is also a necessity to achieve carbon neutrality globally by mid-century. Joint action and global rules are needed to stabilize planetary commons, such as the oceans, biodiversity and agricultural soil. Broad-based support for global governance comes from transnational alliances of pioneering actors of transformative change.

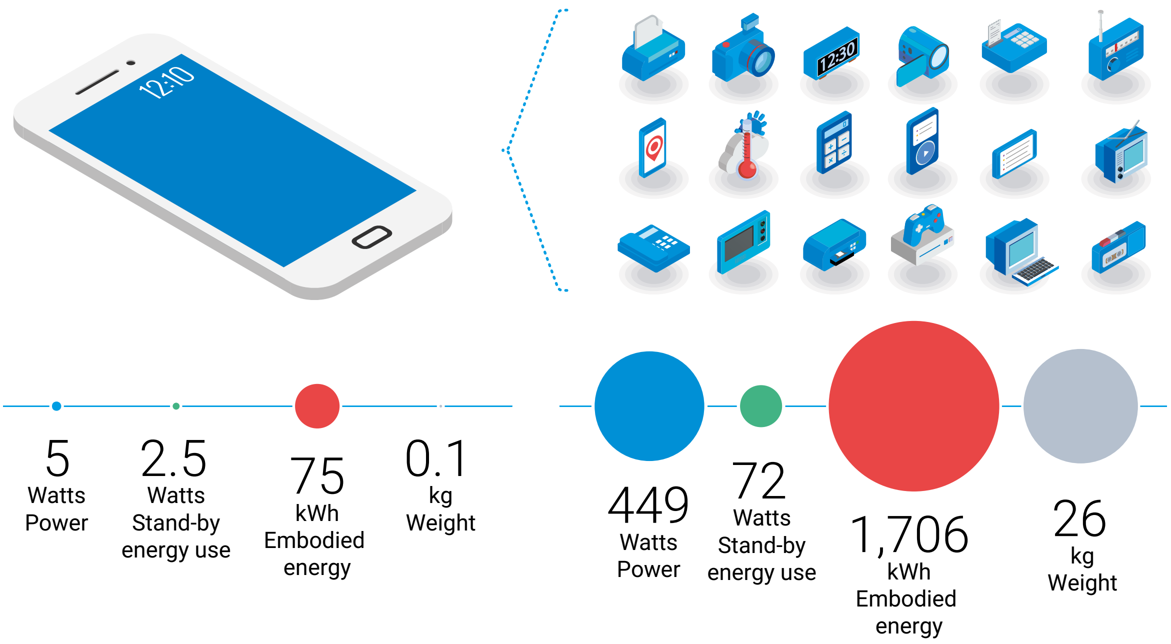
5.3.4. Digitalization and disruptive technological change

Disruptive technological change can enable sustainable development with co-benefits for closing the emissions gap, but can also exacerbate unsustainable patterns of resource use. This is most clearly evidenced by the promises and risks of the digital revolution, constituted by ongoing advances in information and communication technologies, machine learning and artificial intelligence, connectivity, the Internet of Things (IoT), additive manufacturing (3D printing), virtual and augmented reality, blockchain, robotics and synthetic biology.

TWI2050 (2018; 2019) analysed in depth the impacts of digitalization on consumption and production, and resulting GHG emissions. Three trends are particularly important.

First, additional units of information-based services can be provided at an almost zero marginal cost, increasing

Figure 5.2. The energy and material benefits of accessing services via a multipurpose smartphone (left) over owning an array of single-purpose goods (right)



Note: In-use power savings are factor 90 (blue circles), standby power savings are factor 30 (orange), embodied energy savings are factor 25 (green) for a weight reduction of factor 250 (grey).
Source: Grubler *et al.* (2018), based on a visualization by Tupy (2012) array of single-purpose goods (right)

affordability for poorer segments of society. Virtual communication and interaction can also potentially replace a large fraction of long-distance and carbon-intensive business travel.

Second, the possibility of matching supply and demand in real time through digital coordination platforms offers step-change improvements in asset utilization, improved quality of service and potentially lower emissions. This is also the underlying principle of a service-based economy in which 'ownership' of goods shifts to 'usership' of services (e.g. shared vehicle fleets and ride-sharing services, see chapter 7). Figure 5.2 illustrates the potential resource savings from displacing the ownership of many single-purpose analogue devices if equivalent services can be accessed through a single multifunctional interface.

Third, global communication infrastructures and the next generation of virtual spaces can connect people around the globe, accelerate global learning processes and support transnational alliances for sustainable futures. Just as the printing press enabled learning, science, the era of enlightenment, democracy and the Industrial Revolution, digital infrastructures can pave the way towards a global sustainable society.

However, as with all transformational strategies, digitalization also carries significant risks. A lack of access to digital infrastructure and services reinforces the digital divide, marginalization and inequality of opportunity. Conversely, cheaper and more accessible services could lead to 'take-back' (or economic 'rebound'), which further increases in-service demand with resource impacts. Digitalization and automation also further reduce the need for human labour. Big data-driven applications and services raise privacy concerns and enable social control by governments or monopolistic technology providers.

Clear governance and ethical and management strategies are needed to minimize these risks and avoid digital dystopias. Public policy is critical, particularly in the early formative phase of developing new technologies and business models, in terms of regulating standards, data access and privacy, competition, and, above all, infrastructure development, as well as ensuring equitable access. Effective governance of digitalization towards sustainability requires a comprehensive and rapid investment in the digital capabilities of public and regulatory organizations.

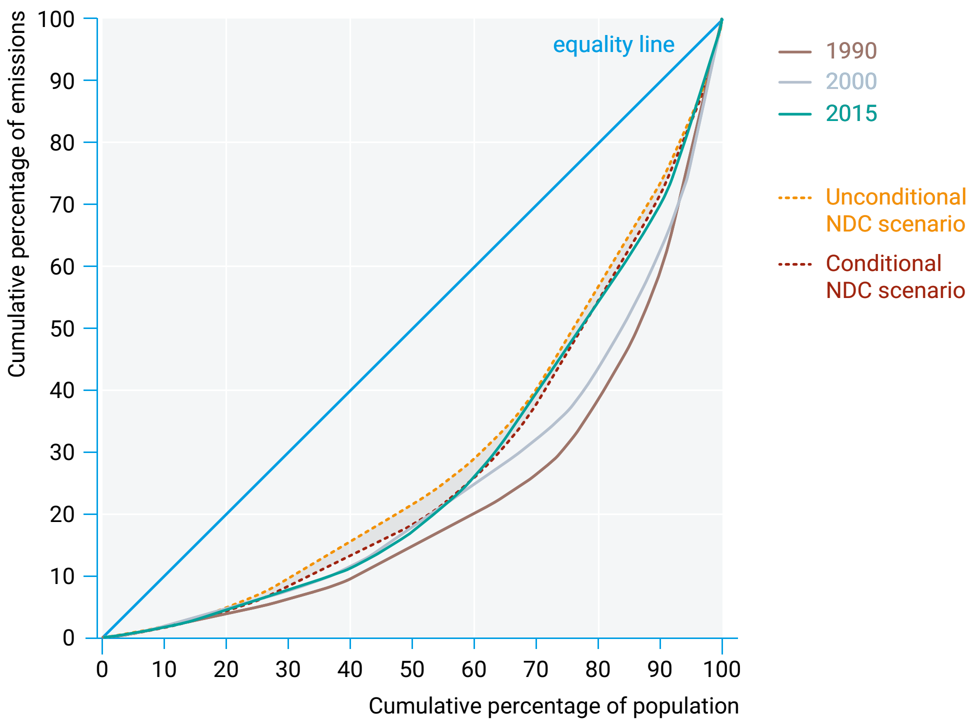
5.3.5. Resource-efficient services for raising living standards

A recent low energy demand (LED) scenario explored the potential for closing the emissions gap while raising living standards in the global South through radical changes in the type and efficiency of energy services (Grubler *et al.* 2018). Unlike other 1.5°C pathways, the LED scenario shows how the ambition of the Paris Agreement is reachable by lowering energy demand by 40 per cent, while at the same time increasing the provision of energy services without having to rely on negative emission technologies or carbon capture and storage (Rogelj *et al.* 2018). The LED scenario was found to have the strongest synergies with other SDGs. This is consistent with other analysis, which shows that energy, land and material-efficient pathways impose the fewest trade-offs with other SDGs (Bertram *et al.* 2018).

The sustainable transformation described by the LED scenario is immensely challenging, with the same services and quality of life taken for granted in modern developed economies becoming available to more people. This depends on seven main strategies for resource-efficient development: (a) electrify energy end use, including vehicles and heat pumps to improve end-use efficiency; (b) digitalize energy-using products and services to optimize infrastructure and resource use; (c) converge onto fewer numbers of multifunctional goods to improve service quality and convenience; (d) shift from ownership to usership to reduce material needs; (e) utilize consumer goods, vehicles and physical infrastructures at higher rates to accelerate the introduction of improved alternatives; (f) innovate business models offering low energy services to appeal to consumers, while making sense commercially; and (g) tighten efficiency standards continually upward to deliver cost, performance, health and other benefits.

The resulting expansion of energy services in the Global South would address historical inequalities created by GHG-intensive development in industrialized countries, where 2 billion people lack improved sanitation (World Health Organization [WHO] and United Nations Children's Fund [UNICEF] 2017), 800 million people go hungry every night (Food and Agriculture Organization [FAO] *et al.* 2018), roughly the same number of people do not have access to electricity, and almost 3 billion cook and heat with solid fuels (International Energy Agency [IEA] 2018). This striking global inequality in living standards is reflected in the marked global inequality in GHG emissions (figure 5.3).

Figure 5.3. Lorenz curves showing inequality in the global distribution of annual per capita GHG emissions for selected past years and two NDC scenarios



Note: The diagonal represents perfect equality. Half of the global population accounts for only 15–20 per cent of global emissions.
Source: Zimm and Nakićenović (2019)

This emissions inequality has reduced slightly in recent history (1990-2015) and looks set to continue through the NDCs. Strengthened action to close the emissions gap can be consistent with social and economic development objectives, if the emissions-intensive development pathways of the top emitters can be avoided.

5.3.6. Sustainable land use, food security and bioenergy

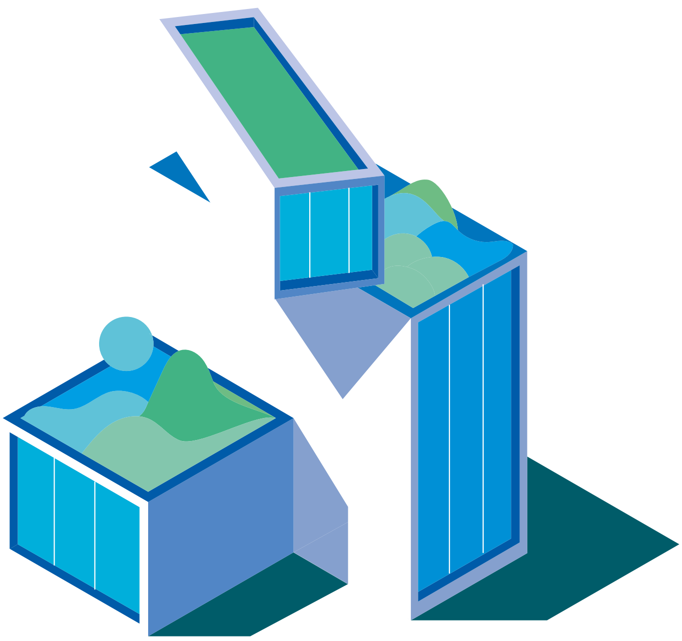
The biologist and naturalist E.O. Wilson has called for protecting half the Earth's land and seas, a project known as Half-Earth (Wilson 2016). Feeding humanity while mitigating human-caused environmental degradation must essentially occur on already transformed and existing agricultural land. This allows the remaining 'Half-Earth' to be safeguarded as natural forest and other ecosystems providing essential services, protecting biodiversity and ensuring resilience.

The global sustainable transformation of agricultural systems and fisheries faces the challenge of providing more and healthier food through sustainable intensification on existing farmland and reducing food waste (TWI2050 2018). For land in agricultural use as croplands, pastures and managed forests, this means widespread adoption of agricultural practices that minimize environmental damage and maximize resilience, including: precision farming to economize on resource inputs while boosting yields; no-till farming to protect soil quality; agroecology to optimize the crop mix in order to sustain biodiversity and resist the dangers of pests and pathogens; and improved harvesting and storage practices to reduce post-harvest losses.

A revolution is also needed in food consumption culture and practices to improve diets and reduce waste, as around a third of food produced currently ends up being wasted (Gustavsson *et al.* 2011). Healthier diets can be promoted by removing subsidies for harmful production techniques, public awareness campaigns and careful management of land use, oceans and other environmental resources (TWI2050 2018).

This agricultural revolution, encompassing both production and consumption, must unfold alongside a massive programme of returning land to nature, including tree planting on degraded land (Bastin *et al.* 2019). For example, over the last 40 years, China has undertaken major projects to enhance soils and regenerate and reforest land (Bryan *et al.* 2018). To close the emissions gap, land use must transition rapidly from being a net source of emissions to a net sink.

There are clear potential synergies between SDG 2 (zero hunger), SDG 7 (affordable and clean energy) and SDG 13 (climate action). Strategies include increasing agricultural productivity, reducing forest clearance for agriculture and shifting diets to healthier, less land-intensive and lower carbon foods. Conversely, the singular pursuit of SDG 13 to close the emissions gap without pursuing sustainable development more holistically can lead to trade-offs. Conversion of agricultural and forest land for bioenergy crop production negatively impacts food security. Such tensions are a particular hallmark of climate mitigation pathways reliant on negative emissions from combining bioenergy combustion with carbon capture and storage.



6 Bridging the gap: global transformation of the energy system

Lead authors:
Yacob Mulugetta (Department of Science, Technology, Engineering & Public Policy, University College London, UK), Pablo E. Carvajal (International Renewable Energy Agency, Germany), James Haselip (UNEP DTU Partnership), Thomas Spencer (The Energy and Resources Institute, India)

Contributing authors:
Edo Abraham (Delft University of Technology), Simon Batchelor (Gamos Ltd, UK), Brigitte Knopf (Mercator Research Institute on Global Commons and Climate Change, Germany)

6.1 Key issues and options for transforming the global energy system

The energy sector will be essential in the enhanced global mitigation efforts required to bridge the emissions gap in 2030 and reach net-zero emissions by 2050. This will necessitate a complete transformation of the way energy is produced and consumed.

To illustrate the scale of the challenge, coal-fired power plants were the single largest contributor to emissions growth in 2018, an increase of 2.9 per cent compared with the previous year and surpassing annual total emissions of 10 $GtCO_2$ (International Energy Agency [IEA] 2019a).

The transformation will be challenged by the fact that demand for energy services will grow 30 per cent by 2040, according to the IEA (2018a). However, primary energy demand will grow by a lesser rate or actually fall, depending on the achieved rate of energy efficiency improvement.

The current global energy system is still highly carbon-intensive with coal, oil and natural gas meeting 85 per cent of all energy needs (IEA 2019e). If the necessary transition does not occur, greenhouse gas (GHG) emissions will continue to increase year-on-year.

In light of this, what needs to happen? Long-term scenarios all point to rapid upscaling of renewables and energy efficiency, in combination with electrification of many new end-uses, as the key ingredients of a successful energy transition driving down energy-related CO_2 emissions (Gambhir *et al.* 2019; Bogdanov *et al.* 2019).

This chapter reviews five key transition options, based on their relevance to a wide range of countries, clear co-benefit opportunities and potential to deliver significant emission reductions. Each transition corresponds to a particular policy rationale or motivation, namely:

1) Easy wins: expanding renewable energy for electrification

2) Broad policy consensus: coal phase-out for rapid decarbonization of the energy system

3) Large co-benefits: decarbonizing transport

4) Hard to abate: decarbonizing energy-intensive industry

5) Leapfrogging potential: avoiding future emissions and ensuring energy access

6.2 Options to decarbonize the energy sector

The energy transition will include several elements, while approaches to transition will vary from one region and country to another. Transition strategies will need to be developed and adapted to fit the specific context, as few parts can be directly copied. Sharing and learning will be important for rapid action.

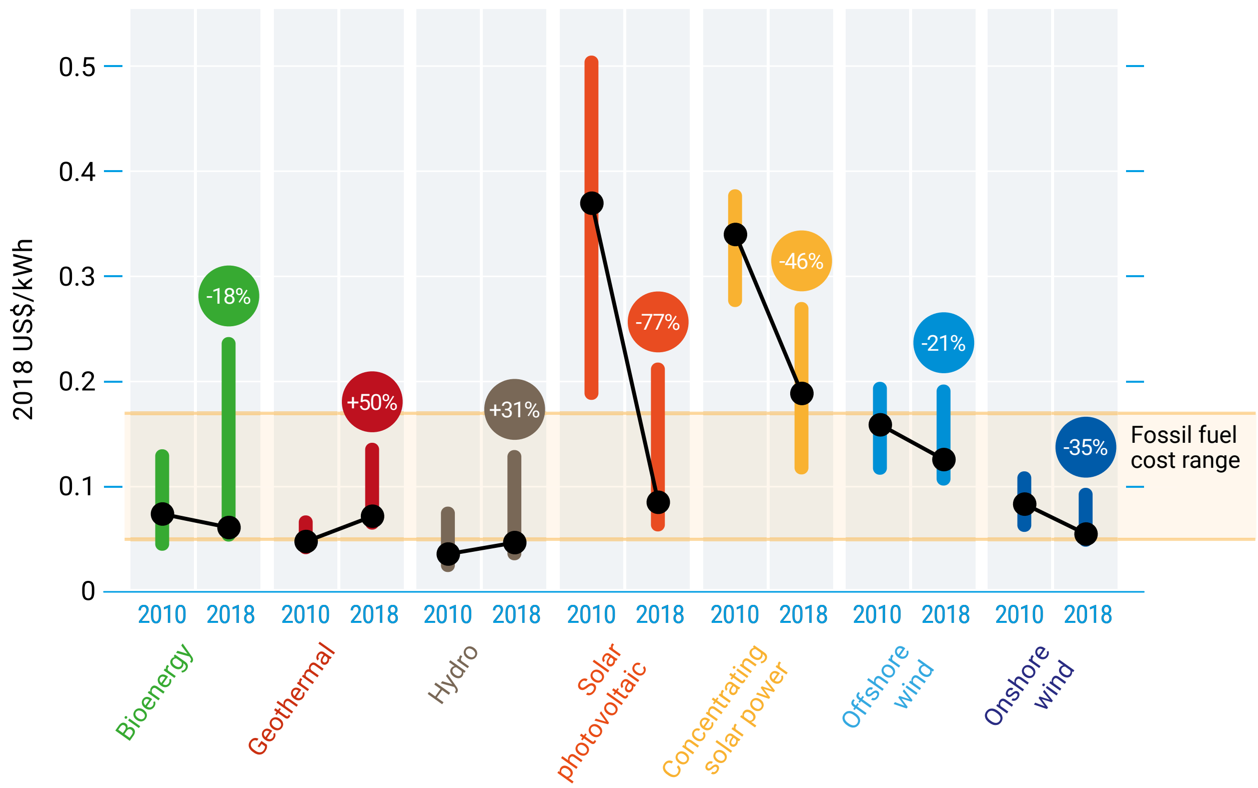
6.2.1 Easy wins: expanding renewable energy for electrification

Technologically speaking, the three pillars of any strategy to decarbonize the power sector are: i) a vast expansion of renewable electricity generation; ii) a smarter and much more flexible electricity grid, and iii) huge increases in the numbers of products and processes that run on electricity (in buildings, transport and industry). The basic technologies needed for expanding electrification based on renewable energy technologies already exist and thus represent a relatively "easy win" for substantial short-term reductions of energy-related CO_2 emissions.

Regarding renewable energy expansion, the world added a record 167 gigawatts (GW) of new capacity in 2018 (excluding large hydropower), with solar photovoltaic (PV) additions hitting a record of 108 GW and wind power an estimated 50 GW. Global investment in renewable energy capacity in 2018 was US$272.9 billion, which was about three times higher than investment in coal and gas-fired generation capacity combined. This allowed for renewable energy (excluding large hydropower) to raise its share of global electricity generation to 12.9 per cent in 2018, helping the world to avoid an estimated 2 gigatons of carbon dioxide emissions (Frankfurt School-United Nations Environment Programme [UNEP] Collaborating Centre and BloombergNEF [BNEF] 2019). Yet, renewables need to grow six times faster to meet climate targets (International Renewable Energy Agency [IRENA] 2019a).

The main enabler for the accelerated deployment of renewable energy in the last decade has been the continued and rapid decline in capital costs. In most parts of the world today, renewables have become the lowest-cost source of new power generation and are generally competitive without incentives when directly compared with fossil alternatives. Since 2010, the global weighted-average levelized costs of electricity (LCOE) from solar photovoltaic, onshore and offshore wind projects, bioenergy and geothermal, have all reduced and are approaching the lower range of fossil-fuel-fired power generation costs (figure 6.1). Continued cost declines are expected during the following decades (IRENA 2019c). The key to integrating larger shares of variable renewable energy into the power supply is system flexibility. Electricity systems with large shares of renewables require investments to address the short- and medium-term variability of both solar and wind energy. There are several categories of power system assets that can be utilized to provide flexibility. Conventional power plants, gas-fired generation and hydropower with reservoirs are currently the predominant sources of system flexibility in modern power systems, but other options will increasingly become important such as electricity networks, battery storage, distributed energy resources and enhanced predictability. Studies show that the cost of flexibility to integrate variable renewable energy is generally quite small (+5 to +13 US$/MWh), with higher values for inflexible systems with dominant shares of coal or nuclear generation (Agora Energiewende 2015). However, beyond enhanced power infrastructure, measures to support power system flexibility can be readily applied and adapted to power systems. These include modifications to “energy strategies, legal frameworks, policies and programmes, regulatory frameworks, market rules, system operation protocols, and connection codes” (IEA 2019c). There are now several examples of countries that have achieved 100 per cent renewable energy electricity for short periods of time (days), with large shares of variable solar and wind (for example, Costa Rica, Denmark, Ireland and Uruguay).

Figure 6.1. Global LCOE of utility-scale renewable power generation technologies, 2010-2018



Source: International Renewable Energy Agency (IRENA) (2019c).

Box 6.1. Germany's coal phase-out

Despite growing its share of renewables in electricity generation from 20 per cent in 2011 to 37.8 per cent in 2018, Germany is Europe's largest coal consumer, accounting for 35 per cent of total power sector emissions in 2018, with 42.6 GW of lignite and hard coal-fired power generation capacity. This means that Germany will most certainly not reach its national target of 40 per cent GHG reduction by 2020 compared with 1990 levels (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety [BMU] 2018).

In January 2019, following a long consultation process, a Government-appointed commission proposed a total phase-out of coal in Germany by 2038 (Federal Ministry for Economic Affairs and Energy [BMWi] 2019). The proposed decommissioning road map foresees a net reduction of 12.5 GW of coal capacity by 2022. By 2030, total coal power capacity should be reduced to a maximum of 17 GW, equal to a total reduction of 25.6 GW compared with 2017. Reviews are proposed for 2023, 2026 and 2029 to take stock of progress and to address concerns over security of supply, especially since Germany has committed to decommission all nuclear power by 2022.

The most important proposed measures to implement the coal phase-out are to cancel the industry's CO_2 certificates issued within the European Emission Trading Scheme and to ensure the expansion of renewable electricity to a share of 65 per cent by 2030. The phase-out plan includes a €40 billion economic package offered to affected coal regions, including alternative industry investment projects and state aid for coal workers.

The Commission's proposal is now in the legislative process. The federal Government has already decided on the law for financing structural change in the coal regions and will officially adopt the decision to phase-out coal by 2038 in November (Cabinet of Germany 2019)

Harnessing the synergy between low-cost renewable power and enhanced end-use electrification is key to driving down energy-related CO_2. According to the International Renewable Energy Agency (IRENA), renewable energy and electrification can deliver 75 per cent of the required emission reductions to bring the temperature rise to the well-below 2°C climate goal (IRENA 2019a). This means that by 2050, 86 per cent of electricity generation would need to be renewable and that the share of electricity in final energy would increase from just 20 per cent today (IRENA 2019a) to almost 50 per cent by 2050. The share of electricity consumed in industry and buildings would need to double (mainly through electric heating and cooling), with transport seeing potentially the largest transformation (see section 6.2.3).

The electrification of the energy system creates the need for enhanced digitalization of end-use technologies, large-scale electrical and heat storage technologies and the need to develop "electro fuels" with green electricity, to be able to substitute liquid fossil fuels (IRENA 2019b). All these technologies exist and are rapidly spreading, especially within Organisation for Economic Co-operation and Development (OECD) economies, and also serve to mitigate the risk of blackouts caused by unfavourable weather.

6.2.2 Broad policy consensus: coal phase-out for rapid decarbonization of the energy system

The combustion of coal currently accounts for 30 per cent of global CO_2 emissions (IEA 2019a). Behind these figures is the reality that globally, about 27 per cent of primary energy needs are met by coal, including around 40 per cent of all electricity generation (BP 2019). After declining consecutively for three years, global coal production increased by 2.8 per cent to 7,428 Mt in 2017 and then rose again by a marginal 0.2 per cent to 7,575 Mt in 2018 (Enerdata 2019), resulting from stronger global economic growth leading to increased industrial output and electricity use. This highlights two obvious but critical points: i) much of the growth in demand was concentrated in Asia, showing a regional shift in consumption and production and thus some headroom for growth; ii) the rapid rate of growth in electricity demand limits the pace at which the power sector can decarbonize, even with high uptake rates of renewables, which reinforces the importance of energy efficiency to keep total demand within the reach of achievable renewables growth.

If operated until the end of their lifetime and not retrofitted with carbon capture and storage (CCS), "committed emissions" from existing coal-fired power plants, built before the end of 2016, are estimated to emit roughly 200 $GtCO_2$ by 2050 (Rogeli *et al.* 2018). Coal-based power plants that are planned or under construction would add a further 100–150 $GtCO_2$ (Edenhofer *et al.* 2018), effectively using up a large share of the remaining carbon budget to stay below two degrees.

Therefore, one of the main challenges for the required energy sector transformation will be to find nationally appropriate solutions for the fast and socially responsible reduction in coal-fired power generation by 2030 and a phase-out by 2050 (Rogeli *et al.* 2018). Box 1 illustrates the complexity of such a phase-out process, using the experience of Germany.

Policies should also look beyond the demand-side considerations to include supply-side interventions (Spencer *et al.* 2018; table 6.1). Supply-oriented considerations are critical given the importance of the coal mining sector in terms of employment, revenues and its place within broader regional economies. Hence, managing coal transitions means not just focusing on "stranded assets", as relating to physical or financial capital in the demand-side policy literature, but also to paying attention to the notion of "stranded regions" where workers, regional governments and the regional economy more broadly are dependent on the coal sector (Spencer *et al.* 2018). This holistic vision is at the heart of a "just transition" that considers the impact of technological change on workers and communities (Caldecott *et al.* 2017), as well as the coal owners and industry, as a way to negotiate a politically feasible reduction in coal power generation, and eventually phase it out altogether (Jordaan *et al.* 2017).

6.2.3 Large co-benefits: decarbonizing transport

Transport accounted for 28 per cent of global final energy demand and 23 per cent of global energy-related CO_2 emissions in 2014 (IEA 2017b). Transport sector emissions are growing rapidly and increased by 2.5 per cent annually between 2010 and 2015 (Rogeli *et al.* 2018), largely driven by economic growth, behavioural changes and population increase. The sector accounts for about 65 per cent of global oil demand, with 92 per cent of final transport energy demand consisting of oil products, making it the least diversified of the major energy end-use sectors.

Deep decarbonization of the transport sector will require a radical shift in the nature and structure of transport demand, major improvements in energy efficiency, changing vehicle types and significant and rapid transitions in the energy mix used (see also chapters 4 and 7).

Aggressive action now would lay the foundation and maintain a healthy momentum towards the longer-term goal. Some of the transport-related climate change mitigation actions that can yield substantial decarbonization as well as economic benefits include: i) compact urban planning; ii) reducing passenger travel demand; iii) shifting passenger travel modes and expanding public transit; iv) improving passenger car efficiency and shifting to electrical engines; v) improving freight logistics; and vi) improving freight vehicle efficiency and electrification (Dhar, Pathak and Shukla 2018; Gouldson *et al.* 2018).

One of the key technical mitigation options, namely electrification of the transport sector, is projected to play a major role in meeting ambitious climate targets. Rapid growth in electric passenger vehicles (EVs) across the members of the G20 has been occurring since 2010, with global cumulative sales of light-duty plug-in vehicles exceeding 5 million units at the end of December 2018 (Vieweg *et al.* 2018; Watson 2019). This amounts to a market share of 2.1 per cent (compared with less than 1 per cent in 2016). China has the largest fleet of EVs with over 2.2 million units, while Norway leads in terms of the market share for new cars, approaching 60 per cent (Williams 2019). In road freight transport (trucks), systemic improvements (for example, in supply chains, logistics, and routing) would also benefit from these innovations, but would need to be combined with efficiency improvement of vehicles.

Shipping and aviation account for 40 per cent of all transport-related emissions but will be significantly more challenging to decarbonize and electrify than road transport (Martinez Romera 2016). Both modes will see high demand growth and would need to pursue ambitious efficiency improvements and use of low-carbon fuels. This would mean the use of advanced biofuels and low-carbon liquid fuels (synthetic fuels) in the near and medium term, with hydrogen fuel for shipping a likely solution in the longer term (IRENA 2019a; IEA 2017b).

While progress has been made, it is far from the scale required to decarbonize transport. Specifically, it will

Table 6.1. Framework of policy challenges related to coal transition

	Policy challenge	Example policy approach
Supply side	Importance of the coal sector as a (regional) employer and generator of added value	Regional diversification plans or coal sector restructuring plans
	Importance of export revenues from coal export	Economic diversification strategies
Demand side	Economic and technological aspects of substitution to move away from coal use	Payments for closure of coal plants; carbon pricing; renewables support schemes

Source: Spencer *et al.* (2018)

require the share of electricity in final energy for transport to increase from just 1 per cent today to 40 per cent by 2050 (IRENA 2019a)[1].

At the same time, decarbonizing transport can deliver multiple significant co-benefits and is one of the sectors in which there are strong links between local and global pollution and human well-being. Specifically, the transportation sector is a major source of particulate matter ($PM_{2.5}$), ozone and nitrogen dioxide concentrations, which are major causes of premature deaths. In 2015, emissions attributed to transport contributed to 385,000 premature deaths out of which 114,000 and 74,000 were in China and India, respectively (Anenberg *et al.* 2019). With vehicle numbers projected to double by 2040, the costs associated with premature mortality are likely to increase in both these countries. However, some solutions are beginning to emerge. For example, there is significant potential for electric two- and three-wheelers as a short-distance transport solution in India, which could enable India to develop a large EV industry and stimulate investment in charging infrastructure that can facilitate diffusion of larger EVs (Dhar, Pathak and Shukla 2017; see also chapter 7).

6.2.4 Hard to abate: decarbonizing energy-intensive industries

Energy-intensive industries, such as steel and cement, account for about 17 per cent of total CO_2 emissions from energy and industrial sources (Energy Transitions Commission [ETC] 2019). These sectors are difficult to decarbonize for a number of reasons. Firstly, there are technical barriers, due to the lack of cost-effective mitigation technologies to reduce emissions from the combustion of fossil fuels to provide high-grade process heat or from the industrial process itself. Secondly, there are political economy barriers, due notably to the international competition for some of these industries and hence the risk of "carbon leakage", as well as the low level of innovation and stock turnover in these sectors[2]. As a result, energy-intensive industries have typically been exempted from national climate policies. Competitiveness pressures and the importance of energy as an input have, however, driven significant energy efficiency improvements, but this has not been enough to move towards decarbonization of these sectors. For example, while the CO_2 intensity of global electricity production has declined by 9.3 per cent between 2000 and 2016, the CO_2 intensity of global crude steel production has increased by 2.8 per cent in the same period[3].

This is concerning because the significant demand for materials will continue, as countries like India and many African countries develop the infrastructure and housing required as a result of their development. Without further policy, emissions from the heavy industry sectors could increase from 17 per cent of global emissions today to 20 per cent by 2050 (ETC 2019). Mitigation of energy-intensive industries requires going beyond incremental improvements in energy efficiency and moving towards more fundamental mitigation options.

Broadly speaking, these options can be broken down into three categories. The first is demand reduction through recycling, materials substitution and dematerialization (see chapter 7). An example of the latter would be lightweighting of automobiles while improving fuel economy and downsizing the powertrain, in order to reduce steel consumption. Significant potential exists to reduce virgin material demand, which could cut emissions from heavy industry by 40 per cent by 2050, compared with a business as usual (BAU) case (ETC 2019; also discussed extensively in chapter 7). This can have the benefit of reducing reliance on more costly mitigation options like carbon capture and storage/use (CCSU) (IEA 2019b).

The second category involves mitigation of emissions in the context of the existing industrial process, the archetypal example of which is the deployment of CCSU. While alternatives to CCSU are emerging in some heavy industry sectors, the deployment of CCSU is likely to be necessary in the cement industry, even given aggressive deployment of clinker substitutes and the development of currently non-commercial alternative cement technologies[4]. The third category of options entails a fundamental transition in the industrial process itself, an example of which would be the substitution of coking coal as a fuel and reducing agent in steel manufacture with hydrogen produced from zero-carbon electricity (Vogl *et al.* 2018).

Therefore, what are the prospects for energy-intensive industry mitigation? The first point to note is that the available technological options are currently at a low level of commercial readiness, necessitating significant progress in research, demonstration and commercialization. Secondly, unlike in other sectors where zero-carbon options may be economically competitive with their fossil alternatives (for example, renewable electricity or electric vehicles), decarbonization of energy-intensive industry appears likely to entail net costs. These costs are likely to be negligible at the level of the macroeconomy and the end-consumer, but significant at the producer level (ETC 2019). This raises questions of managing the implementation of stringent policies to decarbonize heavy industry in the absence of stronger global climate policies and a level playing field. Some form of trade protective measures, such as border adjustments, may be required. Finally, a comprehensive portfolio of policies is likely to be required, ranging from carbon pricing and research and demonstration

1 This is consistent with REN21 (2018) as the bulk of renewable energy used in the sector is biogasoline at 2.5 per cent; biodiesel at 1.4 per cent; and renewable electricity at 0.3 per cent of demand in 2016.

2 For an excellent summary of the challenges of mitigation in the energy intensive industries, see Bataille *et al.* (2018).

3 Calculated on the basis of data from Enerdata (2019) and World Steel Association (2018).

4 For a comprehensive survey of cement mitigation options, see Scrivener *et al.* (2018).

Box 6.2. Clean cooking as an important mitigation option

The Intergovernmental Panel on Climate Change Special Report on 1.5°C (IPCC SR1.5) states that lack of access to clean and affordable energy for cooking is a major policy concern in many countries where major parts of the population still rely primarily on solid fuels for cooking (Roy *et al.* 2018). The amount of fuelwood burned across Africa is estimated to be over 400 million m^3 a year (May-Tobin 2011), releasing over 760 million tons of CO_2e into the atmosphere*, and globally non-renewable biomass fuels alone account for significant emissions. This will continue to increase with the rise in population, as the population of sub-Saharan Africa is projected to double by 2050 (United Nations Department of Economic and Social Affairs [UN DESA] 2019). Black carbon from residential solid fuel burning is estimated to add the equivalent of another 8–16 per cent of the global warming caused by CO_2 (Bailis *et al.* 2015). It is also important to recognize the complexity associated with accounting in terms of the time it takes for replacement trees to sequester the CO_2 emitted by burning a felled tree, and the rate of change in CO_2 sequestration as trees mature. Clean cooking solutions address the most basic needs of the poor. Furthermore, reducing black carbon, methane and other short-lived climate pollutants would have substantial co-benefits on health and local air quality, but can in the short-term contribute significantly to limiting global warming to 2°C and 1.5°C (de Coninck *et al.* 2018; Batchelor *et al.* 2019). A key driver is the trajectory of costs that show "clean" cooking (i.e. with electric or gas) has the potential to reach a price point of affordability with associated reliability and sustainability within a few years.

* Burning 1 kg wood emits 1.9 kg of CO_2. See https://www.transitionculture.org/2008/05/19/is-burning-wood-really-a-long-term-energy-descent-strategy/.

funding to standards and regulation, for example, to promote material demand reduction. For all of this to occur, the salience of energy-intensive industry decarbonization needs to increase in global and national policy discussions.

6.2.5 Leapfrogging potential: avoiding future emissions and ensuring energy access

The issue of energy access and energy poverty is now on top of the global policy agenda. Among Least Developed Countries (LDCs), over 60 per cent of the population have no access to electricity with the figure rising to 80 per cent for people in rural areas (Least Developed Countries Renewable Energy and Energy Efficiency Initiative for Sustainable Development [LDC REEEI] 2019). In non-LDC developing countries, the figure is still significant, at 10 per cent of the population. Those who do have access to electricity often endure problems of unreliable access and frequent blackouts. Beyond electricity, nearly three billion people rely on traditional fuels (such as wood or charcoal) and technologies for cooking and heating. This has severe implications for health (especially the health of women and children), economic livelihoods and the environment, both at a global and local level (Batchelor *et al.* 2019). The burning of non-renewable biomass fuels[5] alone generates a gigaton of CO_2e per year (Bailis *et al.* 2015), about a 2 per cent share of global emissions (see chapter 2). Box 2 discusses the GHG emissions associated with cooking and potential trends for the future.

Improving access to reliable energy services for households and for productive purposes is thus a central policy objective in many LDCs and developing countries. This is explicitly recognized by United Nations Sustainable Development Goal 7 (SDG 7) that calls for action to "ensure access to affordable, reliable, sustainable and modern energy for all", which include targets on renewable energy and energy efficiency. As such, there is evidence of synergies between about 85 per cent of the SDG targets and efforts to achieve SDG 7, as well as some evidence of trade-offs between SDG 7 and about 35 per cent of the SDG targets (Fuso-Nerini *et al.* 2018). However, despite the energy sector's large share of global GHG emissions, achieving universal access to modern energy does not lead to increases in global GHG emissions (Dagnachew *et al.* 2018; IEA *et al.* 2019). Using two scenarios, the New Policies Scenario (NPS) and the Sustainable Development Scenario (SDS)[6] derived from the IEA's World Energy Outlook, reflect the simultaneous pursuit of universal access in sub-Saharan Africa for both electricity and clean cooking solutions yielding net savings of GHG emissions amounting to 45 $MtCO_2e$ and 200 $MtCO_2e$, respectively.

Going beyond addressing energy for basic human needs (i.e. lighting and cooking) to pushing mechanical power, mobility and energy for other productive uses required to drive development and transformation will generate increasing

5 To imply the extraction of biomass from a land area is not sustainable where carbon stocks on the land area decrease over time.

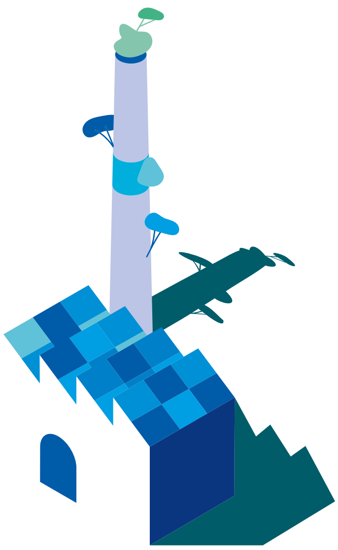
6 The NPS accounts for current and planned policies with a high likelihood of being implemented, including the GHG- and energy-related components of the NDCs pledged under the Paris Agreement. The SDS combines the fundamentals of sectoral energy policy with three closely associated but distinct policy objectives related to the SDG 7 (energy access), SDG 3 (air pollution) and SDG 13 (climate action).

Table 6.2. Transition options and their elements

Option	Major components	Instruments	Co-benefits	Annual GHG emissions reduction potential of renewables, electrification, energy efficiency and other measures by 2050
Renewable energy electricity expansion	• Plan for large shares of variable renewable energy • Electricity becomes the main energy source by 2050, supplying at least 50 per cent of total final energy consumption (TFEC) • Share of renewable energy in electricity up to 85 per cent by 2050 • Transition	• Flexibility measures to take on larger shares of variable renewable energy • Support for deployment of distributed energy • Innovative measures: cost reflective tariff structures, targeted subsidies, reverse auctions, net metering	• Greater efficiency in end-use energy demand • Health benefits • Energy access and security • Employment	• Power sector: 8.1 $GtCO_2$ • Building sector: 2.1 $GtCO_2$ • District heat and others: 1.9 $GtCO_2$
Coal phase-out	• Plan and implement phase-out of coal • Coal to renewable energy transition • Expand carbon capture usage and storage systems • Improve system-wide efficiency	• Regional support programmes • Tax breaks, subsidies • Carbon pricing • Moratorium policies • De-risking of clean energy investments • Relocation of coal workers (mines and power plants)	• Lower health hazards (air, water, land pollution) • Future skills and job creation	• Share of the power emissions reduction from a coal phase-out: 4 $GtCO_2$ (range: 3.6–4.4 $GtCO_2$), with 1 $GtCO_2$ from the OECD and 3 $GtCO_2$ from the rest of the world
Decarbonize transport	• Reduce energy for transport • Electrify transport • Fuels substitution (bioenergy, hydrogen) • Modal shift	• Pathways for non-motorized transport • Standards for vehicle emissions • Establishing of charging stations • Eliminating of fossil-fuel subsidies • Investments in public transport	• Increased public health from more physical activity, less air pollution • Energy security • Reduced fuel spending • Less congestion	• Electrification of transport: 6.1 $GtCO_2$

Decarbonize industry	• Demand reduction (circular economy, modal shifts and logistics) • Electrify heat processes • Improve energy efficiency • Direct use of biomass/ biofuels	• Carbon pricing • Standards and regulations, especially on materials demand reduction	• Energy security • Savings and competitiveness	• Industry: 4.8 $GtCO_2$
Avoid future emissions and energy access	• Link energy access with emission reductions for 3.5 billion energy-poor people	• FiT and auctions • Standards and regulations • Targeted subsidies • Support for entrepreneurs	• Better access • Meet basic needs and SDGs	• N/A

Source: Energy Transitions Commission (2017, 2018); International Renewable Energy Agency (2019a); Climate Analytics (2016)



energy demand. Poor but fast-growing countries in east and south-east Asia have traditionally deployed emissions-intensive coal to meet this demand. However, for countries and regions that host the world's energy-poor, there remains significant scope to shape their energy transitions as they are yet to be locked into a particular pathway (Mulugetta, Ben Hagan and Kammen 2018). Moreover, rapid technological progress in renewable energy is opening up an unprecedented opportunity for a wide range of applications and business models, including electrification through decentralized generation and mini-grids, with rapidly declining costs for photovoltaic modules, batteries, LEDs, smart metering, mini-grids and pay-as-you-go technology (United Nations Conference on Trade and Development [UNCTAD] 2017).

Policymakers in developing countries understand that making a rapid transition sometimes relies on a much slower process of technological and organizational change, for example, to build capacities and knowledge about the technologies required to 'leapfrog'. Moreover, the quality of the transition matters in terms of creating additional value beyond the provision of energy such as good quality jobs and building industrial capacity. For example, while the growth in solar PV markets across Africa is to be welcomed from an energy delivery perspective, a significant proportion of the global value chain for PV has been captured elsewhere, for example, in manufacturing (principally China), as well as financing and engineering services, often provided by institutions in OECD countries (Byrne, Mbeva and Ockwell 2018; Lema *et al.* 2018; Ockwell *et al.* 2018).

More broadly, effort is required to actively connect private business leaders with government-led and donor-backed forums to communicate and unlock new commercial opportunities in PV systems, as has occurred successfully in Kenya and Uganda (Bhamidipati, Haselip and Hansen 2019). However, this requires building innovation systems with the mission to strengthen knowledge and skills base, raise patient capital and mobilize technical assistance, to build strong partnerships with financial providers and domestic entrepreneurs with a deep interest in new and clean technologies (Truffer, Murphy and Raven 2015; Wieczorek 2017).

6.3 Beyond technical measures: pursuing system-wide transformation

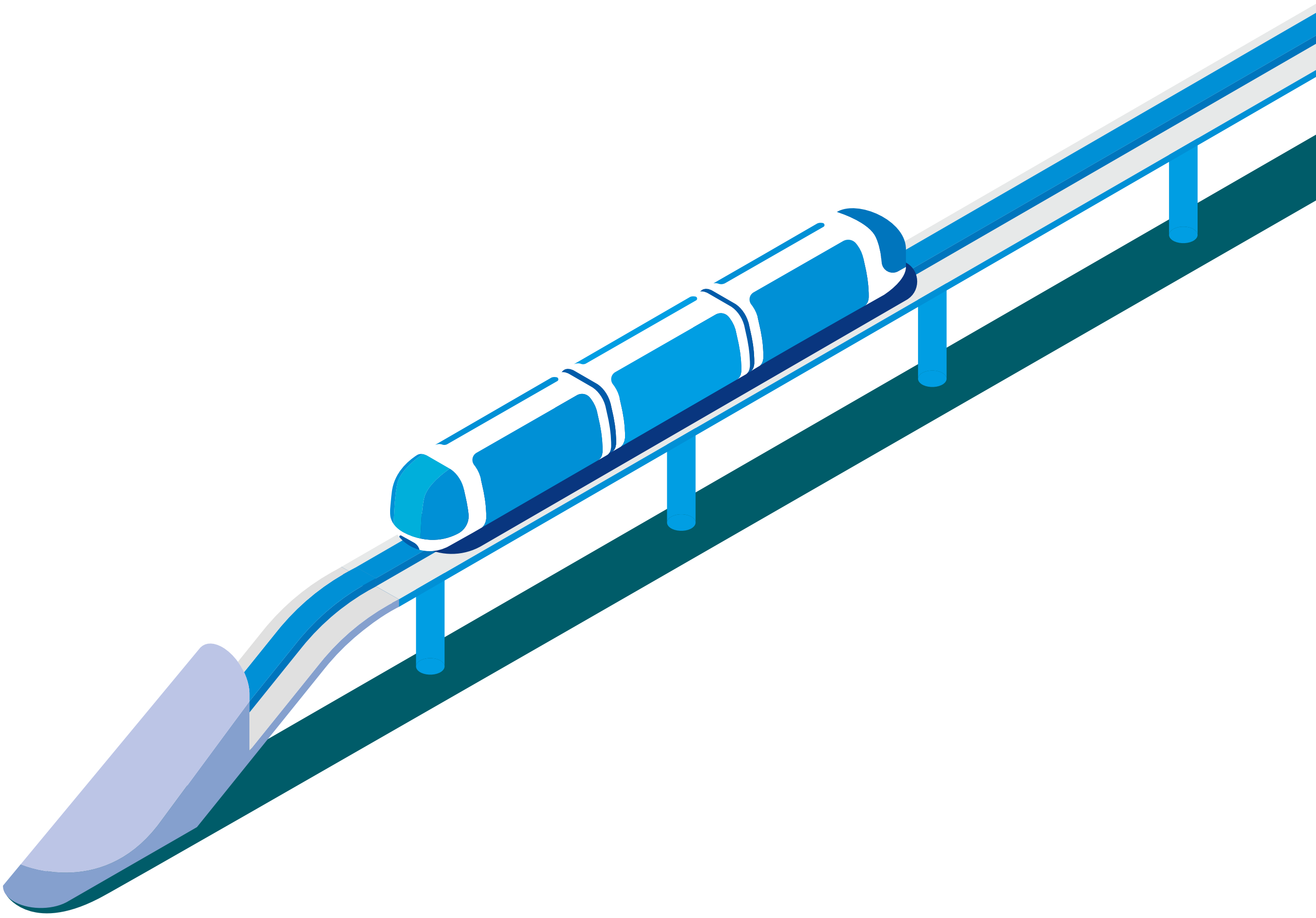
There is a qualitative difference between past energy transitions and the necessary future transition. For one thing, previous transitions were not constrained by time as a key factor for rapid change. More concretely, historical transitions were more "opportunity-driven", whereas low-carbon transitions are more "problem-driven" – the problem being the collective good (i.e. the climate) (Sovacool and Geels 2016). Furthermore, historically, energy "transitions" have occurred only in percentage terms (firstly, coal displacing biomass, then oil displacing coal and now natural gas and renewables displacing oil and coal). In terms of total energy use, the trends have more accurately reflected energy "additions" as all forms of energy rise to meet growing energy demand. Today we consume more coal, gas, oil, nuclear and renewables than ever before. Reducing emissions, however, requires that total hydrocarbon use decline with great expansion of renewable energy (along with technologies to capture or remove their emissions) (University of Columbia Center on Global Energy Policy 2019).

The depth of technological and institutional lock-in of the incumbent energy system is so profound it creates major obstacles or inertia, holding back much needed structural change (Jackson 2016). The rapid and systemic changes needed are radically different from what institutions are accustomed to withstanding. For example, switching to EVs requires multiple changes in the socio-technical system, which involve multi-actor processes of interactions across and between energy and transport regimes. Given the need for these complex and systemic changes, a sector-focused or silo approach will need to give way to decisions and policies that reach across sectoral, geographical and political boundaries. One way to do this is through mission-oriented policies, defined as systemic public policies that draw on frontier knowledge to attain specific goals, often to address "big problems" such as climate change that demand radical innovations and a multi-actor coordination (Mazzucato 2018). This also recognizes the catalytic role that governments can play in creating policies that can shape markets and direct them to meet major societal goals.

Given that energy is an enabler, and thus cuts across sectoral boundaries, low-carbon energy transitions can be well served by being directly linked to opportunities in other sectors such as electrifying transport and heating (including cooking) and decarbonizing energy-intensive industries. Equally important will be linking transitions with their associated co-benefits and costs and how these can be evaluated to provide supplementary information to serve as additional impetus for policymakers, decision makers and civil society to co-own and build consensus around the options (table 6.2).

The sheer scale of investment needed for accelerating energy transitions is very large. Global renewable energy investment in 2018, excluding large hydroelectric projects, exceeded the US$250 billion for a fifth successive year Frankfurt School-UNEP Collaborating Centre and BNEF 2019). However, climate policies that are consistent with the 1.5°C target require upscaling of energy system supply-side investments (resource extraction, power generation, fuel conversion, pipelines/transmission and energy storage), reaching levels of between US$1.6–3.8 trillion per year globally on average over the 2016–2050 time frame (McCollum *et al.* 2018).

The call to redirect investment to low-carbon energy systems raises a number of issues. Firstly, the high upfront capital outlay and low operating costs of



renewables is a new terrain in finance where further innovation is required. Secondly, while the historically low interest rates over the past 10 years have provided a very conducive environment for investment in renewable energy technologies (RETs), energy investment was mostly concentrated in high and upper-middle income countries (IEA 2019d). Thirdly, the high investment requirement in developing countries is being hampered by the high perception of risk, little opportunity for patient capital, and unstable political and regulatory regimes. To this end, multilateral, regional and national development banks could play a major role in leveraging larger finance by helping to de-risk investments. However, this would need to be co-developed where country policymakers play a deeper role by creating stable policy and regulatory conditions to encourage investment. This would also mean appealing to the immediate concerns of decision and policymakers, for example, integrating transport policy with air quality and climate policy and with vehicle emissions regulation. Policies should be harmonized wherever possible to take advantage of interdependencies and prevent undesirable outcomes such as CO_2 “leakage” from one sector to another.

7 Bridging the gap: enhancing material efficiency in residential buildings and cars

Lead authors:

Edgar Hertwich (Norwegian University of Science and Technology), Reid Lifset (Yale School of Forestry & Environmental Studies, USA), Stefan Pauliuk (Faculty of Environment and Natural Resources, University of Freiburg, Germany), Niko Heeren (Yale School of Forestry & Environmental Studies, USA)

Contributing authors:

Saleem Ali (University of Delaware, USA), Peter Berrill (Yale School of Forestry & Environmental Studies USA), Tomer Fishman (Interdisciplinary Center Herzliya, Israel), Qingshi Tu (Yale School of Forestry & Environmental Studies USA), Paul Wolfram (Yale School of Forestry & Environmental Studies, USA)

7.1 Introduction

The production of materials is a significant source of greenhouse gas (GHG) emissions (figure 7.1). In 2015, materials production caused GHG emissions of 11 $GtCO_2e$, up from 5 $GtCO_2e$ in 1995, with the contribution of such production increasing from 15 per cent to 23 per cent of total global emissions over this period (Hertwich 2019). The largest contribution stems from bulk materials production, such as iron and steel, cement, lime and plaster, other minerals mostly used as construction products, as well as plastics and rubber (figure 7.1). Two thirds of the materials are used to make capital goods, with buildings and vehicles among the most important (figure 7.1). While the production of materials consumed in industrialized countries remained within the range of 2–3 $GtCO_2e$ in the 1995-2015 period, there was rapid growth in material-related emissions among developing and emerging economies (Hertwich 2019). Growth in investments is associated with a strong growth in metal consumption. Developing countries have stronger growth in metal consumption with gross domestic product (GDP) than industrialized countries, as a higher share of their GDP comprises investments (Zheng *et al.* 2018).

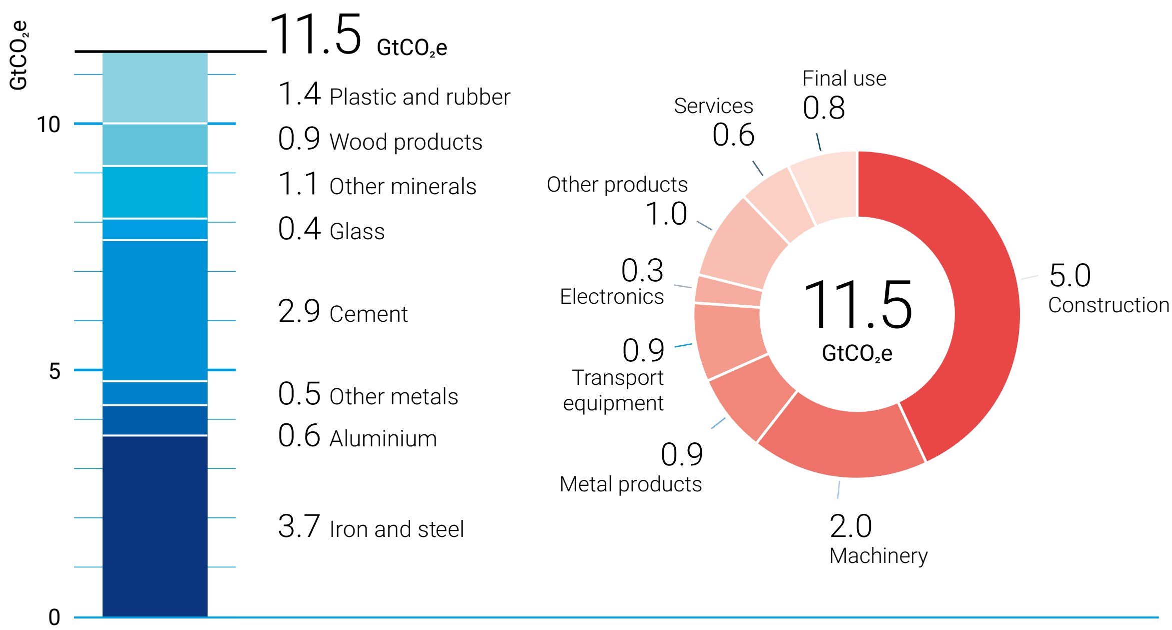
Options to mitigate emissions from materials production include supply-side measures, such as improved energy efficiency in production processes, the use of alternative production routes and raw materials with lower embodied GHG emissions, a shift towards cleaner energy sources and reductants, and CO_2 capture. Reducing the demand for materials is also an option to mitigate emissions and can be achieved through improving their efficiency (International Energy Agency [IEA] 2019a; Worrell *et al.* 2016).

Recent efforts have been made to evaluate the potential contribution of material efficiency to meet climate targets more broadly. In the Clean Technology Scenario of the International Energy Agency (IEA), compared with the baseline, steel demand is reduced by 24 per cent, cement by 15 per cent and aluminium by 17 per cent, which in total comprises around 30 per cent of the combined emission reductions for these materials. Other emission reductions were due to energy efficiency, innovative processes, cleaner energy and CO_2 capture and storage (IEA 2019a). Despite their effectiveness, material efficiency strategies have been systematically overlooked in climate policies (Hernandez *et al.* 2018).

Research on and development of demand-side material efficiency and substitution strategies has progressed substantially in the past decade (Allwood *et al.* 2017; Worrell *et al.* 2016; Zhang *et al.* 2018). Such research addresses the specific technical application of materials in buildings and other structures (Serrenho *et al.* 2019; Dunant *et al.* 2018), machinery (Milford *et al.* 2013) and vehicles (Løvik *et al.* 2014). Recent research combining insights from several bottom-up studies across different applications has identified that material efficiency could reduce emissions from steel production by half (Milford *et al.* 2013).

Material efficiency and substitution strategies affect not only energy demand and emissions during material production, but also potentially the operational energy use of the material products. Analysis of such strategies therefore requires a systems or life cycle perspective. Several investigations into material efficiency have focused on strategies that have little impact on operations, meaning that trade-offs and synergies have been ignored. Many energy efficiency

Figure 7.1. GHG emissions in $GtCO_2e$ associated with materials production by material (left) and by the first use of materials in subsequent production processes or final consumption (right)



Note: The data excludes emissions from land-use change and credits for carbon storage.
Source: Based on Hertwich *et al.* (2019).

strategies have implications for the materials used, such as increased insulation demand for buildings or a shift to more energy-intensive materials in the lightweighting of vehicles. While these additional, material-related emissions are well understood from technology studies, they are often not fully captured in the integrated assessment models that produce scenario results, such as those discussed in this report (Pauliuk *et al.* 2017).

In this chapter, focus is placed on residential buildings and cars, which are the most important individual products in terms of materials and energy use. Material efficiency strategies are reviewed with quantitative results presented of a recent modelling exercise for the implementation of such strategies in the G7 members (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States of America), China and India, based on findings from an International Resource Panel study (International Resource Panel forthcoming). These countries were selected because they represent individually significant economies with varied development levels.
The following demand-side strategies for increased material efficiency in product design and manufacturing, use and end of life are considered for both residential buildings and cars (Allwood *et al.* 2011)

1) **Product lightweighting and material substitution** of high-carbon materials with low-carbon materials to reduce material-related GHG emissions associated with product production, as well as operational energy consumption of vehicles.

2) **Improvements in the yield of material production and product manufacture,** thus reducing the share of material that becomes waste in the production process.

3) **More intensive use, lifetime extension,** component reuse, remanufacturing and repair as strategies to obtain more service from material-based products.

4) **Enhanced recycling and reuse** so that secondary materials reduce the need to produce more emission-intensive primary materials.

7.2 Material-efficient housing

Global construction of buildings and infrastructure and the associated material supply caused 7 $GtCO_2e$ of GHG emissions in 2015, of which 4 $GtCO_2e$ were associated with the use of materials in construction (Hertwich 2019). In comparison, direct CO_2 emissions from fuel combustion in buildings were 3 $GtCO_2$, while emissions associated with the production of electricity consumed in buildings were 6.5 $GtCO_2$ (IEA 2019b). Although current statistics do not disaggregate construction-related emissions into residential and commercial buildings or consider infrastructure at a global scale, country-level results and material-use data suggest that residential buildings contribute 50–65 per cent of such emissions (Hertwich *et al.* 2019). In 2015, about 70 per cent of construction-related emissions were from developing countries (Hertwich 2019).

Despite this, studies of material efficiency options almost exclusively focus on industrialized countries, with just a few studies addressing China. Housing demand, construction style and building lifetimes are important drivers for material-related emissions of residential buildings. Research provides insight on the scope of various material efficiency strategies for residential buildings.

7.2.1 Product lightweighting and material substitution

Buildings often contain more energy-intensive materials such as concrete, steel and glass than technically required. There is a documented tendency for overdesign in larger steel-frame structures of around 20–30 per cent (Dunant *et al.* 2018). Cement, a major building material, is often used more than necessary in various applications, including concrete mixing, where fillers and other cementitious materials can substitute part of the cement with fewer emissions (John *et al.* 2018; Shanks *et al.* 2019). Finally, instead of using reinforced cement, masonry or steel frames, timber, bamboo and other plant fibres can be used as building materials, which has the potential to significantly reduce lifecycle GHG emissions in materials production and carbon storage, even when considering a potential trade-off with operational energy use (Heeren *et al.* 2015). New technology allows for a wider use of timber, even for tall structures. In some regions, building codes are being adapted to recognize these advances and facilitate the increased use of wood in buildings (Mahapatra *et al.* 2012). Large-scale use of wood as construction material necessitates that the forests from which the timber is obtained are managed sustainably (Kane and Yee 2017; Oliver *et al.* 2014). The International Resource Panel (forthcoming) estimates that through lightweighting structures, 8–10 per cent of GHG emissions related to materials in residential building construction in the G7 and China can be saved, with an even larger share in India (figure 7.2). An increased market penetration of wood could also reduce emissions or sequester carbon, corresponding to 10 per cent of GHG emissions from residential building materials, with savings reaching up to 30 per cent in India. At present, the country hardly uses timber in construction and lacks local resources and expertise.

Building codes, which have long been used to improve energy efficiency, present a potential model and platform for developing policies that support lighter-weight structures, the reuse of components and timber-based construction.

The rapid growth of certification systems for construction and building, such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM), and their adoption into building codes by governments worldwide has been an important policy driver for changes in construction practices (de Wilde 2014; Doan *et al.* 2017; Menezes *et al.* 2012). At present, certification is more widely applied to commercial buildings than to residential dwellings. However, the spread of certification systems and their use in building codes presents an opportunity to introduce or enhance material efficiency policies for homes that might not otherwise be politically feasible. The details of such certification systems therefore need to be monitored and evaluated and explicit attention should be given to the use of building codes as a policy instrument for material efficiency.

At the residential level and particularly for single family homes, minimum standards for energy efficiency, such as the International Energy Conservation Code (IECC) in the United States of America (International Code Council [ICC] 2012), have great potential to reduce operational energy consumption at the cost of increased material use. However, increased energy efficiency in buildings is achieved by adding additional or better insulation material and additional building technology, such as heat exchangers in ventilation systems. Compared with conventional buildings, energy-efficient buildings have lower lifecycle emissions, as energy demand is typically the main driver (Karimpour *et al.* 2014; Kristjansdottir *et al.* 2018). Some suggestions have been made to include embodied carbon in codes for new construction, with a focus on cement in concrete in California as one example (King 2018). Although it is unclear how quickly such stipulations will be adopted globally, they could significantly enhance reduced material use and the utilization of low-carbon materials.

7.2.2 Improvements in the yield of material production and product manufacturing

The use of building information systems and of prefabrication can reduce waste in the construction process, thus reducing the amount of primary materials required (Hertwich *et al.* 2019).

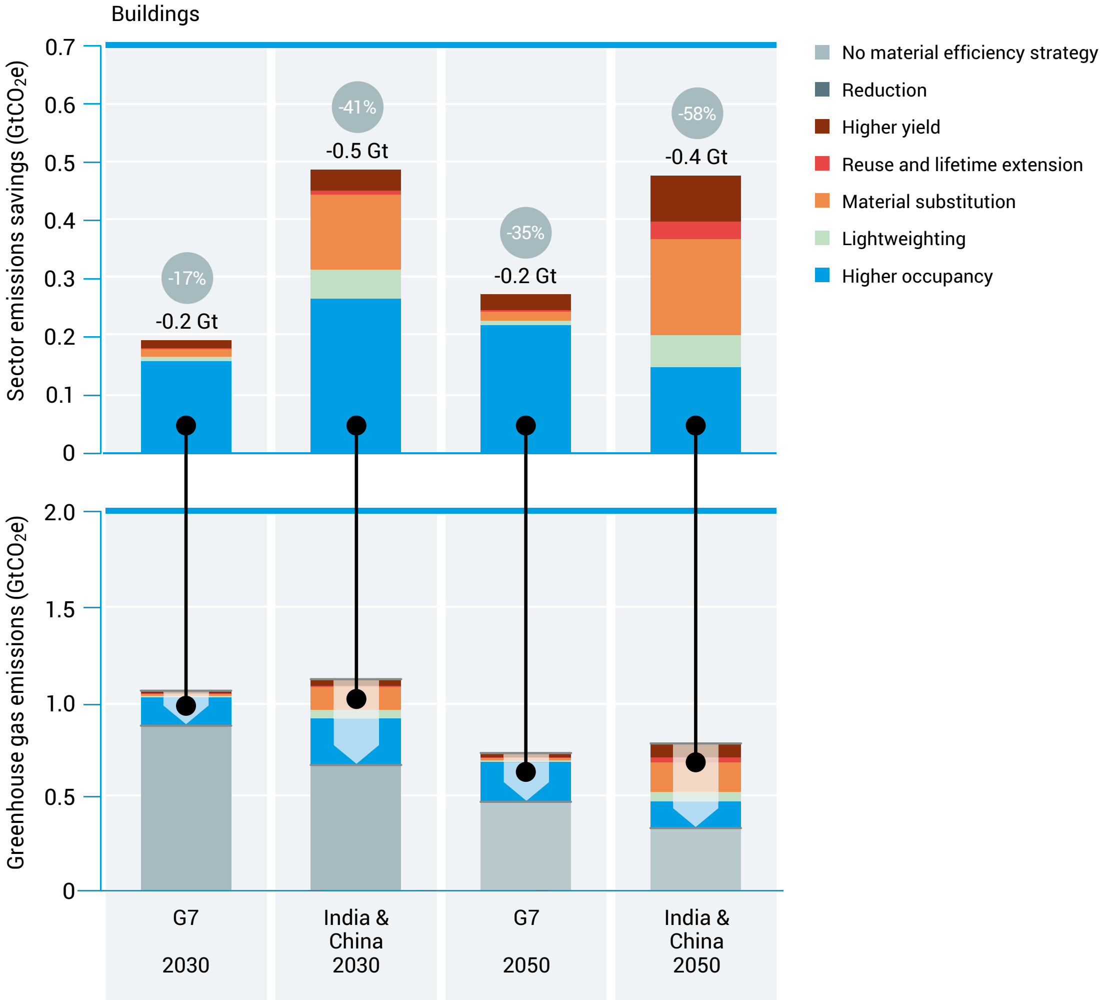
7.2.3 More intensive use and lifetime extension

Housing demand tends to increase with a growing income, but varies widely across similar GDP/capita levels, from 34 m² per person in the United Kingdom to 68 m² in the United States. Such demand is influenced by tradition, planning rules, tax laws and available space. Multifamily and urban residences tend to be smaller than single family, suburban and rural residences. In most countries, the trend is shifting towards a smaller household size, which is leading to an increase in required space as facilities are shared between fewer people. Several studies show that future floor area demand is a crucial variable for GHG emissions and that more intensive use can result in significant reductions of both material and energy related emissions (Serrenho *et al.* 2019; Cao *et al.* 2018; Pauliuk *et al.* 2013). Such a reduction might be the result of urbanization (Güneralp *et al.* 2017), with populations moving from single family rural and suburban residences to multifamily houses in denser urban areas, increases in household size or cohabitation, the smarter design of buildings that allow resizing and tax or other incentives that encourage residents to downsize their residence after changes in family size (Lorek and Spangenberg 2018). The International Resource Panel (forthcoming) suggests that reducing per capita floor space by 20 per cent compared with a scenario that converges an industrialized-country's floor space could reduce the emissions associated with the production of building materials for homes in G7 members by 50–60 per cent by 2050, given the already existing building stock. It would also reduce heating and cooling demand by up to 20 per cent, pending the retrofitting of existing buildings.

Policies that support homeownership may have the undesirable effect of subsidizing large residences through tax breaks and other measures. In some locations, spatial planning prevents the construction of multifamily residences and locks in suburban forms at high social and environmental costs. A reform of planning rules could bring about multiple benefits in this regard (Jones *et al.* 2018). One mechanism to increase the intensity of use is to strengthen incentives for older residents to downsize when children move out. Property taxes as well as an elimination of taxes on property transactions, such as the stamp duty in the United Kingdom, can have such an effect.

There is a wide variation in building lifetimes, from less than 25 years in some East Asian countries to more than 100 years in Europe. Extending building lifetimes can therefore have widely different effect. In China, extending the lifespan of buildings to 50 years could reduce CO_2 emissions by 400 Mt per year or about 20 per cent of construction-related emissions (Cai *et al.* 2015). In Europe, new buildings have lower energy use due to improvements in building standards and technology, with lifetime extensions resulting in higher total emissions compared with replacement buildings, unless the building are retrofit to a high energy standard (Serrenho *et al.* 2019). If only new, efficient buildings have

Figure 7.2. Annual emissions from the construction and operations of buildings in the G7 and in China and India, in a scenario that follows Shared Socioeconomic Pathway SSP1 to mitigate emissions to below 2°C



Source: International Resource Panel (forthcoming).

their lifetime extended, more modest savings will be had (figure 7.2) (International Resource Panel forthcoming). Policies requiring energy retrofit during building renovations, such as those of the European Union, could alleviate the trade-off between emissions savings from lifetime extension and operational energy use (International Energy Agency 2019b), though optimal strategies can only be identified on a case-by-case basis (Itard and Klunder 2007).

7.2.4 Enhanced recycling and reuse

Recycling of valuable materials is already widespread; reuse of building components is less common. When I-beams are reused, GHG savings can be significant, though there is the substantial logistical challenge of matching supply and demand, with reuse practices currently in decline (Densley Tingley *et al.* 2017). The recycling of construction and demolition waste from residential buildings offsets about 13–19 per cent of GHG emissions from building-material production in the G7. Metals are widely recycled and there is some recycling of timber and plastics. The use of concrete and other minerals as aggregates can still be improved, but emission savings are less.

Some policy levers are both well-studied and subject to overt policy worldwide. As is the case for recycling of construction and demolition waste (Brantwood Consulting 2016; Deloitte 2017), many are regulated to achieve other social or environmental goals (for example, limits on short-term lodging in residences), though some are still largely at the exploratory stage (disassembly of buildings).

7.3 Material-efficient cars

In 2015, light-duty vehicles (LDVs) contributed around 14 per cent or 7.5 $GtCO_2e$ to global GHG emissions. Of the emissions, 4.7 $GtCO_2e$ occurred during the operation of the vehicles (International Transport Forum 2019), 1.4 $GtCO_2e$ was associated with the production of fuels and another 1.4 $GtCO_2e$ was associated with the production of the vehicles (Hertwich 2019). Only about half of new vehicles replaced retired vehicles, with the remainder reflecting a growth in vehicle stock. G7 members were responsible for close to 40 per cent of the LDV-related GHG emissions, with the United States of America representing one quarter of global LDV emissions.

7.3.1 Product lightweighting and material substitution

Under a business-as-usual scenario, lightweighting vehicles with materials such as high-strength steel, aluminium or carbon fibre offers significant emission reductions of 3–6 per cent, if proper recycling of these materials can be instituted (Løvik *et al.* 2014; Milovanoff *et al.* 2019). The relative emission reductions from lightweighting are smaller for electric vehicles due to their lower operational emissions. Fuel-efficiency standards, fuel taxes and registration fees tied to the fuel economy are policy instruments that support vehicle lightweighting.

Downsizing the average size of vehicles is another important opportunity. In recent years, there has been a trend towards larger, heavier vehicles, such as sports-utility vehicles (SUVs) and pick-up trucks, which require more materials and higher operational energy use. Reversing that trend would reduce emissions substantially. Reducing the share of SUVs and light trucks in the United States of America from the current 53 per cent to 32 per cent by 2050 would reduce emissions from the production and operation of cars by 10 per cent. Registration fees tied to CO_2 emissions in some European countries have successfully reduced the CO_2 emissions rating of the average new vehicle, in part through shifting demand to smaller vehicles (D'Haultfœuille *et al.* 2016; Yan and Eskeland 2018). Fleets of shared vehicles tend to be smaller, but still provide users with transport capacity when it is needed. Encouraging collective rather than individual vehicle ownership could therefore help reduce vehicle mass and with this both material-related and operational emissions.

7.3.2 Improvements in the yield of material production and car manufacturing

Improvements in the yield of material production and car manufacturing can contribute modest reductions in material use and associated emissions (Milford *et al.* 2013).

7.3.3 More intensive use and lifetime extension

Car sharing, ride sharing and other measures to reduce individual automobility in favour of shared and collective transport can substantially reduce material use (Shaheen and Cohen 2019). Early evidence suggests that car sharing reduces household vehicle ownership and the average vehicle size (Chan and Shaheen 2012; Nijland and van Meerkerk 2017), though it also attracts users of public transport (Becker *et al.* 2018). There is also evidence to suggest that ride-hailing services, such as Uber and Lyft, can have an adverse effect and lead to increased traffic and vehicle size (Schaller 2017; Yin *et al.* 2018). Policies that discourage low-occupancy shared vehicles or penalize the increased congestion resulting from ride hailing, such as priority lanes for cars with three or more occupants or congestion pricing, can improve their environmental impact and material efficiency (Schaller 2018).

The International Resource Panel (forthcoming) estimates that having 25 per cent of drivers shift to car sharing would reduce emissions by 10 per cent, while shifting 25 per cent of trips to shared rides would reduce emissions by 20 per cent (figure 7.3). In some rich countries, car ownership is already starting to reduce, especially among younger urban populations, a trend that can be furthered by tax policies, parking fees and regulatory and institutional support for shared mobility. Most policies on shared mobility, however, currently focus on regulating drivers and services, rather than on environmental impacts and use of resources.

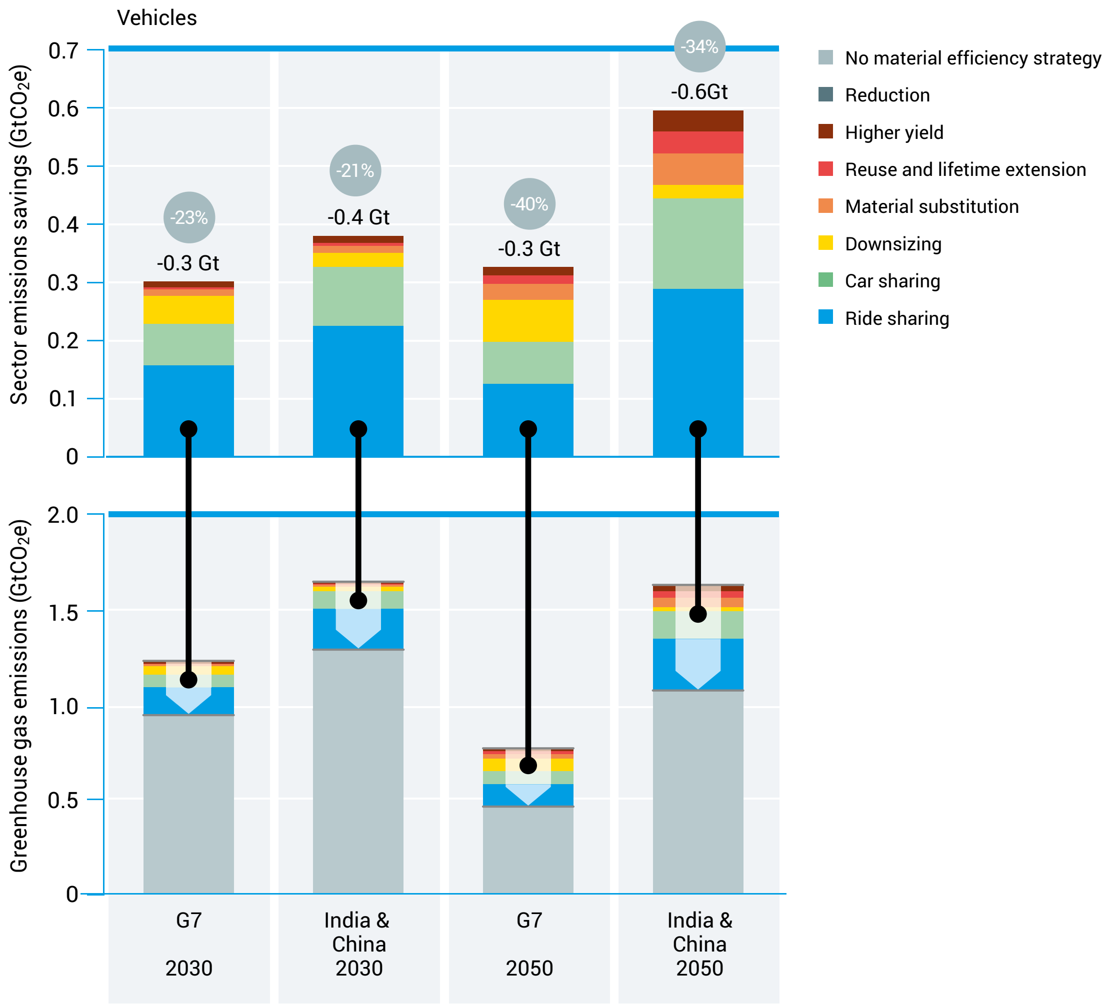
Extending the life of materials, through repair, reuse and remanufacturing, may reduce material-related emissions, but could also increase operational emissions when a newer car may be more efficient or use a cleaner fuel (Kagawa *et al.* 2013; Lenski *et al.* 2013). Much vehicle reuse is connected to the export of vehicles from wealthier to poorer countries, where vehicle recycling is not as well established or sophisticated. In such cases, reuse may meet unmet needs but at the expense of increasing material-related emissions.

In the future, it is anticipated that individual car ownership may be replaced by fleets of self-driving vehicles (Greenblatt and Saxena 2015; Jones and Leibowicz 2019), which could result in a decrease in the number of vehicles needed and an increase in the use of such vehicles. If unregulated, such a trend will also likely increase driving distances which would impact emissions and may move people away from using more efficient public transport. With a policy that discourages individual ownership and enhances interoperability among public transport systems, self-driving cars could offer more ride-sharing services and be used as last-mile solutions in public transport systems (Hertwich *et al.* 2019).

7.3.4 Enhanced recycling and reuse

Current recycling of metals from end-of-life vehicles (ELV) is well established. The International Resource Panel (forthcoming) estimates that recycling of ELV offsets about half of the emissions in the primary production of the materials used to make the vehicle. Strengthening the reuse of components also offers significant savings (International Resource Panel forthcoming; Milford *et al.* 2013). Within policies, recycling is typically measured in terms of recycling rates and landfill diversion rather than GHG emissions (Sawyer Beaulieu and Tam 2006). Adjusting ELV policies to incorporate considerations of embodied carbon warrants attention. The recovery of vehicle parts

Figure 7.3. Annual emissions from the manufacturing and use of passenger vehicles in the G7 and in China and India, in a scenario that follows the Shared Socioeconomic Pathway SSP1 to mitigate emissions to below 2°C



Source: International Resource Panel (forthcoming).

and the alloy-specific (closed-loop) recycling of metals may have a larger emissions pay-off than current shredding practices (Ohno *et al.* 2017; Sato *et al.* 2019). This could be achieved by developing reuse regulations and through more standardization across manufacturers. Some GHG reduction potential is missed because much of the steel in cars is downcycled to uses that are tolerant to copper contamination generated in the shredding of ELVs, such as, for example, reinforcing bar (Daehn *et al.* 2017). If the mixing of steel and copper in the recycling process were reduced, recycled steel could be used for higher value uses, such as car bodies, thereby reducing GHG emissions.

7.4 Summary and link to policy

Research has shown that demand-side material efficiency offers substantial GHG mitigation opportunities that are complementary to those obtained through an energy system transformation (see chapter 6). The potential of purely technical strategies is limited, but considered relatively easy to achieve, whereas the more intense use of housing and vehicles has larger potential, though it would impact social structures and lifestyles. Demand-side material efficiency widens the spectrum of emissions mitigation strategies and may therefore reduce the need for other risky, contested, unproven or expensive technologies.

Knowledge gaps regarding the link between material efficiency and climate change mitigation continue to exist, especially regarding the efficacy of policies where the focus of material efficiency has largely been confined to the end-of-life stage, such as targets for increased recycling. Socioeconomic transformations are crucial to harnessing the full potential of material efficiency, as, for example, greater intensity of use implies significant changes in use patterns or car ownership. The feasibility of and pathway towards such transformations in a carbon-constrained world requires further investigation. More intensive use is likely have a rebound effect, with money saved on car ownership being used for vacation travels or other high-emission activities (Makov and Font Vivanco 2018; Underwood and Fremstad 2018). Carbon pricing is a policy tool that can help minimize a rebound effect. It is important to gain a better understanding of other products and the coupling of sectors and cascading of materials, including implications to material quality resulting from increased reuse and recycling. Furthermore, the influence of the urban form, land-use planning and policies on service demand and consumption patterns need to be better understood.

Demand-side material efficiency and related reductions in energy consumption and GHG emissions could be achieved through a number of policies, including carbon taxation on bulk materials (Neuhoff *et al.* 2016), eco-design laws (Official Journal of the European Union 2009), green public procurement (Organisation for Economic Co-operation and Economic Development [OECD] 2015) or circular economy strategies (Material Economics 2018), as well as sector-specific approaches, such as changes in building codes (ICC 2018). However, not all policies aimed at resource efficiency or circular economy automatically have co-benefits with climate change mitigation. For example, a prolonged product lifetime as a result of policies may under certain circumstances actually delay the introduction of more efficient products, thus leading to higher system-wide emissions. Use of life cycle assessments and related forms of systems measurement, as well as careful and integrative policy design and evaluation are necessary for the more efficient use of resources, which will also lead to reduced emissions.

References

Chapter 1

C

Christensen, J. and Olhoff, A. (2019). Lessons from a decade of emissions gap assessments. Nairobi: United Nations Environment Programme (UNEP). https://wedocs.unep.org/bitstream/handle/20.500.11822/30022/EGR10.pdf?sequence=1&isAllowed=y. Accessed 29 October 2019.

Chapter 2

A

Al-Ghabban, A. (2013). Saudi Arabia's Renewable Energy Strategy and Solar Energy Deployment Roadmap, King Abdullah City for Atomic and Renewable Energy, p. 60. https://www.irena.org/DocumentDownloads/masdar/Abdulrahman Al Ghabban Presentation.pdf.

Al-Sarihi, A. (2019). *Climate Change and Economic Diversification in Saudi Arabia: Integrity, Challenges, and Opportunities*. Washington D.C.: Arab Gulf States Institute in Washington (AGSIW).

Ángel Gurría (2019). Presentation of the OECD "Financing Climate Futures" report. https://www.oecd.org/about/secretary-general/financing-climate-futures-rethinking-infrastructure-mexico-may-2019.htm. Accessed 5 November 2019.

Argentina, Boletín Oficial de la República Argentina (2019). *Resolución* 276/2019. https://www.boletinoficial.gob.ar/detalleAviso/primera/207713/20190517. Accessed 10 September 2019.

Argentina, Gabinete National de Cambio Climático (2019). Planes de Acción Nacionales Sectoriales de Cambio Climático [National Sectoral Climate Change Plans]. https://www.argentina.gob.ar/ambiente/sustentabilidad/planes-sectoriales.

Argentina, Ministerio de Ambiente y Desarrollo Sustentable (2018). *Monitoreo de la superficie de bosque nativo de la República Argentina* [Monitoring the area of Argentina's native forest]. https://www.argentina.gob.ar/sites/default/files/1.informe_monitoreo_2017_tomo_i1_3_0.pdf.

Australia, Department of the Environment and Energy (2018). *Australia's emissions projections 2018*. https://www.environment.gov.au/climate-change/publications/emissions-projections-2018.

Australia, Department of the Environment and Energy (2019). Climate Solutions Fund - Emissions Reduction Fund. https://www.environment.gov.au/climate-change/government/emissions-reduction-fund.

B

Baruj, G. and Drucaroff, S. (2018). *Estimaciones del potencial económico del océano en la Argentina* [Estimations of the ocean's economic potential in Argentina]. Buenos Aires: Centro Interdisciplinario de Estudios en Ciencia, Tecnologiá e Innovación. http://www.ciecti.org.ar/wp-content/uploads/2018/04/IT10-Pampa-azul_vDigital_16-abril-2018.pdf.

Bellini, E. (2019). Saudi Arabia plans new long-term RE targets, will resume tenders, 3 January. https://www.pv-magazine.com/2019/01/03/saudi-arabia-plans-to-set-new-long-term-re-targets-and-to-resume-tenders/. Accessed 10 September 2019.

BP (2019). *BP Statistical Review of World Energy 2019. 68th edition*. London. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf.

Brazil, Electricity Regulatory Agency (2019). *Resumo dos resultados dos Leilões de Geração no ACR de 2005 a 2019* [Summary of generation auctions in the Regulated Contracting Environment 2005 –2019]. Brasilia. https://www.aneel.gov.br/resultados-de-leiloes. Accessed 16 October 2019.

Brazil, Ministry of Science, Technology, Innovation and Communications (2019). *Brazil's third biennial update report to the United Nations Framework Convention on Climate Change.* https://unfccc.int/sites/default/files/resource/2018-02-28_BRA-BUR3_ENG_FINAL.pdf.

Buckley, T. and Garg, V. (2019). IEEFA briefing note: India's electricity sector transition still on track despite a weak FY2018/19, 25 April. http://ieefa.org/ieefa-briefing-note-indias-electricity-sector-transition-still-on-track-despite-a-weak-fy2018-19/. Accessed 13 September 2019.

Buckley, T. and Shah, K. (2019). IEEFA India: New record with renewable energy installations 40 times higher than thermal, 29 January. http://ieefa.org/ieefa-india-new-record-with-renewable-energy-installations-40-times-higher-than-thermal/. Accessed 13 September 2019.

C

Canada, Alberta Queen's Printer (2019). *An Act to Repeal the Carbon* Tax. http://www.qp.alberta.ca/1266.cfm?page=2019ch01.cfm&leg_type=Acts&isbncln=9780779810574.

Chosunilbo (2019). South Chungcheong Governor Resists Gov't's Coal Power Plans, 25 Janaury. http://english.chosun.com/site/data/html_dir/2019/01/25/2019012501708.html. Accessed 10 September 2019.

Chung, J. (2019). South Korea fires up on renewables, to close more coal plants, 18 June. https://www.reuters.com/article/us-southkorea-energy-renewable-analysis/south-korea-fires-up-on-renewables-to-close-more-coal-plants-idUSKCN1TJ0JK. Accessed 10 September 2019.

Clean Energy Regulator (2017). Energy Reduction Fund Project Map, 3 August. http://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/interactive-map. Accessed 10 September 2019.

Clean Energy Regulator (2018). When does the Renewable Energy Target end?, 25 May. http://www.cleanenergyregulator.gov.au/RET/Pages/About the Renewable Energy Target/When-does-the-Renewable-Energy-Target-end.aspx. Accessed 10 September 2019.

Climate Action Tracker (2017). F*oot off the gas: increased reliance on natural gas in the power sector risks an emissions lock-in.* https://climateactiontracker.org/documents/55/CAT_2017-06-16_DecarbNaturalGas_CATAnalysis.pdf.

Climate Action Tracker (2019a). Australia, 17 June. https://climateactiontracker.org/countries/australia/. Accessed 5 November 2019.

Climate Action Tracker (2019b). Brazil, 17 June. https://climateactiontracker.org/countries/brazil/. Accessed 5 August 2019.

Climate Action Tracker (2019c). Canada, 17 June. https://climateactiontracker.org/countries/canada/. Accessed 23 September 2019.

Climate Action Tracker (2019d). Countries. https://climateactiontracker.org/countries/. Accessed 13 August 2019.

Climate Action Tracker (2019e). Indonesia, 17 June. https://climateactiontracker.org/countries/indonesia/.

Climate Change Authority (2017). *Review of the emissions reduction fund. December 2017.* http://climatechangeauthority.gov.au/review-emissions-reduction-fund.

Compañía Administradora del Mercado Mayorista Eléctrico S.A. (CAMMESA) (2019). Renovables Hoy [Renewables Today]. https://despachorenovables.cammesa.com/renovables/. Accessed 13 September 2019.

D

den Elzen, M., Kuramochi, T., Höhne, N., Cantzler, J, Esmeijer, K., Fekete, H. et al. (2019). Are the G20 economies making enough progress to meet their NDC targets? Energy Policy 126, 238–250. https://doi.org/10.1016/j.enpol.2018.11.027.

E

Energy & Climate Intelligence Unit (2019). Net Zero Tracker. https://eciu.net/netzerotracker. Accessed 10 September 2019.

Europe Beyond Coal (2019). Overview: *National coal phase-out announcements in Europe. Status March 2019.*

European Commission (2018a). *A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.* Brussels. COM(2018) 773 final.

European Commission (2018b). In-*depth analysis in support of the Commission Communication COM(2018) 773: A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.* Brussels. https://ec.europa.eu/knowledge4policy/publication/depth-analysis-support-com²018-773-clean-planet-all-european-strategic-long-term-vision_en.

European Commission (2018c). New Renewables, Energy Efficiency and Governance legislation comes into force on 24 December 2018, 21 December. https://ec.europa.eu/info/news/new-renewables-energy-efficiency-and-governance-legislation-comes-force-24-december-2018-2018-dec-21_en. Accessed 16 October 2019.

European Commission (2019a). *Clean mobility: Putting an end to polluting trucks. Commission welcomes first-ever EU standards to reduce pollution from trucks.* 18 February. http://europa.eu/rapid/press-release_IP-19-1071_en.htm.

European Commission (2019b). *Energy Union: Commission calls on Member States to step up ambition in plans to implement Paris agreement.* 18 June. https://ec.europa.eu/clima/news/energy-union-commission-calls-member-states-step-ambition-plans-implement-paris-agreement_en.

European Commission (2019c). *Clean mobility: New CO_2 emission standards for cars and vans adopted.* 15 April. https://ec.europa.eu/clima/news/clean-mobility-new-co2-emission-standards-cars-and-vans-adopted_en.

European Environment Agency (2018) *Trends and projections in Europe 2018. Tracking progress towards Europe's climate and energy targets.* Copenhagen. https://www.eea.europa.eu//publications/trends-and-projections-in-europe-2018.

F

Food and Agriculture Organization Corporate Statistical Database (2019). Land Use Total. http://www.fao.org/faostat/en/#data/GL. Accessed 19 September 2019.

G

Germany, Federal Ministry for Economic Affairs and Energy (2019). *Commission on Growth, Structural Change and Employment. Final Report*. Berlin. https://www.bmwi.de/Redaktion/EN/Publikationen/commission-on-growth-structural-change-and-employment.pdf?__blob=publicationFile&v=3https://www.bmwi.de/Redaktion/EN/Publikationen/commission-on-growth-structural-change-and-employment.pdf?__blob=publicationFile&v=3.

Global Forest Watch (2018). 2017 Was the Second-Worst Year on Record for Tropical Tree Cover Loss, 27 June. https://blog.globalforestwatch.org/data-and-research/2017-was-the-second-worst-year-on-record-for-tropical-tree-cover-loss. Accessed 10 September 2019.

Government of Brazil (2019). Programa de Parcerias de Investimentos [Investment Partnership Program]. https://www.ppi.gov.br/.

Government of Canada (2018a).*Regulations Amending the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations: SOR/2018-263.* Canada Gazette, Part II 152(25).

Government of Canada (2018b). R*egulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity*. Canada Gazette, Part II 152(25). http://www.gazette.gc.ca/rp-pr/p2/2018/2018-12-12/html/sor-dors261-eng.html.

Government of Canada, Transport Canada (2019). Zero-emission vehicles. https://www.tc.gc.ca/en/services/road/innovative-technologies/zero-emission-vehicles.html. Accessed on 5 November 2019.

Government of Mexico (2019). *Tren Maya* [Maya Train]. http://www.trenmaya.gob.mx/.

Grassi, G., House, J., Dentener, F., Federici, S., den Elzen, M., & Penman, J. (2017). The key role of forests in meeting climate targets requires science for credible mitigation, Nature Climate Change, 7, pp. 220–226. doi: 10.1038/nclimate3227.

Gubinelli, G. (2018). *Plazos y tasas del RenovAr: la mirada de entidades bancarias a la hora de financiar proyectos de energías renovables* [RenovAr terms and rates: a look at banking institutions in financing renewable energy projects]. http://www.energiaestrategica.com/plazos-y-tasas-del-renovar-la-mirada-de-entidades-bancarias-a-la-hora-de-financiar-proyectos-de-energias-renovables/. Accessed 13 September 2019.

H

Hang, A. (2019). Is China Ready for Subsidy-Free Renewables, 31 May. https://www.greentechmedia.com/articles/read/is-china-ready-for-subsidy-free-renewables#gs.qmlij0. Accessed 13 September 2019.

He, H. and Cui, H. (2019). China announced 2019 subsidies for new energy vehicles. International Council on Clean Transportation, 18 June. https://theicct.org/publications/china-announced-2019-subsidies-new-energy-vehicles. Accessed 10 September 2019.

Hill, J. S. (2019). China Approves 21 Gigawatts Of Grid-Parity Wind & Solar Projects, 23 May. https://cleantechnica.com/2019/05/23/china-approves-21-gigawatts-of-grid-parity-wind-solar-projects/. Accessed 13 September 2019.

Houghton, R.A. and Nassikas, A.A. (2017). Global and regional fluxes of carbon from land use and land cover change 1850–2015. *Global Biogeochemical Cycles* 31(3), 456–472. https://doi.org/10.1002/2016GB005546.

I

India, Cabinet Committee on Economic Affairs (2018). 100% Electrification of Broad Gauge Routes of Indian Railways. https://pib.gov.in/newsite/PrintRelease.aspx?relid=183399. Accessed 5 November 2019.

India, Cabinet Committee on Economic Affairs (2019). Cabinet approves launch Kisan Urja Suraksha evam Utthaan Mahabhiyan, 19 February. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1565274.

India, Ministry of Environment, Forest and Climate Change (2019a). *India Cooling Action Plan*. New Delhi.

India, Ministry of Environment, Forest and Climate Change (2019b). NCAP: *National Clean Air Programme*. New Delhi.

India, Ministry of Power (2019). Saubhagya Dashboard. http://saubhagya.gov.in/dashboard. Accessed 22 June 2017.

India, Parliamentary Standing Committee on Energy (2018). T*hirty-seventh Report. Stressed/Non-performing Assets in Electricity Sector.* New Delhi. http://164.100.47.193/lsscommittee/Energy/16_Energy_37.pdf.

India, Press Information Bureau (2019). Cabinet approves Scheme for FAME India Phase II. New Delhi. https://pib.gov.in/newsite/PrintRelease.aspx?relid=189081.

Iguacel, J. (2018). Pasado, presente y futuro de la energía en Argentina [Past, present and future of energy in Argentina]. Neuquén, August. https://www.argentina.gob.ar/sites/default/files/2018-08-10_ppt_ji_neuquen_v4.5_f.pdf.

Instituto National de Tecnología Agropecuaria (n.d.). *Programa Nacional de los Suelos* [National Soils Programme]. https://inta.gob.ar/pnsuelos. Accessed 13 September 2019.

Intergovernmental Panel on Climate Change (2018). *Summary for Policymakers. Global Warming of 1.5°C. An IPCC*

Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.

Intergovernmental Panel on Climate Change (2019). *Summary for Policymakers. Climate Change and Land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.*

International Energy Agency (2019). *Global Energy & CO_2 Status Report: The latest trends in energy and emissions in 2018*. https://www.iea.org/geco/. Accessed 10 September 2019.

J

Japan, Ministry of Economy, Trade and Industry (2018). *Long-Term Goal and Strategy of Japan's Automotive Industry for Tackling Global Climate Change.*

Japan, Ministry of Economy, Trade and Industry (2019a). *Kaiyo saisei kano enerugi hatsuden setsubi no seibi ni kakaru kaiiki no riyo no sokushin ni kansuru hōritsu-an' ga kakugi kettei sa remashita* [Act for promoting the utilization of sea areas in the development of power generation facilities using maritime renewables]. Tokyo.

Japan, Ministry of Economy, Trade and Industry (2019b). T*aiyohikarihatsuden jigyo ni kansuru kankyo eikyo hyoka ni tsuite* [About environmental impact assessments for solar power generation projects]. Tokyo.

Japan, Ministry of Economy, Trade and Industry (2019c). *Third interim report by the Committee on Energy Efficiency and Renewable Energy and the Subcommittee on Mass Introduction of Renewable Energy and Next-Generation Electricity Networks of the Electricity and Gas Industry Committee* [in Japanese]. Tokyo.

Japan, Ministry of the Environment (2019). Denryoku bunya no teitansoka ni mukete – *Arata na 3tsu no action* [Three new actions for a low-carbon power sector]. http://www.env.go.jp/press/files/jp/111265.pdf.

Jong, H.N. (2019). Indonesia forest-clearing ban is made permanent, but labeled 'propaganda', 14 August. https://news.mongabay.com/2019/08/indonesia-forest-clearing-ban-is-made-permanent-but-labeled-propaganda/. Accessed 10 September 2019.

K

KBS (2019). 앵커의 눈/단독] '탈석탄·전기요금' 서민 직결 정책 깜깜이 논의 [Anchor's Eye/Exclusive] 'De-coal and Electricity Bill' Direct Policy, 8 June. https://mn.kbs.co.kr/news/view.do?ncd=4217276. Accessed 10 September 2019.

Keesler, D., Orifici, L. and Blanco, G. (2019). *Situación actual y proyección de emisiones de gases de efecto invernadero en la Argentina* [Current situation and projection of greenhouse gas emissions in Argentina]. Buenos Aires: Universidad Nacional del Centro de la Provincia de Buenos Aires. https://www.fio.unicen.edu.ar/images/pdf/2019/Informe_GREENPEACE_-_CTAE-FIO-UNICEN.pdf.

Keramidas, K., Tchung-Ming, S., Diaz-Vazquez, A.R., Weitzel, M., Vandyck, T., Després, J. et al. (2018). Global Energy and Climate Outlook 2018: *Sectoral mitigation options towards a low-emissions economy – Global context to the EU strategy for long-term greenhouse gas emissions reduction*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/67475.

Kingdom of Saudi Arabia (2016). *Vision 2030*. http://vision2030.gov.sa/en/media-center.

KPMG (2019). *Carbon Tax: A Burning Issue*. https://home.kpmg/content/dam/kpmg/xx/pdf/2019/02/tnf-south-africa-feb25-2019.pdf. Accessed 25 April 2019.

Kuramochi, T., Fekete, H., Luna, L., de Villafranca Casa, M.J., Nascimento, L., Hans, F. et al. (2018). *Greenhouse gas mitigation scenarios for major emitting countries. Analysis of current climate policies and mitigation commitments: 2018 update*. NewClimate Institute, PBL Netherlands Environmental Assessment Agency and International Institute for Applied Systems Analysis.

L

Larsen, K., Houser, T. and Mohan, S. (2019). Sizing Up a Potential Fuel Economy Standards Freeze, 3 May. htpps://rhg.com/research/sizing-up-a-potential-fuel-economy-standards-freeze/. Accessed 16 September 2019.

Le Quéré, C., Andrew, R.M., Friedlingstein, P., Sitch, S., Pongratz, J., Manning, A.C. et al. (2018). Global Carbon Budget 2017, *Earth System Science Data* 10, 405–448. https://doi.org/10.5194/essd-10-405-2018.

Le Quéré, C., Korsbakken, J.I., Wilson, C., Tosun, J., Andrew, R., Andres, R.J et al. (2019). Drivers of declining CO_2 emissions in 18 developed economies, *Nature Climate Change* 9(3), 213–217. https://doi.org/10.1038/s41558-019-0419-7.

M

Marsden Jacob Associates (2018). *Modelling Snowy 2.0* in the NEM. Public Report. https://www.snowyhydro.com.au/wp-content/uploads/2018/12/MJA-NEM-Study-Public-Report-3Dec2018.pdf.

Mercado Eléctrico (2019). Se licitarán líneas de transporte junto con las Energías Renovables Ronda Renovar IV [Transport lines will be tendered together with Renewable Energy Round IV], 4 April. http://www.melectrico.com.ar/web/index.php?option=com_content&view=article&id=2362:se-licitaran-lineas-de-transporte-junto-con-las-energias-renovables-ronda-renovar-iv&catid=1:latest-news. Accessed 13 September 2019.

Mexico, Cámara de Diputados del H. Congreso de la Unión (2012). *Ley General de Cambio Climático*. Diario Oficial de la Federación. http://www.diputados.gob.mx/LeyesBiblio/ref/lgcc.htm.

Mexico, Cámara de Diputados del H. Congreso de la Unión (2015). *Ley de Transición Energética*. Diario Oficial de la Federacion. http://www.diputados.gob.mx/LeyesBiblio/pdf/LTE.pdf.

Mexico, Centro Nacional de Control de Energía (2018). Acuerdo de suspensión de la SLP No. 1 2018 [Suspension Agreement for SLP No. 1 2018]. Mexico City.

Mexico, Diario Oficial de la Federación (2019). *Plan Nacional de Desarrollo* 2019-2024. https://www.dof.gob.mx/nota_detalle.php?codigo=5565599&fecha=12/07/2019.

Mexico, Ministry of Energy (2019). *Programa de Desarrollo del Sistema Eléctrico Nacional 2019-2033* [National Electricity System Development Programme 2019–2033]. Mexico City. https://www.gob.mx/sener/documentos/prodesen-2019-2033. Accessed 6 October 2019.

Mongabay (2018). Indonesian president signs 3-year freeze on new oil palm licenses, 20 September. https://news.mongabay.com/2018/09/indonesian-president-signs-3-year-freeze-on-new-oil-palm-licenses/. Accessed 18 April 2019.

N

National Development and Reform Commission of China (2019a). Notice of the NDRC on improving the mechanism for grid-connected prices for solar PV power projects.

National Development and Reform Commission of China (2019b). Notice of the NDRC on improving the policy for grid-connected prices for wind power projects.

National Energy Administration of China (2019). *Notice on coal power planning and construction risks warning for 2022*.

National Energy Administration, National Development and Reform Commission and Ministry of Finance of China (2019). Notice of the NDRC, MOF and NEA on solar PV project generation issues of 2018.

Natural Resources Defense Council (2018). C*omments of the Natural Resources Defense Council on EPA's Proposed Emission Guidelines for Greenhouse Gas Emissions From Existing Electric Utility Generating Units; Revisions to Emission Guideline Implementing Regulations; Revisions to New Source Review*. https://www.nrdc.org/sites/default/files/nrdc-ace-comments-20181031.pdf. Accessed 16 September 2019.

Nereim, V. (2017). Saudi Arabia Slows Pace of Energy Subsidy Cuts to Boost Economy, 19 December. https://www.bloomberg.com/news/articles/2017-12-19/saudi-arabia-slows-pace-of-energy-subsidy-cuts-to-boost-economy. Accessed 15 April 2018.

Nereim, V. and Cunningham, S. (2018). Saudis, SoftBank Plan World's Largest Solar Project, 28 March. https://www.bloomberg.com/news/articles/2018-03-28/saudi-arabia-softbank-ink-deal-on-200-billion-solar-project?utm_source=CP+Daily&utm_campaign=6344d9f796-CPdaily28032018&utm_medium=email&utm_term=0_a9d8834f72-6344d9f796-110247033. Accessed 7 November 2018.

Norway, Ministry of Climate and Environment (2016). *Press release: - Indonesia's Peat Moratorium could benefit people, welfare and climate*. 5 December. https://www.regjeringen.no/en/aktuelt/indonesias-president-forbyr-a-odelegge-torvmyrer/id2522663/. Accessed 10 September 2019.

Notimex (2019). CCE pide a gobierno de AMLO continuar con subastas de energía limpia [CCE asks the AMLO Government to continue clean energy tenders], 31 January. https://www.eleconomista.com.mx/empresas/CCE-pide-a-gobierno-de-AMLO-continuar-con-subastas-de-energia-limpia-20190131-0077.html. Accessed 10 September 2019.

O

Olivier, J.G.J. and Peters, J.A.H.W. (2018). *Trends in global CO_2 and total greenhouse gas emissions:* 2018 report. The Hague: PBL Netherlands Environmental Assessment Agency. https://www.pbl.nl/sites/default/files/downloads/pbl-2018-trends-in-global-co2-and-total-greenhouse-gas-emissons-2018-report_3125_0.pdf.

Olivier, J.G.J. and Peters, J.A.H.W. (2019). *Trends in global CO_2 and total greenhouse gas emissions:* 2019 report. The Hague: PBL Netherlands Environmental Assessment Agency. https://www.pbl.nl/en/publications/trends-in-global-co2-and-total-greenhouse-gas-emissions-2019-report.

P

Pan, C., Peters, G.P., Andrew, R.M., Korsbakken, J.I., Li, S., Zhou, D. and Zhou, P. (2017). Emissions embodied in global trade have plateaued due to structural changes in China, *Earth's Future* 5(9), 934–946. https://doi.org/10.1002/2017EF000625.

Panigatti, J.L. (2010). *Argentina 200 Años 200 Suelos* [Argentina 200 years 200 soils]. https://inta.gob.ar/sites/default/files/script-tmp-inta-200-suelos.pdf.

Peters, G.P., Minx, J.C., Weber, C.L. and Edenhofer, O. (2011). Growth in emission transfers via international trade from 1990 to 2008, *Proceedings of the National Academy of Sciences* 108(21), 8903–8908. https://doi.org/10.1073/pnas.1006388108.

Powering Past Coal Alliance (2018). South Chungcheong Province, home to half of South Korea's coal power generation, joins PPCA, 2 October. https://poweringpastcoal.org/news/member-news/South-Chungcheong-

P

Province-South-Korea-coal-Powering-Past-Coal-Alliance. Accessed 10 September 2019.

President of Indonesia (2018). *Instruksi presiden republik Indonesia nomor 8 tahun 2018 tentang penundaan dan evaluasi perizin* [Presidential Instruction no. 8 of 2018 on the postponement and evaluation of oil palm plantation licensing and improved productivity of oil palm plantations]. Jakarta. https://assets.documentcloud.org/documents/4910673/Inpres-Moratorium-Sawit.pdf.

President of Indonesia (2019). *Penghentian Pemberian Izin Baru dan Penyempurnaan Tata Kelola Hutan Alam Primer dan Laha* [Presidential instruction (Inpres) no. 5 of 2019: Termination of granting new permits and improving governance of primary natural forests and peatlands]. Jakarta. https://peraturan.bpk.go.id/Home/Download/107863/Inpres No. 5 Tahun 2019.pdf.

PRODES (2019). Monitoramento da Floresta Amazônica Brasileira por Satélite [Amazon forest monitoring by satellite]. http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes. Accessed 29 May 2019.

R

Republic of Indonesia (2019). *Rencana Usaha Penyediaan Tenaga Listrik* (RUPTL) 2019–2028 [General Power Supply Plan 2019–2028].

Republic of Indonesia, Ministry of Eenergy and Mineral Resources (2017). *2017 Handbook of Energy and Economic Statistics of Indonesia*. Jakarta. https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-economic-statistics-of-indonesia-2017-.pdf.

Republic of Korea, Ministry of Environment (2018). National greenhouse gas reduction target by 2030: Amended baseline roadmap for achieving the target [in Korean]. Seoul. http://energytransitionkorea.org/sites/default/files/2018-11/18.072030-온실가스-감축로드맵-수정안관계부처-합동 %281%29.pdf.

Republic of South Africa, Department of Energy (2018). Draft Integrated Resource Plan 2018. Pletoria. http://www.energy.gov.za/IRP/irp-update-draft-report2018/IRP-Update-2018-Draft-for-Comments.pdf. Accessed 5 September 2019.

Republic of South Africa, Department of Environmental Affairs (2018). *Climate Change Bill, 2018*. Government Gazette. https://www.environment.gov.za/sites/default/files/legislations/climatechangebill2018_gn41689.pdf.

Reuters (2019). South African parliament approves long-delayed carbon tax bill, 19 February. https://www.reuters.com/article/us-safrica-carbontax/south-african-parliament-approves-long-delayed-carbon-tax-bill-idUSKCN1Q81U8. Accessed 25 April 2019.

Rochedo, P.R.R., Soares-Filho, B., Schaeffer, R., Viola, E., Szklo, A., Lucena, A.F.P. et al. (2018). The threat of political bargaining to climate mitigation in Brazil, *Nature Climate Change* 8, 695–698. https://doi.org/10.1038/s41558-018-0213-y.

Rogelj, J., Nabel, J., Chen, C., Hare, W., Markmann, K., Meinshausen, M. et al. (2010). C*openhagen Accord pledges are paltry, Nature* 464, 1126–1128. https://doi.org/10.1038/4641126a.

Rogelj, J., den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H. et al. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 °C, *Nature* 534, 631–639. https://doi.org/10.1038/nature18307.

S

Sauer, N. and Collett-White, R. (2019). Russia floats first law to regulate CO_2 emissions, 22 March. https://www.climatechangenews.com/2019/03/22/russia-floats-first-law-regulate-carbon-emissions/. Accessed 2 May 2019.

Singh, N. (2019). El PRODESEN 2019-2033 planea más de 50 proyectos de expansión de redes de transmisión y distribución para lograr una mejor integración de renovables, Energía Estratégica [PRODESEN 2019-2033 plans more than 50 projects to expand transmission and distribution networks to better integrate renewables], 3 June. https://www.energiaestrategica.com/el-prodesen-2019-2033-planea-mas-de-50-proyectos-de-expansion-de-redes-de-transmision-y-distribucion-para-lograr-una-mejor-integracion-de-renovables. Accessed 13 September 2019.

Solís, A. (2018a). AMLO apuesta por el carbón para producir más electricidad [AMLO bets on coal to produce more electricity], 24 December. https://www.forbes.com.mx/amlo-apuesta-por-el-carbon-para-producir-mas-electricidad/. Accessed 10 September 2019.

Solís, A. (2018b). CFE gastará más en plantas de carbón que en centrales renovables [CFE spends more on carbon plants than renewable plants], 18 December. https://www.forbes.com.mx/en-cfe-gastara-mas-en-plantas-de-carbon-que-en-centrales-renovables/. Accessed 5 November 2019.

T

Torchia, A., Kalin, S. and Rashad, M. (2018). Saudi's PIF invested in 50-60 firms via SoftBank fund: director, 23 October. https://www.reuters.com/article/us-saudi-investment-pif/saudis-pif-invested-in-50-60-firms-via-softbank-fund-director-idUSKCN1MX12X. Accessed 5 November 2019.

Tu, Q., Betz, R., Mo, J., Fan, Y. and Liu, Y (2019). Achieving grid parity of wind power in china – Present levelized cost of electricity and future evolution, *Applied Energy* 250, 1053–1064. https://doi.org/10.1016/j.apenergy.2019.05.039.

U

U.S. Climate Alliance (2019). Montana Governor Steve Bullock Becomes 25th Governor to Join U.S. Climate Alliance, 1 July. https://www.usclimatealliance.org/publications/2019/7/1/montana-governor-steve-bullock-becomes-25th-governor-to-join-us-climate-alliance. Accessed 10 September 2019.

U.S. Energy Information Administration (2018). Today in Energy: U.S. energy-related CO_2 emissions fell slightly in 2017, 5 September. https://www.eia.gov/todayinenergy/detail.php?id=36953. Accessed 10 September 2019.

United Nations (2019). Climate Action Summit Delivers Major Step-Up in National Ambition, Private Sector Initiatives on Pathway to Key 2020 Deadline, 23 September. https://www.un.org/press/en/2019/envdev1998.doc.htm. Accessed 5 November 2019.

United Nations, Department of Economic and Social Affairs, Population Division (2019). *World Population Prospects 2019*. https://population.un.org/wpp/Download/Standard/Population/. Accessed 13 August 2019.

United Nations Environment Programme (2018). *The Emissions Gap Report 2018*. Nairobi. https://www.unenvironment.org/resources/emissions-gap-report-2018.

United Nations Framework Convention on Climate Change (2018). NDC registry (interim). http://www4.unfccc.int/ndcregistry/Pages/All.aspx. Accessed 1 August 2018.

United Nations Framework Convention on Climate Change (2019a). Communication of long-term strategies. https://unfccc.int/process/the-paris-agreement/long-term-strategies. Accessed 9 May 2019.

United Nations Framework Convention on Climate Change (2019b). Highlights from Parties at the Multilateral Assessment session at SBI 50. Bonn, June. https://unfccc.int/sites/default/files/resource/SBI50_MA_key_messages_summary.pdf.

V

Van Sant, S. (2019). California Signs Deal With Automakers To Produce Fuel-Efficient Cars. 25 July. https://www.npr.org/2019/07/25/745389326/california-signs-deal-with-automakers-to-produce-fuel-efficient-cars?t=1569794744209. Accessed 10 September 2019.

Vembadi, S., Das, N. and Gambhir, A. (2018). 175 Pune: Prayas (Energy Group). http://www.prayaspune.org/peg/publications/item/405-175-gw-renewables-by-2022-a-september-2018-update.html.

Vigliotti, M. (2019). Federal carbon tax to be introduced in Alberta in January: McKenna, 13 June. https://ipolitics.ca/2019/06/13/federal-carbon-tax-to-be-introduced-in-alberta-in-january-mckenna/.

X

Xiao, M. (2019). What Impact Will China's 2019 New Energy Vehicle (NEV) Subsidy Policy Have?, 11 April. https://www.interactanalysis.com/what-impact-will-chinas-2019-new-energy-vehicle-nev-subsidy-policy-have/. Accessed 20 September 2019.

Chapter 3

A

Allen, M.R., Dube, O.P., Solecki, W., Aragón-Durand, F., Cramer, W., Humphreys, S., Kainuma, M. et al. (2018). Framing and context. I*n Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change/World Meteorological Organization. 47–92.

B

Bertoldi, P., den Elzen, M., Ford, J., Klein, R., Ley, D., Roberts, T., Rogelj, J., (2018). Cross-Chapter Box 11. Consistency Between Nationally Determined Contributions and 1.5°C Scenarios. *In Global warming of 1.5°CAn IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change/World Meteorological Organization. 47–92.

C

Climate Action Tracker (2019). Climate Action Tracker – CAT Emissions Gap (updated December, 2018). https://climateactiontracker.org/documents/508/CAT_2018-12-09_PublicData_EmissionsGaps_Dec2018update.xls. Accessed 5 July 2019.

Clarke, L., Jiang, K., Akimoto, K., Babiker, M., Blanford, G., Fisher-Vanden, K., et al. (2014). Assessing transformation pathways. *In Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Edenhofer, O.R., Pichs-Madruga, Y., Sokona, E., Farahani, S., Kadner, K., Adler, S.A., Baum, I., Brunner, S. Eickemeier, P., Kriemann, B., Savolainen, S., Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. 413–510.

D

de Coninck, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A. et al. (2018). Strengthening and implementing the global response. *In Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change/World Meteorological Organization.

F

Fuss, S., Lamb, W.F., Callaghan, M.W., Hilaire, J., Creutzig, F., Amann, T. et al. (2018). Negative emissions—part 2: costs, potentials and side effects. *Environmental Research Letters* 13(6), 063002.

H

Huppmann, D., Kriegler, E., Krey, V., Riahi, K., Rogelj, J., Rose, S.K. et al. (2018a). IAMC 1.5°C Scenario Explorer and Data Hosted by IIASA. https://data.ene.iiasa.ac.at/iamc-sr15-explorer. Accessed 7 November 2019.

Huppmann, D., Rogelj, J., Kriegler, E., Krey, V. and Riahi, K. (2018b). A new scenario resource for integrated 1.5 °C research. *Nature Climate Change* 8(12), 1027–1030.

I

International Energy Agency (2018). *World Energy Outlook 2018*. Paris, France.

Intergovernmental Panel on Climate Change (2014). C*limate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva, Switzerland.

Intergovernmental Panel on Climate Change (2018). Summary for policymakers. In Global Warming of 1.5°C. *An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change/World Meteorological Organization. 32.

J

Jeffery, M.L., Gütschow, J., Rocha, M.R. and Gieseke, R. (2018). Measuring success: improving assessments of aggregate greenhouse gas emissions reduction goals. *Earth's Future* 6(9), 1260–1274.

Joos, F., Roth, R., Fuglestvedt, J.S., Peters, G. P., Enting, I.G., von Bloh, W. et al. (2013). Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: a multi-model analysis. *Atmospheric Chemistry and Physics* 13(5), 2793–2825.

L

Le Quéré, C., Andrew, R.M., Friedlingstein, P., Sitch, S., Pongratz, J., Manning, A.C., Korsbakken, J.I. et al. (2018). Global Carbon Budget 2017*. Earth System Science Data* 10, 405–448.

M

McCollum, D.L., Zhou, W., Bertram, C., de Boer, H.-S., Bosetti, V., Busch, S., Després, J. et al. (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nature Energy* 3(7), 589–599.

Meinshausen, M., Meinshausen, N., Hare, W., Raper, S.C.B., Frieler, K., Knutti, R. et al. (2009). Greenhouse-gas emission targets for limiting global warming to 2°C. Nature 458(7242), 1158–1162.

Meinshausen, M., Raper, S.C.B. and Wigley, T.M.L. (2011). Emulating coupled atmosphere-ocean and carbon cycle models with a simpler model, MAGICC6 – part 1: model description and calibration. *Atmospheric Chemistry and Physics* 11(4), 1417–1456.

R

Ricke, K.L. and Caldeira, K. (2014). Maximum warming occurs about one decade after a carbon dioxide emission. *Environmental Research Letters* 9(12), 124002.

Rogelj, J., den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H. et al. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature* 534(7609), 631–639.

Rogelj, J., Forster, P.M., Kriegler, E., Smith, C.J. and Séférian, R. (2019). Estimating and tracking the remaining carbon budget for stringent climate targets. *Nature* 571(7765), 335–342.

Rogelj, J., Meinshausen, M., Sedláček, J. and Knutti, R. (2014). Implications of potentially lower climate sensitivity on climate projections and policy. *Environmental Research Letters* 9(3), 031003.

Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V. et al. (2018). Mitigation pathways compatible with 1.5°C in the context of sustainable development. *In Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change/World Meteorological Organization. 93–174.

Roy, J., Tschakert, P., Waisman, H., Abdul Halim, S., Antwi-Agyei, P., Dasgupta, P. et al. (2018). Sustainable development, poverty eradication and reducing inequalities. *In Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change/World Meteorological Organization.

S

Schleussner, C.-F., Rogelj, J., Schaeffer, M., Lissner, T., Licker, R., Fischer, E.M. et al. (2016). Science and policy characteristics of the Paris Agreement temperature goal. *Nature Climate Change* 6(9), 827–835.

Stocker, T.F., Qin, D., Plattner, G.-K., Alexander, L.V., Allen, S.K., Bindoff, N.L. et al. (2013). Technical Summary. In Climate Change 2013: *The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M. Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (eds.). Cambridge, United Kingdom and New York, USA: Cambridge University Press, 33–115.

T

Tchung-Ming, S., Diaz-Vazquez, A.R., Keramidas, K. and Kitous, A. (2018). *Global Energy and Climate Outlook 2018: greenhouse gas emissions and energy balances. Supplementary material to "Global Energy and Climate Outlook 2018: sectoral mitigation options towards a low-emissions economy.* Luxembourg: Publications Office of the European Union. http://ec.europa.eu/jrc/en/geco

Tokarska, K.B. and Zickfeld, K. (2015). The effectiveness of net negative carbon dioxide emissions in reversing anthropogenic climate change. *Environmental Research Letters* 10(9), 094013.

U

United Nations Environment Programme (2010). The Emissions Gap Report - Are the Copenhagen Accord Pledges Sufficient to *Limit Global Warming to 2°C or 1.5°C?.* Nairobi.

United Nations Environment Programme (2015). The Emissions Gap Report 2015: A UNEP Synthesis Report. http://www.unep.org/emissionsgapreport2015/. Accessed 7 November 2019.

United Nations Environment Programme (2018). The Emissions Gap Report 2018. https://www.unenvironment.org/resources/emissions-gap-report-2018. Accessed 7 November 2019.

United Nations Framework Convention on Climate Change (2015). *Adoption of the Paris Agreement.* Paris. FCCC/CP/2015/L.9/Rev.1. 1-32.

Z

Zickfeld, K. and Herrington, T. (2015). The time lag between a carbon dioxide emission and maximum warming increases with the size of the emission. *Environmental Research Letters* 10(3), 031001.

Zickfeld, K., MacDougall, A.H. and Matthews, H.D. (2016). On the proportionality between global temperature change and cumulative CO_2 emissions during periods of net negative CO_2 emissions. *Environmental Research Letters 11*(5), 055006.

Chapter 4

B

Bloomberg NEF (2018). Electric Vehicle Outlook 2018. https://about.bnef.com/electric-vehicle-outlook/. Accessed 7 October 2018.

C

Christensen, J. and Olhoff, A. (2019). *Lessons from a decade of emissions gap assessments.* Nairobi: United Nations Environment Programme.

F

Food and Agriculture Organization Corporate Statistical Database (2018). Land Use Total – (Emissions – Land Use). Accessed 7 November 2019.

Farand, C. (2019). What is the UN climate action summit?, 16 September. https://www.climatechangenews.com/2019/09/16/un-climate-action-summit/.

I

International Energy Agency (2019). Tracking Clean Energy Progress 2019. https://www.iea.org/tcep/. Accessed 13 September 2019.

International Energy Agency (2018). *World energy balances* (2018 edition). Paris.

Intergovernmental Panel on Climate Change (2018). Summary for policymakers. In *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). Geneva, Switzerland: Intergovernmental Panel on Climate Change/World Meteorological Organization.

International Renewable Energy Agency (2019). *Renewable power generation costs in 2018.* Abu Dhabi.

J

Jewell, J., Vinichenko, V., Nacke, L. and Cherp, A. (2019). Prospects for powering past coal. *Nature Climate Change 9,* 592–597. https://doi.org/10.1038/s41558-019-0509-6

K

Kuramochi, T., Höhne, N., Schaeffer, M., Cantzler, J., Hare, B., Deng, Y. et al. (2018). Ten key short-term sectoral benchmarks to limit warming to 1.5°C. *Climate Policy* 18, 287–305. https://doi.org/10.1080/14693062.2017.1397495

N

New Development Bank (2018). The MDBs' alignment approach to the objectives of the Paris Agreement: working together to catalyse low-emissions and climate-resilient development, 3 December. https://www.ndb.int/press_release/mdbs-alignment-approach-objectives-paris-agreement-working-together-catalyse-low-emissions-climate-resilient-development/

O

Olivier, J.G.J. and Peters, J.A.H.W. (2018). *Trends in global CO_2 and total greenhouse gas emissions: 2018 report* (PBL Report No. 3599). Bilthoven: PBL Netherlands Environmental Assessment Agency.

S

Smouse, S.M., Jones, A., Fapohunda, B.O., Render, M. and Hindman, J.W. (2018). Coal- and gas-fired power construction and cancellation trends in countries with the most new coal power capacity since 2003. In ASME 2018 *Power Conference.* Lake Buena Vista: American Society of Mechanical Engineers. https://doi.org/doi:10.1115/POWER2018-7466

T

The New Climate Economy (2018). *Unlocking the inclusive growth story of the 21st Century: accelerating climate action in urgent times.* Washington, D.C.

U

United Nations Environment Programme (2017). *The Emissions Gap Report 2017*. Nairobi. https://doi.org/ISBN 978-92-9253-062-4

United Nations Environment Programme (2018). *The Emissions Gap Report 2018.* Nairobi.

United Nations Framework Convention on Climate Change (2015). *Paris Agreement - Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015 Addendum Part two: Action taken by the Conference of the Parties at its twenty-first session.* Bonn. Decision 1/CP.21.

United Nations Framework Convention on Climate Change (2019). Communication of long-term strategies. https://unfccc.int/process/the-paris-agreement/long-term-strategies. Accessed 5 September 2019.

W

World Bank (2019). Carbon Pricing Dashboard: up-to-date overview of carbon pricing initiatives. https://carbonpricingdashboard.worldbank.org/map_data. Accessed 7 November 2019.

World Resources Institute (2019). Case studies on existing long-term strategies. https://www.wri.org/climate/case-studies. Accessed 17 September 2019.

Chapter 5

B

Bastin, J.-F., Finegold, Y., Garcia, C., Mollicone, D., Rezende, M., Routh, D. et al (2019). The global tree restoration potential. *Science* 365(6448), 76–79. https://doi.org/10.1126/science.aax0848.

Bertram, C., Luderer, G., Popp, A., Minx, J.C., Lamb, W.F., Stevanović, M. et al. (2018). Targeted policies can compensate most of the increased sustainability risks in 1.5 °C mitigation scenarios. E*nvironmental Research Letters* 13(6), 064038. https://doi.org/10.1088/1748-9326/aac3ec.

Bryan, B. A., Gao, L., Ye, Y., Sun, X., Connor, J.D., Crossman, N.D., et al. (2018). China's response to a national land-system sustainability emergency. *Nature* 559(7713), 193–204. https://doi.org/10.1038/s41586-018-0280-2.

C

Creutzig, F., Agoston, P., Minx, J.C., Canadell, J.G., Andrew, R.M., Le Quéré, C. et al. (2016). Urban infrastructure choices structure climate solutions. *Nature Climate Change* 6, 1054–1056. https://doi.org/10.1038/nclimate3169.

Creutzig, F., Baiocchi, G., Bierkandt, R., Pichler, P.-P. and Seto, K.C. (2015). Global typology of urban energy use and potentials for an urbanization mitigation wedge. *Proceedings of the National Academy of Sciences* 112(20), 6283–6288. https://doi.org/10.1073/pnas.1315545112.

F

Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Childrens' Fund, World Food Programme and World Health Organization (2018). *The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition.* Rome: FAO.

G

Global Energy Assessment (2012). *Global Energy Assessment – Toward a Sustainable Future.* Cambridge and New York: Cambridge University Press; Laxenburg: International Institute for Applied Systems Analysis.

Grubler, A., Bai, X., Buettner, T., Dhakal, S., Fisk, D.J., Ichinose, T. et al. (2012). Urban Energy Systems. In Global Energy Assessment – Toward a Sustainable Future. Johansson, T.B., Patwardhan, A., Nakićenović, N. and Gomez-Echevarri, L. (eds.). Cambridge and New York: Cambridge University Press; Laxenburg: International Institute for Applied Systems Analysis. Chapter 18. 1307–1400.

Grubler, A., Wilson, C., Bento, N., Boza-Kiss, B., Krey, V., McCollum, D.L. et al. (2018). A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. Nature Energy 3(6), 515–527. https://doi.org/10.1038/s41560-018-0172-6.

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R. and Meybeck, A. (2011). Global food losses and food waste. Rome: Food and Agriculture Organization of the United Nations (FAO). http://www.fao.org/fileadmin/user_upload/suistainability/pdf/Global_Food_Losses_and_Food_Waste.pdf.

I

International Energy Agency (2018). *World Energy Outlook 2018*. Paris.

Intergovernmental Panel on Climate Change (2014). *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, A. et al. (eds.). Cambridge and New York: Cambridge University Press.

Intergovernmental Panel on Climate Change (2018). Summary for Policymakers. *In Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., et al. (eds.). Geneva: World Meterological Organization.

L

Lelieveld, J., Klingmüller, K., Pozzer, A., Burnett, R.T., Haines, A. and Ramanathan, V. (2019). Effects of fossil fuel and total anthropogenic emission removal on public health and climate. Proceedings of the *National Academy of Sciences* 116(15), 7192–7197. https://doi.org/10.1073/pnas.1819989116.

Lucon O., Ürge-Vorsatz, D., Ahmed, A.Z., Akbari, H., Bertoldi, P., Cabeza, L.F. et al. (2014). Buildings. In Climate Change 2014: *Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Edenhofer, O., Pich-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, A. et al. (eds.). Cambridge and New York: Cambridge University Press. Chapter 9. 671–738.

M

McCollum, D.L., Echeverri, L.G., Busch, S., Pachauri, S., Parkinson, S., Rogelj, J. et al. (2018). Connecting the sustainable development goals by their energy inter-linkages. *Environmental Research Letters* 13(3), 033006. https://doi.org/10.1088/1748-9326/aaafe3.

McCollum, D.L., Krey, V. and Riahi, K. (2011). An integrated approach to energy sustainability. *Nature Climate Change* 1(9), 428-429. https://doi.org/10.1038/nclimate1297.

N

Nakićenović, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S. et al. (2000). *Special report on Emissions Scenarios.* Cambridge: Cambridge University Press.

P

Preston, I., White, V., Thumim, J., Bridgeman, T. and Brand, C. (2013). *Distribution of carbon emissions in the UK: implications for domestic energy policy.* York: Joseph Rowntree Foundation.

R

Riahi, K., van Vuuren, D.P., Kriegler, E., Edmonds, J., O'Neill, B.C., Fujimori, S. et al. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change* 42, 153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009.

Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakićenović, N. and Schellnhuber, H.J. (2017). A roadmap for rapid decarbonization. Science 355(6331), 1269–1271. https://doi.org/10.1126/science.aah3443.

Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V. et al. (2018). Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In Global Warming of 1.5°C. *An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J. Shukla, P.R. et al. (eds.) Geneva: World Meterological Organization. Chapter 2. 93–174.

S

Sachs, J.D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakićenović, N. and Rockström, J. (2019). Six Transformations to achieve the Sustainable Development Goals. *Nature Sustainability* 2(9), 805–814. https://doi.org/10.1038/s41893-019-0352-9.

Schumpeter, J.A. (1935). The analysis of economic change. *The Review of Economics and Statistics* 17(4), 2–10.

Seto, K.C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G.C., Dewar, D. et al. (2014). Human Settlements, Infrastructure and Spatial Planning.

T

Tupy, M.L. (2012). Dematerialization (update), 12 July. https://www.cato.org/blog/dematerialization-update. Accessed 6 November 2019.

The World in 2050 (TWI2050) (2018). *Transformations to Achieve the Sustainable Development Goals. Report prepared by The World in 2050 initiative*. Laxenburg: International Institute for Applied Systems Analysis (IIASA).

The World in 2050 (TWI2050) (2019). *The Digital Revolution and Sustainable Development: Opportunities and Challenges. Report prepared by The World in 2050 initiative.* Laxenburg: International Institute for Applied Systems Analysis (IIASA).

U

United Nations, Department of Economic and Social Affairs, Population Division (2018). *World Urbanization Prospects: The 2018 Revision.* New York.

V

van Vuuren, D.P., Riahi, K., Calvin, K., Dellink, R., Emmerling, J., Fujimori, S. et al. (2017). The Shared Socio-economic Pathways: Trajectories for human development and global environmental change. *Global Environmental Change* 42, 148–152. https://doi.org/10.1016/j.gloenvcha.2016.10.009.

World Health Organization (2019). Air pollution. https://www.who.int/airpollution/en/.

World Health Organization and United Nations Childrens' Fund (2017). *Progress on Drinking Water, Sanitation and Hygiene. 2017 update and SDG baselines*. Geneva.

Wilson, E.O. (2016). Half-earth. Our Planet's Fight for Life. London: WW Norton & Company.

Z

Zimm, C. and Nakićenović, N. (2019). What are the implications of the Paris Agreement for inequality? *Climate Policy*, 1-10. https://doi.org/10.1080/14693062.2019.1581048.

Chapter 6

A

Agora Energiewende (2015). *The integration costs of wind and solar power. An overview of the debate on the effects of adding wind and solar photovoltaic into power systems.* https://www.agora-energiewende.de.

Anenberg, S., Miller, J., Henze, D. and Minjares, R. (2019). *Global snapshot of the air pollution-related health impacts of transportation sector emissions in 2010 and 2015.* Washington, D.C.: International Council on Clean Transportation and Climate & Clean Air Coalition. https://theicct.org/sites/default/files/Global_health_impacts_transport_emissions_2010-2015_20190226_1.pdf

B

Bailis, R., Drigo, R., Ghilardi, A. and Masera, O. (2015). The carbon footprint of traditional woodfuels. Nature Climate Change 5, 266–272.

Bataille, C., Åhman, M., Neuhoff, K., Nilsson, L.J., Fischedick, M., Lechtenböhmer, S. et al. (2018). A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement. *Journal of Cleaner Production* 187, 960–973. https://doi.org/10.1016/j.jclepro.2018.03.107

Batchelor, S., Brown, E., Scott, N. and Leary, J. (2019). Two birds, one stone — reframing cooking energy policies in Africa and Asia. *Energies* 12(9), 1591.

Bhamidipati, P.L., Haselip, J. and Hansen, U.E. (2019). How do energy policies accelerate sustainable transitions? Unpacking the policy transfer process in the case of GETFiT Uganda. *Energy Policy* 132, 1320–1332.

BloombergNEF (2019). *Clean energy investment trends 2018*. https://data.bloomberglp.com/professional/sites/24/BNEF-Clean-Energy-Investment-Trends-2018.pdf

Bogdanov, D., Farfan, J., Sadovskaia, K., Aghahosseini, A., Child, M., Gulagi, A. et al. (2019). Radical transformation pathways towards sustainable electricity via evolutionary steps. *Nature Communications* 10, 1077.

BP (2019). *Statistical review of world energy 2019*, 68th edition. London. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf

Byrne, R., Mbeva, K. and Ockwell, D. (2018). A political economy of niche-building: neoliberal-developmental encounters in photovoltaic electrification in Kenya. *Energy Research and Social Science* 44, 6–16.

C

Caldecott, B., Sartor, O. and Spencer, T. (2017). *Lessons from previous 'coal transitions.' High level summary for decision-makers*. Paris: Institute for Sustainable Development and International Relations and Climate Strategies. https://coaltransitions.files.wordpress.com/2016/09/coal_synthesisreport_v04.pdf.

Cardoso, A. and Turhan, E. (2018). Examining new geographies of coal: dissenting energyscapes in Colombia and Turkey. *Applied Energy* 224, 398–408. https://doi.org/10.1016/j.apenergy.2018.04.096

Climate Analytics (2016). *Implications of the Paris Agreement for coal use in the power sector.* Berlin.

Climate Analytics (2017). *Synthesis of the Least Developed Countries' NDCs.* Berlin. https://climateanalytics.org/publications/2017/synthesis-of-the-least-developed-countries-ndcs/

D

Dagnachew, A.G., Lucas, P.L., Hof, A.F. and van Vuuren, D. (2018). Trade-offs and synergies between universal electricity access and climate change mitigation in Sub-Saharan Africa. *Energy Policy* 114, 355–366.

de Coninck, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A. et al. (2018). Strengthening and implementing the global response. I*n Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). In Press.

Dhar, S., Pathak, M. and Shukla, P.R. (2017). Electric vehicles and India's low carbon passenger transport: A long-term co-benefits assessment. *Journal of Cleaner Production* 146, 139–148. https://doi.org/10.1016/j.jclepro.2016.05.111

Dhar, S., Pathak, M. and Shukla, P.R. (2018). Transformation of India's transport sector under global warming of 2°C and 1.5°C scenario. Journal of Cleaner Production 172, 417–427.

E

Edenhofer, O., Steckel, J.C., Jakob, M. and Bertram, C. (2018). Reports of coal's terminal decline may be exaggerated. *Environmental Research Letters* 13(2), 024019. https://doi.org/10.1088/1748-9326/aaa3a2.

Enerdata (2019). Global Energy Statistical Yearbook 2019. https://yearbook.enerdata.net/coal-lignite/coal-production-data.html. Accessed 25 October 2019.

Enerdata (2019). Global Energy and CO_2 Data. https://www.enerdata.net/research/energy-market-data-co2-emissions-database.html. Accessed 25 October 2019.

Energy Transitions Commission (2019). *Mission possible: reaching net-zero carbon emissions from harder-to-abate sectors by mid-century.* London, United Kingdom. http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf

F

Frankfurt School-United Nations Environment Programme Collaborating Centre and BloombergNEF (2019). *Global trends in renewable energy investment 2019.* Frankfurt am Main. https://fs-unep-centre.org/fileadmin/user_upload/GTR_2019.pdf

Fuso-Nerini, F.F., Tomei, J., To, L.S., Bisaga, I., Parikh, P., Black, M. et al. (2018). Mapping synergies and trade-offs between energy and the Sustainable Development Goals. *Nature Energy* 3, 10–15. https://doi.org/10.1038/s41560-017-0035-5

G

Gambhir, A., Rogelj, J., Luderer, G., Few, S. and Napp, T. (2019). Energy system changes in 1.5 °C, well below 2 °C and 2 °C scenarios. *Energy Strategy Reviews* 23, 69–80.

Garg, A. and Steckel, J.C. (2017). Bridging the gap: phasing out coal. In *The Emissions Gap Report 2017* – A UN Environment Synthesis Report. United Nations Environment Programme. Nairobi. Chapter 5. https://wedocs.unep.org/bitstream/handle/20.500.11822/22106/EGR_2017_ch_5.pdf?isAllowed=y&sequence=1

Germany, Cabinet of Germany (2019). Climate Action Programme 2030. https://www.bundesregierung.de/bregen/issues/climate-action/klimaschutzprogramm-2030-1674080. Accessed 1 November 2019.

Germany, Federal Ministry for Economic Affairs and Energy Commission on Growth, Structural Change and Employment (2019). *Structural change and employment. Final report*, 2019. https://www.bmwi.de/Redaktion/EN/Publikationen/commission-on-growth-structural-change-and-employment.html

Germany, Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (2018). Klimaschutzbericht 2018: *zum Aktionsprogramm Klimaschutz 2020 der Bundesregierung.* https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzbericht_2018_bf.pdf

Gouldson, A., Sudmant, A., Khreis, H. and Papargyropoulou, E. (2018). *The economic and social benefits of low-carbon cities: a systematic review of the evidence.* London and Washington, D.C.: Coalition for Urban Transitions. http://newclimateeconomy.net/content/cities-working-papers

I

International Energy Agency (2017a). *World energy outlook* 2017. Paris.

International Energy Agency (2017b). E*nergy technology perspectives 2017*: catalyzing energy technology transformations. Paris. https://webstore.iea.org/download/direct/1058?fileName=Energy_Technology_Perspectives_2017.pdf

International Energy Agency (2018a). *Key world energy statistics 2018*. Paris.

International Energy Agency (2018b). W*orld energy outlook 2018*. Paris.

International Energy Agency (2019a). *Global energy and CO_2 status report: the latest trends in energy and emissions 2018.* Paris. https://www.iea.org/geco/emissions/

International Energy Agency (2019b). *Material efficiency in clean energy transitions*. Paris. https://webstore.iea.org/download/direct/2454?fileName=Material_efficiency_in_clean_energy_transitions.pdf

International Energy Agency (2019c). *Status of power system transformation 2019 power system flexibility.* Paris. https://webstore.iea.org/download/direct/2782?fileName=Status_of_Power_System_Transformation_2019.pdf

International Energy Agency (2019d). *World energy investment 2017.* Paris. https://www.iea.org/publications/wei2017/

International Energy Agency (2019e). *Key world energy statistics 2018.* https://webstore.iea.org/download/direct/2831?fileName=Key_World_Energy_Statistics_2019.pdf

International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank and World Health Organization (2019). *Tracking SDG 7*: the energy progress report 2019. Washington, D.C. http://documents.worldbank.org/curated/en/517781558037625254/pdf/Main-Report.pdf

International Renewable Energy Agency (2019a). *Global energy transformation: a roadmap to 2050* (2019 edition). Abu Dhabi.

International Renewable Energy Agency (2019b). *Innovation landscape for a renewable-powered future.* Abu Dhabi.

International Renewable Energy Agency (2019c). *Renewable power generation costs in 2018*. Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf

J

Jackson, T. (2016). *Prosperity without Growth*, 2nd edition. London: Routledge.

Jordaan, S.M., Romo-Rabago, E., McLeary, R., Reidy, L., Nazari, J. and Herremans, I.M. (2017). The role of energy technology innovation in reducing greenhouse gas emissions: a case study of Canada. *Renewable and Sustainable Energy Reviews* 78, 1397–1409. https://doi.org/10.1016/j.rser.2017.05.162

L

Least Developed Countries Renewable Energy and Energy Efficiency Initiative for Sustainable Development (2019). LDC REEEI. https://www.reeeei.org. Accessed 1 November 2019.

Lema, R., Hanlin, R., Hansen, U.E. and Nzila, C. (2018). Renewable electrification and local capability formation: linkages and interactive learning. *Energy Policy* 117, 326–339.

M

Martinez Romera, B. (2016). The Paris Agreement and the regulation of international bunker fuels. *Review of European Community and International Environmental Law* 25(2), 215–227.

May-Tobin, C. (2011). Wood for fuel. In *The Root of the Problem. What's Driving Tropical Deforestation Today?* Cambridge, Massachusetts: Union of Concerned Scientists. https://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/UCS_DriversofDeforestation_Chap8_Woodfuel.pdf.

Mazzucato, M. (2018). Mission-oriented innovation policies: challenges and opportunities. *Industrial and Corporate Change* 27(5), 803–815. https://doi.org/10.1093/icc/dty034

McCollum, D.L., Zhou, W., Betram, C., de Boer, H-S, Bosetti, V. Busch, S. *et al.* (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nature Energy* 3(7), 589–599. https://doi.org/10.1038/s41560-018-0179-z

Mulugetta, Y., Ben Hagan, E. and Kammen, D. (2018). Energy access for sustainable development. *Environmental Research Letters* 14(2). https://doi.org/10.1088/1748-9326/aaf449

O

Ockwell, D., Byrne, R., Hansen, U.E., Haselip, J. and Nygaard, I. (2018). The uptake and diffusion of solar power in Africa: socio-cultural and political insights on a rapidly emerging socio-technical transition. *Energy Research and Social Science* 44, 122–129.

R

Raven, R. and Verbong, G. (2007). Multi-regime interactions in the Dutch energy sector: the case of combined heat and power technologies in the Netherlands 1970-2000. Technology Analysis and Strategic Management 19(4), 491–507.

Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V. et al. (2018). Mitigation pathways compatible with 1.5°C in the context of sustainable development. In Global Warming of 1.5°C. *An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). In Press.

Roy, J., Tschakert, P., Waisman, H., Abdul Halim, S., Antwi-Agyei, P., Dasgupta, P. et al. (2018). Sustainable development, poverty eradication and reducing inequalities. In Global Warming of 1.5°C. *An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.* Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.). In Press.

S

Scrivener, K.L., Vanderley M.J. and. Gartner, E.M. (2018). Eco-efficient cements: potential economically viable solutions for a low-CO_2 cement-based materials industry. *Cement and Concrete Research* 114, 2–26. https://doi.org/10.1016/j.cemconres.2018.03.015

Shearer, C., Neha, M-S., Myllyvirta, L., Yu, A. and Nace, T. (2019). Boom and bust 2018: *tracking the global coal plant pipeline.* CoalSwarm, Greenpeace USA, and Sierra Club.

Sovacool, B. and Geels, F. (2016). Further reflections on the temporality of energy transitions: a response to critics. E*nergy Research & Social Science* 22, 232–237. https://doi.org/10.1016/j.erss.2016.08.013

Spencer, T., Colombier, M., Sartor, O., Garg, A., Tiwari, V., Burton, J. et al. (2018). The 1.5°C target and coal sector transition: at the limits of societal feasibility. *Climate Policy*, 18(3), 335–331. https://doi.org/10.1080/14693062.2017.1386540

T

Truffer, B., Murphy, J.T. and Raven, R. (2015). The geography of sustainability transitions: contours of an emerging theme. *Environmental Innovation and Societal Transitions* 17, 63–72.

U

United Nations Conference on Trade and Development (2017). *The Least Developed Countries report 2017: transformational energy access.* Geneva. https://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=1902

United Nations Department of Economic and Social Affairs (2019). *World population prospects.* Geneva. https://www.un.org/en/development/desa/population/index.asp

University of Columbia Center on Global Energy Policy (2019). Energy transition fact sheet. https://energypolicy.columbia.edu/sites/default/files/file-uploads/Energy%20Transition%20Fact%20Sheet.pdf

V

Vieweg, M., Bongardt, D., Hochfeld, C., Jung, A, Scherer, E., Adib, R. et al. (2018). *Towards decarbonising transport - a 2018 stocktake on sectoral ambition in the G20.* Berlin: Agora Verkehrswende and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Vogl, V., Åhman, M. and Nilsson, L.J. (2018). Assessment of hydrogen direct reduction for fossil-free steelmaking. *Journal of Cleaner Production* 203, 736–745. https://doi.org/10.1016/j.jclepro.2018.08.279

W

Watson, F (2019). December global electric vehicle sales set new record: S&P Global Platts, London, 11 Feb. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/021119-december-global-electric-vehicle-sales-set-new-record-sampp-global-platts-data. Accessed 25 October 2019.

Wieczorek, A.J. (2017). Sustainability transitions in developing countries: major insights and their implications for research and policy. *Environmental Science & Policy,* 204–216.

Williams, D. (2019). For the first time ever, electric cars outsold gas and diesel vehicles in Norway, 4 April. https://edition.cnn.com/2019/04/04/world/norway-zero-emission-vehicles-trnd/index.html

World Steel Association (2018). *Steel statistical yearbook 2018.* Brussels.

Chapter 7

A

Allwood, J.M., Ashby, M.F., Gutowski, T.G. and Worrell, E. (2011). Material efficiency: A white paper. *Resources, Conservation and Recycling* 55(3), 362–381. https://doi.org/10.1016/j.resconrec.2010.11.002.

Allwood, J.M., Gutowski, T.G., Serrenho, A.C., Skelton, A.C.H. and Worrell, E. (2017). Industry 1.61803: The *transition to an industry with reduced material demand fit for a low carbon future. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 375(2095). https://doi.org/10.1098/rsta.2016.0361.

B

Becker, H., Ciari, F., Axhausen, K.W. (2018). Measuring the car ownership impact of free-floating car-sharing – A case study in Basel, Switzerland. *Transportation Research Part D: Transport and Environment* 65, 51–62. https://doi.org/10.1016/j.trd.2018.08.003.

Brantwood Consulting (2016). *Guide for Selecting Policies to Reduce and Divert Construction, Renovation, and Demolition Waste.*

C

Cai, W., Wan, L., Jiang, Y., Wang, C. and Lin, L. (2015). Short-lived buildings in China: impacts on water, energy, and carbon emissions. *Environmental Science & Technology* 49, 13921–13928. https://doi.org/10.1021/acs.est.5b02333.

Cao, Z., Shen, L., Zhong, S., Liu, L., Kong, H. and Sun, Y. (2018). A probabilistic dynamic material flow analysis model for Chinese urban housing stock. *Journal of Industrial Ecology* 22, 377–391. https://doi.org/10.1111/jiec.12579.

Chan, N.D. and Shaheen, S.A. (2012). Ridesharing in North America: past, present, and future. *Transport Reviews* 32, 93–112. https://doi.org/10.1080/01441647.2011.621557.

D

D'Haultfœuille, X., Durrmeyer, I., and Février, P. (2016). Disentangling sources of vehicle emissions reduction in France: 2003–2008. International Journal of Industrial Organization 47, 186–229. https://doi.org/10.1016/j.ijindorg.2016.05.002.

Daehn, K.E., Serrenho, A.C. and Allwood, J.M. (2017). *How will copper contamination constrain future global steel recycling? Environmental Science & Technology* 51, 6599–6606. https://doi.org/10.1021/acs.est.7b00997.

de Wilde, P. (2014). The gap between predicted and measured energy performance of buildings: a framework for investigation. *Automation in Construction* 41, 40–49. https://doi.org/10.1016/j.autcon.2014.02.009.

Deloitte (2017). *Resource Efficient Use of Mixed Wastes: Improving management of construction and demolition waste.* Final Report. Prepared for the European Commission, Directorate-General for Environment (DG ENV).

Densley Tingley, D., Cooper, S. and Cullen, J. (2017). Understanding and overcoming the barriers to structural steel reuse, a UK perspective. *Journal of Cleaner Production* 148, 642–652. https://doi.org/10.1016/j.jclepro.2017.02.006.

Doan, D.T., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Ghaffarianhoseini, A. and Tookey, J. (2017). A critical comparison of green building rating systems. *Building and Environment* 123, 243–260. https://doi.org/10.1016/j.buildenv.2017.07.007.

Dunant, C.F., Drewniok, M.P., Eleftheriadis, S., Cullen, J.M. and Allwood, J.M. (2018). Regularity and optimisation practice in steel structural frames in real design cases. *Resources, Conservation and Recycling* 134, 294–302. https://doi.org/10.1016/j.resconrec.2018.01.009.

G

Greenblatt, J.B. and Saxena, S. (2015). Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. *Nature Climate Change* 5, 860–863.

Güneralp, B., Zhou, Y., Ürge-Vorsatz, D., Gupta, M., Yu, S., Patel, P.L., Fragkias, M., Li, X. and Seto, K.C. (2017). Global scenarios of urban density and its impacts on building energy use through 2050. *Proceedings of the National Academy of Sciences* 114, 8945–8950. https://doi.org/10.1073/pnas.1606035114.

H

Heeren, N., Mutel, C.L., Steubing, B., Ostermeyer, Y., Wallbaum, H. and Hellweg, S. (2015). Environmental impact of buildings—what matters? *Environmental Science & Technology* 49, 9832–9841. https://doi.org/10.1021/acs.est.5b01735.

Hernandez, A.G., Cooper-Searle, S., Skelton, A.C.H. and Cullen, J.M. (2018). Leveraging material efficiency as an energy and climate instrument for heavy industries in the EU. *Energy Policy* 120, 533–549. https://doi.org/10.1016/j.enpol.2018.05.055.

Hertwich, E. (2019). The Carbon Footprint of Material Production Rises to 23 per cent of Global Greenhouse Gas Emissions. https://doi.org/10.31235/osf.io/n9ecw.

Hertwich, E.G., Ali, S., Ciacci, L., Fishman, T., Heeren, N., Masanet, E., Asghari, F.N., Olivetti, E., Pauliuk, S., Tu, Q. and Wolfram, P. (2019). Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—a review. Environmental Research Letters 14, 043004. https://doi.org/10.1088/1748-9326/ab0fe3.

I

International Code Council (2012). International Energy Conservation Code.

International Code Council (2018). 2018 International Green Construction Code. https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/igcc/. Accessed 31 May 2019.

International Energy Agency (2019a). *Material Efficiency in Clean Energy Transitions*. Paris.

International Energy Agency (2019b). *Perspectives for the Clean Energy Transition*. The Critical Role of Buildings. Paris.

International Resource Panel (forthcoming). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. Hertwich, E., Lifset, R., Ali, S., Pauliuk, S., Heeren, Tu, Q. A report of the International Resource Panel Nairobi: United Nations Environment Programme (UNEP). https://doi.org/10.5281/zenodo.3542681

International Transport Forum (2019). *ITF Transport Outlook 2019*. Paris: Organisation for Economic Co-operation and Development (OECD). https://doi.org/10.1787/transp_outlook-en-2019-en.

Itard, L. and Klunder, G. (2007). Comparing environmental impacts of renovated housing stock with new construction. *Building Research & Information* 35(3), 252–267. https://doi.org/10.1080/09613210601068161.

J

John, V.M., Damineli, B.L., Quattrone, M. and Pileggi, R.G. (2018). Fillers in cementitious materials — Experience, recent advances and future potential. *Cement and Concrete Research* 114, 65–78. https://doi.org/10.1016/j.cemconres.2017.09.013.

Jones, C.M., Wheeler, S.M., Kammen and D.M. (2018). Carbon footprint planning: Quantifying local and state mitigation opportunities for 700 California cities. *Urban Planning* 3(2), 35–51. https://doi.org/10.17645/up.v3i2.1218.

Jones, E.C. and Leibowicz, B.D. (2019). Contributions of shared autonomous vehicles to climate change mitigation. Transportation Research Part D: *Transport and Environment* 72, 279–298. https://doi.org/10.1016/j.trd.2019.05.005.

K

Kagawa, S., Hubacek, K., Nansai, K., Kataoka, M., Managi, S., Suh, S. and Kudoh, Y. (2013). Better cars or older cars? Assessing CO_2 emission reduction potential of passenger vehicle replacement programs. *Global Environmental Change* 23(6), 1807–1818. https://doi.org/10.1016/j.gloenvcha.2013.07.023.

Kane, M. and Yee, R. (2017). The Walworth alternative: Retaining and enhancing Britain's social housing estates utilising contemporary timber construction. *Journal of Green Building* 12(1), 11–35. https://doi.org/10.3992/1552-6100.12.1.11.

Karimpour, M., Belusko, M., Xing, K. and Bruno, F. (2014). Minimising the life cycle energy of buildings: Review and analysis. *Building and Environment* 73, 106–114. https://doi.org/10.1016/j.buildenv.2013.11.019.

King, B. (2018). *A Low Carbon Concrete Building Code*. Towards a carbon-sequestering built environment. https://www.ecobuildnetwork.org/images/pdfs/A-Low-Carbon-Concrete-Building-Code10-9.pdf. Accessed 5 November 2019.

Kristjansdottir, T.F., Heeren, N., Andresen, I. and Brattebø, H. (2018). Comparative emission analysis of low-energy and zero-emission buildings. *Building Research & Information* 46(4), 367–382. https://doi.org/10.1080/09613218.2017.1305690.

L

Lenski, S.M., Keoleian, G.A. and Moore, M.R. (2013). *An assessment of two environmental and economic benefits of 'Cash for Clunkers'. Ecological Economics* 96, 173–180. https://doi.org/10.1016/j.ecolecon.2013.10.011.

Lorek, S and Spangenberg, J.H. (2019). I*dentification of promising instruments and instrument mixes to promote energy sufficiency.* Deliverable 5.5. EUFORIE – European Futures for Energy Efficiency.

Løvik, A.N., Modaresi, R. and Müller, D.B. (2014). Long-term strategies for increased recycling of automotive aluminum and its alloying elements. *Environmental Science & Technology* 48(8), 4257–4265. https://doi.org/10.1021/es405604g.

M

Mahapatra, K., Gustavsson, L. and Hemström, K. (2012). Multi-storey wood-frame buildings in Germany, Sweden and the UK. *Construction Innovation* 12(1), 62–85. https://doi.org/10.1108/14714171211197508.

Makov, T. and Font Vivanco, D. (2018). Does the Circular Economy Grow the Pie? The Case of Rebound Effects From Smartphone Reuse. Frontiers in Energy Research 6. https://doi.org/10.3389/fenrg.2018.00039.

Material Economics (2018). *The Circular Economy – A Powerful Force for Climate Mitigation.*

Menezes, A.C., Cripps, A., Bouchlaghem, D. and Buswell, R. (2012). Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. *Applied Energy* 97, 355–364. https://doi.org/10.1016/j.apenergy.2011.11.075.

Milford, R.L., Pauliuk, S., Allwood, J.M. and Müller, D.B. (2013). The roles of energy and material efficiency in meeting steel industry CO_2 targets. *Environmental Science & Technology* 47(7), 3455–3462. https://doi.org/10.1021/es3031424.

Milovanoff, A., Kim, H.C., De Kleine, R., Wallington, T.J., Posen, I.D. and MacLean, H.L. (2019). A dynamic fleet model of U.S light-duty vehicle lightweighting and associated greenhouse gas emissions from 2016 to 2050. *Environmental Science & Technology* 53, 2199–2208. https://doi.org/10.1021/acs.est.8b04249.

N

Neuhoff, K., Ismer, R., Acworth, W., Ancygier, A., Fischer, C., Haussner, M. et al. (2016). *Inclusion of Consumption of carbon intensive materials in emissions trading – An option for carbon pricing post-2020.* Climate Strategies.

Nijland, H. and van Meerkerk, J. (2017). *Mobility and environmental impacts of car sharing in the Netherlands. Environmental Innovation and Societal Transitions* 23, 84–91. https://doi.org/10.1016/j.eist.2017.02.001.

O

Official Journal of the European Union (2009). Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

Ohno, H., Matsubae, K., Nakajima, K., Kondo, Y., Nakamura, S., Fukushima, Y. and Nagasaka, T. (2017). Optimal recycling of steel scrap and alloying elements: Input-output based linear programming method with its application to end-of-life vehicles in Japan. *Environmental Science & Technology* 51(22), 13086–13094. https://doi.org/10.1021/acs.est.7b04477.

Oliver, C.D., Nassar, N.T., Lippke, B.R. and McCarter, J.B. (2014). Carbon, fossil fuel, and biodiversity mitigation with wood and forests. Journal of Sustainable Forestry 33(3), 248–275. https://doi.org/10.1080/10549811.2013.839386.

Organisation for Economic Co-operation and Development (2015). *Going Green: Best Practices for Sustainable Procurement.* Paris.

P

Pauliuk, S., Sjöstrand, K. and Müller, D.B. (2013). Transforming the Norwegian dwelling stock to reach the 2 degrees Celsius climate target. *Journal of Industrial Ecology* 17, 542–554. https://doi.org/10.1111/j.1530-9290.2012.00571.x.

Pauliuk, S., Arvesen, A., Stadler, K. and Hertwich, E.G. (2017). Industrial ecology in integrated assessment models. *Nature Climate Change* 7, 13–20. https://doi.org/10.1038/nclimate3148.

S

Sato, F.E.K., Furubayashi, T. and Nakata, T. (2019). Application of energy and CO_2 reduction assessments for end-of-life vehicles recycling in Japan. *Applied Energy* 237, 779–794. https://doi.org/10.1016/j.apenergy.2019.01.002.

Sawyer Beaulieu, S.S. and Tam, E.K.L. (2006). Regulation of end of life vehicle (ELV) retirement in the US compared to Canada. *International Journal of Environmental Studies* 63(4), 473–486. https://doi.org/10.1080/00207230600802106.

Schaller, B. (2017). Unsustainable? *The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City.* New York: Schaller Consulting.

Schaller, B. (2018). The New Automobility: Lyft, Uber and the Future of American Cities. New York: Schaller Consulting.

Serrenho, C.A., Drewniok, M., Dunant, C. and Allwood, J.M. (2019). Testing the greenhouse gas emissions reduction potential of alternative strategies for the English housing stock. *Resources, Conservation and Recycling* 144, 267–275. https://doi.org/10.1016/j.resconrec.2019.02.001.

Shaheen, S. and Cohen, A. (2019). Shared ride services in North America: definitions, impacts, and the future of pooling. *Transport Reviews* 39(4), 427–442. https://doi.org/10.1080/01441647.2018.1497728.

Shanks, W., Dunant, C.F., Drewniok, M.P., Lupton, R.C., Serrenho, A. and Allwood, J.M. (2019). How much cement can we do without? Lessons from cement material flows in the UK. *Resources Conservation and Recycling* 141, 441–454. https://doi.org/10.1016/j.resconrec.2018.11.002.

Underwood, A. and Fremstad, A. (2018). Does sharing backfire? A decomposition of household and urban economies in CO_2 emissions. *Energy Policy* 123, 404–413. https://doi.org/10.1016/j.enpol.2018.09.012.

W

Worrell, E., Allwood, J., Gutowski, T. (2016). The role of material efficiency in environmental stewardship. *Annual Review of Environment and Resources* 41, 575–598. https://doi.org/10.1146/annurev-environ-110615-085737.

Y

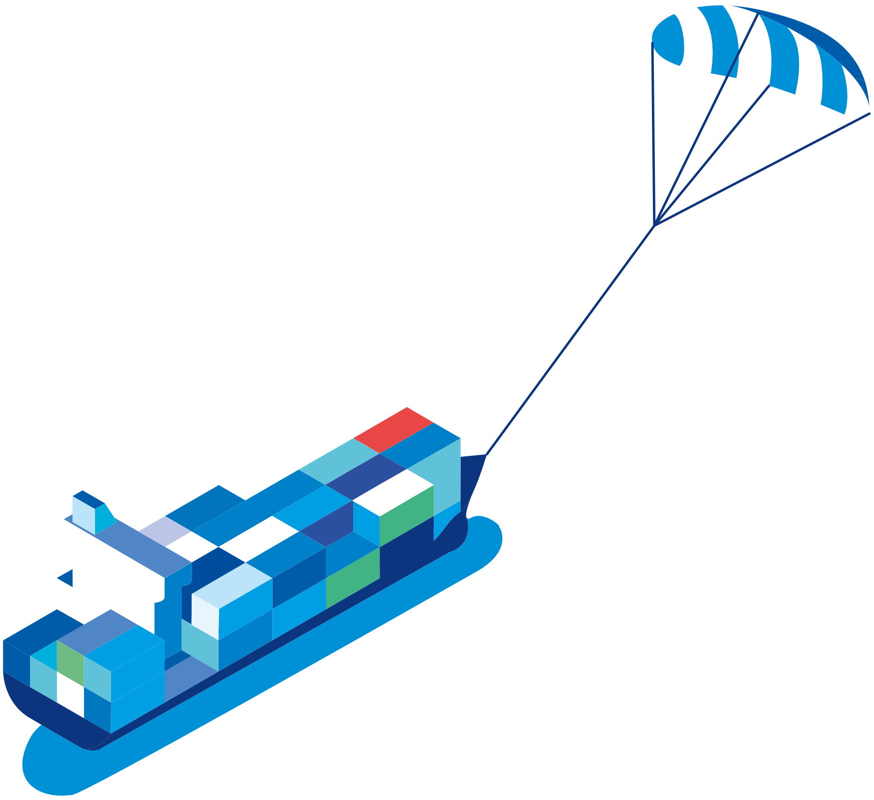
Yan, S. and Eskeland, G.S. (2018). Greening the vehicle fleet: Norway's CO_2-differentiated registration tax. *Journal of Environmental Economics and Management* 91, 247–262. https://doi.org/10.1016/j.jeem.2018.08.018.

Yin, B., Liu, L., Coulombel, N. and Viguie, V. (2018). Appraising the environmental benefits of ride-sharing: The Paris region case study. *Journal of Cleaner Production* 177, 888–898.

Z

Zhang, C., Chen, W.-Q., Ruth, M. (2018). *Measuring material efficiency:* A review of the historical evolution of indicators, methodologies and findings. Resources, *Conservation and Recycling* 132, 79–92. https://doi.org/10.1016/j.resconrec.2018.01.028.

Zheng, X., Wang, R., Wood, R., Wang, C. and Hertwich, E.G. (2018). High sensitivity of metal footprint to national GDP in part explained by capital formation. *Nature Geoscience* 11, 269–273. https://doi.org/10.1038/s41561-018-0091-y.



UN environment programme

United Nations Avenue, Gigiri
P O Box 30552, 00100 Nairobi, Kenya
Tel +254 20 76 1234 |
publications@unenvironment.org
www.unenvironment.org

United States
Environmental Protection
Agency

Growing Toward More Efficient Water Use:

Linking Development, Infrastructure, and Drinking Water Policies



Acknowledgements

This report was written by Paula Van Lare of EPA's Development, Environment, and Community Division and Danielle Arigoni of ICF Consulting. We would like to recognize the following individuals for their contributions and comments on earlier versions of this document: Buddy Atkins, South Carolina Public Utilities Commission; Jan Beecher, Michigan State University; Keyvan Izadi, National Association of Homebuilders; Bob Kaufman, Augustine Development; Lora Lucero, Esq., American Planning Association; Tim Williams, Water Environment Federation, and Kristin M. Anderson, Benton County Planning Department. We also would like to recognize the peer reviewers of this document: Professors Jan Beecher, Michigan State University; Jesse Richardson, Virginia Polytechnic Institute and State University; and A. Dan Tarlock, Chicago-Kent College of Law. We would like to acknowledge EPA staff who provided comments: Steve Allbee, Jane Anderson, Jamal Kadri, Sylvia Malm, Phil Metzger, and Peter Shanaghan, all of EPA's Office of Water; Geoffrey Anderson, Lynn Richards, Megan Susman, and Tim Torma, all of EPA's Development, Environment, and Community Division.

For additional copies of this report, please send an e-mail to smartgrowth@epa.gov. For an electronic version, please visit: <www.epa.gov/smartgrowth>.

About the EPA office that produced this report:

Development, Community, and Environment Division (DCED)
DCED works with communities, states, and the development industry to help them reach more environmentally friendly development alternatives while improving economic conditions and quality of life. DCED provides information, education, and technical assistance. For more information about EPA's smart growth program, visit <www.epa.gov/smartgrowth>.

Cover Photos:
Paul Muldower, FAIA (top left)
Ellen Greenberg (bottom right)

Contents

1. Land Use Decisions and Water Systems

In many communities, growth has brought problems related to water. Growth affects costs of water infrastructure, demand for water, and efficiency of water delivery. However, the relationship is a dynamic one: water policies influence growth decisions and outcomes—which in turn affect infrastructure and water resources.

Communities face two growing and related issues: huge financial needs for water infrastructure and concerns about the availability of water. Drinking water utilities will have to increase their spending by $263 billion over the next 20 years to maintain adequate service,[1] money that will come from either increased water rates or taxes or both. Cities and towns in the arid West have long faced water scarcity; now cities across the country—even in areas with plentiful rainfall—are facing water shortages. The city of Frederick, Maryland, was forced to impose a building moratorium in 2001 as it scrambled to secure a new source of water and build a new treatment plant.[2] A subsequent ordinance setting out priorities for allocating scarce water among development projects remains in effect.[3] On a larger scale, Alabama, Georgia, and Florida have fought in and out of court for 15 years over water allocations from two major river basins that they share. As these three states continue to grow rapidly, resolving their water claims becomes ever more urgent. Even states and provinces along the Great Lakes are taking measures to promote water efficiency and prevent the export of water outside the watershed. Although the Great Lakes are the largest reservoir of fresh water in the world, water experts warn that changes in policies and practices are necessary to preserve the lakes' contribution to the region's quality of life and economic growth.[4]

Water availability and cost are also related to the quality of existing and potential source waters. Utilities must use more chemicals and other treatment methods to bring polluted water up to national standards for drinking water, thus increasing its cost. The quality of source waters depends in part on the ability of surrounding land to filter out potential pollutants. Many areas are working to preserve land that is critical to protecting source waters. Preserving undeveloped land by focusing development in appropriate areas is emerging as a key strategy for maintaining water quality. This topic is covered in greater depth in a recent U.S. Environmental Protection Agency (EPA) publication, "Protecting Water Resources with Smart Growth," and will not be covered in depth here.

This report focuses on the nexus between water and growth. Part I summarizes the challenges of meeting demand for safe drinking water. Part II asks: "Is there a way to accommodate growth that minimizes its effects on water consumption and distribution costs?" Part III asks: "What water policies can support this type of growth?"

1.1 Residential and Commercial Water Use in Context

Only 1 percent of the Earth's total water is fresh water available for use. In the United States, nearly two-thirds of this resource is ground water, which supplies water for 95 percent of rural households, half of all agricultural irrigation, and one-third of industrial water needs.

** Available at <www.epa/smartgrowth/publications.htm>*

The remaining third is surface water, which is the primary source for public supply. Public water supplies serve piped water to a minimum of 25 customers and have at least 15 service connections.[5]

This report focuses on public supply. Drawing on both surface and ground water, public supply is the source of water for 85 percent of the U.S. population and represents roughly 12 percent of all freshwater withdrawals in the United States. The U.S. Geological Survey (USGS) estimates that, of this 12 percent, household use accounts for 56 percent of all public water supplied, commercial purposes constitute 17 percent, industrial users account for 12 percent, and public and other uses are 15 percent.[6]

From 1950 to 2000, the population served by public water systems grew 159 percent, from 93.4 million to 242 million people. During the same time, public water use—primarily household, government, and commercial uses—grew 207 percent, from 14 billion to 43 billion gallons per day. Over the same period, total per capita water use has grown from 149 to 179 gallons per day. Per capita water use did not change from 1995 to 2000, but it declined slightly from 184 gallons per day in 1990 to 179 in 1995, perhaps due to conservation efforts that have since been overtaken by other factors.[7]

Although residential, commercial, and government customers account for less than 12 percent of total water use, their use is significant. During droughts or in areas where water is scarce, even relatively small changes in demand can make the difference between normal service and water shortages. Consistent water service is essential to daily life; shortages and price increases make news and can have serious political implications. While local governments often are responsible for ensuring this water supply for residents and businesses, they have little or no control over the largest water users: agriculture and power generation, which together account for about 80 percent of all freshwater withdrawals. Local governments thus focus their policies where they can have some effect: on residential, commercial, and government demand.

1.1.1 Water-poor communities are often high-growth communities

Many areas facing rapid population growth and increasing development pressure already have difficulty providing adequate water to their residents. A 2005 Brookings Institution report showed that 10 of the 15 fastest-growing metropolitan areas are in the relatively arid western states of Nevada, California, Texas, Colorado, Arizona, and Utah.[8] The West also has some of the highest per capita residential water use in the nation. Lack of rain and its residents' landscaping preferences contribute to per capita water use in the West that far exceeds the national average of 179 gallons per day. In Colorado average use is 240 gallons per day, in Utah it is 292, and in Nevada it is 336.[9] The combination of high growth rates and high water use is rapidly depleting aquifers in the region. Aquifers in the Denver region are falling 30 feet per year, and the Texas portion of the High Plains aquifer has decreased by 27 percent over the past 50 years.[10]

> Utah is not only one of the fastest growing areas, it is also one of the thirstiest, with an average per capita use more than double the national average.

Drought can further compound the difficulties of meeting demand even in areas not typically considered to be water poor. A drought that began in 1998 eventually led the Delaware River

Basin Commission to issue a drought emergency in 2001 that reduced allotments for New York City and the four states that draw on its supply.[11] By the summer of 2002, half of the continental United States experienced drought conditions ranging from mild to extreme, triggering widespread water restrictions in many cities across the country.[12]

1.2 Development patterns and water demand

Population and economic growth inevitably create more demand for water. How that growth takes place affects how much additional water is needed and how much it will cost to deliver. The most common characteristics of new conventional growth—large lots, low density, and dispersed development—all increase the cost of delivering water. Homes on large lots and commercial facilities often consume large quantities of water for lawns and landscaping. Low-density, dispersed development requires longer pipes, which lose more water through leakage and raise transmission costs. Infrastructure investments that support water system expansion over the upgrading and maintenance of existing networks can lead to increasingly inefficient systems, greater waste, and higher capital and operating costs.

1.2.1 Large lots increase water demand

Large lots are a major contributor to both residential and commercial water use. Lawn care, car washing, swimming pools, and other outdoor uses can account for 50 to 70 percent of household water use.[13] Lawn care alone accounts for an average of 50 percent of all household water use nationally.[14] Office buildings also use significant quantities of water for landscaping. According to the USGS, "lawn watering and air conditioning use more water than sanitation or cleaning"[15] in commercial buildings. As would be expected, the amount of water used for lawns varies significantly from region to region based on local climate.

However, no matter where they are, areas with low density, large lots, and large lawns require more water than areas with high density, small lots, and small lawns. In 1997, the Minnesota Department of Agriculture estimated that in Minnesota, the average lawn size in more compact urban watersheds measures 0.05 acres (2,250 square feet), while suburban lawns average over four times that size, at 0.21 acres (9,265 square feet).[16] In Utah, planners have determined that water demand drops from approximately 220 gallons per capita per day at a density of two units per acre, to about 110 gallons per acre at a density of five units per acre.[17] In a study of household water use in Sacramento, California, demand by units in the Metro Square development (a neighborhood of 46 single-family homes on compact lots) was 20 to 30 percent less than demand by their suburban counterparts.[18] A study of Seattle-area households found that moving from 12 dwelling units per acre to four units per acre decreases density by 67 percent but increases water use for landscaping by 158 percent per household. Put another way, Seattle homes on 6,500-square-foot lots use 60 percent less water than those on 16,000-foot lots.[19]

Lot size also increases the length, and thus the cost, of the pipes serving households and commercial buildings. Neighborhood water pipes fall into two types: transmission mains that run under or along streets and distribution mains that connect each house or building to the transmission pipes. A house on a smaller lot typically is closer to the transmission main, and thus a shorter distribution main. Neighborhoods with smaller lots will have more houses per block of transmission main, so the cost of that main will be less per house than in neighborhoods with larger lots.

> Lot size has a greater effect on water system costs than how isolated a site is or how far it is from the water service center.

A recent study in the *Journal of the American Planning Association* used an engineering cost model to assess the influence of land use on the cost of water distribution and sewer services. The study estimated service costs at $143 for a household located on a 0.25 acre lot in a compact development near the service center. If the same household moved to a 1-acre lot in a similar location, its annual service cost would be $272, even if it did not increase its water use. If that household used the same amount of water on a 1-acre site in a dispersed development far from the service center, its water and sewer service would cost $388 annually.[20] Although this analysis looked at the cost of both water and sewer service, the cost of water only would be lower than the numbers given here, but the relationships among infrastructure cost, distance, and lot size would remain essentially the same.

The study found that the infrastructure and pumping costs of water service are more sensitive to lot size than any other factor. The principal source of this difference is the longer distribution mains required for larger lots. Costs for water transmission mains will be higher for developments farther away from the water supply source, but transmission mains account for an average of only 16 percent of the total infrastructure and pumping costs.

In some communities, developers—and ultimately property owners—are required to pay the cost of providing water service to new developments. Other communities, however, impose these costs on the existing water system, ultimately passing the costs on to all system users. When existing systems pay to extend service to new, large-lot, dispersed developments, they generally raise all water rates, effectively forcing existing users, including those on small lots in central areas, to pay for service to new users.

1.2.2 Low density means more leakage and increases both demand and cost

All water systems leak. They leak both through pipes and at joints. Depending on their condition, drinking water systems can lose 6 to 25 percent or more of their water through leaks and breaks.[21] In 1995, water systems in the United States leaked 25.3 billion gallons of water per day (approximately 9.2 trillion gallons per year).[22]

> Water systems lose 6 to 25 percent of their water through leaks and breaks.

Two major factors determining leakage are length and system pressure. Longer systems leak more than shorter ones; systems that operate at higher pressures leak more than systems that operate at lower pressures. Systems in low-density areas must use higher pressures to push water through longer mains. Because low-density areas tend to have higher demand for water for lawns, water pressures must be increased even more during dry months.[23]

Once again the form of development affects water use. Development that is more spread out—less dense—needs a longer system than development that is more compact. Therefore, in general, water systems in less dense developments will leak more than systems in compact developments.

Of course, if the central pumping station is located on the urban fringe, nearby low-density users will not generate as much loss as their more distant counterparts in other parts of the metropolitan area. Nonetheless, highly dispersed communities will need longer systems and incur greater loss overall than would more compact communities, regardless of where the main pumping system is located.

Leaks are a financial burden for drinking water systems, imposing costs that are ultimately borne by ratepayers or, if the system is subsidized, taxpayers. According to one researcher:

> Lost water is lost money.…If losses are caused by leaks, you've lost the money it cost to produce or purchase that water. In some cases, curbing large water losses from leaks can save a town or district the cost of finding additional water sources. Wasted water means wasted dollars. Since 1989, [the Kansas Rural Water Authority] has completed 564 water loss surveys locating an annual loss of 2.387 billion gallons. The annual costs to purchase or produce this loss would have been $3.586 million.[24]

1.2.3 Building new systems while deferring maintenance on older ones worsens water losses and raises costs

Many water systems throughout the country face maintenance backlogs and looming replacement costs. Older pipes and joints leak more than newer ones, and all pipes need to be replaced at the end of their useful lives.[25] Demand for new water systems in developing areas may lead communities to lay new pipes rather than fix old ones. As a result, the leakage and breaks common to older systems grow, and the cost of operating an increasingly inefficient system grows with them.

The American Water Works Association (AWWA) estimates that large portions of many water infrastructure systems will have to be replaced over the next 30 years.[26] The Government Accounting Office (GAO) estimates that 20 percent of pipelines are already near the end of their useful life in one-third of utilities, and that more than half of pipelines are near the end of their useful life in approximately 10 percent of utilities.[27] Replacing obsolete infrastructure simply to maintain existing service will require utilities to find new revenue, either from rate hikes or public subsidies. EPA estimated that even if utilities could increase their revenue by 3 percent per year (above inflation), they still would be $45 billion short of what they will need to replace deteriorated pipes over the next 20 years. Without revenue growth, they will fall $102 billion short of their replacement needs and $161 billion short of their operations and maintenance needs.

GAO found that roughly 29 percent of utilities defer maintenance because of insufficient funds, noting that "public drinking water utilities are more likely than their privately owned counterparts to defer maintenance and major capital projects."[28] GAO also reported that while most utilities preventatively rehabilitate and replace their system pipelines, roughly 60 percent of water utilities state that the rate of preventative work is less than desired, and many have deferred maintenance, capital expenditures, or both. While many utilities have plans to finance future capital needs, almost half believe that their projected revenues would be insufficient to carry out their plans.

1.2.4 Development on and beyond the fringe can reduce return on investment in infrastructure and raise costs

> One local official estimates it costs his city $10,000 more to provide infrastructure to a suburban house than one in the urban core.

Another way development patterns affect cost is through the location of new development. Building new infrastructure to serve developments on the urban fringe can decrease the overall return on a community's water infrastructure investment. Often, metropolitan service areas have excess capacity. Adding new developments to the existing network spreads the system's capital costs over a larger customer base, lowering the cost of water service per customer. If, instead, new infrastructure is built for these new customers, the opportunity to improve the efficiency of the existing system is lost, leading to higher costs per customer than if the new customers joined the existing system. This phenomenon can be observed in metropolitan Cleveland, where population shifts have led to overcapacity in parts of its suburban water system, reducing the system's efficiency and raising unit costs for users.[29]

These changes directly affect municipalities' and users' bottom lines. According to an official of a large western city, it costs the city $10,000 more to provide infrastructure services to a house on the suburban fringe than one in the urban core.[30] Systems that operate at less than full capacity also increase the per unit cost for water delivery. Recognizing this dynamic, Fluvanna County, Virginia, stated in its 2000 Comprehensive Plan:

> If a water and sewer system is developed, it should be provided in a cost efficient and effective manner. Service costs associated with this type of infrastructure are strongly influenced by a development's location and density. Therefore, any new system should be located within existing communities that are also growth areas. This provision will allow for the county to build upon existing infrastructure while providing new infrastructure in the areas where it is most needed.[31]

2. Smart Growth Can Help Communities Reduce Costs and Conserve Water

The U.S. population will continue to grow. How that growth is accommodated will affect the quantity of water needed and its cost. The research reviewed in Part 1 suggests that more compact growth, use of existing infrastructure, and investment in system maintenance can substantially reduce costs and make current water resources go farther. Communities across the country are using these techniques as part of a "smart growth" strategy.

Smart growth practices promote development that enhances the community, economy, public health, and the environment. The Smart Growth Network,* a coalition of more than 30 environmental, real estate, historic preservation, development, academic, and governmental organizations, has developed a set of principles reflecting the experiences of successful communities around the nation (Exhibit 1). The principles include encouraging compact development and leveraging scarce public funds to improve existing assets, including water systems.

Applying smart growth principles can significantly reduce the cost of water provided by communities and the quantity of water demanded by their residents. More compact development allows for shorter transmission systems, making them more efficient to operate and less susceptible to water loss through leakage. Encouraging compact neighborhood design on smaller lots reduces water demand for landscaping. Directing development to areas served by existing infrastructure and maintaining that infrastructure can make systems more efficienct.

Exhibit 1: Smart Growth Principles

1. Mix land uses.
2. Take advantage of compact building design.
3. Create a range of housing opportunities and choices.
4. Create walkable neighborhoods.
5. Foster distinctive, attractive communities with a strong sense of place.
6. Preserve open space, farmland, natural beauty, and critical environmental areas.
7. Strengthen development and direct it toward existing communities.
8. Provide a variety of transportation choices.
9. Make development decisions predictable, fair and cost-effective.
10. Encourage community and stakeholder collaboration in development decisions.

** A list of the members of the Smart Growth Network partners and resources for communities to use in implementing smart growth are at www.epa.gov/smartgrowth and www.smartgrowth.org.*

2.1 Compact development

Communities can save money on new infrastructure by developing more compactly. Commercial and residential users that are closer together will need fewer feet of pipe than users that are more spread out. When this development takes place in areas already served by water mains, the cost of infrastructure is further reduced.

2.1.1 Smart growth promotes compact development, reducing infrastructure costs

Robert Burchell of Rutgers University has developed detailed models and estimates of infrastructure cost savings associated with compact development. He estimated that more compact growth nationwide would save $4.77 billion, or 6.5 percent of total water infrastructure costs, from 2000 to 2025.[32] The savings would be particularly significant in the South and the West, where growth has been greatest and is expected to continue.

Another analysis, published by the American Planning Association, provides a more detailed look at the different roles played by lot size and community compactness. In one example, the annual cost of providing water and sewer service to a half-acre lot in a centrally located, dense development is $283 per household, while it is $472 for the same lot in a highly dispersed development far from the water service center. The relationship between increased cost and increased distance from the water center is mostly linear: in the highly compact, small-lot development, each additional mile (from 1 up to 4 miles) from the center adds roughly $50,000 to the 30-year cost of service provision per household. However, in the low-density, large-lot development each additional mile (from 1 up to 5) adds approximately $122,000 to the cost.[33]

2.1.2 Smart growth promotes compact neighborhood design, reducing water demand

As shown in Sections 1.2.2 and 1.2.3, landscaping accounts for approximately 50 percent of household water demand and is also a significant factor in commercial water demand. Water demand for landscaping is directly related to lot size. Compact neighborhood design, which makes maximum use of smaller lots, has less landscaping and thus less demand for water. Ultimately, this could make the difference between a community needing to develop new water sources, with the attendant costs and environmental impact, and using existing water sources efficiently and well into the future.

> EPA and its partners in the Smart Growth Network, a coalition of more than 30 environmental, real estate, historic preservation, development, academic, and governmental organizations, have developed numerous tools and resources to help communities improve their quality of life. Many of these are available at *www.epa.gov/smartgrowth* and *www.smartgrowth.org*.

Smart growth also promotes development with a sense of place, which can include landscaping that reflects distinctive regional ecosystems. Communities can reduce water demand by encouraging use of native plants and ground covers that require little or no irrigation.

2.1.3 Smart growth directs development to existing communities—and their infrastructure

Communities following smart growth principles place a priority on fixing existing water systems and directing development to the areas these systems already serve. Recent studies by AWWA and the Water Infrastructure Network have shown that much of the nation's existing infrastructure will need to be replaced in the coming decades. Already systems are deferring maintenance because of lack of funding and inadequate planning, according to EPA and GAO. Expanding water systems incurs additional financial demands, in some cases further delaying maintenance and replacement. As maintenance and replacement lag, old, badly leaking pipes lose more and more water, raising current costs while the ultimate bill for system renewal continues to grow. Concentrating resources on system maintenance rather than expansion can minimize the cost of delivering water during these crucial decades of system replacement.

To encourage growth in already-developed areas, the state of Maryland has started to help pay to upgrade inadequate city water infrastructure systems. The program's financial assistance can be used for projects such as upgrading aging and poorly operating water treatment facilities; replacing leaking water mains; and repairing or replacing storage tanks. Local water authorities can also use these funds to connect residences to the public supply if wells are contaminated or inadequate, or to upgrade existing water facilities to meet federal and state standards.[34]

2.2 Spotlight on reduced water cost and use: Envision Utah

Envision Utah is a public-private partnership formed in 1997 to evaluate the economic, environmental, and quality of life benefits that a new approach to growth could yield in the greater Wasatch area (GWA), home to 80 percent of Utah residents. Through extensive public participation and modeling, Envision Utah estimated the potential impacts to the GWA from a "quality growth" approach that advocated strategies such as infill development, open space preservation, and mixed-use construction. The results were based on an estimated population increase to 2.7 million (from the current level of 1.7 million) residents by 2020 and compared against a 1997 baseline approach that assumed no change in the way land was developed or natural resources managed. In both the amount of water demanded and the cost of water infrastructure, the quality growth strategy improved on the current, conventional approach to growth.

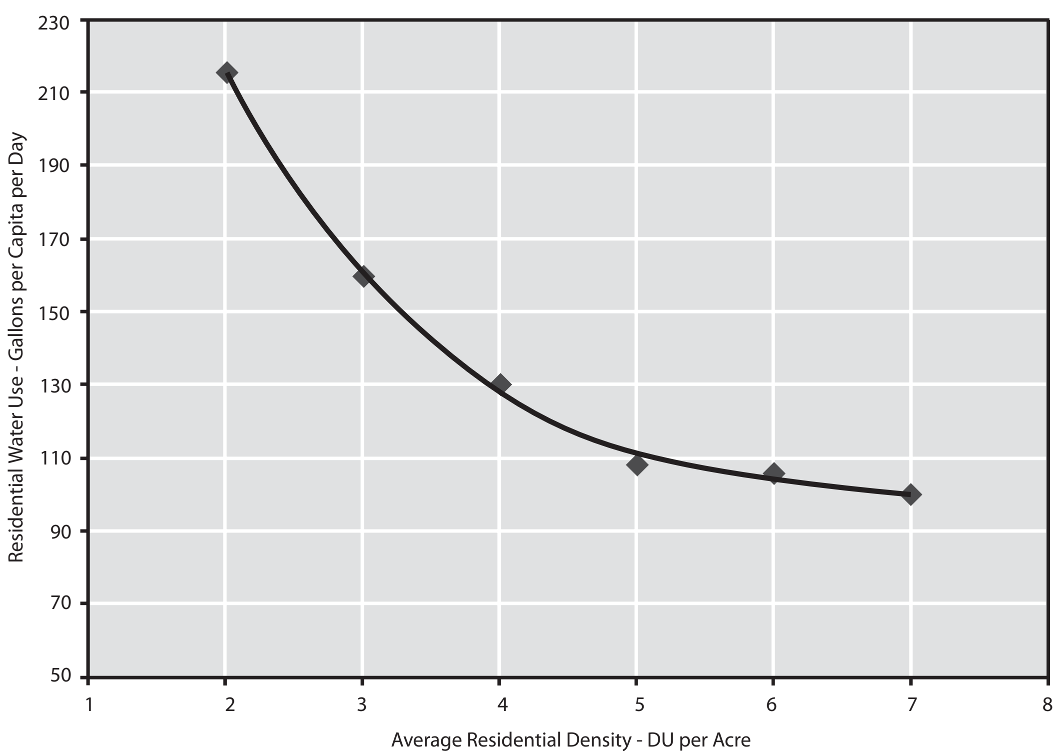
Envision Utah proposed four development scenarios for the project, ranging from low-density, auto-oriented (Scenario A) to very compact, transit-oriented development (Scenario D). The scenario that saves the most money on infrastructure (identified in Exhibit 3) is Scenario C, described as: "The focus of new development and growth on unused land would be walkable and transit-oriented development. There would be more infill and redevelopment and investments would be made to extend public transit systems and alternatives to the automobile."[35]

EXHIBIT 2: Envision Utah Quality Growth Impacts

	Approaches	Baseline	Quality Growth	Quality Growth Savings
Water Demand	• Changes in lot size • Different allocation of population and employment across area • Use of conservation pricing (although overall price of water did not change)	298 gallons per day per capita	267 gallons per day per capita	10.4%
Cost of Infrastructure	• Reduced length of new pipes required • Expanded use of existing infrastructure through infill development	$2.629 billion (in 1999 dollars)	$2.087 billion (in 1999 dollars)	20.6%

EXHIBIT 3: Per Capita Water Use Declines with Higher Densities

Per Capita Residential Water Use as a Function of Residential Density



Dave Eckhoff, PSOMAS Engineering
Source: Tim Watkins, Envision Utah, June 24, 2003

Scenario C's density level also appears to be the most effective in reducing per capita water demand. A study by Envision Utah demonstrated that per capita water demand in the GWA decreases dramatically as development becomes more compact, from approximately 210 gallons per day at a density of two dwelling units per acre to roughly 110 gallons per day at five dwelling units per acre (see Exhibit 3).

Densities beyond five units per acre reduce per capita water demand somewhat, but the water efficiency gains for increased densities are smaller. Although this curve may hold in other areas, only an analysis based on local conditions can determine the level of density where efficiency gains begin to taper off. Also, each community should determine for itself whether to encourage higher densities that save even more water.

3. Policy Options To Better Manage Water Demand

The previous parts of this paper have established that how a community grows affects its water use and the cost of water. This part explores how water policies can affect growth. This section identifies water policies that directly affect water use and cost and indirectly affect growth patterns. Water policies that promote more efficient growth are likely to be doubly effective in helping communities reach their water goals.

The policies discussed here offer a range of options to state and local governments and to utilities. Each policy is described, compared to conventional practice, and linked to community efforts to create water-friendly development practices. Also included, where appropriate, are issues to consider, practice tips, or case studies that can help implement the policy.

3.1 State governments

States indirectly influence local decisions on water rates and infrastructure in two ways.

First, states influence investment in water infrastructure through their administration of the Safe Drinking Water and Clean Water State Revolving Funds (SDW SRF and CW SRF, respectively). States have more discretion under the CW SRF than under the SDW SRF. Under federal law, EPA grants money to individual state funds based on a survey of their drinking water needs. States, in turn, loan money to publicly and privately owned community water systems. Among other functions, states select projects for funding and set interest rates for the revolving funds. Revolving fund loans are made at below-market interest rates—sometimes at zero percent interest—for projects to rehabilitate or replace a system's drinking water source; to consolidate with a stronger system; or to upgrade or replace treatment, storage, or transmission and distribution facilities. From 1997 to 2001, EPA contributed $4.2 billion to the SDW SRF.[36] States matched this with $2.5 billion in state funds.[37] Many states also have their own water infrastructure funding programs.

Second, states have broad authority over local planning and municipal finance. States also have funds that are explicitly directed toward other goals, such as economic development and affordable housing, but that also may be used on water infrastructure. State tax and municipal finance laws govern the ability of localities to raise their own funds, for example, through tax increment funding and local bond issues. Thus, state policies shape the options available to local governments for reconciling water demand and growth.

3.1.1 Administer the state revolving funds to support smart growth

Federal law establishes priorities for loans from the SDW SRF. Top priority must be given to projects that 1) address the most serious risk to human health, 2) are necessary to ensure compliance with safe drinking water standards, and 3) assist systems most in need on a per household basis. These priorities apply to all loan applications, regardless of whether the project contributes to more efficient growth or undermines it. However, states can use smart growth criteria to distinguish among projects that rank equally on the three main priorities and give preference to projects that meet other community goals. Projects that address deterioration in older systems may meet the three main priorities as well as promote the "fix it first" policy discussed in section 3.1.2.

Both the SDW SRF and the CW SRF can support more efficient growth by purchasing undeveloped land or conservation easements on land to protect source water quality. Cleaner source water reduces the cost of water treatment. One study has shown that a 10 percent loss of forest cover in a source watershed raises treatment costs by $8.80 per million gallons treated. The increase in treatment cost is mainly due to the need for more chemical use in the treatment process.[38] Under the Safe Drinking Water Act, a state may set aside up to 10 percent of its revolving fund for land conservation. As of 2003, only $2.7 million of SDW funds have been used to protect less than 2,000 acres of land.

The CW SRF provides more flexibility for states to conserve and restore land. In addition to the preservation of undeveloped land, CW SRF funds may be used to clean up and reuse brownfields. Brownfield redevelopement projects not only reduce the risk of contaminating source water, but also can focus growth on areas that are already served by existing water systems, reducing pressure for system expansion. In 2004, the CW SRF loaned $180 million to projects such as land preservation, brownfield renewal, reducing polluted runoff from agriculture, and other activities.

Case study

The state of Ohio uses CW SRF money to support its Water Pollution Control Loan Fund for brownfield assessment and clean up. A $1.6 million loan covered the cost of treating contaminated subsurface soil and groundwater at a centrally located brownfield in Cleveland. This loan helped Grant Realty to redevelop the site as its new corporate headquarters.[39]

Issues to consider

SRF program officers may need to be educated about the connection between SRF funding and smart growth. Program officers may want to consider whether SRF funding has encouraged growth in areas where growth should be discouraged. They could then develop additional criteria for SRF loans that encourage infill and brownfield development as well as improve water quality.[40]

3.1.2 Fix it first

Some states are looking for ways to direct growth to existing neighborhoods. Many older neighborhoods or small towns have old infrastructure that may need substantial repair. While some older systems have excess capacity, others may not have the capacity to serve new growth, creating a serious barrier to private investment in infill areas. To address these concerns, state policy could favor repairing and upgrading existing systems over new construction. This "fix-it-first" philosophy is most often used for transportation investments—as, for example, New Jersey and Michigan—but could easily be applied to water infrastructure.

State funds powerfully influence how and where growth and development occur. Using these resources to upgrade water infrastructure in existing urban areas reduces development pressure on the urban fringe, thereby preserving critical open space. Further, using state funds to support new development in existing neighborhoods rather than new neighborhoods can improve the efficiency of existing systems and reduce the quantity of water demanded. Finally, the clear identification of priority funding areas can make the development process more transparent and predictable for everyone.

Case study

In its 2001 State Development and Redevelopment Plan, New Jersey classified areas within the state as "areas for growth," "areas for limited growth," and "areas for conservation." These designations determine how future state investments in infrastructure and conservation are allocated.[41] In a similar effort in Michigan, the bipartisan Land Use Leadership Council recommended that state funds be used to "support and encourage compact mixed-use development and infill while discouraging fragmentation and consumption of open space." The council's final report says: "State and federal infrastructure funding should be prioritized to support existing developed areas [and] improve and maintain the effectiveness and integrity of existing infrastructure." The report also embraces the principle that "Infrastructure policies and decisions support and encourage compact and mixed-use development and infill, while discouraging fragmentation and consumption of open space."[42]

Issues to consider

Partnerships are critical to ensure that all involved parties are educated about the policy and how it supports the community's goals. States will need to educate the public about the importance of repairing and upgrading existing systems and how "fix it first" can encourage high-quality development. Elected officials need public support to effectively undertake potentially contentious policy changes.

3.1.3 Authorize the formation of special districts to finance water system expansion

Local governments increasingly are looking to developers to pay more of the cost of expanding water systems to serve new developments. Localities, in turn, rely on state governments to provide enabling legislation for these efforts. Some states have allowed local governments to establish "limited-purpose governments" that finance infrastructure for new developments.

States can authorize local governments to designate areas within their jurisdictions as "special districts" and to authorize in turn the developers of the districts to create limited-purpose governments to serve them. Special districts can issue bonds to fund infrastructure and impose user fees, impact fees, and special assessments on property owners. These fees and assessments repay the bonds and pay for operation and maintenance. Special districts are subject to local regulations, such as zoning, but are financially and administratively independent of the local government. They can issue tax-free bonds, like local governments, but the bonds are not backed by the local government and do not count against local debt limits. Local governments can create special districts just to provide water infrastructure and service, or they can fund a much wider range of facilities, such as sewage, streets, parks, or schools.

This financing mechanism can shift infrastructure costs more directly onto the users of infrastructure. It can save the locality from tying up capital funds in system expansion, preserving resources to upgrade and maintain existing systems. It can provide an alternative to impact fees where impact fees either are not allowed or have proven difficult to assess or implement.

Case study

Several states have authorized special districts. California and Arizona call them "Community Facilities Districts," and Florida calls them "Community Development Districts." Since they were authorized in 1980, about 200 Community Development Districts have been created in Florida. Supporters note that the districts generally have provided good-quality public facilities and services to their residents. They also have helped reduce political battles over infrastructure costs.

Issues to consider

Some of Florida's Community Development Districts have been accused of being unresponsive and undemocratic.[43] State law allows developers to limit homeowners' participation in district decisionmaking for the first six years, and a few developers have retained control far longer.[44] In at least one case, a developer has been accused of steering infrastructure contracts to friends and relatives who have overcharged homeowners for their work.[45] Homeowners also have charged that state and local officials have been lax in overseeing the districts.

Creating special districts fragments government in ways that can make coordination difficult. Special districts may raise the overall cost of public administration, since they establish another local bureaucracy in addition to the existing general-purpose government. Finally, allowing some community residents to essentially opt out of local government services can reduce support for those governments and their ability to provide services to residents not in special districts.

3.1.4 Connect water and land use planning to provide predictability in the development process

In most cases, different levels of government conduct land use planning and water planning. Localities develop general plans that then become the basis for specific area plans, zoning decisions, and building permits. Meanwhile, state water agencies develop integrated resource plans that serve as the basis for water management plans, which are the basis for formal commitments to provide water service ("will serve" letters) and eventually water hookups for individual buildings.

Once development is in place, water agencies have had little choice but to serve it. In cases where existing water supplies have run short, local officials have been forced to halt new development until an adequate water supply can be ensured. In March 2001, Frederick, Maryland, declared a moratorium on new development and annexations after discovering that the city's water system could no longer support its growth. Frederick suffered water shortages during a severe drought in 2002. In the fall of 2002, the city adopted a water allocation ordinance and in 2003 began to issue water allocations. Currently, developers must secure a water allocation and sign a water service contract with the city before applying for a building permit.[46] These restrictions will remain in place until Frederick completes construction of a new water treatment plant.

Making development more predictable is a key principle of smart growth. Further, the better that a community understands its future water availability and the best options to protect water quality, the more likely it is to support a realistic and sustainable approach to growth that minimizes demand, improves efficiency, and protects water quality and future supply. Two recent laws in California attempt to make the development process more predictable by better linking the land use and water planning processes.

California's SB 610 requires water suppliers to estimate their projected water supply/demand balance for jurisdictions served by their systems. Cities and counties are then required to consider this estimate before approving large-scale residential, commercial, and industrial developments. This law does not require cities and counties to reject developments that are inconsistent with the estimated water supply—it only requires that they take water into consideration when deciding whether to approve them.

A second law, SB 221, requires water agencies or appropriate city or county jurisdictions to verify an adequate water supply for developments before they issue building permits.[47] This review is required only for residential developments of 500 units or more, although infill projects and housing developments for low- and very low-income households are exempt.[48]

Incorporating "consistency provisions" into state planning statutes also can help ensure that comprehensive land use plans are consistent with other local plans and regulations. While several states, including Arizona, Connecticut, Florida, and Washington, require land use plans to be consistent with each other, few have gone the additional step of specifically requiring land use and water plans to be consistent. Both consistency provisions and the new California laws can support community efforts to incorporate the water implications of new growth into long-term planning and make the development approval process more predictable.[49]

Case study

In 1990, the state of Washington adopted the Growth Management Act. Among the act's 13 goals are concurrency for public facilities and services, reduction of sprawl into rural areas, and encouragement of development in urban areas. The act requires countywide planning policies that designate urban growth areas and identify sites for county services. Local comprehensive plans then address land use, utilities, capital facilities, transportation, and housing. Both the policies and the plan must be implemented by development regulations, such as zoning, that ensure concurrency and consistency with the urban growth areas. These planning activities must also be consistent with local capital budget decisions.

While it remains controversial, the Growth Management Act is credited with raising the profile of water issues and with making local, water-infrastructure decisionmaking more transparent and predictable.[50]

In the more arid Southwest, where water supplies are increasingly tight, New Mexico has begun to require communities to have the water rights in place before they can build new development. Previously, the state allowed communities to build first and secure the water rights later.[51]

Issues to consider

"Consistency" and "concurrency" requirements get mixed reviews. Requirements for transportation concurrency in Florida have been criticized as ineffective or counterproductive. Transportation concurrency may have encouraged development in previously undeveloped areas because these areas usually have excess road capacity.

3.1.5 Clarify a utility's "duty to serve"

Public utility law generally has held that "a public utility has a duty to serve all customers within its service area who can pay for the cost of service…"[52] The duty to serve can, and at times does, conflict with a utility's or community's efforts to control water costs and ensure adequate quantities for existing customers. In such cases, the duty to serve has traditionally superseded other considerations, sometimes undermining other community goals, such as orderly growth and long-term, stable water provision.

Limited water supplies in many parts of the country, however, have led to a shift in legislation and case law. California laws SB 221 and SB 610 (see Section 3.1.4) exemplify this shift, enabling communities to control the timing and type of development in order to ensure an adequate water supply. Recent legislation in Idaho and Arizona has also weakened the duty to serve and strengthened localities' ability to plan for long-term, sustainable growth. Courts have held that "a city should not be required to undermine its own growth management policy simply because it is a water supplier. Non-municipal suppliers should be subordinate to this policy so long as the policy does not impair their constitutionally guaranteed fair rate of return."[53] Nevertheless, localities' duty to provide water often remains unclear.

Clarifying state law on this subject is critical to localities' ability to plan for future growth with confidence that they will not be undermined by claims for service to new development beyond their desired boundaries. The growing maturity of this issue is also evidence of communities' recognition that the manner in which they grow has a direct and significant impact on water and that their water policies have a direct effect on how they grow.

Case study

In 2003 the state of Washington passed the Municipal Water Supply—Efficiency Requirements Act, which directed the state Department of Health to more closely align water planning with local land use plans. The law specifically requires that water utilities' service areas must be consistent with "local land use plans, comprehensive plans, coordinated water system plans, watershed plans, and development regulations."[54] Since the duty to serve applies only within a utility's service area, carefully delineating service areas that reflect land use plans helps to minimize the conflict between land use and water provision.

Issues to consider

Clarifying the relationship among (in some cases) 100-plus-year-old state water laws, complex property law, and the legal authority of communities to plan for future growth is a complicated task. In many places, local comprehensive plans are inconsistent with development regulations; thus, linking water system plans with comprehensive plans could worsen conflicts between development and water provision. States considering following Washington's lead may wish to provide additional planning assistance to localities. This assistance could be directed toward improving consistency among local plans and their implementing codes and regulations, among other goals.

3.2 Local and regional governments

Municipalities have a powerful effect on system efficiency and the demand for and cost of water. Municipalities that run water utilities affect water demand directly through their infrastructure and pricing policies. As has been discussed, these policies can directly influence water use and development patterns, which in turn affect water use. Localities that wish to ensure efficient water use can focus on system maintenance and set prices that reflect the true cost of water delivery. These policies will encourage compact development that reduces the cost of water delivery. Municipalities can further encourage compact development with zoning, subdivision regulations, infrastructure spending, tax incentives, and other land use policy tools. In particular, local policies that encourage infill development can support states' and utilities' "fix it first" policies, minimizing expensive new extensions. This, in turn, can reduce the cost of water service and the overall demand for water.

3.2.1 Integrate water budgeting into land use planning

As discussed in Sections 3.1.3 and 3.1.4, lack of coordination between land use planning and water planning can frustrate a predictable development decision process. Regardless of how the legal issues surrounding communities' duties to serve are resolved, municipalities can reduce the risk of water shortages by creating water budgets that are based on water supply assessments.

Water planning at the state or regional level often is not detailed enough for communities to match their water use to their water supply. A water budget can help a community to better understand the locally available water resources and compare them to the water demand. Seasonal shortfalls and long-term discrepancies between supply and demand can prompt communities to implement conservation measures, such as xeriscaping, block pricing, or other efforts.

Establishing a water budget may involve appointing a broad-based advisory committee consisting of citizens, landowners and developers, local officials, and experts in water system management. The advisory committee could collect data on water use and trends, identify potential shortfalls, and recommend measures to better align water demand with anticipated resources. The recommendations may provide local governments with guidance and support for integrating demand-reducing measures into local land use plans, regulations, and incentive programs.[55]

The regional aspect of the supply and demand assessment also provides a solid basis for actions that extend beyond local borders to coordinate how and where development takes place. Efforts to direct development to already-developed areas, and especially to compact, central areas, can help to bring a region's water demand into better balance with its limited supplies.

Case study

Albuquerque, New Mexico, recently passed a resolution to develop a regional water budget that details its water "revenue" (supplies) and "expenditures" (uses). The water budget is part of a larger effort within the region to re-examine its traditional approach to water. For decades, Albuquerque had extracted water from an underground aquifer. Recent data, however, indicated that the aquifer was being "mined"—water was being withdrawn faster than it was being replenished—and probably could not meet the community's water needs in the future. The water budget will help the city to manage future water use to avoid deficits.[56]

3.2.2 Use private activity bonds strategically to finance upgrades in existing service areas and planned growth areas

Although some water systems may be able to expand while keeping up with maintenance and replacement of existing pipes, many cannot without additional resources. EPA projects that systems will face up to $205 billion in unfunded but necessary capital expenditures over the next 20 years. [57, 58] One way local governments can finance these expenditures is by issuing private activity bonds. Such bonds can be a cost-effective way of financing needed water system replacement or upgrades that will support infill development and relieve growth pressures outside the existing system.

Communities that decide to develop beyond their existing service areas can conserve financial resources by designating zones or tiers for development. They can delineate and prioritize areas where public funds, in conjunction with private activity bonds or other assistance, will support infrastructure for new growth. Local governments may designate boundaries beyond which no public funds will be available, leaving the cost of infrastructure wholly to the private sector.

In sum, these approaches help communities use public funds to encourage growth in targeted areas and reduce or eliminate subsidies for growth in areas where growth is not desirable.

Case study

Florida's Growth Policy Act recognizes infill development and redevelopment as important to promoting and sustaining urban cores. Florida's definition of urban infill and redevelopment areas includes those where public services, such as water and wastewater, transportation, schools, and recreation, are already available or are scheduled to be provided within five years. A local government with an adopted urban infill and redevelopment plan may issue revenue bonds and employ tax increment financing to finance the plan. These urban infill and redevelopment areas have priority in the allocation of private activity bonds.[59]

Issues to consider

Drinking-water facilities generally are exempt under private activity bond regulations and therefore are eligible for tax-exempt status. However, federally mandated caps limit the amount of tax-exempt private activity bonds that can be issued in a state. States can prioritize bond allocation to support projects that implement smart growth strategies and upgrade water infrastructure.

3.2.3 Introduce service availability fees to better capture the marginal cost of system expansion and household water demand

Local governments can assess service availability fees (also known as exactions, impact fees, service development fees, or facility charges) on a developer to cover the costs of existing and/or future water infrastructure for new development. "Latecomer fees" also may be levied on developments occurring within a reasonable period of time, such as 15 years, after a water system is built. The local water utility may directly levy some service extension fees. A recent study found that 77 percent of drinking water utilities recover some of the cost of service extension through developer contributions.[60]

Service availability fees can reduce water cost and demand in two ways. First, communities can offer full or partial fee waivers for growth in targeted neighborhoods already served by existing infrastructure or for compact projects in undeveloped areas. Second, communities can calculate fees for new construction in outlying areas that more closely approximate the marginal costs of system expansion, rather than its average costs. Another way of assessing fees is to establish zones in which fees are based on distance from existing facility centers.

Many fees are calculated as an average cost of existing system construction or use costs without regard to distance or location, rather than the true marginal cost of expanding a water system to a given project site. Fees that more accurately evaluate the cost of growth and development by location are as predictable for developers as average fees. Further, targeted waivers or fee reductions can encourage development in existing neighborhoods or other compactly designed areas.

Case study

Salt Lake City applies two sets of fees: one to infill sites within existing city lines and one to the growing Northwest Quadrant area.[61] San Antonio waives water and other fees in infill areas the city has targeted for redevelopment. San Antonio also charges lower water rates to customers inside the city limits.[62]

Issues to consider

Some communities have misused service availability fees by spending fee revenue on projects that do not directly benefit the assessed development or to subsidize general revenue. These practices are not allowed under most state laws and are vulnerable to court challenge.[63]

Because the developer will pass on at least a portion of the fees to the homebuyer, fees can raise housing costs. Some cities have exempted or otherwise reduced fees on residences that qualify as "affordable housing" according to the U.S. Department of Housing and Urban Development.

3.2.4 Encourage natural landscaping in residential and commercial buildings

Large grass lawns are a basic feature of traditional landscaping for both homes and businesses. Homeowners' associations and neighborhood covenants often require grass or turf lawns; commercial sites usually incorporate acres of grass. Constant watering and irrigation of these lawns demand large amounts of water, particularly in arid climates. The sandy soils found in arid areas do not hold water well, increasing water demand as commercial building managers and homeowners struggle to maintain a green lawn.

Traditional landscaping is expensive as well as water-hungry. The Conservation Design Forum has estimated that the initial cost of a traditional 10-acre corporate landscape would be 48 percent more than a "sustainable landscape" planted with native plants. Over the first 10 years after installation, the traditional landscape would cost 52 percent more and, in later years, 82 percent more than a sustainable landscape. These estimates include the cost of additional watering for the traditional landscape.[64]

Landscaping that uses native plants will require little additional water beyond what the local climate provides once the plants are established. Xeriscaping explicitly seeks to conserve water through landscaping in which "plants whose cultural requirements are appropriate to the local climate are emphasized, and care is taken to avoid wasting water to evaporation and run-off."[65] Xeriscaping can reduce long-term water use for landscaping by 70 percent or more.[66] Some utilities, particularly those in the arid Southwest such as Tucson and Denver, also offer their customers information on xeriscaping and its benefits.

Local governments can encourage natural landscaping by collaborating with homeowners' associations, local landscapers, and other organizations to educate citizens. Localities could provide financial incentives, such as property tax breaks, for commercial building managers and homeowners who implement and maintain natural landscaping on their properties. Finally, local and regional governments can lead by example by creating natural landscaping demonstration projects on public grounds and parks.

Some local governments, primarily in arid regions, have adopted ordinances that require landscapers to use plants that are adapted to the local climate and need little or no additional water after the plants are established. These ordinances restrict the use of turf, list plants that can be used, or regulate the type of irrigation allowed. Some ordinances exempt single-family homes.[67]

Natural landscaping can foster distinctive communities with a sense of place by creating neighborhoods with native plants and unique regional features. Rather than trying to emulate the grassy yards of less arid regions, property owners in dry areas can reflect their natural surroundings and help create a visual identity for their communities.

Case study

Local governments and utilities are experimenting with incentives for less thirsty landscaping. Las Vegas pays homeowners one dollar for every square foot of turf removed. Denver's water board recently began a rebate program for homeowners who purchase trees and shrubs with low water needs. The city of Denver launched a Community Conservation Gardens Project that is planting parks with water-conserving landscapes. This project trains teens for work in the landscaping industry, creates beautiful public spaces in both prominent and neglected parks, and serves as a model to homeowners and businesses.

Issues to consider

Natural landscaping and xeriscaping have met with resistance in some communities. Efforts to educate communities about xeriscaping may conflict with entrenched attitudes about what makes lawns, yards, and public places inviting and attractive. Some homeowners' associations have rules that force residents to plant thirsty, non-native grasses in arid areas.

3.3 Utilities

Water utilities play a major role in influencing water demand by setting the rates that determine how much customers pay for water. Many utilities find it difficult to determine fees that capture true costs. Calculating the true cost of delivery for a household or business—the individual user's incremental cost increase to the system—is all but impossible in practice. On the other hand, charging each user rates based on the average cost of serving all users can overcharge users who live in compact, central neighborhoods and can produce the subsidies discussed in Part 1. Furthermore, utilities face political pressure to keep rates low—so low, in fact, that many utilities do not recover their full cost of doing business. Because water is such a basic necessity, utilities also must address concerns that customers with low incomes may not be able to afford rate increases, although poorer inner-city residents would benefit from lower rates that more accurately reflect the lower cost of serving them. In the face of these challenges, utilities have developed a variety of pricing structures. Pricing can reinforce or undercut other policies that encourage compact development.

3.3.1 Fix it first

While states can target financial assistance in ways that encourage repairs and upgrades to existing water networks, the utilities themselves ultimately decide which parts of their systems receive priority for improvements or expansion. Utilities that implement fix-it-first policies can improve their own financial situation, conserve water, and lower costs for their customers. Fix-it-first policies can be especially effective when they are combined with fees for system expansion and local efforts toward redeveloping existing neighborhoods.

Many utilities face declining rate bases as customers move from neighborhoods served by the existing system to outlying areas. Utilities expand their systems to these new neighborhoods, recapturing old customers. At this point, however, the utilities have to pay for building the new systems as well as maintaining the old ones even though they may have roughly the same number of customers. Utilities can recoup their investment and maintain their systems through three mechanisms: they can raise rates on all customers; they can charge service expansion fees to customers or developers in the new neighborhoods; or they can acquire new customers in the old neighborhoods.

How utilities balance their spending among system repair, system replacement, and system expansion and how they set rates and fees are important to their financial health. Utilities often borrow money on the bond market to pay for their capital projects. The interest rate that a utility must pay is determined by the market's assessment of its management, and particularly the utility's management of its physical assets: treatment plants, pipes, and pumps. A fix-it-first policy that stresses maintenance of existing physical assets can contribute to higher bond ratings, lower borrowing costs, and lower overall costs for water delivery.

Moody's Investors Service is one of three major credit-rating agencies that rate bonds and strongly influence utilities' borrowing costs. While some of Moody's key rating factors are clearly beyond utility managers' control—the health of the local economy, for example, or customer income—other rating factors evaluate utility management policies. "Maintenance of assets" is a key rating factor. Moody's also grades utilities on their "strategic focus" and on "regulatory compliance," which indirectly support fix-it-first policies, since compliance and focus are related to the health of the existing system and its orderly expansion.[69]

A recent analysis by Public Financial Management also emphasizes the importance of the fix-it-first policy. It states: "A particular challenge of water and wastewater systems is their ability to meet capital investment requirements of aging systems, and their success in doing so is scrutinized by credit rating agencies." The analysis noted that credit-rating agencies also rewarded utility management strategies that combined fix-it-first policies with fees that assessed new users—rather than all users—for the cost of system expansion.[70]

Case study

Philadelphia's water department is one of the oldest water utilities in the country. Like many older cities, Philadelphia has an aging water system, declining population in its central service areas, and increasing demand in suburban areas. In the early 1990s, Standard and Poor's (S&P) noted that parts of the system were more than 100 years old and needed "extensive repair and replacement." In 1991, the water department had a deficit of $42.5 million on an operating budget of $270.4 million.[71]

The water department made several financial and administrative improvements over the rest of the 1990s. It created a rate stabilization fund dedicated to capital expenses and vastly improved metering and bill collection. In 1996, the city created a Capital Program Office to track the condition of infrastructure and planning and to manage capital improvements. The system's bond rating improved along with its capital and operational reforms, saving the city millions of dollars in interest. By 2001, the water department's bonds had been upgraded to "A-" (S&P) and "A3" (Moody's). Both services highlighted the department's capital improvement program for reconstructing its water conveyance system and improving its water treatment plants.[72]

The Philadelphia Water Department also takes a proactive approach to protecting the quality of its drinking water sources. It helped to develop a watershed land protection collaborative for the Schuylkill River that works to preserve natural lands that have high value for water quality.[73]

Issues to consider

Utilities that are faced with declining customer bases along with increasing repair and replacement costs find it very difficult to maintain their systems even with a fix-it-first policy. Local governments can help these utilities by targeting growth to areas on the existing system.

Utilities can focus system upgrades in the targeted areas to make them more attractive to new development. When that development occurs, the increase in customers will generate new revenue that often pays both for the targeted upgrades and for other improvements to the existing system. This can generate an upward spiral of system improvement supporting redevelopment that funds further system improvement.

3.3.2 Set rates that fully cover costs

A recent GAO report found that over one-quarter of public utilities charge rates that do not cover the full cost of water service, including depreciation, debt service, taxes, and operations and maintenance.[74] These artificially low rates encourage customers to use more water than they would if they paid full price. Inadequate rates also contribute to the gap that exists in many systems between available funds and the cost of needed repairs and replacement.

> Over one-quarter of municipalities charge water rates that do not cover their costs.

Water utilities may be publicly or privately owned. Public water utilities generally calculate rates differently than investor-owned utilities. Public water utilities often use the "cash needs" approach, which considers operation and maintenance expenses, tax equivalents (e.g., payments in lieu of taxes), debt-service payments (including both interest charges and repayment of principal), contributions to specified reserves, and capital expenditures not financed by either debt or contributions. Private and investor-owned utilities more commonly use the "utility" approach, which considers operation and maintenance expenses, taxes, depreciation, and a rate of return on the value of the utilities' assets less accumulated depreciation.[75] The utility approach is more likely to generate adequate revenue, in part because it explicitly considers the utility's cost of capital and the cost of depreciation. Public authorities may wish to consider the utility approach. However, neither approach will result in adequate revenue unless maintenance and system replacement needs are carefully assessed.

Unrealistically low water rates undermine efforts and incentives to reduce water use by all users. Those who use little water receive a small subsidy, while those who use large amounts of water receive larger subsidies. This encourages water-consumptive growth patterns and deprives those who choose less water-consumptive lifestyles of the full benefits of their choice. In fact, customers who use less water may be charged for the cost for new drinking water supplies that would not be needed if water were priced correctly.

Case study

A 2003 water-pricing study by an advisory committee in Fort Worth, Texas, found that rates were failing to cover increasing costs of electricity, security, environmental compliance, and pipe replacement. Residential users were paying nearly 8 percent less than the cost of their water consumption, and commercial users were underpaying by more than 5 percent. In response, the Fort Worth Water Department raised rates and changed its rate structure to encourage conservation.[76] The rate structure is discussed further in the case study for the next section, 3.3.3.

Issues to consider

For public water utilities, changes may require the approval of a board of directors, composed in part of elected officials. In private investor-owned water utilities, rate changes are subject to approval by the state public utilities commission (or public services commission). In some cases, utilities may be subject to legislation or other regulation that limits the amount, frequency, and type of fee increases.

3.3.3 Implement conservation pricing

Consumers pay for water in two ways: hookup (connection) fees and volume charges.[77] A connection fee may be a flat rate, vary by type of unit added to the system, or vary by the size of meter used for the new unit. Typically, residential connection fees vary with the size of the meter. Some systems use a more complex calculation, varying fees by lot size, value of the property, or distance from the treatment station.

Volume charges ("rates") can be uniform—the same amount for each gallon used—or can employ "block pricing" under which rates vary with water consumption. When used to promote conservation, this practice—also known as conservation pricing or incremental pricing—increases water rates for higher levels of water use. Base amounts sufficient to meet basic household needs are assessed at the lowest per unit rate. Additional blocks (e.g., the next 5,000 gallons consumed) of water consumed are charged at incrementally higher rates. Similar efforts apply surcharges for use beyond a base amount in times when demand is greatest and supply is lowest; seasonal or drought-impacted charges are two examples. Peak charges encourage conservation, especially for uses such as lawn watering, when conservation is most needed. According to a 2002 survey of 153 systems, 36 percent of the systems charged uniform rates, 30 percent charged declining block rates, and 30 percent charged increasing block rates.[78] Thus, less than one-third of water utilities surveyed use rate structures that encourage conservation.

Water rate structures that charge less for higher levels of consumption encourage more water use and more water-consumptive development patterns. Like the artificially low water rates discussed above, discounts for high water use not only penalize users who live in water-efficient neighborhoods, but also increase the likelihood that those users will eventually have to pay for new water supplies and new water plants.

Case study

In February 2004, the Fort Worth Water Department raised rates to cover increasing costs. Rate hikes were higher for households that consumed the most water. Under the new rates, customers using less than 1,000 cubic feet per month pay $1.66 per 100 cubic feet, those using between 1,000 and 3,000 cubic feet pay $1.98 per 100 cubic feet, and households using more than 3,000 cubic feet pay $2.40 per 100 cubic feet. The average household in Fort Worth consumes about 12,000 cubic feet per year.[79] Following the rate hike, in July 2004, city-wide water consumption was 11 percent less than the average of the previous four years.[80]

Issues to consider

Commercial customers are accustomed to discounts for volume and may perceive conservation pricing as a threat to economic development. Conservation pricing could generate higher costs that unduly burden low-income households. Utilities can protect against this by ensuring that the base block quantity is adequate to meet basic household needs and that higher fees are levied on amounts necessary only for more discretionary purposes.

From the utility perspective, block rates can make revenue less stable than uniform pricing systems, and their success at encouraging water conservation can vary. Studies have shown that, without other conservation measures or overall rate hikes, conservation pricing reduces water demand by 5 to 8 percent or more.[81]

Finally, the political nature of rate increases makes it a potentially difficult issue for many utilities. Public education and outreach[82] or citizens' advisory committees that coordinate research and offer recommendations[83] can mitigate this challenge.

3.3.4 Implement zone pricing for water users

Typical water-pricing structures spread costs evenly among all customers without regard to the actual price of delivering water to them. A 1995 Rutgers study on New Jersey infrastructure estimated that the cost of providing water to households in dispersed developments was roughly 13 percent higher than the cost of doing so in a more compact area.[84] Elevation, as well as distance from the water plant affects the cost of pumping water to a user. Yet, as already discussed, most utilities charge uniform rates, regardless of the higher cost of serving dispersed development, developments at higher altitudes, and large-lot developments. Utilities can set up rate structures wherein customers in lower-cost areas pay less for water than those in higher-cost areas. Such rates more accurately reflect the additional costs of pumping treated water to distant locations or to higher elevations.

Some utilities set lower rates for customers inside city limits, but this discount usually is not based on the difference in cost of service. These lower rates are intended to compensate city residents whose tax revenues support subsidies given by their city governments to the utilities. Zone pricing goes further by tying the price of water more explicitly to the cost of delivering water to the zone and the cost of maintaining the system infrastructure that serves the zone. It may consider factors such as density, distance from treatment center, and elevation to better reflect the cost-effectiveness of water delivery in compact, centrally located neighborhoods. Zone-based costs may also better capture utility expenditures on system upgrades and expansion in the absence of adequate hookup fees.

By setting up rates to reflect the true cost benefits of water conveyance and operation and maintenance, utilities can help encourage development that uses less water and is more efficient to serve. Further, zone pricing helps to make individual users responsible for the cost of serving them, ensuring that those who impose lower costs on the system receive the benefit of lower prices.

Case study

The Cleveland Division of Water (CDOW), the regional water purveyor for most of the Cleveland area, is one of the few systems in the United States that employs spatially variable user rates. This system recovers costs from pumping to higher elevations, which happen to correspond to areas of less density and more dispersed development. Customers located in CDOW's three higher-pressure zones pay rates that are 1.7, 2.0, and 2.3 times greater than those in the lowest pressure zone. On average, residents outside of the city (but inside the CDOW service area) pay approximately twice as much as city residents for their water. Although intended to cover extra operating costs, this ratio also corresponds closely to CDOW's expenditures for capital improvements: 65 percent of all CDOW capital improvement dollars funded projects outside the city, while 35 percent were spent in the city—a ratio of nearly two to one.[85]

Issues to consider

Some water users may perceive zone pricing as unfair, while others may perceive the current pricing system as unfair. Utilities may want to educate consumers about the relationship of costs to the new prices.

3.3.5 Engage a citizens' advisory committee on water

Local resident and stakeholder involvement in developing strategies to address water issues can be effective in tackling current problems and preempting future ones. Collecting and considering the opinions, concerns, and needs of utility customers can better inform plans to service future growth and development. Involving citizens in the discussion of tradeoffs between options improve their understanding and reduce chances of litigation over final decisions.

A citizens' advisory committee (CAC) is usually made up of representatives of the community and selected expert groups. CACs meet regularly, developing trust as well as knowledge of the issues. These groups can effectively represent customer needs and concerns and are useful in addressing potential conflicts in the community. Citizen involvement can not only help identify opportunities to reduce water demand or make existing systems more efficient, it can also lead to stronger stakeholder involvement in related development decisions, thereby enlisting residents in determining their community's future.

Many communities already have organizations that are developing plans to protect sources of drinking water. These groups are often broadly based, including local officials and watershed associations as well as citizens. They may provide a useful forum for addressing water demand and growth issues.

Case study

In Boston, a citizen "watchdog" group was formed during the late 1970s in response to concerns about expanding the water supply and was later financially supported by the water utility district. Instead of promoting additional sources for Boston's water supply, the citizen group helped lead a conservation effort that focused on finding and fixing leaks. Due to this and other conservation measures (e.g., customers received free water-saving devices, and the utility increased water rates), water demand dropped by 16 percent between 1985 and 1992. The Boston experience was "orderly, constructive, and economical, albeit very time-consuming."[86]

Issues to consider

Despite their benefits, CACs can be, as mentioned above, time-consuming and challenging to manage. Participants must be sure that their involvement is taken seriously and will be used constructively to shape project goals and outcomes, particularly since they often are uncompensated. Advisory groups must be on guard for citizens who come to the table with an explicit agenda that could undermine the group's larger goals and efforts to create consensus, cooperation, and compromise. Finally, substantial time and resources may be needed to support the group.

End Notes

1 U.S. Environmental Protection Agency. 2002. "The Clean Water and Drinking Water Infrastructure Gap Analysis." EPA-816-R-02-020. September.

2 Boyd, Charles W., Chairman of the Water Service Committee, City of Frederick. 2004. "Got Water?" Presentation to the 7th Annual Southeast Watershed Roundtable, Nashville, Tennessee. October 30.

3 City of Frederick. 2005. "Water and Sewer Allocation Master List Update" (November 21, 2005). <http://www.cityoffrederick.com/PublicInfo/PressReleases/2005/november/11-21-waterlistupdate.htm>. Accessed November 30, 2005.

4 Michigan Land Use Institute. 2005. "Water Works: Growing Michigan's Great Lakes Opportunities." Page 6. <http://www.mlui.org/downloads/waterworks.pdf>. Accessed November 30, 2005.

5 International City/County Management Association. "Source Water Protection: Plain and Simple" <http://www.lgean.org/documents/intro.pdf>.

6 U.S. Geological Survey. 1995. "Estimated Use of Water in the United States in 1995." Circular 1200, Chapter 6: Trends. <http://water.usgs.gov/watuse/pdf1995/html>. Accessed September 12, 2002.

7 U.S. Geological Survey. 2004, 2005. "Estimated Use of Water in the United States in 2000." Circular 1268. <http://pubs.usgs.gov/circ/2004/circ1268/htdocs/text-trends.html>. Accessed November 30, 2005.

8 Frey, William H. 2005. "Metro America in the New Century: Metropolitan and Central City Shifts Since 2000." Washington, DC: Brookings Institution. <http://www.brookings.edu/metro/pubs/20050906_metroamerica.pdf>. Accessed September 16, 2005.

9 U.S. Geological Survey. 2004, 2005 op. cit. Calculations are the author's, based on Table 5, "Public supply water withdrawals."

10 Lubick, Naomi. 2004. "Western Aquifers Under Stress." Geotimes. <http://www.geotimes.org/may04/feature_westernaq.html>. Accessed September 16, 2005.

11 Revkin, Andrew C. 2002. "Beyond a Drought, Water Worries Grow." New York Times, February 24.

12 National Oceanic and Atmospheric Administration. 2002. Drought data from the National Climatic Data Center, Asheville, NC. <http://lwf.ncdc.noaa.gov/oa/climate/research/drought/drought.html>.

13 American Water Works Association. 2004. Fact sheets. <http://www.awwa.org/pressroom>. Accessed August 4, 2004.

14 Ibid.

15 U.S. Geological Survey. National Handbook of Recommended Methods for Water Data Acquisition. <http://water.usgs.gov/pubs/chapter11/chapter11E.html>.

16 Minnesota Department of Agriculture. 1997. "Master Gardener Survey Results: October 9, 1997; Homeowner Lawn Care Survey Results." Cited in Purdue Pesticide Programs. The Label, April 1998, p. 3.

17 Eckhoff, Dave. 2003. "Per Capita Residential Water Use as a Function of Density" PowerPoint slide, provided to author by Tim Watkins of Envision Utah, June 24, 2003.

18 Natural Resources Defense Council. 2000. "Environmental Characteristics of Smart Growth Neighborhoods." <http://www.nrdc.org/cities/smartGrowth/char/charinx.asp>.

19 Sakrison, Rodney G. 1997. Water Use in Compact Communities: The Effect of New Urbanism, Growth Management and Conservation Measures on Residential Water Demands. Summary of doctoral dissertation for the Department of Urban Design and Planning, College of Architecture and Planning, University of Washington, Seattle, Washington.

20 Speir, Cameron, and Kurt Stephenson. 2002. "Does Sprawl Cost Us All? Isolating the Effects of Housing Patterns on Public Water and Sewer Costs." Journal of the American Planning Association 68(1): 56-70.

21 Levin, Ronnie B., Paul R. Epstein, Tim E. Ford, Winston Harrington, Erik Olson, and Eric G. Reichard. 2002. "U.S. Drinking Water Challenges in the Twenty-First Century." Environmental Health Perspectives 110(suppl 1): 43-52. See press release at <http://www.win-water.org/win_news/021402article.html>.

22 Total freshwater consumptive use in 1995 was about 100,000 million gallons per day (U.S. Geological Survey, 1995).

23 International Water Supply Association. 1991. Cited at <http://www.nrc.ca/irc/leak/leakdetect.html>.

24 Kenny, Joan. 1999. "Water Loss Determination: For What It's Worth." The Kansas Lifeline. July. <http://ks.water.usgs.gov/Kansas/pubs/reports/water.loss.html>. Accessed September 12, 2002.

25 Cast iron pipes have an average life expectancy of 120 years, pipes laid in the 1920s have an average life expectancy of 100 years, and pipes laid after WWII may only last 75 years. (American Water Works Association. 2001. Dawn of the Replacement Era: Reinvesting in Drinking Water Infrastructure. p. 17.)

26 American Water Works Association. 2001. Dawn of the Replacement Era: Reinvesting in Drinking Water Infrastructure. p. 17.

27 General Accounting Office. 2002. "EPA, GAO Examine Water Industry." 2002. Wasteworld. November. <http://www.win-water.org/win_news/1102article.html>.

28 Ibid.

29 Natural Resources Defense Council. 1998. Another Cost of Sprawl: Effects of Land Use on Wastewater Utility Costs. <http://www.nrdc.org/cities/smartGrowth/cost/costinx.asp>.

30 Office of Technology Assessment. 1995. The Technological Reshaping of Metropolitan America. OTA-ETI-643.

31 Fluvanna County, Virginia. 2000. Comprehensive Plan 2000. Chapter 8, "Infrastructure." <http://www.co.fluvanna.va.us/compplan/contents.htm>. Accessed September 11, 2003.

32 Burchell, Robert W., et al. 2002. Costs of Sprawl-2000. Transportation Cooperative Research Program Report 74. Washington, National Research Council. p. 222.

33 Speir, Cameron, and Kurt Stephenson. 2002. "Does Sprawl Cost Us All? Isolating the Effects of Housing Patterns on Public Water and Sewer Costs." Journal of the American Planning Association 68(1): 56-70.

34 Maryland Department of the Environment. 2002. Water Supply Financial Assistance Program. <http://www.mde.state.md.us/environment/sm_grwth/wsassist.html>.

35 Envision Utah. "Phase II: Scenario Development." <http://www.envisionutah.org>. Accessed June 24, 2003.

36 U.S. Environmental Protection Agency. 2003. The Drinking Water State Revolving Fund Program: Financing America's Drinking Water From the Source to the Tap, a Report to Congress. May. <http://www.epa.gov/safewater/dwsrf/pdfs/dwsrf_congressreport-main.pdf>.

37 Ibid.

38 Trust for Public Land. 2004. "Protecting the Source." p. 22.

39 Norfleet, Tracy. 2002. "Using the Clean Water Revolving Fund for Brownfields and USTfields." Washington, DC: Northeast-Midwest Institute. pp. 7-8. <http://www.nemw.org/CleanWaterBF.pdf>. Accessed December 2, 2005.

40 U.S. Environmental Protection Agency. 2004. "Protecting Water Resources with Smart Growth." EPA 231-R-04-002. May. p. 39. <http://www.epa.gov/smartgrowth/pdf/waterresources_with_sg.pdf>. Accessed December 3, 2004.

41 New Jersey Department of Community Affairs. "New Jersey State Development and Redevelopment Plan." <http://www.nj.gov/dca/osg/plan/index.shtml>. Accessed on September 29, 2003.

42 Michigan Land Use Leadership Council. 2003. Michigan's Land, Michigan's Future. August. <http://www.michiganlanduse.org/mlulc_chp7.pdf>. Accessed October 4, 2004.

43 From a classroom presentation by Professor Timothy S. Chapin, Florida State University Department of Urban and Regional Planning, fall 2003. <http://garnet.acns.fsu.edu/~tchapin/>. Accessed November 9, 2004.

44 Van Sickler, Michael. 2004. "His Empire on the Lake." St. Petersburg Times. September 20. <http://www.ccfj.net/CDDempire.html>. Accessed March 16, 2005.

45 Ibid.

46 Boyd, Charles W., Chairman of the Water Service Committee, City of Frederick. 2004. Presentation to the 7th Annual Southeast Watershed Roundtable, Nashville, Tennessee. October 28.

47 The Metropolitan Water District of Southern California has prepared a study of water supply and demand in southern California, to guide local communities and utilities in determining their ability to accommodate the water needs of new growth. The study, Report on Metropolitan's Water Supplies, can be viewed at <http://www.mwd.dst.ca.us/mwdh2o/pdf/sb221/sb221.pdf>.

48 Kanouse, Randele. 2002. "Show Me the Water: Quenching California's Growing Thirst." February. <http://www.kmtg.com/pdfs/EBMUDSlidePres.pdf>.

49 Tarlock, A. Dan, and Lora A. Lucero. 2002. "Connecting Land, Water, and Growth." Land Use Law & Zoning Digest, American Planning Association. April.

50 State of Washington Department of Community, Trade and Economic Environment. "What Is a Comprehensive Plan?" <http://www.cted.wa.gov/DesktopDefault.aspx?tabid=485&tabindex=61>. Accessed March 10, 2004.

51 Neary, Ben. 2001. "State engineer issues landmark water decision." The New Mexican. October 18.

52 Tarlock, Dan. 1998. "Water Supply as New Growth Management Tool." Land Use Law. November.

53 Tarlock, A. Dan. 2000. "Contested Landscapes and Local Voice." Washington University Journal of Law and Policy. Evolving Voices in Land Use Law: A Festschrift in Honor of Daniel R. Mandelker. pp. 513-537. <http://www.law.wustl.edu/journal/3/pg513to537.pdf>. Accessed October 1, 2003.

54 Washington State Department of Health, Office of Drinking Water. 2004. "Municipal Water Law Interim Planning Guidance for Water System Plan/Small Water System Management Program Approvals." Revised March 2004. Attachment 6. <http://www.doh.wa.gov/ehp/dw/Publications/ mwl-revised_interim_direction-finaljpr_end.pdf>. Accessed November 15, 2005.

55 Susquehanna River Basin Commission. 2003. "Analyzing the Availability of Water in Northern Lancaster County." March. <http://www.srbc.net/docs/Lancaster Study (Mar 03) pdf.pdf>. Accessed October 15, 2003.

56 Griego, Eric. 2003. "City Aims to Protect Aquifer." Editorial. Albuquerque Journal. April 5.

57 U.S. Environmental Protection Agency. 2004. "Protecting Water Resources with Smart Growth." EPA 231-R-04-002. May. <http://www.epa.gov/smartgrowth/pdf/ waterresources_with_sg.pdf>. Accessed December 3, 2004.

58 U.S. Environmental Protection Agency. 2002. "The Clean Water and Drinking Water Infrastructure Gap Analysis." EPA-816-R-02-020. September.

59 South Florida Community Development Coalition. "Florida Tax Increment Financing Districts." <http://www.floridacdc.org/policy/tif2.htm>. Accessed December 3, 2004.

60 Raftelis Financial Consulting, PA. 2002. Raftelis Financial Consulting 2002 Water and Wastewater Rate Survey. Charlotte, NC: Raftelis Financial Consulting, PA.

61 City Council of Salt Lake City. 2000. "An Ordinance Amending Chapter 18.98 of the Salt Lake City Code, Relating to Impact Fees." <http://www.ulct.org/ULCTLeg.nsf/b388d79d2de086f787256ddd007e2565/91668b366ed4ae52872570b70045c14d?OpenDocument>. Accessed October 18, 2004.

62 City of Antonio City Council. 2001. "City Council Adopts New Impact Fees: Executive Summary." <http://www.saws.org/business_center/developer/impactfees/impactfees.pdf>. Accessed December 6, 2004.

63 Bartlett, Phil. 2003. "Maine Superior Court Rules on Impact Fee" Gorham Times. October 10. <http://www.gorhamtimes.com/maine_superior_court_rules_on_im.htm>.

64 Conservation Design Forum. "A Comparison Of Sustainable and Traditional Landscapes." <http://www.cdfinc.com/CDF_Resources/Sustainable_Landscape_Cost_Comparison.pdf>. Accessed March 11, 2004.

65 Wikipedia contributors. "Xeriscaping." Wikipedia, the Free Encyclopedia. <http://www.wikipedia.org/wiki/Xeriscaping>. Accessed October 15, 2003.

66 Xeriscape Colorado!, Inc. <http://www.xeriscape.org>. Accessed March 12, 2004.

67 Anderson, Kristin M. 2004. An Investigation into What Planning Departments and Water Authorities Can Learn from Eleven Communities' Waterwise Landscaping Ordinances. Unpublished terminal project, Department of Planning, Public Policy & Management of the University of Oregon. Eugene, OR.

68 City of Denver press release "Mayor Hickenlooper Launches Community Conservation Gardens Project," June 8, 2005. Available at <http://www.denvergov.org/SDIMO/2049 press1738.asp>.

69 Westerman, Nicole, Dean Kaplan, and Michael Nadol. 2003. "Wall Street Bond Rating Perspectives on Capital Program Best Practices." American Water Works Association Joint Management Conference. <http://www.awwa.org/CorePage.cfm?CI=5>.

70 Ibid.

71 Haarmeyer, David. 1992. "Privatizing Infrastructure: Options for Municipal Water Supply Systems." PS Number 151: Reason Public Policy Institute. October. <http://www.rppi.org/ps151.html#03>. Accessed December 3, 2004.

72 City of Philadelphia Water Department. 2001. "Standard & Poor's, Moody's upgrade city's water and wastewater revenue bonds." Press release. November 11. <http://www.phila.gov/water/pr/pr011110.htm>. Accessed December 3, 2004.

73 Trust for Public Land. 2005. "Path to Protection: Ten Strategies for Successful Source Water Protection."

74 General Accounting Office. 2002. Water Infrastructure: Information on Financing, Capital, Planning and Privatization. August. <http://www.gao.gov/new.items/d02764.pdf>. Summary available at <http://www.win-water.org/win_news/1102article.html>.

75 Ibid.

76 Lee, Mike. 2004. "Fort Worth Water Bills to Increase in February." Fort Worth Star-Telegram (Metro section). January 1. p. 2B.

77 Consumers also pay indirectly for water and other municipal services through general taxes. These charges, however, often do not include household type or water consumption in their calculation of taxes due.

78 Raftelis Financial Consulting, PA, 2002.

79 Lee, 2004.

80 Calculated from data from the Fort Worth Water Department Web site. <http://www.fortworthgov.org/water/waterflows/monthwtrusage.htm>. Accessed March 16, 2005.

81 Stallworth, Holly. 2000. "Conservation Pricing of Water and Wastewater" April 10. <http://www.epa.gov/owm/water-efficiency/water7.pdf>.

82 An EPA publication, "Building Support for Increasing User Fees" (1989), is available to support communities in this process: <http://www.epa.gov/clariton/clhtml/pubtitle.html>.

83 Stallworth, 2000.

84 Burchell, R.W., and D. Listokin. 1995. "Land, Infrastructure, Housing Costs and Fiscal Impacts Associated with Growth: The Literature on the Impacts of Sprawl Versus Managed Growth." Center for Urban Policy Research, Rutgers University. As summarized in The Technological Reshaping of Metropolitan America, Office of Technology Assessment. OTA-ETI-643.

85 Natural Resources Defense Council. 1998. Another Cost of Sprawl: Effects of Land Use on Wastewater Utility Costs. <http://www.nrdc.org/cities/smartGrowth/cost/costinx.asp>.

86 Platt, Rutherford H. 1995. "The 2020 Water Supply Study for Metropolitan Boston: The Demise of Diversion." Journal of the American Planning Association 61(2): 186. For more information on the Boston example see <http://www.mwra.state.ma.us/02org/html/ wscac.htm>.

United States
Environmental Protection Agency
(1807-T)
Washington, DC 20460

Official Business
Penalty for Private Use $300

EPA 230-R-06-001
January 2006
www.epa.gov/smartgrowth

Recycled/Recyclable--Printed with vegetable oil based inks on 100% postconsumer, process chlorine free recycled paper.

2019

Southern Resident Orca Task Force

Final Report and Recommendations

November 2019

Cascadia Consulting Group

Table of Contents

With deep appreciation

Over the past two years, members of the task force and working groups have contributed their expertise, passion and countless hours to the consensus-driven, science-based process that led to these comprehensive recommendations. Task force members and working group participants, along with tribal co-managers, worked together in good faith and with a shared commitment to achieve a thriving and resilient population of Southern Residents and a healthy ecosystem. The task force particularly commends and expresses its deepest appreciation to:

- **Gov. Jay Inslee** for his leadership in initiating this effort, taking immediate executive action to address the needs of the Southern Residents and supporting the task force's recommendations in the Legislature.
- **The Legislature** for authorizing significant investment and statutory changes in the 2019 session to initiate implementation of the task force's recommendations.
- **Tribal partners and co-managers** who have participated in this process, even as they engage government-to-government to resolve the issues facing their people, orcas and salmon. By their words and deeds, tribal representatives consistently reminded us of their cultural and spiritual connections with the orca.
- **Our Canadian counterparts** for coordinating Southern Resident recovery efforts across boundaries. Representatives from Canada and Washington have participated in each other's working group, advisory group and task force meetings, sharing lessons learned through their respective processes and identifying opportunities for transboundary collaboration.
- **The leadership and staff at state and federal government agencies,** including the Governor's Office; Office of Financial Management; Governor's Salmon Recovery Office; Washington State Recreation and Conservation Office; Puget Sound Partnership; Washington State Parks and Recreation Commission; Washington State departments of Fish and Wildlife, Ecology, Natural Resources, Agriculture, Transportation and Licensing; National Oceanic and Atmospheric Administration; Region 10 of the Environmental Protection Agency; and the Marine Mammal Commission, for their unending dedication to the recovery of the Southern Residents and contribution of their time and expertise throughout the process.
- **Members of the public**, for showing up to every meeting no matter the location, for demonstrating how much they care and for constantly reminding us to take bold and aggressive action. Over 18,000 insightful public comments poured in with heartfelt testimony and pleas urging the task force not to let these magnificent creatures go extinct. This call to action has resonated across borders, gaining global media attention and reminding us that the survival of these orcas is imperative to us all — both within and beyond Washington state.

Co-chair letter of transmittal

Governor Jay Inslee
Office of the Governor
Olympia, WA 98504

Dear Gov. Inslee,

We are pleased to submit the following final report and recommendations of the Southern Resident Orca Task Force. It has been our honor and privilege to serve as co-chairs these past two years alongside such a dedicated and diverse team of task force members, working groups and tribal partners who have devoted countless hours to the recovery of Southern Residents.

The following report is a summary of this team's extraordinary work over the past two years — as well as an urgent call to action: **With only 73 individuals remaining, there is no time to waste — the road to sustained Southern Resident recovery is through swift, bold and impactful solutions**. The loss of three adult orcas this year was a tragic reminder that the Southern Residents are struggling from a lack of Chinook salmon, compounded by the stresses from vessel noise and disturbance, contaminants in their ecosystem and the long-term threats to their survival from climate change, ocean acidification and human population growth.

While the challenges threatening the Southern Residents have felt overwhelming at times, we are encouraged that this task force has been a high-profile platform to bring important scientific focus, resources and momentum to the crisis facing the orcas for the first time in years. In 2018, the task force developed 36 bold science-based recommendations for moving the needle on orca recovery and we were heartened to see many elements of these recommendations advance through leadership at the Governor's Office and in the Legislature.

Building on this vital energy and momentum, we continued this work in 2019 by working to implement the task force's 36 recommendations, escalating recommendations that have not advanced enough to achieve their goals, and proposing 13 additional recommendations that we believe are critical for orca recovery. These new recommendations emphasize the importance of (1) effectively addressing climate change, human population growth and human sources of nutrients to enable long-term orca survival, (2) developing dedicated funding to support recovery efforts and (3) continuing the mission of orca recovery.

Together, these 49 recommendations provide multiple benefits that, if sustained, will lead to better water quality, a healthier ecosystem and more robust salmon runs. Ultimately all Washingtonians, our sovereign tribal partners and communities beyond our borders will benefit from less pollution, better fishing and shellfish harvesting, more access to recreation and the opportunity for future generations to enjoy and appreciate the majesty of the orca and the beauty and abundance of the greater Northwest ecosystem.

This task force laid a strong foundation for orca recovery, but this work must find a new home where it will continue to be one of the governor's and the Legislature's top priorities. As the current Southern Resident Orca Task Force sunsets, we remain committed to ensuring this urgent and critical work continues. The Southern Residents need all of us to stay engaged and keep these task force recommendations front and center. We must continue to work with local, state and federal policymakers to demand swift action on funding and policy that will help lead to the orcas recovery.

This task force invites and encourages the entire Washington community to join us in these efforts to achieve our shared vision of a "thriving and resilient population of Southern Resident orcas, living in healthy waters and inspiring our descendants with their majesty." We are immeasurably grateful to the public for their compassion and dedication these past two years and call on them again to stay involved and advocate for institutional change, while making personal commitments to support our orcas and the ecosystems on which they depend.

We are deeply grateful to the team of task force members, working groups and tribal partners for showing up in good faith to recover these orcas through science-based, consensus-driven recommendations. We are especially grateful to our sovereign tribal partners for their crucial leadership and constructive participation in these task force and working group meetings while they also engage government-to-government on salmon and orca recovery efforts. Tribal representatives generously contributed their time and expertise to this process while deepening task force members' knowledge of co-management, treaty-reserved rights and the fundamental need to restore salmon runs for orcas and tribal people.

We've all worked hard to be a voice for the Southern Resident orcas these past two years, but it was the actions of a mother orca named Tahlequah and her valiant swim for 1,000 miles and 17 days with her dead newborn calf that captured the hearts of people around the world. Witnessing Tahlequah's grief galvanized greater public understanding and support for what we must do to save the Southern Residents and the ecosystem they depend upon. People from around the globe called on the task force and elected officials to take bold action to save these magnificent orcas.

We dedicate this final report of the Southern Resident Orca Task Force to Tahlequah, and pledge to work urgently to see its recommendations enacted by our policy makers. We also dedicate this report to the two new orca calves born in 2019 (L124 and J56) and the hope that they bring for the future. Their future depends on all of us in Washington State and British Columbia working together to put the health of the orcas, the salmon and our people first.

Sincerely,

Dr. Les Purce and Stephanie Solien

Executive summary

The power, beauty, intelligence and grace of the Southern Resident orca touch us all. How thrilling for locals and visitors alike to glimpse a pod of Southern Residents frolicking in the waters of the Salish Sea or the Pacific Ocean. How privileged we are to experience an orca sighting whether from land, by boat or even as a ferry passenger! Orcas — especially our Southern Residents — connect us to the beauty and bounty of nature and remind us of the interconnectedness of all living things.

Today, the iconic Southern Resident orca population is in decline and threatened with extinction. Despite federal and state endangered species protections, the population has dropped to only 73 individuals — the lowest level in over four decades. These orcas face several complex threats: lack of Chinook salmon (their primary food source), disturbance from noise and vessel traffic, toxic contaminants, the emerging impacts of climate change and the cumulative effects of continuous population growth across the region.

Year One: Formation of the Southern Resident Orca Task Force and development of recommendations

Recognizing the urgency of the threats facing the Southern Residents and the unacceptable loss extinction would bring, Gov. Jay Inslee established the Southern Resident Orca Task Force through Executive Order 18-02 in March 2018. The governor appointed nearly 50 representatives from diverse sectors to the task force. As sovereign nations, several tribes also chose to send representatives to engage with the task force while engaging government-to-government to resolve the issues facing the orcas and salmon.

The governor charged this task force with preparing comprehensive recommendations to ensure a healthy and resilient ecosystem that supports a thriving Southern Resident orca population, protected from extinction. From May through November 2018, the task force convened to learn about the threats facing Southern Residents, identify solutions and formulate consensus recommendations. Working groups consisting of subject matter experts, tribal representatives and key stakeholders supported the task force, using the best available science to identify and analyze potential actions.

The task force submitted its Year One Report with a set of 36 bold recommendations for orca recovery to the governor and Legislature in November 2018. These recommendations resulted in significant new investments, policies and regulatory initiatives to help recover Southern Residents and supported four goals: (1) increase Chinook abundance; (2) decrease disturbance of and risk to Southern Resident orcas from vessels and noise and increase their access to prey; (3) reduce the exposure of Southern Resident orcas and their prey to contaminants; and (4) ensure that funding, information and accountability mechanisms are in place to support effective implementation.

Year Two: Assessing progress, addressing emerging issues and looking to the future

Continuing to meet throughout 2019, the task force (1) assessed progress made on implementing Year One recommendations; (2) identified outstanding needs and emerging threats; and (3) formulated new recommendations to address them.

Progress highlights

Thanks to leadership from the governor, Legislature and state agencies, several Year One task force recommendations resulted in significant policies and regulatory initiatives to help recover Southern Residents, representing an encouraging first step in Southern Resident recovery. The enacted 2019–21 biennial budgets (operating, capital and transportation) provided $1.1 billion to support the recovery of Southern Residents and implement the recommendations of the Governor's Southern Resident Orca Task Force. Important and notable successes include:

- **Prey**: Increased hatchery production to increase food for orcas; improved habitat protections; took actions to increase survival through the hydropower system; and decrease predation from pinnipeds and predatory fish. Funding provided for fish barrier corrections; habitat protection, restoration, enforcement and technical assistance;

increased hatchery production; and a process to address issues associated with the possible breaching or removal of the lower Snake River dams.

- **Vessels**: Strengthened distance and speed restrictions near Southern Residents; legislation directing the establishment of commercial whale watching licensing system; established new standards for oil barge tug escorts; broadened education and outreach efforts to promote compliance; and developed voluntary standards to reduce the potential interference of depth finders on Southern Resident echolocation. Funding provided for Washington State Department of Transportation ferry electrification and increased enforcement of vessel regulations.
- **Contaminants**: New state authorities created to prioritize chemicals of concern. Funding provided for water quality enforcement staff and contaminant prevention and cleanup.

Outstanding needs

To address critical gaps and accelerate progress, the task force recommends that the Legislature, governor, agencies and co-managers "double down" on implementing and funding recommendations that address unmet needs and gaps, capitalize on initial progress and ensure that recovery efforts are sustained over time:

- **Prey**: Sustain the priority focus on increasing Chinook abundance through habitat protection and restoration, increased hatchery production while minimizing competition with wild stocks and decreased predation.
- **Vessels**: Advance and fund solutions to vessel disturbances and noise and respond to emerging threats.
- **Contaminants**: Provide resources for implementation, update standards, prioritize actions based on emerging threats to Southern Residents and address nutrient pollution.

Emerging issues and new recommendations

The task force developed 13 new recommendations in Year Two to tackle emergent threats and enable sustained and successful long-term recovery. Five of these new recommendations address the threat of contaminants, including three recommendations that specifically address human sources of nutrients. The task force also focused on two systemic threats to the Southern Residents in Year Two that, if left unchecked, will undermine recovery efforts: (1) climate change and ocean acidification and (2) rapid human population growth and development. The task force established two new goals and formulated seven new recommendations to respond to and mitigate these threats.

Sustainable funding

Accelerating action on the ground, mitigating the threat posed by climate change and managing human population growth to minimize impacts on the orca requires funding at scale, sustained over the long term. Most of the task force's Year One recommendations also require sustained operating resources for effective implementation, while several others require significant capital investments. Although new funds have been appropriated in many instances, in others they have not, and many that will require consistent funding over multiple biennia.

With great urgency, the task force calls upon elected officials — working with representatives from tribal governments — to engage stakeholders, experts and the public to preserve existing funding and identify and secure new funding sources to meet these needs at the state, local and federal levels. This funding is vital to bringing to scale the work now underway for Southern Resident and Chinook survival and recovery.

Continuing the mission of Southern Resident orca recovery

The Southern Resident Orca Task Force sunsets on Nov. 8, 2019. After this point, it is critically important that the state continues to monitor progress, advocate for the ongoing implementation of the recommendations and adapt to changing conditions by issuing new recommendations as needed. As such, the task force recommends that an oversight committee or similar body be established to continue the vital work of orca recovery and to monitor and advocate for the Southern Residents once the task force disbands. The task force has laid a foundation for Southern Resident recovery; strong, dedicated leadership and governance are necessary to build on this foundation with meaningful, immediate and sustained action.

Southern Resident Orca Task Force
FINAL RECOMMENDATIONS

Bolded recommendations require legislative policy and/or funding:

1. **Significantly increase investment in restoration and acquisition of habitat in areas where Chinook stocks most benefit Southern Resident orcas.**
2. **Immediately fund acquisition and restoration of nearshore habitat to increase the abundance of forage fish for salmon sustenance.**
3. Apply and enforce laws that protect habitat.
4. Immediately strengthen protection of Chinook and forage fish habitat through legislation that amends existing statutes, agency rulemaking and/or agency policy.
5. Develop incentives to encourage voluntary actions to protect habitat.
6. **Significantly increase hatchery production and programs to benefit Southern Resident orcas consistent with sustainable fisheries and stock management, available habitat, recovery plans and the Endangered Species Act. Hatchery increases need to be done in concert with significantly increased habitat protection and restoration measures.**
7. Prepare an implementation strategy to reestablish salmon runs above existing dams, increasing prey availability for Southern Resident orcas.
8. Increase spill to benefit Chinook for Southern Residents by adjusting total dissolved gas allowances at the Snake and Columbia River dams.
9. Establish a stakeholder process to discuss potential breaching or removal of the lower Snake River Dams for the benefit of Southern Resident orcas.
10. Support full implementation and funding of the 2019–28 Pacific Salmon Treaty.
11. Reduce Chinook bycatch in West Coast commercial fisheries.
12. **Direct the appropriate agencies to work with tribes and National Oceanic and Atmospheric Administration to determine if pinniped (harbor seal and sea lion) predation is a limiting factor for Chinook in Puget Sound and along Washington's outer coast and evaluate potential management actions.**

13. **Support authorization and other actions to more effectively manage pinniped predation of salmon in the Columbia River.**
14. **Reduce populations of nonnative predatory fish species that prey upon or compete with Chinook.**
15. **Monitor forage fish populations to inform decisions on harvest and management actions that provide for sufficient feedstocks to support increased abundance of Chinook.**
16. **Support the Puget Sound zooplankton sampling program as a Chinook and forage fish management tool.**
17. Establish a statewide “go-slow” bubble for small vessels and commercial whale watching vessels within half a nautical mile of Southern Resident orcas.
18. Establish a limited-entry whale-watching permit system for commercial whale-watching vessels and commercial kayak groups in the inland waters of Washington state to increase acoustic and physical refuge opportunities for the orcas.
19. **Create an annual Orca Protection endorsement for all recreational boaters to ensure all boaters are educated on how to limit boating impacts to orcas.**
20. **Increase enforcement capacity and fully enforce regulations on small vessels to provide protection to Southern Residents.**
21. Discourage the use of echo sounders and underwater transducers within 1 kilometer of orcas.
22. Implement shipping noise-reduction initiatives and monitoring programs, coordinating with Canadian and U.S. authorities.
23. Reduce noise from the Washington state ferries by accelerating the transition to quieter and more fuel-efficient vessels and implementing other strategies to reduce ferry noise when Southern Residents are present.
24. Reduce the threat of oil spills in Puget Sound to the survival of Southern Residents.
25. Coordinate with the Navy in 2019 to discuss reduction of noise and disturbance affecting Southern Resident orcas from military exercises and Navy aircraft.
26. Revise chapter 77.15.740 RCW to increase the buffer to 400 yards behind the orcas.

27. Determine how permit applications in Washington state that could increase traffic and vessel impacts could be required to explicitly address potential impacts to orcas.
28. Suspend viewing of Southern Resident orcas.
29. Accelerate the implementation of the ban on polychlorinated biphenyls in state-purchased products and make information available online for other purchasers.
30. **Identify, prioritize and take action on chemicals that impact orcas and their prey.**
31. **Reduce stormwater threats and accelerate clean-up of toxics harmful to orcas.**
32. **Improve effectiveness, implementation and enforcement of National Pollutant Discharge Elimination System permits to address direct threats to Southern Resident orcas and their prey.**
33. Increase monitoring of toxic substances in marine waters; create and deploy adaptive management strategies to reduce threats to orcas and their prey.
34. **Provide sustainable funding for implementation of all recommendations.**
35. **Conduct research, science and monitoring to inform decision-making, adaptive management and implementation of actions to recover Southern Residents.**
36. Monitor progress of implementation and identify needed enhancements.
37. Protect against regulatory rollbacks at the federal and state level.
38. **Explore setting minimum standards for local stormwater funding to ensure that all programs have the resources necessary to protect water quality.**
39. **Develop a National Pollutant Discharge Elimination System permit framework for advanced wastewater treatment in Puget Sound to reduce nutrients in wastewater discharges to Puget Sound by 2022.**
40. Better align existing nonpoint programs with nutrient reduction activities and explore new ways to achieve the necessary nonpoint source nutrient reductions.
41. **Collect high-quality nutrient data in watersheds to fill key knowledge gaps of baseline conditions.**

42. **Create one or more entities with authority and funding to recover and advocate for Southern Resident orcas by implementing task force recommendations, creating new recommendations as needed and reporting to the public, governor and tribal co-managers on status.**

43. **Take aggressive, comprehensive and sustained action to reduce human-caused greenhouse gas emissions, with the goal of achieving net zero emissions by 2050.**

44. **Increase Washington's ability to understand, reduce, remediate, and adapt to the consequences of ocean acidification.**

45. **Mitigate the impact of a changing climate by accelerating and increasing action to increase the resiliency and vitality of salmon populations and the ecosystems on which they depend.**

46. **Expand the Governor's Maritime Blue scope of work and provide funding to implement recommendations from the Southern Resident Orca Task Force and pursue shipping and other maritime innovations that benefit Southern Residents.**

47. Identify and mitigate increased threats to Southern Residents from contaminants due to climate change and ocean acidification. Prioritize actions that proactively reduce exposure where the increased impacts are expected to be most severe.

48. **Adopt and implement policies, incentives and regulations for future growth and development to prevent any further degradation of critical habitat and sensitive ecosystems; enable and channel population growth in ways that result in net ecological gain; evaluate and report outcomes for all jurisdictions at the state, county, tribal and municipal level.**

49. Conduct a comprehensive environmental review and take action to minimize potential whale-strike risk and underwater noise posed by the growing number and distribution of fast-ferries and water taxis in Southern Resident critical habitat.

Chapter 1. Task force – purpose, process and outcomes

Introduction

Southern Resident orcas hold significant value throughout the Pacific Northwest as a treasured and iconic species. Many sovereign tribal nations consider these orcas ancestors, protectors of humankind and family members. The Lummi people call the orcas qwe 'lhol mechen, which means "our relations under the waves." As Leonard Forsman, chairman of the Suquamish Tribe, put it, "The Southern Resident killer whales are like us: They depend on these waters for their survival, for their well-being, for food and recreation, for their spirituality as well [1]."

These whales are highly intelligent and complex beings, evolving to become the top predators in their ecosystems. Their lives show many similarities to ours — including their incredibly close social bonds. Southern Residents travel in pods (J, K and L) of extended family members from central Southeast Alaska to central California but spend most of the year in the Salish Sea near the San Juan Islands, on the outer coast of Washington and the outer coast of southern Vancouver Island. In pursuit of migrating salmon, Southern Residents are known to forage farther south in Puget Sound during the fall and spend time near the mouth of the Columbia River in winter [2].[1]

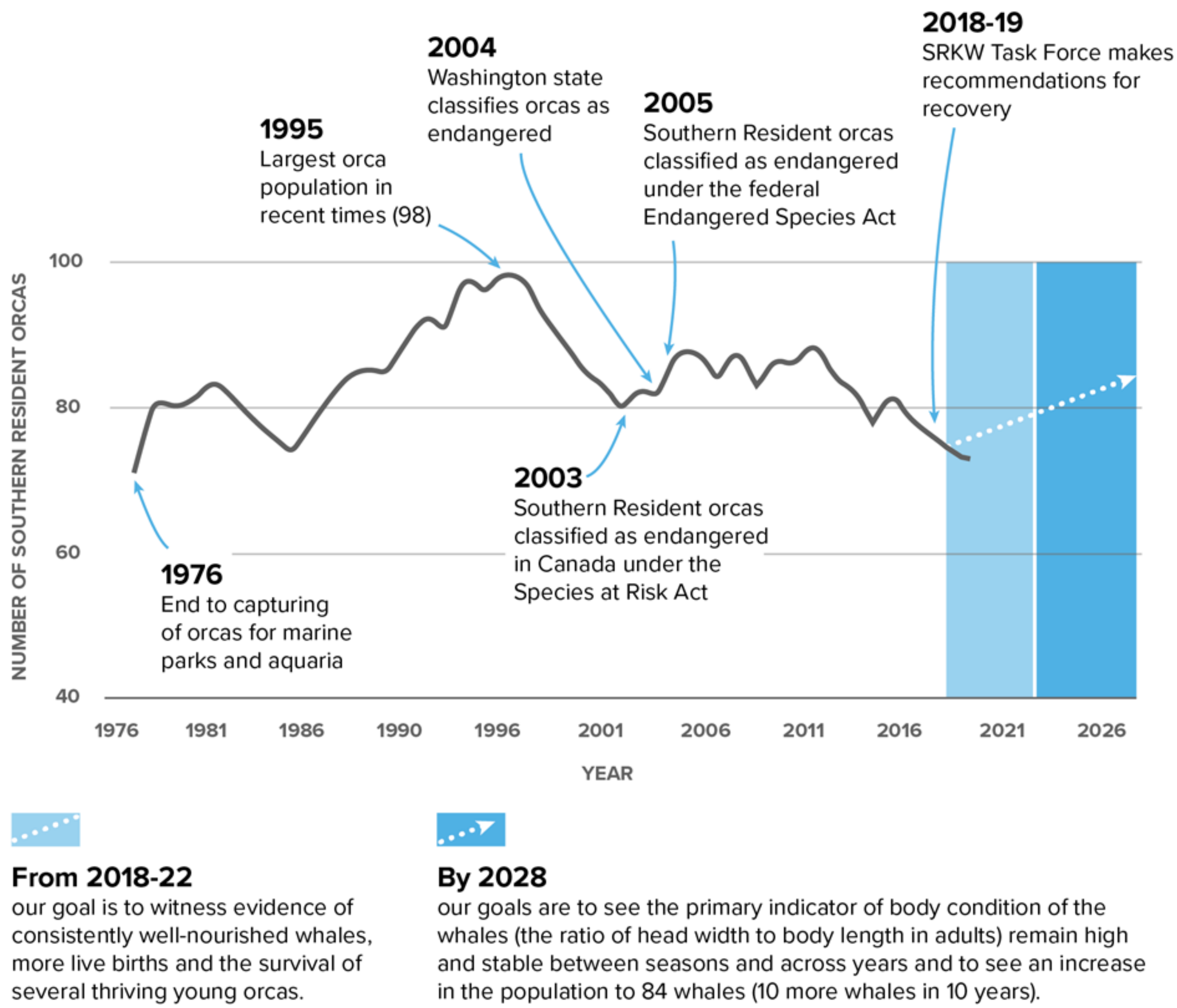
The first Southern Resident orca population census in 1973 identified 66 orcas. It included reductions due to captures for marine parks between 1965 and 1975. Since 1975, the population has experienced periods of growth, and in 1995 reached a high of 98 orcas (**Figure 1**). However, between 1995 and 2003, the population dropped by 16%, down to 82 orcas, which prompted

[1] NOAA has issued a proposal to expand the Southern Resident orca critical habitat designation to include the coastal waters of Washington, Oregon and California (to Point Sur). The expansion would provide additional habitat protection in acknowledgment that the full extent of the orcas' range is critical for their survival and recovery [78].

their listing as an endangered species [3]. Canada classified Southern Resident orcas as endangered under the Species at Risk Act in 2003. Washington state classified them as endangered in 2004, and the United States followed suit under the federal Endangered Species Act in 2005. The 2005 ESA listing identified three major threats to Southern Resident orcas: lack of prey, disturbance from noise and vessel traffic and toxic contaminants.

Despite federal and state protections, Southern Resident population numbers have continued to fall — reaching the lowest level in more than four decades. Swift and bold near-term actions and effective long-term actions are urgently needed to help secure a healthy and sustained Southern Resident orca population and the entire ecosystem we depend upon.

Figure 1. Southern Resident orca population trends and recovery goals [4].



Formation of the Southern Resident Orca Task Force

Recognizing the urgency of the threats facing the Southern Residents and the unacceptable loss extinction would bring, Gov. Inslee established the Southern Resident Orca Task Force through Executive Order 18-02. The governor directed this newly formed task force to meet over two years to (1) recommend priority actions, legislation and funding in Year One and (2) monitor progress, identify lessons learned and address outstanding needs in Year Two.

The governor appointed nearly 50 representatives from diverse sectors to the task force, including federal, local and other state governments, the Washington State Legislature, state agencies, the private sector, nonprofit organizations and the Government of Canada. As sovereign nations, several tribes also chose to send representatives to engage with the task force, sharing their perspectives and knowledge about orcas, salmon recovery and treaty rights.

Year One: A road map to recovery through bold actions

From May through November 2018, the task force convened to learn about the threats facing Southern Residents, identify solutions and formulate consensus recommendations. The task force developed the following vision to guide their work:

> ***We envision a thriving and resilient population of Southern Resident orcas, living in healthy waters and inspiring our descendants with their majesty.***

The task force aligned with the National Marine Fisheries Service 2008 Recovery Plan, and its goal of an average population growth rate of 2.3% per year for 28 years. The task force set out to increase the Southern Resident population to 84 whales by 2028 — 10 more whales in 10 years. The task force also defined near-term criteria for recovery that include evidence of (1) consistently well-nourished whales; (2) more live births; and (3) the survival of several thriving young orcas.

Responding to this call to action, prey, vessels and contaminants working groups — consisting of subject matter experts, tribal comanagers and key stakeholders — supported the task force in their goals and commitments, using the best available science to identify and analyze potential recommendations. A steering committee also supported the task force, charged with ensuring and enabling a smooth and effective process that meets the goals and timeliness of the governor's executive order. Refer to **Appendix 3** for a full list of task force, working group and steering committee members.

Throughout 2018, tragedies in the Southern Resident population continued to put a spotlight on the need for urgent and effective action. Tahlequah (J35) carried her deceased newborn calf for 17 days in late July and early August for more than 1,000 miles in an apparent act of grief and mourning. Three-year-old Scarlet (J50) was presumed dead in September after showing signs of severe emaciation. Eighteen thousand public comments poured in during the task force's first year, with heartfelt testimony and pleas to not let these magnificent creatures go extinct.

The task force submitted its Year One Report with a set of 36 bold recommendations for orca recovery to the governor and Legislature in November 2018. These recommendations have resulted in significant new investments, policies and regulatory initiatives to help recover Southern Residents.

Year Two: Monitoring progress, addressing emerging issues and navigating the road ahead

Despite this progress, the status of the Southern Resident population remains critical. In 2019, the task force celebrated the birth of two new orca calves (L124 and J56), while mourning the loss of three adult orcas in the same year (J17, K25 and L84). These tragic losses have resulted in the fewest number of Southern Residents in over 40 years — just 73 individuals (**Figure 1**). While observations in summer of 2019 indicate that many orcas appear to be in improved body condition, the entire population has not been assessed, and underlying health issues may be unknown.

Although Southern Residents have historically frequented the Salish Sea in summer months, they were present in their accustomed summer foraging area for only two days in June and July 2019. This extended absence is an unprecedented seasonal shift in use of their historic core and critical habitat. While the cause is unclear, continued or worsening pressure from known threats such as lack of prey and vessel noise and disturbance likely led or contributed to their displacement. For example, several Chinook stocks, such as from the Fraser River, saw extremely low numbers of returning Chinook. The successful recovery of Southern Resident orcas and their prey will continue to hinge on coordinated U.S. West Coast and transboundary monitoring and management actions, especially as species alter their geographical distributions due to climate change [5].

With a declining population, a continued lack of prey and ever-increasing adverse impacts from vessels, noise and toxics, Southern Resident orcas are still in crisis. Picking up where they left off in Year One, the task force continued to meet throughout 2019, supported by the working groups and steering committee. The task force focused their Year Two efforts on (1) assessing progress made on Year One recommendations; (2) identifying outstanding needs and emerging threats; and (3) formulating new recommendations to address them.

The following chapters of this report present the outcome of these deliberations:

- **Chapter 2**: Assessment of Year One recommendations
- **Chapter 3**: Emerging issues addressed in Year Two
- **Chapter 4**: Continuing the mission of Southern Resident orca recovery

Chapter 2. Assessment of Year One recommendations — progress made and outstanding needs

Introduction

In its first year, the task force focused on developing a bold package of 36 recommendations. If implemented, these recommendations would collectively have the impact needed to achieve the vision of a thriving and resilient Southern Resident orca population and support four goals:

- **Goal 1:** Increase Chinook abundance [**16 recommendations**].
- **Goal 2:** Decrease disturbance of and risk to Southern Resident orcas from vessels and noise and increase their access to prey [**12 recommendations**].
- **Goal 3:** Reduce the exposure of Southern Resident orcas and their prey to contaminants [**5 recommendations**].
- **Goal 4:** Ensure that funding, information and accountability mechanisms are in place to support effective implementation [**3 recommendations**].

In its second year, the task force focused on implementing and monitoring these recommendations. Working groups met throughout summer 2019 to evaluate progress and the task force reviewed the outputs of these deliberations, highlighting the notable accomplishments to date, as outlined in this chapter.

While several Year One recommendations made noteworthy progress, some recommendations have not advanced enough to achieve their respective goals. As a result, the task force proposes urgent actions and/or additional funding to advance these recommendations as outlined in this chapter.[2] Refer to the following sections of this chapter for the task force's assessment of progress, outstanding needs, and lessons learned for Year One task force recommendations. Refer to **Table 1** for a legend of the progress indicator icons used in this chapter.

Table 1. Progress indicator icon legend.

	All pieces of recommendation are moving forward (or have been completed).
	Some pieces of recommendation are moving forward.
	Recommendation is not on track to achieve respective goal.

Goal 1: Increase Chinook abundance

While other populations of killer whales prey upon a variety of marine mammal or shark species, Southern Residents have uniquely evolved to prey upon salmon — with Chinook making up about 80% of their diet [6]. Many Chinook populations across the Pacific Northwest have declined to a fraction of their historic abundance and are listed as either threatened or endangered under the Endangered Species Act. In addition, Chinook are returning younger and smaller than they have historically. These significant shifts in abundance and size are making Chinook less available and less nutritious for Southern Resident orcas.

To put Southern Resident orcas on the path to recovery:

- **They need healthy ecosystems and food sources in Washington and throughout the west coast of the United States and Canada**. Southern Residents make their home in Washington's marine waters for a large portion of the year, but they are also migratory, seeking Chinook along the West Coast from Northern California to Southeast Alaska.
- **Chinook populations in these regions need to be abundant, diverse and accessible**, which requires productive and protected habitat and a reliable forage fish food source for Chinook and other salmon. Multiple factors combine to affect salmon abundance and productivity, including habitat loss and degradation, fish passage, harvest, hydropower survival, hatcheries, predation and forage fish and food web interactions.

In Year One, the task force developed 16 recommendations for increasing Chinook abundance, presented below with respective progress indicators as of November 2019. Refer to **Appendix 2** for detailed dashboard of Year One recommendations and progress made on each.

---

[2] **Urgent actions** emphasize one or more components of a Year One recommendation that has not advanced enough to achieve its goal. **Additional components** fill a gap in a Year One recommendation.

Table 2. Year One prey recommendations - progress as of November 2019.

Progress	Recommendation	
+	1	Significantly increase investment in restoration and acquisition of habitat in areas where Chinook stocks most benefit Southern Resident orcas.
+	2	Immediately fund acquisition and restoration of nearshore habitat to increase the abundance of forage fish for salmon sustenance.
+	3	Apply and enforce laws that protect habitat.
+	4	Immediately strengthen protection of Chinook and forage fish habitat through legislation that amends existing statutes, agency rule making and/or agency policy.
+	5	Develop incentives to encourage voluntary actions to protect habitat.
+	6	Significantly increase hatchery production and programs to benefit Southern Resident orcas consistent with sustainable fisheries and stock management, available habitat, recovery plans and the Endangered Species Act. Hatchery increases need to be done in concert with significantly increased habitat protection and restoration measures.
✓	7	Prepare an implementation strategy to reestablish salmon runs above existing dams, increasing prey availability for Southern Resident orcas.
✓	8	Increase spill to benefit Chinook for Southern Residents by adjusting total dissolved gas allowances at the Snake and Columbia River dams.
✓	9	Establish a stakeholder process to discuss potential breaching or removal of the lower Snake River Dams for the benefit of Southern Resident orcas.
✓	10	Support full implementation and funding of the 2019–28 Pacific Salmon Treaty.
+	11	Reduce Chinook bycatch in west coast commercial fisheries.
−	12	Direct the appropriate agencies to work with tribes and National Oceanic and Atmospheric Administration to determine if pinniped (harbor seal and sea lion) predation is a limiting factor for Chinook in Puget Sound and along Washington’s outer coast and evaluate potential management actions.
+	13	Support authorization and other actions to more effectively manage pinniped predation of salmon in the Columbia River.
+	14	Reduce populations of nonnative predatory fish species that prey upon or compete with Chinook.
✓	15	Monitor forage fish populations to inform decisions on harvest and management actions that provide for sufficient feedstocks to support increased abundance of Chinook.
+	16	Support the Puget Sound zooplankton sampling program as a Chinook and forage fish management tool.

Progress highlights:

Increased hatchery production to increase food for orcas.

Washington state, tribes and public utility districts received $13.54 million from the Legislature (operating budget) to increase hatchery production consistent with sustainable fisheries and stock management, available habitat, recovery plans and the Endangered Species Act. Increases in production will occur in state, tribal and public utility district facilities, resulting in 26.84 million additional smolts annually. The Legislature also provided nearly $40 million (a 20% increase) to make capital improvements to state hatcheries (**Recommendation 6**).

Improved habitat protections, restoration, enforcement and technical assistance.

The state passed governor-requested House Bill 1579 in 2019, addressing habitat protection of shorelines and waterways, specifically increasing Washington Department of Fish and Wildlife civil enforcement authority for hydraulic project approvals and removing key exemptions (Chapter 290, Laws of 2019 (2SHB 1579)) (**Recommendations 3 and 4**).

$10.3 million was included in the operating budget and $447.8 million in the capital budget for salmon habitat restoration programs. This funding represents a 22.1% increase in capital funding from the previous biennium (**Recommendations 1 and 5**).

$4.5 million was provided to increase technical assistance and enforcement of state water quality, water quantity and habitat protection laws. This funding will result in four additional WDFW enforcement officers to enforce hydraulic project approval permits. The Washington State Department of Ecology will hire three additional nonpoint source water quality specialists, three additional water quality inspectors focusing on point source pollution and five additional water masters in Puget Sound to enforce instream flow rules (**Recommendation 3**).

Increased survival through the hydropower system.

On March 29, 2019, Ecology issued a short-term modification for total dissolved gas criteria for areas on the lower Snake and lower Columbia rivers so that the allowable 120% total dissolved gas aligned with Oregon. In May 2019, Ecology initiated a rulemaking process to update Washington's total dissolved gas criteria for these rivers, allowing spill up to 125% total dissolved gas. If adopted, the rule would allow the U.S. Environmental Protection Agency the regulatory time frame to approve revised total dissolved gas water quality criteria by the 2020 spring spill season (**Recommendation 8**).

Decreased predatory fish impacts.

The state passed legislation in 2019 to decrease impacts of predatory fish on salmon, directing WDFW to develop rules to increase bag limits for certain species that overlap with and prey on salmon (Chapter 290, Laws of 2019 (2SHB 1579)) (**Recommendation 14**).

Decreased pinniped predation on the Columbia River.

Congress passed the federal Endangered Salmon Predation Prevention Act (PL 115-329), giving state and tribal resource managers more flexibility to manage sea lion predation in the Columbia River to minimize impacts to salmon. The law allows the National Oceanic and Atmospheric Administration's National Marine Fisheries Service to approve permits for Washington, Oregon, Idaho and several area tribes that will streamline the removal process of a designated number of sea lions from a portion of the Columbia River and adjacent tributaries each year (**Recommendation 13**).

Washington State Department of Transportation fish passage.

$275 million was provided to WSDOT to complete fish barrier corrections necessary to meet the requirements of the U.S. federal court culvert injunction. This funding is a $176 million, or 177%, increase from the previous biennium (**Recommendation 1**).

Lower Snake River dams stakeholder process.

$750,000 was approved to implement a stakeholder engagement process to determine the economic, social and environmental impacts of the potential breaching or removal of the lower Snake River dams (**Recommendation 9**).

Outstanding needs:

Fully fund salmon recovery plans.

Increase funding and partnerships to fully implement priority habitat actions in salmon recovery plans, working with legislators, stakeholders and tribes. Focus on implementing habitat restoration and protection projects that local experts have prioritized in each salmon recovery region and that will benefit Chinook and Southern Residents. Ensure funding includes administration and local capacity-building to accelerate projects that are underway or have committed resources. Ensure greater collaboration between hatchery and habitat restoration efforts so that habitat is available to recover wild fish and for newly produced hatchery fish (**urgent action for Recommendations 1, 2 and 6, requires legislative funding**).

A recent estimate of the costs and potential funding gaps to implement regional salmon recovery plans is currently unavailable. The latest, most comprehensive estimate of the statewide cost of implementing the habitat-related elements of regional salmon recovery plans was completed in 2011:

- That report estimated the cost to implement regional salmon recovery plans for all species for the period of 2010–19 to be $5.5 billion, with $4.7 billion in capital costs and nearly $800 million in non-capital costs [7].
- This funding translates to $550 million in annual costs. The report found that if current state, federal and local sources were maintained for the coming 10 years, they would

support approximately 25% of the actions recommended in regional recovery plans statewide.

- This estimate does not include the costs of non-habitat-related actions (hydropower, hatcheries, harvest, predation and invasive species) needed to recover salmon.
- This estimate is likely to be somewhat higher than what would be needed solely for orca recovery since it includes costs for salmon species that are not a primary food source for Southern Residents.
- City and county governments are critical salmon recovery partners. These estimates to implement the salmon recovery plans do not fully encompass the costs to local governments for restoration activities and land use protection and regulatory programs. Additional work is required to generate these estimates, and to provide the necessary support and funding to local governments for salmon recovery plan implementation.

Although some overlap with fish passage barrier projects in the Regional Salmon Recovery plans exists, a significant funding gap for the correction of state and local fish passage barriers remains:

- Under a federal injunction, WSDOT has 992 remaining fish passage barriers on state highways to correct in Puget Sound and along the Washington coast north of the Willapa and Columbia River drainages.
- Four hundred and fifteen of these barriers with significant habitat blockages need to be corrected by 2030 to meet the injunction's requirements.
- WSDOT's current estimate to comply with the injunction by 2030 is an additional $3.1 billion and would be expected to increase if implementation is delayed [8].

In addition to state fish passage barriers, local governments also have barriers blocking fish passage:

- Approximately 3,200 county culverts are within the injunction case area and will cost an estimated $7.7 billion to correct [9, 10].
- The Association of Washington Cities has estimated a potential cost of $4.2 billion to correct its 1,233 known city barriers [11].
- So far, no long-term funding source has been identified to fix the fish blockages in local government jurisdictions.

Assuming that state funding of $225 million annually in the 2019–21 biennium capital budget continues, current funding sources would be providing approximately 50% of the annual need for salmon habitat restoration.

- This estimate is not adjusted for inflation and does not reflect projects which have been funded or new projects that may have been developed since 2011.

- The Puget Sound Partnership's 2018–22 Action Agenda for Puget Sound Recovery, completed in December 2018, estimates a total cost of implementation of a little more than $1.3 billion.
- To date, secured funding of $254 million amounts to only 19% of projected costs [12].

Focusing only on Chinook recovery in Puget Sound yields a similar result:

- The 2018–22 Action Agenda estimates a cost of $729 million to implement the Chinook Salmon Priority focus area over those four years.
- The $135 million in secured funding to date represents only 18.5% of the funding necessary to implement the near-term actions related to Chinook recovery [13].

These estimates for Chinook recovery and overall Puget Sound recovery do not reflect the actual increase in funding in the 2019–21 biennial budget, so they are likely overestimating the funding gap.

Increase habitat protection.

Reduce the impacts from development on critical habitat and sensitive ecosystems that Southern Residents and the food web rely upon. Revise statutes to shift from a "no net loss" standard to a "net ecological gain" standard to better protect salmon and orcas. Provide adequate funding and support to state natural resource agencies and local governments to improve planning, permitting and enforcement activities that protect habitat, while funding restoration efforts (**additional component of Recommendations 3 and 4 and NEW Recommendation 48**).

Investigate and address pinniped predation.

Provide funding to WDFW to (1) determine if pinniped predation is a limiting factor for Chinook in Puget Sound and along Washington's outer coast and (2) more effectively manage pinniped predation in the Columbia River (**urgent action for Recommendations 12 and 13, requires legislative funding**).

Increase early marine survival research and monitoring in Puget Sound.

Increase funding to PSP and WDFW for salmon marine survival research and monitoring projects through the Puget Sound Action Agenda to ensure that results may be integrated in recovery and management plans, as appropriate. Research and monitoring projects could include Puget Sound Atlantis Modeling, zooplankton monitoring, salmon and forage fish sampling and pinniped predation work (**urgent action for Recommendations 12, 15, 16, requires legislative funding**).

Prevent northern pike expansion into the Columbia River.

Increase funding to WDFW for northern pike eradication and containment efforts to prevent predation on salmon in the Columbia River (**additional component of Recommendation 14, requires legislative funding**).

Improve water quality.

Encourage Ecology to proceed with language in new rules on increasing the standard for total dissolved gas allowances in the Columbia and Snake rivers that will ensure the durability of the new rule (**urgent action for Recommendation 8**).

Lessons learned:

Reduced age and size of Chinook at return.

The reduced age and size of Chinook at return increases concern about prey quality and quantity available to Southern Residents. Additional investigation and adaptive management are needed to better understand and address the underlying reasons for these changes in prey. Tracking progress and effectiveness of task force recommendation implementation around prey is critical to maintaining recovery momentum and achieving recovery goals.

Efforts to reduce Chinook bycatch.

In recent years, substantial progress has been made by the Pacific Fishery Management Council and North Pacific Fishery Management Council to reduce the bycatch of Chinook in federal groundfish fisheries in the Bering Sea, the Gulf of Alaska and off the coasts of Washington, Oregon and California.

For example, 2018 Chinook bycatch levels in the Bering Sea and Gulf of Alaska were 34,288 (NPFMC), well below the upper limit of about 109,000. Bycatch in the West Coast groundfish fisheries was 7,492 Chinook (West Coast Groundfish Observer Program) in 2018, which is also considerably lower than the limit of 20,000.

Task force Recommendation 11 requested that WDFW continue to work with regional councils and stakeholders to further reduce bycatch in West Coast fisheries. While changes to timing, gear and harvest areas have contributed to the bycatch reductions to date, WDFW will need to continue to work within the councils to seek further reductions when and where possible as new technology and research become available.

Goal 2: Decrease disturbance of and risk to Southern Resident orcas from vessels and noise and increase their access to prey

Southern Residents travel in pods from central southeast Alaska to central California, spending most of the year in the Salish Sea near the San Juan Island, along the outer coasts of Washington and southern Vancouver Island. Vessels transiting near Southern Resident orcas can disturb and displace them from their preferred areas. Underwater noise can mask or impair orca communication and echolocation (the method orcas use to find their prey). Even virtually silent vessels (e.g., kayaks) can disturb the orcas and reduce the time they devote to foraging by 15-20%, which decreases their potential prey intake while increasing their energy expenditure [14]. Models suggest Southern Resident orcas lose several hours of foraging time per day from May to September due to vessel noise and avoidance behaviors associated with ships and boat presence [15]. Key sources of concern include ships, small vessels, echo sounders and oil spills.

In Year One, the task force developed 12 recommendations for decreasing disturbance of — and risk to — Southern Resident orcas from vessels and noise, presented below with respective progress indicators as of November 2019. Refer to **Appendix 2** for a detailed dashboard of Year One recommendations and progress made on each.

Table 3. Year One vessels recommendations - progress as of November 2019.

Progress	Recommendation	
✓	17	Establish a statewide “go-slow” bubble for small vessels and commercial whale watching vessels within half a nautical mile of Southern Resident orcas.
✓	18	Establish a limited-entry whale-watching permit system for commercial whale-watching vessels and commercial kayak groups in the inland waters of Washington state to increase acoustic and physical refuge opportunities for the orcas.
+	19	Create an annual Orca Protection endorsement for all recreational boaters to ensure all boaters are educated on how to limit boating impacts to orcas.
✓	20	Increase enforcement capacity and fully enforce regulations on small vessels to provide protection to Southern Residents.
+	21	Discourage the use of echo sounders and underwater transducers within one kilometer of orcas.
+	22	Implement shipping noise-reduction initiatives and monitoring programs, coordinating with Canadian and U.S. authorities.
✓	23	Reduce noise from the Washington state ferries by accelerating the transition to quieter and more fuel-efficient vessels and implementing other strategies to reduce ferry noise when Southern Residents are present.
+	24	Reduce the threat of oil spills in Puget Sound to the survival of Southern Residents.
+	25	Coordinate with the Navy in 2019 to discuss reduction of noise and disturbance affecting Southern Resident orcas from military exercises and Navy aircraft.
✓	26	Revise chapter 77.15.740 RCW to increase the buffer to 400 yards behind the orcas.
+	27	Determine how permit applications in Washington state that could increase traffic and vessel impacts could be required to explicitly address potential impacts to orcas.
−	28	Suspend viewing of Southern Resident orcas.

Progress highlights:

Rapid implementation of state legislation passed in 2019.

- All vessels must now stay 300 yards away on either side and 400 yards in front of and behind Southern Resident orcas and must slow down to seven knots within half nautical mile of Southern Resident orcas (Chapter 291, Laws of 2019 (2SSB 5577)) (**Recommendations 17, 26, 28**).

- WDFW will establish a licensing system for commercial whale watching operations (Chapter 291, Laws of 2019 (2SSB 5577)) (**Recommendation 18**).
- Washington will establish new standards for tug escorts for oil barges in Rosario Strait to improve protection from oil spills (Chapter 289, Laws of 2019 (SHB 1578)) (**Recommendation 24**).
- The state broadened outreach efforts to educate boaters and promote compliance through Be Whale Wise (Chapter 293, Laws of 2019 (SB 5918)) (**Recommendation 19**).
- $1.36 million was provided to WDFW to implement new legislation and will result in increased officer presence/number of patrols (Chapter 291, Laws of 2019 (2SSB 5577)) (**Recommendation 17**).

New voluntary guidelines limiting boaters' use of echo sounders near orcas.

In both Puget Sound and Canadian waters, maritime groups established safe, voluntary standards to reduce the potential interference of depth finders with Southern Residents' echolocation (**Recommendation 21**).

Electrification of ferries.

$140 million was included in the transportation budget to acquire one new hybrid electric ferry and to convert up to two existing ferries to hybrid electric (**Recommendation 23**).

Outstanding needs:

Increase funding for education and enforcement.

Increase funding and make funding ongoing to WDFW for additional officers and equipment for enforcement of vessel regulations (**urgent action for Recommendation 20, requires legislative funding**).

Provide resources to WDFW and other groups to (1) expand boater education and enforcement to central Puget Sound in the fall, (2) seek vessel mitigation opportunities and (3) extend outreach to promote compliance by vessel operators in newly proposed critical habitat on the outer coast of Washington (**additional component of Recommendation 19, requires legislative funding**).

Create a transboundary forum.

Create and charter a transboundary forum for waterways management and Southern Resident conservation by working with the appropriate federal partners, tribes and agencies to integrate and coordinate state, federal and Canadian actions. Evaluate cumulative impacts of vessel traffic (**additional component of Recommendations 22, 24 and 27**).

Actively promote compliance with Canada's foraging sanctuary zones.

Actively promote compliance by the United States shipping sector and recreational vessels with Canada's interim and potential future foraging sanctuary zones such as Swiftsure Bank and Pender Island (**additional component of Recommendation 22**).

Ensure the State Environmental Policy Act review of marine facilities.

Help ensure that the State Environmental Policy Act review of marine facilities is routinely applied to standard and atypical changes in use and ownership that may lead to increased vessel traffic or changes in vessel traffic dynamics. Provide tools for local and state governments to identify and evaluate potential impacts and recommend potentially appropriate mitigation measures (**additional component of Recommendation 27**).

Reduce noise and disturbance from U.S. Navy military exercises.

The Navy has proposed new and continued training and testing activities off the coast of Washington, Oregon and California, as described in the 2019 Northwest Training and Testing Draft Supplemental Environmental Impact Statement/Overseas Environmental Impact Statement. New activities include testing with explosives and the use of new technologies such as high-energy lasers, kinetic energy weapons and biodegradable polymers. The Navy will be consulting with the NOAA NMFS on its activities to address potential impacts that may affect Southern Resident Killer Whales.

In 2019, the draft supplemental environmental impact statement for these activities revealed several significant concerns. Gov. Inslee, Seattle Mayor Jenny Durkan, WDFW, PSP and many other organizations submitted formal comments to the Navy to express concerns and recommend measures to mitigate potential impacts related to sound, emerging technologies and spatial and temporal overlaps between Navy activities and orca populations. Specific concerns include:

- Navy testing is already altering the soundscape in areas where orcas are present. These new activities are highly likely to increase noise and related disturbances that adversely affect the Southern Residents, with the potential to cause direct mortality, displacement from preferred habitats and interference with critical behaviors including breeding, nursing, foraging and socializing [16, 17].
- The draft supplemental environmental impact statement does not appear to take into account research by NOAA describing the overlap between the Navy's current and planned activities and places where orcas are present (e.g., offshore of Cape Flattery), as indicated by NOAA's offshore hydrophone network [16].
- Underwater explosive detonations are projected to continue. Detonations can cause ruptured or hemorrhaged organs in marine mammals that can be fatal [17].
- New sonar testing is proposed both pier-side and at sea. Surface ship sonar maintenance is proposed to increase by over 90%. Sonar can cause temporary hearing loss, behavioral reactions, masking of sounds and stress in orcas [17].

- The Navy's new activities will incorporate new technologies with unknown effects, such as high-energy lasers, kinetic energy weapons and biodegradable polymers. They will also increase the use of unmanned systems, which raises concerns about underwater noise, sonar use, radio transmissions and use of lasers. Although the Navy proposes to use surface-level lookout systems for whales, these lookouts are inadequate because (1) the visual range of human lookouts is limited and (2) historically one-quarter of Navy tests have occurred at night, further limiting visibility [16].
- The proposed Navy activities do not account for the Southern Residents' seasonal behaviors; by assessing the orcas' seasonal movements — and adjusting planned Naval activities accordingly — the Navy can reduce negative impacts to Southern Resident orcas and other species [16].
- NOAA recently proposed expansion of designated critical habitat for Southern Resident orcas to include coastal areas from Washington to central California. It is unclear to what extent the Navy's proposed training and testing activities in the northern offshore area of Washington would be confined to the area known as the "Quinault Range." Public comments on the proposed rule are open through December 18, 2019.

While the federal regulatory process for the draft supplemental environmental impact statement is underway, the Navy has proactively participated in the vessels working group. The Navy is exploring the opportunity to follow the precedent set by Washington State Ferries to be an early adopter of the Whale Report Alert System from Canada, as mariners and experienced observers in Puget Sound try to extend the tool's effective range southward [16]. WRAS would provide the Navy with an additional source of nearly real-time information on the location of Southern Residents before conducting operations that might affect the whales.

The Governor's Office and state agencies should coordinate with NOAA and the Navy to reduce noise and disturbance affecting Southern Resident orcas from military exercises. In particular, the final decisions on training and testing activities conducted in the Northwest training and testing study area between November 2020 and November 2027 should eliminate impacts from current, new or additional exercises involving mid-frequency sonar, explosives and other activities with the potential to adversely affect Southern Resident orca recovery or incorporate enhanced mitigation measures to reduce impacts (**urgent action on Recommendation 25**).

Goal 3: Reduce the exposure of Southern Resident orcas and their prey to contaminants

Southern Residents are exposed to pollutants primarily through their prey and also through transfers from their mothers. Their prey (salmon) are exposed to pollutants in their freshwater and marine habitats throughout their lives. Many pollutants are poorly metabolized, persist in the environment and bioaccumulate and bio-magnify in the food web. These toxics can reduce salmon survival by making them more susceptible to disease, which in turn means less food available for the orcas. Toxic contaminants can also reduce immunity and cause reproductive disruption in orcas.

In Year One, the task force developed five recommendations for reducing the exposure of Southern Resident orcas and their prey to contaminants, presented below with respective progress indicators as of November 2019. Refer to **Appendix 2** for a detailed dashboard of Year One recommendations and progress made on each.

Table 4. Year One contaminants recommendations - progress as of November 2019.

Progress	Recommendation	
⊕	29	Accelerate the implementation of the ban on polychlorinated biphenyls in state-purchased products and make information available online for other purchasers.
✓	30	Identify, prioritize and take action on chemicals that impact orcas and their prey.
⊕	31	Reduce stormwater threats and accelerate clean-up of toxics that are harmful to orcas.
⊕	32	Improve effectiveness, implementation and enforcement of National Pollutant Discharge Elimination System permits to address direct threats to Southern Resident orcas and their prey.
⊕	33	Increase monitoring of toxic substances in marine waters; create and deploy adaptive management strategies to reduce threats to orcas and their prey.

Progress highlights:

New state authorities created to prioritize chemicals.

Includes new authority for Ecology to prioritize chemicals for species, develop chemical action plans and ban chemicals in products. $4.7 million and $3.7 million were included in the operating and capital budgets, respectively, to prevent toxics from entering the environment (**Recommendation 30**).

Contaminant cleanup.

$4.8 million was provided in the operating budget and $136.6 million in the capital budget to clean up toxics sites and contaminants. This funding represents a 27.3% increase in capital funding from the previous biennium (**Recommendation 31**).

Additional water quality enforcement capacity.

The Legislature provided funding for water quality enforcement staff at Ecology. Newly issued municipal stormwater permits now require smaller jurisdictions to implement local source control (**Recommendation 32**).

Outstanding needs:

Maintain Model Toxics Control Act funding.

Toxics control funding provided though the state's MTCA should be maintained for preventing and cleaning up toxics (**additional component of Recommendation 31**).

Fund source local control program and increase incentives to reduce stormwater threats.

Additional funding should be provided for Ecology staff to support contaminants recommendations and pass-through funding to support local source control inspectors (**urgent action on Recommendations 30, 31 and 32, requires legislative funding**).

Funding should also be provided for incentives to reduce stormwater threats (**urgent action on Recommendation 31, requires legislative funding**).

Increase funding for infrastructure improvements.

Increase funding to specific accounts that support infrastructure improvements, including the Clean Water Pollution State Revolving Fund, Stormwater Financial Assistance Program and Public Works Trust Fund. Increase caps on utility fees to help fund improved treatment of wastewater, stormwater and other contaminant sources (**additional component of Recommendation 31, requires legislative funding**).

Prioritize stormwater cleanup based on salmon population productivity.

It is critical that we find ways to prioritize discretionary stormwater management and cleanup based on evidence of toxic impacts limiting salmon population productivity. Current state-level stormwater funding could be better targeted to priority areas. Programs currently do not seek highest-priority projects (**urgent action on Recommendation 31**).

Prioritize contaminants of emerging concern and update aquatic life water quality standards.

The state should support ongoing prioritization work that addresses contaminants of emerging concern. Ecology should update aquatic life water quality standards focused on pollutants most harmful to Southern Resident orcas and their prey (**urgent action on Recommendations 30 and 32, requires legislative funding**).

Increase monitoring and associated funding.

Weave monitoring into each recommendation and dedicate funding to Ecology, PSP and WDFW to provide data on effectiveness (**additional component of Recommendation 33**).

Lessons learned:

Stormwater management on state highways.

Roadways accumulate toxics; when not adequately managed, the runoff that contains those toxics can be lethal to salmonids. As methods are available to reduce the impact of road runoff, the contaminants working group recognized the importance of accelerating work on public highways to address them as a source of toxic contaminants. Finding ways to do more, faster is an important long-term need for recovering Southern Resident orcas and their prey.

The WSDOT should work with Ecology to explore opportunities to increase the pace of stormwater retrofits and ways to provide increased stormwater treatment on state highways. As state highways only constitute a small portion of the statewide road system, any state-level effort should serve as a model for addressing roads maintained by local jurisdictions (**Recommendation 31**).

Holding producers of toxics accountable.

Shifting the cost burden to producers of toxic contaminants is critical to supporting their long-term reduction. It is important to find ways to ensure that the costs of remediating contaminants are borne by those responsible for introducing them in the first place. The task force supports the Attorney General’s Office efforts to pursue the polychlorinated biphenyl (more commonly referred to as “PCB”) case against Monsanto (**Recommendation 31**).

Long-term infrastructure planning.

Planning our infrastructure systems over a timeline that sets us up for long-term success is crucial. If the state economy continues to grow and attract new jobs as planned, the Puget Sound region's population will roughly double by 2070. Higher or lower rates of economic growth would drive faster or slower human population growth. We should incorporate the long-term challenges of human population growth and climate change in a way that clearly recognizes the scale of each of these challenges during planning.

The state should provide local governments with funding as necessary to conduct facilities planning through 2070 that looks at population growth through a wastewater, stormwater and centralized and onsite sewage lens to ensure increased contaminant loads do not impact salmon and orcas (**Recommendation 32**).

Goal 4: Ensure funding, information and accountability mechanisms are in place to support effective implementation

In Year One, the task force recognized that its recommendations would not be successful without adequate funding, information and accountability mechanisms in place. They developed three recommendations to support effective implementation, presented below with their respective progress indicator as of November 2019. Refer to **Appendix 2** for a detailed dashboard of Year One recommendations and progress made on each.

Table 5. Year One funding, information and accountability recommendations - progress as of November 2019.

Progress	Recommendation	
⊕	34	Provide sustainable funding for implementation of all recommendations.
⊕	35	Conduct research, science and monitoring to inform decision making, adaptive management and implementation of actions to recover Southern Residents.
✔	36	Monitor progress of implementation and identify needed enhancements.

Progress highlights:

The enacted 2019–21 biennial budgets (operating, capital and transportation) provided $1.1 billion to support the recovery of Southern Residents and implement the recommendations of the Governor's Southern Resident Orca Task Force (summarized above under Goals 1, 2 and 3).

Outstanding needs:

Although significant additional investments occurred in the 2019–21 biennium, considerable outstanding costs for implementing projects and programs for salmon and orca recovery remain. These investments are necessary to ensure that funding, information and accountability mechanisms are in place to support effective implementation of the task force's Year One and Year Two recommendations.

Transition one-time investments in orcas and salmon in 2019 into ongoing investments.

Much of the increase in funding that WDFW received as part of the Southern Resident orca package was one-time funding. To most benefit orcas, this funding should be sustainable (**additional component of Recommendation 34, requires legislative funding**).

Provide funding to evaluate the effectiveness of task force recommendations.

Provide funding to PSP, WDFW, the Governor's Salmon Recovery Office and Ecology to evaluate the effectiveness of task force recommendations through monitoring and adaptive management while leveraging existing efforts (**urgent action on Recommendation 35, requires legislative funding**).[3]

[3] Note that all research projects are carefully reviewed and authorized under the Endangered Species Act and Marine Mammal Protection Act in the United States. The review includes assessments under the National Environmental Policy Act, consultation under Section 7 of the ESA. Any invasive techniques are also reviewed by an Institutional Animal Care and Use Committee. Cumulative impacts of all research projects and benefits to conservation are considered and the permits are issued with conditions to minimize impacts, facilitate coordination among researchers, and also to limit the number of research boats in close proximity to the whales at any time. NOAA Fisheries and Department of Fisheries and Oceans Canada have been working together to host transboundary research coordination calls and meetings so that the research community is well informed about plans for all field activities, can collaborate, and communicate well during their field seasons.

Chapter 3. Emerging issues addressed in Year Two

Introduction

Since the task force finalized its Year One recommendations in November 2018, additional **contaminants** considerations emerged (including the impacts of human sources of nutrients) and were evaluated by the working groups, steering committee and task force, as outlined below. These deliberations resulted in **five new task force recommendations**.

The task force also discussed long-term needs, including an oversight committee or similar body to **continue the mission of orca recovery after the task force sunsets in 2019**. The task force developed **one new recommendation** for the formation of this oversight body which will monitor progress, advocate for the implementation of the task force's recommendations and adapt to changing conditions by issuing new recommendations as needed. This recommendation includes three options for the Governor's Office to consider.

Additional long-term considerations evaluated by the task force in 2019 included the impacts of climate change and a growing human population on Southern Resident health and recovery. Left unchecked, both of these overarching threats are expected to exacerbate current stresses on the Southern Residents and undermine recovery efforts. Leveraging knowledge gained through presentations from experts, subgroup meetings and reviewing available research, the task force developed **five new recommendations to address the impacts of climate change** and **two new recommendations to respond to the impacts of a growing human population**.

Refer to **Appendix 1** for actions and implementation details related to the 13 new recommendations developed and approved by the task force in 2019.

Contaminants

Regulatory rollbacks at federal and state level

The regulations that protect Southern Residents from contaminant threats are a mixture of state and federal laws and implementation. Historically, the relationship between state and federal regulators has been characterized by cooperative federalism and delegated authority. This historical precedent is being challenged through federal regulatory rollbacks to the Clean Water Act (including water quality standards and the definition of Waters of the U.S.), Endangered Species Act and other foundational laws. Given the current federal regulatory environment, the governor and state agencies should ensure that state authority, rules and regulatory protections are sufficient to prevent moving backwards. The state should maintain and strengthen state authority, rules and regulatory protections.

NEW Recommendation 37: Protect against regulatory rollbacks at the federal and state level.

- Refer to **Appendix 1** for related actions and implementation details.

Minimum standards for local stormwater funding

A primary barrier to effective stormwater management is local government capacity to implement stormwater management programs. With too little staff capacity or limited capital funding, it is unlikely that jurisdictions will be capable of innovating, or even implementing requirements expected to be more stringent in the future. In many cases, local governments with the best, most intact natural resources often have the least capacity protect them.

Local government spending on stormwater programs varies from jurisdiction to jurisdiction, leaving some programs without adequate funding. Additionally, it can be problematic when stormwater funding is forced to compete with other “general fund” priorities. We should seek to better understand the varying funding streams, relative funding rates, and what can reasonably constitute adequate funding for different jurisdictions.

It would be beneficial for existing county and city organizations or workgroups to convene a meeting of jurisdictions in the Puget Sound region to identify what funding levels would be adequate to meet the need to control stormwater, explore funding alternatives and discuss how to establish a “floor” for minimum investments. The Washington State Department of Commerce and Washington State Department of Ecology should participate in those discussions. With a better understanding, the state should explore legislation to set minimum standards for local stormwater funding, ensuring that all programs have the resources necessary to protect water quality.

NEW Recommendation 38: Explore setting minimum standards for local stormwater funding to ensure that all programs have the resources necessary to protect water quality.

- Requires legislative funding.
- Refer to **Appendix 1** for related actions and implementation details.

Human sources of nutrients

In addition to the emerging contaminants-related considerations described above, Ecology's 2019 Salish Sea Modeling Report[4] evaluated the impact of human sources of nutrients on Puget Sound water quality. The report found that the excess of nutrients from human sources is causing or contributing to low dissolved oxygen in many sensitive inlets and bays within Puget Sound, resulting in oxygen levels that fall below the concentrations needed for marine life to thrive.

Significant human sources of nutrients in diffuse or direct discharges can include municipal wastewater, agriculture, forestry and other land use activities. In addition to lowering dissolved oxygen, excess nutrients can impair the foundations of the marine food web by degrading the habitat and water quality conditions conducive to healthy and robust populations of marine species.

Recommendations 39, 40 and 41 below were developed by Ecology and informed through discussions with regional stakeholders and tribes at the Puget Sound Nutrient Reduction Forum to address these threats. Refer to **Appendix 4** for further information on the impacts of human sources of nutrients on marine water quality.

National Pollutant Discharge Elimination System permit framework

Discharges from wastewater treatment plants represent more than 50% of the human sources of nutrients into Puget Sound and contribute significantly to low dissolved oxygen levels. Ecology proposes developing a Puget Sound Nutrients General Permit to control nutrient discharges from domestic wastewater treatment plants (sewage treatment plants) through its National Pollutant Discharge Elimination System[5] regulatory authority. The alternative to a general permit is to include nutrient control requirements in each wastewater treatment plant's individual permits, one by one, as they are reissued over the next five to 10 years.

---

[4] The Salish Sea Model is a three-dimensional scientific and engineering simulation of hydrodynamic and water quality processes in Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia, as well as inputs from 64 rivers and streams and 99 facilities/point sources (mostly municipal wastewater treatment plants) in the U.S. and Canada. The model includes simulated water quality features including a total of 19 state variables, two species of algae, dissolved and particulate carbon, and nutrients [68].

[5] Created in 1972 by the Clean Water Act, the NPDES permit program regulates point sources that discharge pollutants to U.S. waters. The permit provides two levels of control: technology-based limits and water quality-based limits [77].

NEW Recommendation 39: Develop a National Pollutant Discharge Elimination System permit framework for advanced wastewater treatment in Puget Sound to reduce nutrients in wastewater discharges to Puget Sound by 2022.

- Requires legislative funding.
- Refer to **Appendix 1** for related actions and implementation details.

Aligning nonpoint source programs with nutrient reduction activities

Ecology should establish minimum requirements for nonpoint source best management practices to ensure they meet water quality standards. Existing nonpoint source programs can be expanded to address known problems related to nutrient runoff from agricultural, suburban/urban and rural land use activities. Many of these nonpoint source implementation actions have multiple benefits for water quality improvement, including nutrient reduction.

NEW Recommendation 40: Better align existing nonpoint programs with nutrient reduction activities and explore new ways to achieve the necessary nonpoint source nutrient reductions.

- Refer to **Appendix 1** for related actions and implementation details.

Collecting high-quality nutrient data in watersheds

Making science-based nutrient management decisions depends on having the right tools and high-quality data. The Salish Sea Model is our best tool for understanding the marine waters of Puget Sound and evaluating the best suite of nutrient load reductions necessary to achieve water quality standards. Ecology should augment key watershed monitoring stations with continuous nutrient monitoring technology to improve our understanding of watershed nutrient loads and establish baseline conditions to measure future change.

NEW Recommendation 41: Collect high-quality nutrient data in watersheds to fill key knowledge gaps of baseline conditions.

- Requires legislative funding.
- Refer to **Appendix 1** for related actions and implementation details.

Climate change and ocean acidification

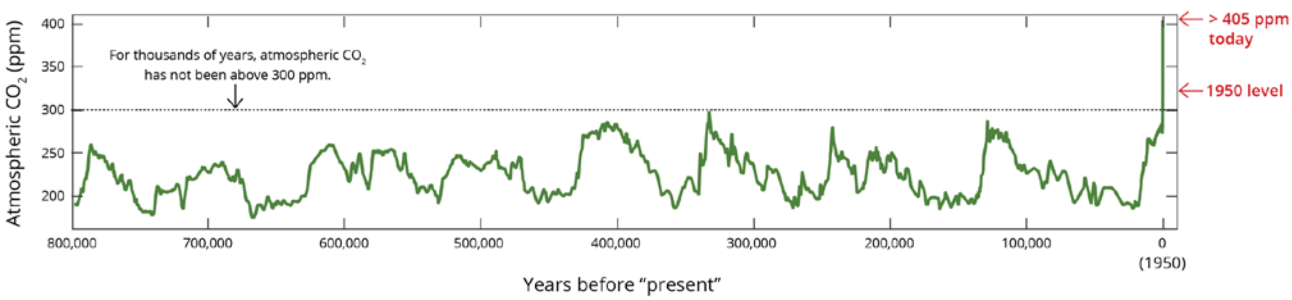
Southern Resident orcas are highly endangered, making them especially sensitive to changes in their environment. Climate change, ocean warming and increasing ocean acidification compound the stressors already limiting their survival and the productivity of their food web, undermining ongoing recovery efforts.

In response, the task force urges immediate and aggressive action in Washington state and beyond to reduce human-caused greenhouse gas emissions, consistent with the best available science, and to increase the resilience of our ecosystem to climate-induced changes. Findings and recommendations related to addressing the impacts of climate change and ocean acidification on Southern Residents are presented below, along with cross-cutting recommendations that address root causes and increase resiliency.

Human-caused emissions

As shown in **Figure 2**, the level of carbon dioxide in the atmosphere remained below 300 parts per million for thousands of years prior to 1950 [18]. Human activities related to transportation, electricity, industry and consumption have increased accumulation of CO_2 in the atmosphere to 405 ppm, causing global temperatures to rise by about 1°C above pre-industrial levels [18]. About 25% of these CO_2 emissions are absorbed by the ocean, resulting in ocean acidification, or the decrease of oceanic pH [18].

Figure 2. Atmospheric carbon dioxide parts per million over the past 800,000 years [18].



Human activity also releases other potent greenhouse gases, which are rapidly accumulating in the atmosphere and are major drivers of climate change. For example, methane gas is emitted as a byproduct of coal and natural gas production, distribution and use, as well as from the agriculture and waste management sectors. Methane is 34 times more potent than CO_2 over a 100-year period and 86 times more potent over a 20-year period, magnifying its short-term impact on climate change relative to CO_2 emissions [19].

Although the effects of climate change are already observable due to the current 1.0°C increase in global temperatures, human activities continue to add approximately 0.2°C to global average temperatures each decade [18]. Scientists project catastrophic and irreversible changes to life on Earth when global warming surpasses 1.5°C, with even greater consequences after 2.0°C. For example, 1.5°C of warming is projected to cause marine fisheries to decline by 4.5 million metric tons, while 2.0°C of warming is projected to cause a 6.0 million metric ton decline (1.3 times worse) [18].

If current trends continue, the University of Washington Climate Impacts group projects that 1.5°C of warming could be reached as soon as 2030 and will result in the following conditions in Washington [18]:

- 67% more days above 90°F
- 38% decrease in snowpack
- 16% increase in winter streamflow
- 23% decrease in summer streamflow

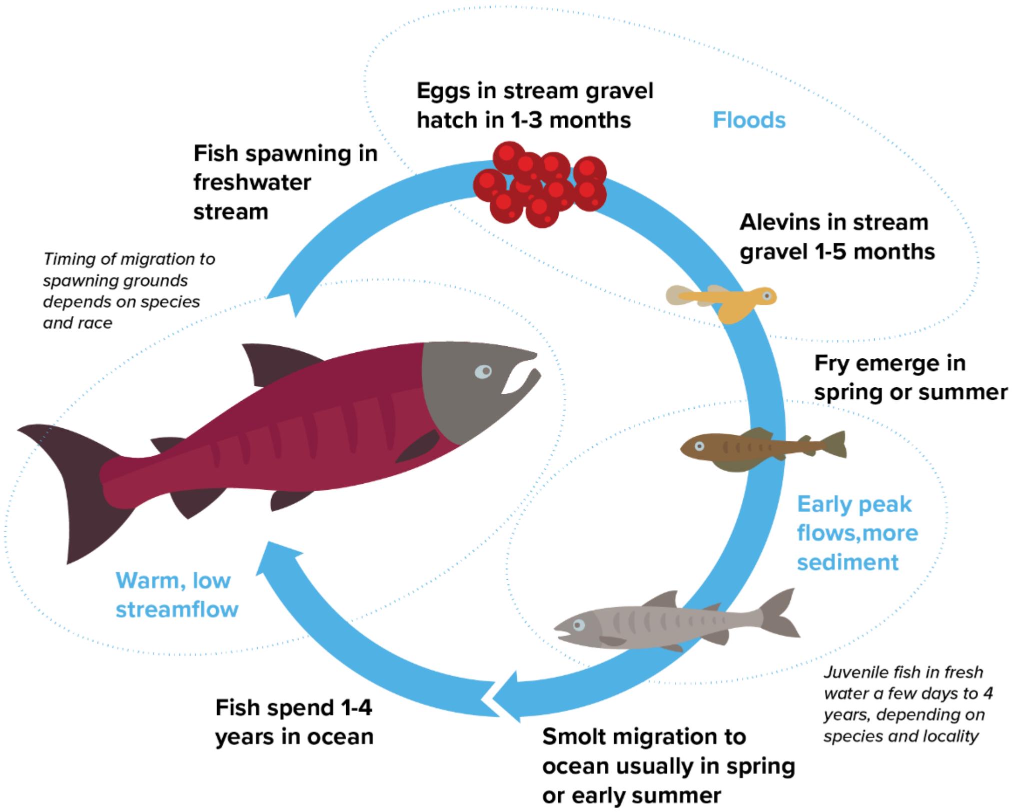
Without significant reductions in emissions of CO_2 and other greenhouse gases, global average warming will likely reach 1.5°C between 2030 and 2052 [18]. These changes will lead to further deterioration in conditions for the Southern Residents and their prey, underscoring the urgency of action to limit emissions and stabilize global temperatures.

To limit warming to 1.5°C, globally we must reduce global CO_2 emissions by 45% from 2010 levels by 2030 and reach net zero emissions by about 2050 [18]. To limit warming to 2.0°C, globally we must reduce global CO_2 emissions by 25% from 2010 levels by 2030 and reach net zero emissions by about 2070 [18].

Climate change effects on Southern Residents

Climate change is already exacerbating existing stresses on Southern Residents and the ecosystems upon which they depend, including salmon and forage fish. As temperatures continue to rise, Southern Residents will be affected primarily through their food web. Higher temperatures will impact salmon habitats and populations at each life stage (**Figure 3**).

Figure 3. Effects of climate change on salmon throughout their lifecycle (modified from The Wilderness Society, 1993).



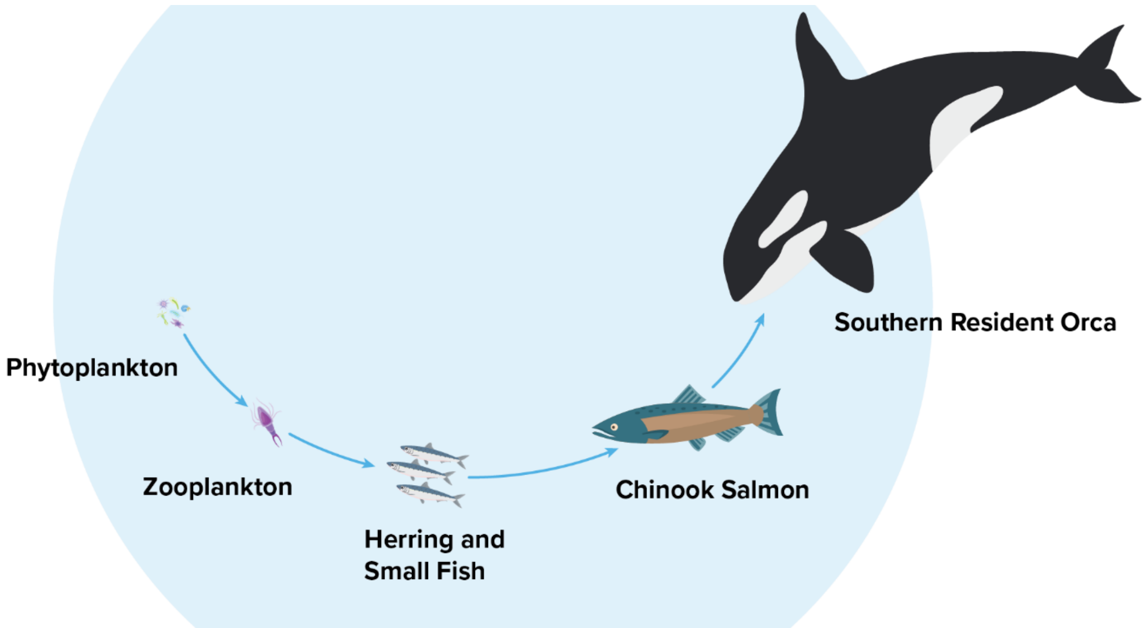
The Cascade Mountains have seen a 25% decrease in snowpack levels since 1950 due to increasing global temperatures, which cause this snow to melt earlier [20]. At the same time, heavier winter rainstorms caused by a warming climate lead to flooding and other high-flow events. These conditions cause more water to enter streams during the winter (nearly a 20% increase since 1950) [20], which can scour riverbeds and destroy or smother salmon redds (nests), increasing egg and fry mortality. Flooding can also increase the amount of sediment entering streams, burying spawning gravels.

Lower snowpack and changing precipitation patterns caused by the warming climate are also damaging salmon populations by lowering summer streamflows. Although winter streamflows continue to increase, summer streamflows have decreased up to 15% since 1950 [20]. Lower streamflows in the summer increase water temperature, which decreases suitable salmon habitat, shifts salmon activities upstream and impedes migration. Increasing water temperatures act as a pollutant, placing further metabolic demands on salmon; warmer water depletes their energy reserves, reduces growth, increases disease susceptibility, impedes migration and increases vulnerability to predators. The end result is fewer salmon in our streams, rivers and oceans — and, consequently, less food for the Southern Residents.

Most Puget Sound glaciers are in decline, with measured volume decreases ranging from 56% loss in the North Cascades from 1900–2009 to 34% in the Olympic Range from 1980–2009 [21]. Glacial melt caused by warming temperatures affects the streams, aquifers and river systems on which juvenile salmon and their prey depend, thereby impacting Southern Residents at the top of the food chain. These declines will continue, increasing summer meltwater from some glaciers in the near term but dramatically reducing meltwater in the second half of the 21st century. Other impacts that affect salmon, forage fish and the viability of the food web include increased localized flooding, erosion and sedimentation [21].

In the marine environment, warming ocean temperatures can affect the base of the orca food web, changing the phytoplankton and zooplankton composition to lower-calorie species (**Figure 4**) [22, 23]. Warming ocean temperatures also decrease oxygen levels and promote the abundance of harmful algal blooms (toxic to fish) and plankton grazers such as jellyfish, which are a caloric dead-end in the food web due to their few predators [24, 25]. These issues can ripple out into the food web and affect the growth and survival of juvenile salmon and forage fish. Forage fish support both salmon and higher-order predators such as piscivorous fish, marine mammals and seabirds. When forage fish abundance is limited, these predators can increase predation on juvenile salmon.

Figure 4. Southern Resident orca food web diagram.



Warmer ocean temperatures can also bring more predators into the region, favoring warm-adapted nonnative fishes that could outcompete or prey on salmon [26]. They also reduce kelp abundance, resulting in a loss of critical fish habitat [27, 28]. Higher ocean temperatures also promote new pathogen and disease vectors that could be harmful for orcas, while accelerating the rate at which excess human nutrients change the base of the marine food web.

Further, as sea levels rise, long-buried, legacy shoreline waste sites are likely to become inundated, resulting in a new source of toxics entering the marine environment and inland waters. Combined sewer overflows and overflows from sewage treatment facilities occur more frequently with flooding and high-flow events, increasing the quantity of toxic substances that enter water bodies. The region is already experiencing an increase in combined sewer overflow events that cause untreated sewage to enter marine and inland waters. As orcas starve from insufficient prey, they metabolize more of the toxics stored in their bodies, increasing their potential to experience neurological problems and disease.

Similarly, sea level rise caused by climate change will permanently inundate and destroy coastal habitat, which is important for juvenile salmon and their prey. It will also reduce habitat and spawning grounds available to forage fish, which spawn in the intertidal and shallow subtidal zones. For example, surf smelt and sand lance depend on high, extensive beaches for spawning. With sea level rise, beaches will naturally tend to migrate inland. Bulkheads and other structures may impede this movement and complicate both natural and human efforts at resiliency and adaptation [29].

Collectively, these impacts compound existing stressors on Chinook, further reducing their abundance and leaving Southern Residents hungry. Many of these changes have already been observed in the Pacific Northwest. For example, during the drought of 2015, average air temperatures were approximately 2.7°C warmer than pre-industrial averages and Washington state snowpack was 70% below normal [18]. These conditions led to low summer streamflow and warm waters, resulting in lethal strandings, fishery closures and die-offs of salmon and steelhead across the Pacific Northwest, including over 250,000 Columbia River sockeye salmon [18].

In 2015–16, the region also experienced a marine heat wave, with ocean temperatures up to 7°C warmer than average, and the emergence of “the blob” — a large mass of water off the coast with temperatures 5.4 °F above normal. These conditions triggered the largest and most persistent harmful algal bloom ever recorded on the West Coast and contributed to weak salmon returns. In the summer of 2015, the Hoh Rain Forest received 0.17 inches of rain in June — the lowest rainfall on record. Water temperatures spiked inland. The state experienced some of its most intense wildland fires on record. Human bucket brigades helped deepen channels in the Dungeness River with volunteers hand-carrying fish over obstacles to try to mitigate the impact of these events.

These conditions reduced survival among young salmon, caused humpback whales to become entangled in fishing gear as they hunted closer to shore, stranded thousands of young sea lions on beaches as their mothers foraged far out to sea, and caused an algae bloom that shut down crabbing and clamming activities. The Washington Department of Fish and Wildlife lost about 1.5 million juvenile fish in overheated rivers and streams. State and federal agencies declared several fisheries to be disasters and many fisheries closed. While the origins of these warmer waters are not fully understood, their presence is unprecedented and portends risks in the years ahead from a warming planet.

Ocean acidification effects on Southern Residents

While the changes described above are due primarily to elevated CO_2 accumulation in the atmosphere, ocean acidification results from atmospheric CO_2 being absorbed by the ocean. CO_2 reacts with marine waters to form carbonic acid, which increases hydron ion (H+) concentrations and results in lower oceanic pH.

Although climate change and ocean acidification are related (and both stem from CO_2 emissions), the term "climate change" refers to the changes in the Earth's heat budget, which cause global warming and changes in weather patterns. The term "ocean acidification" specifically refers to the lowering of ocean pH resulting from absorption of CO_2 from the atmosphere and does not include the warming of the ocean [30].

Ocean acidification is progressing 10 to 100 times faster than it did in the previous 50 million years, outpacing inhabitants' ability to adapt and evolve to the changes [31]. Pacific Northwest waters are particularly vulnerable to ocean acidification due to several contributing factors:

- Atmospheric CO_2 in the Puget Sound area is increasing faster than the global average [32].
- Puget Sound is colder and has more freshwater (salt-free) than the global average, allowing CO_2 to dissolve more effectively [31].
- Natural upwelling mixes deep waters with the already-acidified surface water layer [33]. These deep waters carry increasing amounts of legacy human-generated CO_2 from 30 to 50 years ago when the water was last in contact with the atmosphere [33]. As a result, conditions will continue to acidify from upwelled waters for several decades due to the existing carbon load [33].
- Ocean waters receive freshwater discharge from surrounding rivers and streams. Freshwater is typically more acidic than the ocean and carries dissolved nutrients like nitrogen, phosphorous and organic carbon. These nutrients enter the marine environment and contribute significantly to ocean acidification in certain areas of Puget Sound by adding CO_2 to the water as a product of microbial decomposition [33].
- Scientific studies suggest that nutrients can also stimulate harmful algal blooms, which may produce more toxins under acidified conditions [33]. Human sources of nutrients, such as sewage treatment plants, septic systems and runoff from both urban and rural land practices (e.g., lawn fertilizers and livestock) are significant contributors to acidification in many parts of Puget Sound.

Ocean acidification is already affecting shellfish in Puget Sound — particularly juvenile forms such as oyster larvae — and threatens to undermine the livelihoods of rural communities that grow oysters and harvest crabs commercially [29]. The phenomenon primarily impacts Southern Residents and salmon through their highly interconnected food web (**Figure 4**), the same system on which all apex predators depend for survival. Zooplankton species such as pteropods and copepods that support the base of the orca food web grow more slowly in acidified waters [33].

Recent studies on juvenile coho salmon exposed to low-pH water showed disruption of olfactory-driven behaviors and related neural signaling pathways. Although the salmon's ability to smell remained intact, their response to alarm odors was indifference, rather than typical fear and avoidance. Olfaction plays a central role in salmon survival, navigation and reproduction. These neural signaling pathways are highly conserved across many species, indicating that other salmon species could be at risk as well [34]. Although few studies exist on the direct effects of ocean acidification on Pacific salmon species, studies of projected future ocean acidification scenarios on tropical reef fish showed reduced growth, behavioral changes and decreased survival [35, 36].

Ocean acidification also increases the bioavailability of metals including iron and copper in orcas, which has the potential to adversely affect the food web and orcas over time. Further, ocean acidification extends the spatial spread of underwater noise (for frequencies up to 10kHz), making it more difficult for orcas to communicate [28, 37]. Ocean acidification will continue to "amplify" underwater noise by reducing the natural absorption of sound at lower frequencies, allowing sounds to propagate further and making it harder for orcas to locate their prey [28, 37].

New goal and recommendations

Existing stressors on endangered Southern Residents and Chinook have already increased their likelihood of extinction. Without intervention, the compounding effects of changing ocean conditions due to climate change will continue to exacerbate these stressors, pushing Chinook salmon and orcas even closer to the tipping point. In response, the task force developed the following new goal and set of recommendations, summarized here and outlined with supplemental action items and implementation details in **Appendix 1**:

Goal 5: Reduce the threat from climate change, including ocean acidification, to Southern Residents, the region's biodiversity and, ultimately, the well-being of Washington's people and economy.

The task force urges aggressive and sustained action in Washington state to (1) do its part to reduce human-caused emissions, consistent with the best available science and the goal of limiting planetary warming to 1.5-2.0 °C, (2) minimize the causes and consequences of ocean acidification and (3) act aggressively to increase the resiliency of the habitat and ecosystems that orcas and salmon depend upon for their survival.

As an overarching guiding principle and approach to doing business, state agencies responsible for implementing task force recommendations should adopt a "climate lens" to ensure that actions and investments are made based on the best available science, and include a focus on monitoring ecosystem changes and impacts, increasing resiliency and adapting to impending changes. Most recent climate projections and modeling should be incorporated into assessments and decision-making.

Five recommendations to achieve these outcomes and support Goal 5 are presented below; they encompass short-, near- and longer-term actions identified to benefit orcas now and over time. Progress must be made on each one to enable the survival of the Southern Residents.

Reducing human-caused greenhouse gas emissions.

Most of the greenhouse gas emissions in Washington state are from transportation, electricity generation and residential, industrial, commercial and agricultural activities. The task force urges all members of the Washington community to examine their own contributions to climate change and both directly take, and advocate for, forceful action and policies to reduce emissions.

NEW Recommendation 43: Take aggressive, comprehensive, and sustained action to reduce human-caused greenhouse gas emissions, with the goal of achieving net zero emissions by 2050.

- Requires legislative funding and policy.
- Refer to **Appendix 1** for related actions and implementation details.

Reduce, remediate, and adapt to ocean acidification.

The task force supports continued implementation of actions in the state's Ocean Acidification Action Plan and the Marine Resources Advisory Council's recommended priorities. Washington should continue leading, collaborating, advocating for and advancing policies at the regional, national and international levels in partnership with leading state-based businesses and organizations, elected officials and others.

NEW Recommendation 44: Increase Washington's ability to understand, reduce, remediate, and adapt to the consequences of ocean acidification.

- Requires legislative funding.
- Refer to **Appendix 1** for related actions and implementation details.

Accelerate action to increase resiliency of salmon populations.

Fully implement and fund salmon recovery plans. Increase access to cold water habitats and refugia. Selectively remove, design and retrofit infrastructure to ensure climate resiliency and account for future changes in flows and water temperatures. Significantly increase the scale and scope of habitat protection and restoration investments that focus on habitat complexity to increase the diversity and resiliency of wild and hatchery salmon stocks.

NEW Recommendation 45: Mitigate the impact of a changing climate by accelerating and increasing action to increase the resiliency and vitality of salmon populations and the ecosystems on which they depend.

- Requires legislative funding.
- Refer to **Appendix 1** for related actions and implementation details.

Pursue maritime innovations that benefit Southern Residents.

Although reducing emissions is a top priority, underwater noise is another serious concern. While some emerging vessel propeller technologies may reduce emissions, they can also increase underwater sounds at frequencies that interfere with orca communication and echolocation. Addressing this trade-off will require research, innovation and investment to develop and deploy technologies that reduce both noise and carbon emissions.

To catalyze this research and innovation, the task force recommends supporting Washington Maritime Blue, a strategic alliance for maritime innovation and sustainability. Maritime Blue is an independent, nonprofit partnership between industry, the public sector, research and training institutions and community organizations tasked with implementing Washington State's Strategy for the Blue Economy. Maritime Blue should modify its governance structure (for example, by creating a dedicated board member seat or subgroup) to address Southern Resident orca issues and coordinate closely with the successor to this task force.

NEW Recommendation 46: Expand the Governor's Maritime Blue scope of work and provide funding to implement recommendations from the Southern Resident Orca Task Force and pursue shipping and other maritime innovations that benefit Southern Residents.

- Requires legislative funding.
- Refer to **Appendix 1** for related actions and implementation details.

Mitigate increased threats from contaminants due to climate change and ocean acidification.

With runoff anticipated to increase as climate change drives increased precipitation, flooding and sea level rise, additional work is needed to address increasing levels of contaminants in the state's waters. Nutrient loadings will increase with these events, and exposure to other toxics could increase as well. Increased bioavailability of toxics will accumulate up the food chain, ultimately threatening Chinook. In addition, the increased quantity and intensity of flows due to climate change are highly problematic, impacting the hydrology of basins and water systems and destroying forage fish and Chinook habitat.

The task force recommends adapting stormwater retrofits to account for the impacts of climate change, accelerating clean-up of toxics and waste sites, modifying or moving treatment facilities to withstand sea-level rise and increased flooding and increasing protection for low-lying infrastructure facilities (without hardening adjacent shorelines).

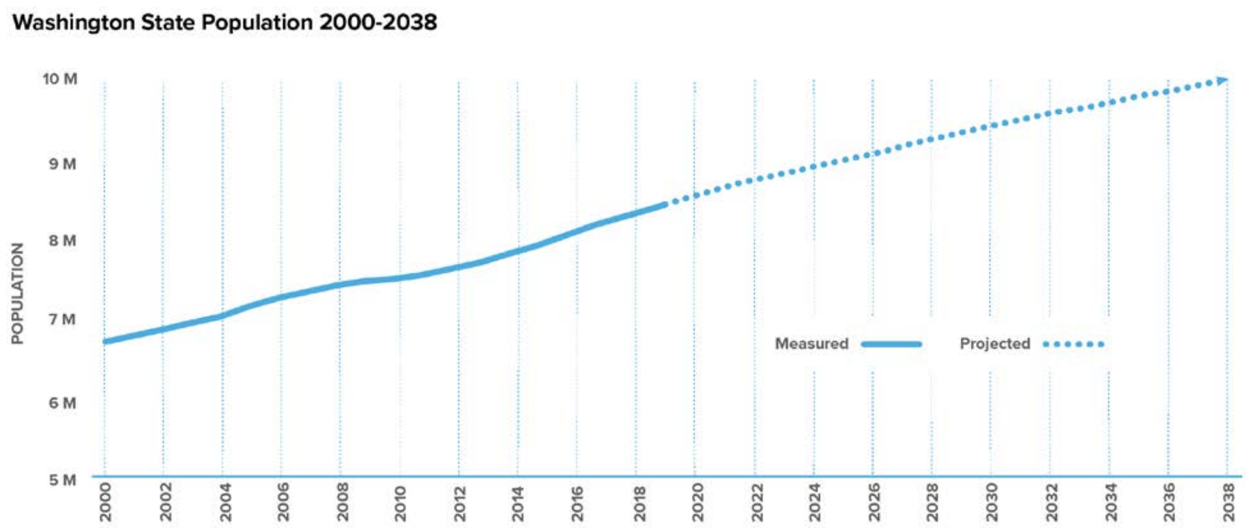
NEW Recommendation 47: Identify and mitigate increased threats to Southern Residents from contaminants due to climate change and ocean acidification. Prioritize actions that proactively reduce exposure where the increased impacts are expected to be most severe.

- ➲ Refer to **Appendix 1** for related actions and implementation details.

Human population growth and development

As shown in **Figure 5**, Washington's population has grown over 30% in the past 20 years — increasing by an average of 87,900 people each year — primarily due to net migration into the state (people moving in versus moving out) [38]. While this growth is indicative of strong economic opportunities in the state, uncoordinated and unplanned growth can pose a threat to the environment.

Figure 5. Washington population growth from 2000, projected to 2038 [39].



The Growth Management Act, adopted by the Legislature in 1990, recognizes this tradeoff and provides a series of statutes requiring cities and counties to develop comprehensive plans for managing their population growth [40]. These plans are designed in part to prevent net loss of ecological functions by reducing sprawl and protecting natural resources. Similarly, the Shoreline Management Act requires counties and cities with shorelines to develop and implement shoreline master programs to prevent uncoordinated development of shorelines and includes the "no net loss" of ecological function standard.

Despite the components of the GMA and SMA intended to protect natural resources and sensitive ecosystems, important wildlife habitat lands are being converted for development faster than they are being restored. At the current rate of human population growth and development, a "business as usual" approach to zoning, transportation, wastewater regulations and infrastructure will result in continued loss of critical habitat, further imperiling salmon and orcas. Without substantial changes, we will not recover salmon or orcas.

New goal and recommendations

To prevent further degradation of critical habitat and restore what has already been lost, the task force urges transformational change to Washington's growth management regulations and practices. The GMA and SMA should be more responsive to the needs of the ecosystem, treating habitat as critical public infrastructure and emphasizing protection over mitigation. In response, the task force developed the following new goal and set of recommendations, summarized here and outlined with supplemental action items and implementation details in **Appendix 1**:

> **Goal 6: Reduce the threats from population growth and development on the important habitats, sensitive ecosystems and food webs that Southern Residents orcas rely on.**

Habitat

The task force urges shifting away from the "no net loss" standard — which has not successfully prevented the loss of critical habitat and sensitive ecosystems — toward a "net ecological gain" standard. Net ecological gain in this context refers to taking actions through development and land management that result in improvement to the quality and quantity of the functions of the natural environment. Key elements include:

- Following the mitigation sequence of first avoiding impacts, then minimizing impacts and finally — offsetting impacts that cannot be avoided. Recognizing that mitigation efforts aimed at no net loss have not achieved and are not likely to achieve 100% success at offsetting impacts, additional mitigation should be required.
- Establishing and defining the environmental baseline from which we are measuring improvement.
- Considering future population projections or sea level rise predictions that could compromise ecological gains.
- Considering local site-specific and a larger watershed scale.

This lens should be adopted to (1) prevent environmental harm associated with growth and (2) use ongoing development and retrofitting opportunities to improve ecological conditions. Adequate funding and support are essential to both state natural resource agencies and local governments to engage with communities, update policies and regulations and effectively implement and enforce statutes that protect habitat.

NEW Recommendation 48: Adopt and implement policies, incentives and regulations for future growth and development to prevent any further degradation of critical habitat and sensitive ecosystems; enable and channel population growth in ways that result in net ecological gain; evaluate and report outcomes for all jurisdictions at the state, county, tribal and municipal levels.

- Requires legislative funding and policy.
- Refer to **Appendix 1** for related actions and implementation details.

Fast ferries and water taxis

According to Puget Sound Harbor Safety Committee bi-monthly report summaries, the volume of fast ferry and water taxi traffic has risen dramatically in recent years, and the levels rank near the top of all vessel classes in Puget Sound (but far exceeded by Washington State Ferries and tugs and barges). Based on Puget Sound Partnership's assessment of automatic identification system information, such vessels travel over 300,000 miles (in more than 10,000 hours) annually in Puget Sound.

Since issuing its recommendations in 2018, the vessels working group and task force became aware of the development of several new fast ferry and water taxi operations in Puget Sound. Kitsap Transit and King County currently operate fast ferries, with other communities planning similar operations to the south and north. These ferries make multiple roundtrips in the morning and afternoon, traveling at relatively high speeds in an area frequented by Southern Residents (especially in the fall).

The vessels working group expressed concerns about the elevated risk of collisions with Southern Residents as some of these vessels can travel faster than the top speed of orcas. The emergence of similar fast ferry networks elsewhere in the world (e.g., the Canary Islands and Korea) has led to more ship strikes with whales and dolphins. The International Whaling Commission has recommended several precautionary measures to mitigate related risks [41].

The task force urgently recommends working with the fast ferry and water taxi sector on potential bridge lookout policies and technological mitigations due to (1) the small size of the Southern Resident population, (2) evidence of collisions leading to the injury or death of Southern Residents and (3) the comparatively high vulnerability of calves and other young whales to this potential threat.

NEW Recommendation 49: Conduct a comprehensive environmental review and take action to minimize potential whale-strike risk and underwater noise posed by the growing number and distribution of fast ferries and water taxis in Southern Resident critical habitat.

- Refer to **Appendix 1** for related actions and implementation details.

Chapter 4. Continuing the mission of Southern Resident orca recovery

The Southern Resident Orca Task Force sunsets on November 8, 2019. After this point, it is critically important that an oversight committee or similar body continues to monitor progress, advocate for the ongoing implementation of the recommendations and adapt to changing conditions by issuing new recommendations as needed. The task force agreed that executive-level attention in the Governor's Office coupled with professional support from state agencies is needed to fulfill the mission of orca recovery. State agency leaders contributed significant staff resources and technical expertise over the past two years to support the task force; however, without additional oversight, these orca-focused efforts could easily be displaced by other business that the agencies conduct. As such, the task force recommends the following path forward:

NEW Recommendation 42: Create one or more entities with authority and funding to recover and advocate for Southern Resident orcas by implementing task force recommendations, creating new recommendations as needed and reporting to the public, governor and tribal co-managers on status.

- ➲ Requires legislative funding.

The task force recommends that any oversight group incorporates the following elements:

- Is co-managed by the Governor's Office and tribes.
- Coordinates with federal agencies in both the United States and Canada to stay connected to ongoing policies around species recovery.
- Aligns with governor's priority on diversity, equity and inclusion and environmental justice.
- Maintains some element of the working group structure and provides ongoing support and facilitation of working groups by state agencies.
- Continues engagement with nonprofits, businesses and other stakeholders to monitor implementation of existing recommendations, consider new recommendations and recommend course corrections for continued recovery.
- Maintains and enhances public visibility and interest in this crisis and facilitates a robust public engagement process.
- Builds on ongoing monitoring and reporting to maintain accountability to the public.
- Maximizes institutional durability, at least until the population reaches 84 whales by 2028.[6]

The task force has identified three general options (not listed in priority order) for moving this recommendation forward. By selecting one of the following options, the state can better ensure that between now and 2022, we witness evidence of consistently well-nourished whales, more live births and the survival of several thriving young orcas. With adequate consistency and attention, by 2028, we could see the primary indicator of body condition of the whales (the ratio of head width to body length in adults) remain high and stable between seasons and across years and finally see their population increase to 84 whales — an increase of 10 whales in 10 years. Options are summarized below:

Option 1: Expand existing agency capacity.

Expand the capacity and function of the Governor's Salmon Recovery Office to include orca recovery (e.g., Governor's Salmon and Orca Recovery Office). This option leverages existing agency infrastructure in the GSRO and is modeled after the Salmon Recovery Funding Board, with policy coordination and administration functions within the proposed Governor's Salmon and Orca Recovery Office and a policy board of governor-appointed members and agency heads.

Option 2: Create a new executive level team in Governor's Office.

Create an executive-level salmon and orca leadership team in the Governor's Office. This option includes explicit tribal co-manager engagement by the Governor's Office. This option

[6] In its 2018 report, the task force set forth the goal of increasing the Southern Resident population to 84 whales by 2028, or "10 more whales in 10 years."

houses the main functions of the policy leadership team within the Governor's Office and maintains an executive-level focus on recovery.

Option 3: Create a new orca recovery office.

Create an orca recovery office led by technical experts. This option creates a new office that is staffed to implement actions. This office can be located within the Governor's Office or within an existing agency. The key element of this option is that it is not a stakeholder-led process.

The task force also recommends incorporating PSP's recovery system into any of these options, as appropriate. PSP is well positioned to contribute to vessels recommendations, coordinate with Canadian representatives and actions, support scientific monitoring, advise on communications and track progress. Likewise, Salmon Recovery Councils on the Columbia River and Washington Coast could be useful partners.

Table 6 and **Appendix 5** provide additional implementation details on the three options summarized above for the Governor's Office to consider. The task force has laid a foundation for the Southern Resident recovery; strong governance will be necessary to build on this foundation with immediate, sustained and meaningful action.

Table 6. Summary of proposed options for continuing Southern Resident orca recovery.

<table>
<tr><th>Option 1</th><th>Option 2</th><th>Option 3</th></tr>
<tr><th>Governor’s Salmon and Orca Recovery Office</th><th>Governor’s Salmon and Orca Leadership Team</th><th>Governor’s Orca Recovery Office</th></tr>
<tr><th colspan="3">SUPPORT</th></tr>
<tr><td colspan="3">Puget Sound Partnership Recovery System
• Science, monitoring, and adaptive management
• Coordination with Canada, Columbia, and the Coast
• Tracking and updating recommendations
• Vessels
• Communications</td></tr>
<tr><td colspan="3">Columbia River and Coast Salmon Recovery Councils
• Science, monitoring, and adaptive management
• Tracking and updating recommendations</td></tr>
<tr><th colspan="3">STRUCTURE</th></tr>
<tr><th colspan="3">Leadership and representation</th></tr>
<tr><td>• Governor-appointed executive-level board or council to oversee orca recovery.
• GSRO provides policy support in coordination with the Governor’s Office.
• Executive-level membership includes appointments by the governor, ex-officio state agency representatives and tribal representatives.
• Staffed by designated agency representatives.</td><td>• Governor’s Office leadership as Chief Executive in co-manager role with tribes.
• Governor-appointed Leadership Team monitors implementation of existing recommendations, considers new working group recommendations, and recommends course corrections.</td><td>• Executive team chaired or co-chaired by technical experts.
• Team size should be lean and nimble.
• One or two leads for each threat (prey abundance, contaminants, vessel impacts, climate change, population growth, and any new/emerging threats).
• Tribal representatives participate as they see fit.</td></tr>
<tr><th colspan="3">Reporting structure</th></tr>
<tr><td>• GSRO statutory authority expanded to include orca recovery (“Governor’s Salmon and Orca Recovery Office”).</td><td>• Leadership Team meets twice per year (open to public).
• Reports to the public, governor, and tribes as co-managers, with biennial comprehensive reviews and brief annual updates.</td><td>• Reports directly to the governor or Governor’s Recreation and Conservation Office; analogous to the GSRO. Governor’s Office provide executive support and continuity between administrations.</td></tr>
</table>

Option 1	Option 2	Option 3
Governor's Salmon and Orca Recovery Office	**Governor's Salmon and Orca Leadership Team**	**Governor's Orca Recovery Office**
Key goals and actions		
• Maintain momentum and focus on orca recovery. • Coordinate policy and budget initiatives. • Coordinate the actions, science and progress through individual agencies.	• Maintain executive-level attention on salmon and orca recovery. • Track progress on Southern Resident Orca Task Force actions, recommend new actions, identify course corrections and maintain a broad coalition.	• Achieve orca recovery goals. • Prioritize and implement recommendations. • Amend and develop new task force recommendations. • Measure and track progress. • Promote transparency and accountability. • Identify roles and schedules for each recommendation.
PARTNERS AND STAKEHOLDERS		
Tribal co-managers		
• Tribes engage as co-managers on multiple fronts as appropriate, including appointments to the board or council.	• Accountable as co-managers. • Develop Leadership Team recommendations with stakeholders, agencies and others. • Members of working groups.	• Seats on council and working groups as co-managers. Additional roles per input from tribes.
Partner agencies		
• Hybrid executive-level and GSRO structure offers a statewide and transboundary perspective.	• Develop Leadership Team recommendations with tribes, stakeholders, and others. • Facilitate working groups. • Transboundary consultation.	• Collaborators and implementers.
Public		
• Engaged via multiple pathways.	• Consulted; public engagement brought these issues to the forefront and remains critical.	• Provides feedback and accountability.

Option 1	Option 2	Option 3
Governor's Salmon and Orca Recovery Office	**Governor's Salmon and Orca Leadership Team**	**Governor's Orca Recovery Office**
IMPLEMENTATION		
Effort and funding		
• GSRO staffing (one FTE). • Operational costs for the executive team and board coordination. • Agency staff support from PSP, WDFW, and ECY (three FTE).	• "Results Washington"-style meetings with the Governor and tribes. • Leadership Team meets twice annually (all-day public meetings). • Four working groups meet quarterly or semi-annually. • Website communication tools. • More detailed biennial report. • Agency staff support (PSP, DFW, ECY, GSRO) and facilitation contracts.	• Five to seven FTEs for Office (executive director, leads, public engagement). • Quarterly reports. • Technology (e.g., monitoring dashboard). • Communication and public engagement through dashboard, quarterly reports, and quarterly public meetings. • Stipend for working group travel.
Timeline		
• Could be implemented relatively quickly.	• By January 2020, transition to interim structure. • By winter/spring 2020, form new Leadership Team and secure legislative funding.	• Executive order to start as soon as possible, should be in place by end of legislative session or sooner.

Appendix 1. Southern Resident Orca Task Force final recommendations

In 2018, the task force developed a bold package of 36 recommendations that, if implemented, would collectively have the impact needed to achieve the vision of a thriving and resilient Southern Resident orca population. The task force continued these efforts in 2019 by:

- Evaluating progress made on Recommendations 1–36.
- Elevating recommendations that have not advanced enough to achieve their respective goals. **Urgent actions** emphasize one or more components of a Year One recommendation that has not advanced enough to achieve its goal. **Additional components** fill a gap in a Year One recommendation.
- Developing Recommendations 37–49 to address lessons learned and/or new issues that emerged since the release of the 2018 task force report.

The complete package of 49 recommendations outlined in this appendix are grouped under six overarching goals and include details for the governor, the Legislature, agencies and partners to consider during implementation. Recommendations 37–49 are embedded throughout the report under their respective goals (not presented in numeric order).

Legislative action required:

Policy		
• Recommendation 43	• Recommendation 48	

Funding		
• Recommendation 1	• Recommendation 19	• Recommendation 39
• Recommendation 2	• Recommendation 20	• Recommendation 41
• Recommendation 6	• Recommendation 30	• Recommendation 42
• Recommendation 12	• Recommendation 31	• Recommendation 43
• Recommendation 13	• Recommendation 32	• Recommendation 44
• Recommendation 14	• Recommendation 34	• Recommendation 45
• Recommendation 15	• Recommendation 35	• Recommendation 46
• Recommendation 16	• Recommendation 38	• Recommendation 48

Urgent actions on Year One recommendations:

Fully fund salmon recovery plans.

Increase funding and partnerships to fully implement priority habitat actions in salmon recovery plans, working with legislators, stakeholders and tribes. Focus on implementing habitat restoration and protection projects that local experts have prioritized in each salmon recovery region and that will benefit Chinook and Southern Residents. Ensure funding includes administration and local capacity-building to accelerate projects that are underway or have committed resources. Ensure greater collaboration between hatchery and habitat restoration efforts so that habitat is available to recover wild fish and for newly produced hatchery fish (**Recommendations 1, 2 and 6**).

Investigate and address pinniped predation.

Provide funding to the Washington Department of Fish and Wildlife to (1) determine if pinniped predation is a limiting factor for Chinook in Puget Sound and along Washington's outer coast and (2) more effectively manage pinniped predation in the Columbia River (**Recommendations 12 and 13**).

Increase early marine survival research and monitoring in Puget Sound.

Increase funding to Puget Sound Partnership and WDFW for salmon marine survival research and monitoring projects through the Puget Sound Action Agenda to ensure that results may be integrated in recovery and management plans, as appropriate. Research and monitoring projects could include Puget Sound Atlantis Modeling, zooplankton monitoring, salmon and forage fish sampling and pinniped predation work (**Recommendations 12, 15 and 16**).

Improve water quality.

Encourage the Washington State Department of Ecology to proceed with language in new rule on increasing the standard for total dissolved gas allowances in the Columbia and Snake rivers that will ensure the durability of the new rule (**Recommendation 8**).

Increase funding for education and enforcement.

Increase funding and make funding ongoing to WDFW for additional officers and equipment for enforcement (**Recommendation 20**).

Reduce noise and disturbance from U.S. Navy military exercises.

The Governor's Office and state agencies should coordinate with the National Oceanic and Atmospheric Administration and the Navy to reduce noise and disturbance from military exercises affecting Southern Resident orcas. In particular, the final decisions on training and testing activities conducted in the Northwest training and testing study area between November 2020 and November 2027 should eliminate impacts from current, new or additional exercises involving mid-frequency sonar, explosives and other activities with the potential to adversely affect Southern Resident orca recovery, or incorporate enhanced mitigation measures to reduce impacts (**Recommendation 25**).

Fund source local control program and increase incentives to reduce stormwater threats.

Additional funding should be provided for Ecology staff to support contaminants recommendations and should include pass-through funding to support local source control inspectors (**Recommendations 30, 31 and 32**). Funding should also be provided for incentives to reduce stormwater threats (**Recommendation 31**).

Prioritize stormwater cleanup based on salmon population productivity.

It is critical that we find ways to prioritize discretionary stormwater management and cleanup based on evidence of toxic impacts limiting salmon population productivity. Current state-level stormwater funding could be better targeted to priority areas. Programs currently do not seek highest-priority projects (**Recommendation 31**).

Prioritize contaminants of emerging concern and update aquatic life water quality standards.

The state should support ongoing prioritization work that addresses contaminants of emerging concern. Ecology should update aquatic life water quality standards focused on pollutants most harmful to Southern Resident orcas and their prey (**Recommendations 30 and 32**).

Provide funding to evaluate the effectiveness of task force recommendations.

Provide funding to PSP, WDFW, the Governor’s Salmon Recovery Office and Ecology to evaluate the effectiveness of task force recommendations through monitoring and adaptive management while leveraging existing efforts (**Recommendation 35**).

Additional components of Year One recommendations:

Increase habitat protection.

Reduce the impacts from development on critical habitat and sensitive ecosystems that Southern Residents and the food web rely upon. Revise statutes to shift from a "no net loss" standard to a "net ecological gain" standard to better protect salmon and orcas. Provide adequate funding and support to state natural resource agencies and local governments to improve planning, permitting and enforcement activities that protect habitat, while funding restoration efforts (**Recommendations 3, 4 and 48**).

Prevent northern pike expansion into the Columbia River.

Increase funding to WDFW for northern pike eradication and containment efforts to prevent predation on salmon in the Columbia River (**Recommendation 14**).

Increase funding for education and enforcement.

Provide resources to WDFW and other groups to (1) expand boater education and enforcement to central Puget Sound in the fall, (2) seek vessel mitigation opportunities and (3) extend outreach to promote compliance by vessel operators in newly proposed critical habitat on the outer coast of Washington (**Recommendation 19**).

Create a transboundary forum.

Create and charter a transboundary forum for waterways management and Southern Resident conservation by working with the appropriate federal partners, tribes and agencies to integrate and coordinate state, federal and Canadian actions. Evaluate cumulative impacts of vessel traffic (**Recommendations 22, 24 and 27**).

Actively promote compliance with Canada's foraging sanctuary zones.

Actively promote compliance by the United States shipping sector and recreational vessels with Canada's interim and potential future foraging sanctuary zones such as Swiftsure Bank and Pender Island (**Recommendation 22**).

Ensure the State Environmental Policy Act review of marine facilities.

Help ensure that the State Environmental Policy Act review of marine facilities is routinely applied to standard and atypical changes in use and ownership that may lead to increased vessel traffic or changes in vessel traffic dynamics. Provide tools for local and state governments to identify and evaluate potential impacts and recommend potentially appropriate mitigation measures (**Recommendation 27**).

Maintain Model Toxics Control Act funding.

Toxics control funding provided though the state's MTCA should be maintained for preventing and cleaning up toxics (**additional component of Recommendation 31**).

Increase funding for infrastructure improvements.

Increase funding to specific accounts that support infrastructure improvements, including the Clean Water Pollution State Revolving Fund, Stormwater Financial Assistance Program and Public Works Trust Fund. Increase caps on utility fees to help fund improved treatment of wastewater, stormwater and other contaminant sources (**Recommendation 31**).

Increase monitoring and associated funding.

Weave monitoring into each recommendation and dedicate funding to Ecology, PSP and WDFW to provide data on effectiveness (**Recommendation 33**).

Transition one-time investments in orcas and salmon in 2019 into ongoing investments.

Much of the increases in funding that WDFW received as part of the Southern Resident orca package was one-time funding. To most benefit orcas, this funding should be sustainable (**Recommendation 34**).

Goal 1: Increase Chinook abundance

Habitat restoration and acquisition: Increase Chinook abundance by restoring and acquiring salmon habitat and food sources

Recommendation 1: Significantly increase investment in restoration and acquisition of habitat in areas where Chinook stocks most benefit Southern Resident orcas.

- Provide capital budget funding to support the existing lists of projects and Salmon Recovery Funding Board requests intended to improve Chinook and forage fish habitat.
- Accelerate the implementation of currently funded Chinook restoration projects known to provide survival benefits to Southern Resident orcas.
- Significantly increase funding for a minimum of 10 years for high-priority actions or projects targeted to benefit Chinook stocks.
- Emphasize large-scale estuary restoration programs and prioritize grant making for restoration that increases Chinook recovery in the short term.
- To complement forest Road Maintenance and Abandonment Plans and Washington State Department of Transportation fish passage improvement efforts, continue to use a strategic approach for using Recreation and Conservation Office administered programs to remove barriers (for example, culverts and small dams) where removal would provide a high benefit to Chinook.
- Create a new funding source to support the significant increases in investments in the habitat protection and restoration programs. This should be done in conjunction with the development of a sustainable funding source for the implementation of all task force recommendations.
- The Legislature should fully fund payment in lieu of taxes to counties to compensate for the loss of revenue associated with the land that is acquired by the state for habitat protection and restoration projects.
- The Legislature should ensure adequate funding for the operations and maintenance of lands acquired by the state for habitat protection and restoration projects.
- Support a more robust monitoring and adaptive management system to better ascertain restoration project compliance and measurable ecological benefits.
- Support funding for completion of Chinook recovery plan updates for 14 of 16 remaining Puget Sound watersheds.

Implementation details:

In 2019, the governor and Legislature should fully fund the Recreation and Conservation Office's budget requests for existing capital budget salmon recovery accounts (Salmon Recovery Funding Board, Puget Sound Acquisition and Restoration Program, Estuary and Salmon Restoration Program, the Fish Passage Barrier Removal Board and the Washington Coast Restoration and Resilience Initiative) with no changes to existing ranked lists.

In 2019, the governor and Legislature should also support programs administered by the Department of Ecology and the Department of Fish and Wildlife that directly benefit Chinook salmon, including Floodplains by Design, Puget Sound Nearshore Estuary Restoration Project, the Office of the Chehalis Basin Strategy and the Yakima Basin Integrated Plan.

Regions should work within their existing priorities that are consistent with high-priority Chinook stocks to accelerate the pace of restoration throughout the Puget Sound, Washington coast and Columbia Basin. Regions — including state natural resource agencies — should fully exercise their technical and policy capacity to accelerate full implementation of habitat restoration projects that are currently under consideration, that have an established funding source and that have feasibility studies indicating the project would provide survival benefits to salmon stocks important to the Southern Resident orcas. Consistent with restoration programs to date, projects on private lands will be limited to high priority habitat areas with willing sellers. Additional state funding should be provided for at least 10 years (five biennia) to focus specifically on high-priority actions for the stocks that most benefit Southern Residents. These programs have traditionally allocated approximately 80% of their funding towards projects that benefit Chinook.

When lands are acquired by state agencies for salmon and Southern Resident orca recovery, the Legislature should fully fund payment in lieu of taxes to counties to compensate for the loss of revenue associated with the land acquired by the state for habitat protection and restoration projects. Natural resource managers should be adequately funded for operations and maintenance of lands acquired. In addition, support for comprehensive and systematic evaluation of fish/habitat response/interactions to restoration actions could potentially: (1) provide further detailed information on the mechanistic links or processes that benefit the individual or population as a function of habitat restoration and (2) help prioritize future restoration actions.

Critically important but costly estuary restoration work should be evaluated and prioritized where juvenile Chinook production could be increased in the very near term. Any estuary selected for restoration should be a high-priority Chinook salmon estuary and identified as being important for the Southern Resident orcas. Possible estuaries to focus on are the Nooksack, Skagit, Stillaguamish, Elwha, Dungeness, Snohomish, Green-Duwamish, Puyallup, Nisqually, Skokomish, Snohomish, the mouth of the Columbia and Chehalis, all benefitting high-priority Chinook for Southern Residents.

To complement forest Road Maintenance and Abandonment Plans and WSDOT fish passage improvement efforts, use Recreation and Conservation Office administered programs to fund the removal of barriers (for example, culverts and small dams) where removal would provide a high benefit to Chinook. The Legislature should provide funding for barrier removal projects that already have broad support, such as the Middle Fork Nooksack and Pilchuck dams. In addition, the Governor's Salmon Recovery Office should coordinate with Washington Department of Fish and Wildlife, the Fish Barrier Removal Board, regional salmon recovery organizations and partners to compile and develop a strategic approach to removing remaining barriers that would benefit Chinook, including those locally or privately owned, where community and technical support can be attained. A draft list of barriers shall be developed by March 2019 and provided to the task force, Governor's Office and Office of Financial Management as Phase I of this recommendation. Phase II will include further assessment of those barriers and any further steps needed for potential removal of those barriers (for example, stakeholder outreach), plus identification of any additional barriers by June 2020. This assessment should be iterative and should be revised as new information becomes available. The Legislature should provide funding via the capital budget for removal of barriers identified through this process that have community support.

Recommendation 2: Immediately fund acquisition and restoration of nearshore habitat to increase the abundance of forage fish for salmon sustenance.

Provide funding for the immediate implementation of nearshore habitat restoration projects.

Implementation details:

The governor and Legislature should fully fund the projects by the Puget Sound Acquisition and Restoration, Washington Coast Restoration Initiative, Salmon Recovery Funding Board and Estuary and Salmon Restoration Programs that address nearshore habitat and that were approved during the 2018 grant round.

Habitat protection and enforcement: Protect habitat through improved enforcement of existing laws, strengthening laws and ensuring compliance

Recommendation 3: Apply and enforce laws that protect habitat.

- Washington Department of Fish and Wildlife, Washington Department of National Resources and Washington Department of Ecology must strongly apply and enforce existing habitat protection and water quality regulations. Provide WDFW, DNR and Ecology with the capacity for implementation and enforcement of violations.

- Direct DNR, WDFW and Ecology to identify and report to the task force before July 2019 on approaches using existing habitat, instream flow and water quality regulations to improve prey availability.
- Coordinate state and local enforcement efforts.
- Develop and adopt rules to implement and enforce the Fishway, Flow and Screening statute.
- Enhance penalties and WDFW's enforcement of the state Hydraulic Code and fish passage regulations.
- Increase prosecution of violations of state and local habitat protection and water quality regulations, including seeking to hold both property owners and contractors accountable, when appropriate.

Implementation details:

As soon as possible, the governor should direct WDFW staff to develop rules to fully implement and enforce the Fishway, Flow and Screening statute (chapter 77.57 RCW).

WDFW and Ecology should work with the Attorney General's Office and local prosecutors to increase compliance with habitat protection and water quality regulations. The number of WDFW and Ecology staff should be increased to improve implementation, compliance and civil enforcement.

The Legislature should amend WDFW's civil penalty statute (chapter 77.55.291 RCW) to provide the department with enforcement tools equivalent to those of local governments, Ecology and DNR.

Increase coordination among local governments, Ecology and WDFW in reviewing shoreline armoring proposals to better protect forage fish by advancing the Puget Sound Partnership's Shoreline Armoring Implementation Strategy.

> The governor and Legislature must support and provide clear direction to Ecology, WDFW and DNR to facilitate improvements in implementation and increasing compliance to improve Southern Resident prey availability through existing habitat and water quality regulations. The agencies should report back to the task force before July 2019 on progress made. At the state level, the governor and Legislature must provide clear direction and support to facilitate change from the status quo (due to variable implementation).

Recommendation 4: Immediately strengthen protection of Chinook and forage fish habitat through legislation that amends existing statutes, agency rule making and/or agency policy.

- Strengthen legislation, agency rules, or agency internal policies, where appropriate, for Ecology and WDFW to better protect Chinook and forage fish.
- Direct WDFW to develop a plan with local governments for analyzing cumulative impacts and amend existing authority to allow WDFW to require mitigation for cumulative impacts over time under the Hydraulic Project Approval authority.
- Provide agencies with clear authority to prohibit or mitigate certain actions.

Implementation details:

Meet regularly with the Governor's Office, legislators, tribes, DNR, WDFW, Ecology, salmon recovery regional representatives and other partners and stakeholders with the goal of developing a habitat protection/regulatory reform legislative packages for the 2019 and subsequent legislative sessions and rulemaking.

Improve coordination of local and state permits by requiring that local shoreline permits for single-family residential bulkheads, shoreline armor or rock walls be issued prior to the issuance of an HPA by WDFW. This would be added to the HPA statute (chapter 77.55.021 RCW).

Repeal the section of the HPA statute that requires the issuance of a permit (with or without conditions) for a single-family residential bulkhead, shoreline armor or rock wall to allow WDFW to consider the full impacts of these proposals consistent with its consideration of other aquatic projects.

Direct WDFW to develop a plan with local governments for analyzing cumulative impacts of projects permitted under the HPA program and ask the Legislature to rescind or amend appropriate portions of WDFW's HPA authority (chapter 77.55.231[1] RCW) to enable the agency to require mitigation for cumulative impacts over time. This should be coupled with increased enforcement capacity.

Habitat protection: Increase incentive programs to encourage salmon habitat conservation

Recommendation 5: Develop incentives to encourage voluntary actions to protect habitat.

- State agencies should identify and implement incentives for landowners to voluntarily protect shorelines and habitats to benefit salmon and Southern Resident orcas.

- Increase funding for existing and seek to develop additional cooperative conservation programs.

Implementation details:

The Legislature and federal agencies such as the Natural Resource Conservation Service should create additional mechanisms and increase financial assistance for cooperative conservation programs (for example, fish screens, riparian areas, commodity funding for voluntary riparian implementation to Site Potential Tree Height, private fish passage upgrades and enhanced wildlife forage budget for WDFW wildlife areas with estuary restoration potential) implemented by conservation districts, lead entities, Regional Fisheries Enhancement Groups or individual landowners. Relevant existing programs include Floodplains by Design, the Shore Friendly Program, Forest Riparian Easement Program, Rivers Habitat Open Space Program and the Conservation Reserve and Enhancement Program. Salmon recovery regions and state and federal agencies should develop a 10-year funding proposal for incentives by June 2020 to complement habitat restoration and acquisition. The Legislature should allocate funding in the 2019–21 biennium for implementation in select watersheds in Puget Sound, Washington Coast and Columbia Basin.

Hatcheries: Provide additional Chinook through increased hatchery production

Recommendation 6: Significantly increase hatchery production and programs to benefit Southern Resident orcas consistent with sustainable fisheries and stock management, available habitat, recovery plans and the Endangered Species Act. Hatchery increases need to be done in concert with significantly increased habitat protection and restoration measures.

- Authorize/provide funding for the Washington Department of Fish and Wildlife and co-managers to significantly increase hatchery production at facilities in Puget Sound, on the Washington Coast and in the Columbia River basin in a manner consistent with sustainable fisheries and stock management and the ESA. Decisions on hatchery production are made by WDFW and tribal co-managers, with Endangered Species Act consultation from the National Oceanic and Atmospheric Administration and the U.S. Fish and Wildlife Service where appropriate. The Washington Fish and Wildlife Commission adopted a policy statement in 2018 indicating support for hatchery increases of approximately 50 million smolts beyond 2018 levels to produce more Southern Resident orca prey and fisheries benefits; the task force supports significant increases in hatchery production and habitat protection and restoration.

- In 2019, undertake hatchery pilots to test and refine methods and practices (location, timing of release, age, size) that maximize production of Chinook for the benefit of Southern Resident orcas while minimizing competition with wild stocks.
- Manage the increase in hatchery production consistent with available and improved habitat to enable survival of both hatchery and wild fish stocks.
- Provide increased funding to cover the operational, infrastructure, management and monitoring costs associated with increased hatchery production.
- Conduct ongoing adaptive management, five-year comprehensive reviews and the science needed to support a sustained increase in hatchery production.

Implementation details:

To supplement 2019 hatchery production increases, fund WDFW and co-managers in fiscal year 2020 and into the future to increase hatchery production for the benefit of Southern Resident orcas at facilities in Puget Sound, on the Washington Coast and in the Columbia River basin, in a manner consistent with sustainable fisheries and stock management, state and federally adopted recovery plans and the ESA. Increased production can be assessed at appropriate state, tribal, federal or private facilities that most benefit orcas. The governor should also ask other funders – such as NOAA, USFWS, Bonneville Power Administration and the Oregon Department of Fish and Wildlife – of hatchery programs for Chinook stocks that are a priority for Southern Resident orcas to maintain or increase production levels for those stocks, so additional hatchery investments result in an overall increase in prey abundance. Increasing hatchery production will require funding for the following activities:

- Adaptive management and five-year comprehensive reviews. To continue ongoing hatchery production with funding at the increased levels, WDFW must conduct annual adaptive management and five-year comprehensive reviews and adjust production and practices accordingly to limit impacts on natural salmon stocks if the reviews provide evidence of significant risk to the recovery of natural salmon stocks. These reviews should consider stray rates, productivity, juvenile rearing carrying capacity, density dependence, smolt-to-adult ratios, genetic fitness and other appropriate metrics to determine if action is needed to ensure the health or recovery of natural stocks. In coordination with this effort, annual and five-year reviews will evaluate the effectiveness of increased hatchery production to increase salmon available to Southern Resident orcas at times and locations determined critical to successful feeding, and to ensure effective support of fisheries management plans related to the Pacific Salmon Treaty, tribal treaty right fisheries and other plans and adjust hatchery production and practices to also maximize benefits to orcas and fisheries. Accomplishing this review will require additional state funding for WDFW and co-managers in future years (such as in years when hatchery-produced fish return to Washington waters).

- Production at the 2019 level. Although the Legislature provided funding in fiscal year 2019 to increase hatchery production with existing infrastructure, continued funding is needed to continue these production increases.
- Additional science and infrastructure to support increased production for orcas. Additional funding is needed to expand production beyond the 2019 level driven by the Southern Residents' needs. Expanding production significantly will require additional hatchery facility capacity upgrades and should use the best available science on hatchery production to adaptively manage the program to consider the factors listed above.
- Collaboration among WDFW and co-managers on hatchery production decisions.

The governor and Legislature should also provide funding to WDFW and co-managers to coordinate with NOAA and Long Live the Kings and begin testing pilot actions in hatcheries in 2019. These pilots should aim to: (1) increase marine survival of Chinook, (2) adjust return timing and locations to align with orcas' needs, (3) assess the feasibility and develop a plan to potentially increase size and age of returns and (4) reduce potential competition with wild fish. This work should build from and test findings of the Salish Sea Marine Survival Project, NOAA's salmon ocean program and other relevant efforts that are working to determine what is driving the survival of Chinook as they migrate downstream and through the marine environment. Hatchery pilots may require additional production to ensure existing production levels are not affected by these trials, which have uncertain outcomes in terms of fish survival. Pilot hatchery actions should be used to gather science to adaptively manage hatchery production levels and practices, including guiding the continued increases of hatchery production over time to provide more adult Chinook for Southern Residents, while ensuring increases are done in a manner that complies with ESA guidelines and that does not impact Chinook recovery.

Hydropower operations: Improve survival and distribution of Chinook populations

Recommendation 7: Prepare an implementation strategy to reestablish salmon runs above existing dams, increasing prey availability for Southern Resident orcas.

- Provide funding to Washington Department of Fish and Wildlife and regional salmon organizations to coordinate with partners to determine how to reestablish sustainable salmon runs above dams including, but not limited to, the Chief Joseph and Grand Coulee Dams on the Columbia River and the Tacoma Diversion, Howard Hanson and Mud Mountain dams in the Puget Sound. Provide policy support for actions needed. Prioritize projects that produce downstream adult Chinook.

Implementation details:

In 2019, the governor and Legislature should provide funding through WDFW and regional salmon recovery organizations to coordinate with tribes, local governments, National Oceanic and Atmospheric Administration and other key partners to assess and prioritize appropriate locations based on potential benefits, costs, management, operations and other key information necessary to reestablish salmon runs as soon as possible above the dams and in the watersheds agreed to by the parties. Provide policy support for Chinook reintroduction upstream of dams such as Chief Joseph and Grand Coulee Dams for both the near-term trap-and-haul efforts (cultural releases implemented by the Upper Columbia tribes). In addition, provide policy support for the long-term phased approach in the Northwest Power and Conservation Council's Fish and Wildlife Program and support the U.S. entity's regional recommendation concerning the Columbia River Treaty. Prioritize projects that can produce downstream adult Chinook and areas with suitable habitat or areas targeted for habitat restoration in the near term.

Recommendation 8: Increase spill to benefit Chinook for Southern Residents by adjusting total dissolved gas allowances at the Snake and Columbia River dams.

- Direct the Department of Ecology to increase the standard for dissolved gas allowances from 115% to up to 125%, to allow use of the best available science to determine spill levels over these dams to benefit Chinook and other salmonids for Southern Residents.
- Coordinate with the Oregon Department of Environmental Quality to align standards across the two states.
- Maintain rigorous monitoring of impacts to juvenile Chinook and resident fish to ensure any changes in spill levels do not negatively impact salmon or other aquatic species.
- Work with tribes, salmon recovery regions, Ecology and WDFW to minimize revenue losses and impacts to other fish and wildlife program funds.

Implementation details:

Ecology should move to immediately eliminate the current 115% standard for the forebay of the eight dams on the lower Snake and lower Columbia rivers and adjust total dissolved gas allowances to up to 125%, as measured at tail races. The intent is to create flexibility to adjust spill regimes, using the best available science, to benefit Chinook salmon and other salmonids. Ecology should work as expeditiously as possible with the WDFW and Oregon Department of Environmental Quality to align at this level. Any new spill levels tested through this flexibility in spill regimes should be monitored and adaptively managed to minimize any negative effects on resident and anadromous fish species.

Recommendation 9: Establish a stakeholder process to discuss potential breaching or removal of the lower Snake River Dams for the benefit of Southern Resident orcas.

- In conjunction with the states of Idaho and Oregon, Washington should act quickly to hire a neutral third party to establish a tribal and stakeholder process for local, state, tribal and federal leaders to address issues associated with the possible breaching or removal of the four lower Snake River dams.

Implementation details:

The task force requests the creation of an open collaborative process, the purpose of which is to address a series of questions related to the potential breaching or removal of the lower Snake River dams and associated economic and social impacts and mitigation costs. These should include the potential economic impacts or benefits to coastal fishing communities, both tribal and non-tribal. This local collaborative effort should work in conjunction with the states of Washington, Idaho and Oregon to support a technically sound process.

The work should not interfere with the current Columbia River Systems Operation National Environmental Policy Act process. Washington state will continue its current active support as a cooperating agency in the NEPA process.

The state shall develop a scope of work in conjunction with the National Research Council by March 2019. This process will include engagement from local, state, tribal and federal governments, along with interested stakeholders, to begin developing a regional understanding and potential recommendations for the lower Snake River dams. The process should include consideration of services provided by the dams, potential biological benefits/impacts to Chinook and Southern Resident orcas, as well as other costs and uncertainties related to the question of breaching or retaining the lower Snake River dams.

The task force should be updated on progress by the summer of 2019.

Harvest: Increase adult Chinook abundance through reduced catch and bycatch

Recommendation 10: Support full implementation and funding of the 2019–28 Pacific Salmon Treaty.

- Washington's congressional delegation should prioritize securing appropriations to implement this treaty. Delegation members, the governor, task force members and others should advocate for these appropriations.

- The treaty and its appropriations will result in harvest reductions, reduced bycatch, increased hatchery production and investments in habitat restoration, which are crucial to reducing harvest thereby increasing Chinook for the benefit of Southern Resident orcas.

Implementation details:

Support the full implementation of the 2019–28 Pacific Salmon Treaty, with the funding components that benefit Southern Resident orcas. Elements of the renegotiations included reductions in impacts on Chinook to make more prey available to Southern Resident orcas. Related funding elements should include investments in habitat and hatcheries to increase Chinook abundance. The governor should express the need for approval of the appropriations requests to the Washington federal delegation. Task force members should also reach out to the delegation for its support of the funding components.

Recommendation 11: Reduce Chinook bycatch in west coast commercial fisheries.

- Washington Department of Fish and Wildlife should work with regional councils and stakeholders to implement practices and regulations in west coast fisheries that further reduce bycatch of Chinook – allowing more of these Chinook to reach Southern Residents.

Implementation details:

The governor should direct WDFW representatives on the Pacific Fishery Management Council and North Pacific Fishery Management Council to work with regional stakeholders and manager starting in 2019 to avoid bycatch and further reduce the bycatch of Chinook in west coast fisheries to the extent practicable to ensure more Chinook reach Southern Residents. Discussions should take into account the effectiveness of existing bycatch reduction measures and provisions of existing federal agency requirements such as the Endangered Species Act.

Predation of Chinook: Decrease the number of adult and juvenile Chinook lost to predation by species other than Southern Residents

Recommendation 12: Direct the appropriate agencies to work with tribes and National Oceanic and Atmospheric Administration to determine if pinniped (harbor seal and sea lion) predation is a limiting factor for Chinook in Puget Sound and along Washington’s outer coast and evaluate potential management actions.

- Conduct a pilot project for the removal or alteration of artificial haul out sites where sites are associated with significant outmigration and predation of Chinook smolts. Fund a study to determine if pilot removal accomplishes the goal of significantly reducing Chinook smolt predation.

- Complete ongoing regional research and coordinate an independent science panel (Washington Academy of Sciences or National Academy of Sciences) to review and evaluate research needed to determine the extent of pinniped predation on Chinook salmon in Puget Sound and Washington's outer coast. The ongoing and new work should include an assessment of factors that may exacerbate or ameliorate predation such as infrastructure haul-outs, hatchery strategies, the increased presence and impact of transient killer whales and the presence/absence of forage fish or other fish that are staple food for pinnipeds.
- Engage NOAA to determine the optimal sustainable populations of harbor seal stocks in Puget Sound.
- Convene a management panel of state, tribal and federal agencies to communicate with the independent science panel, review the results of the ongoing regional research and independent scientific review and assess appropriate management actions. Citizen stakeholders should also be engaged in the process. If pinniped removal is identified as a management option, secure authorization through the Marine Mammal Protection Act.
- Provide funding for the science, research, coordination, decision making and, if deemed necessary, removal.

Implementation details:

In the 2019–21 biennium, the governor and Legislature should begin to fund Washington Department of Fish and Wildlife to work with tribes and NOAA to pilot the removal or alteration of artificial haul-out sites used by pinnipeds in the Puget Sound in places that may improve Chinook survival. Funding should include implementation and monitoring components to assess the effectiveness of this approach to guide potential future haul-out removals.

Starting immediately, the governor, Legislature and NOAA should support and fund the coordination and continued development of science to determine the extent of pinniped predation on Chinook salmon in Puget Sound and Washington's outer coast.
WDFW and the Puget Sound Partnership – or an appropriate board or partner designated by them – should convene a science workgroup to coordinate ongoing research and provide a comprehensive report on the state of science on pinniped predation. The comprehensive report of science should include:

- An analysis to help determine the extent to which pinniped predation is a limiting factor for Chinook survival in Puget Sound and the outer coast that should be completed by WDFW. Further, WDFW should continue to assess the status of the harbor seal and sea lion populations in these areas.
- An assessment of factors that may exacerbate or ameliorate predation, including infrastructure haul-outs, hatchery strategies, the increased presence of transient killer

whales and the presence/absence of forage fish or other fish that are staple food for pinnipeds. Strive to complete the assessment in a timeframe that would help inform increases in hatchery production.

- Continue science to identify potential negative feedbacks associated with pinniped removal (using NOAA's Atlantis modeling and other efforts as needed). For example, if the consumption of Pacific hake and spiny dogfish by harbor seals declines, will the increased abundance of those fish lead to higher rates of predation by them on Chinook?
- A quantitative and spatial assessment of the consumption of harbor seals and sea lions by transient killer whales in Puget Sound and the effect of potential removals on transient populations.

WDFW and/or PSP should convene an independent science panel through the Washington Academy of Sciences or National Academy of Sciences to conduct an initial independent science review of the research program and then review the comprehensive report.

At the same time, the governor should ask NOAA to expediently complete an assessment to determine the optimal sustainable populations of the harbor seal stocks of Puget Sound and then convene the Pacific Scientific Review Group to review the assessment.

To ensure emerging science and the independent science panel review are promptly used to improve management, WDFW should expediently convene a panel of state, tribal and federal managers in 2019. The management panel will provide feedback to the science workgroup on specific information required to assess Puget Sound and outer coast pinniped predation and be updated on the state of the science. After completion of the independent science review, the management panel should examine where and what types of management actions are best suited to the situation and, if needed, provide any information necessary to secure authorization to perform needed management actions. The management panel will also ensure participation and input from stakeholders. The panel should clarify management goals and assess actions that may exacerbate or ameliorate predation, including infrastructure haul-outs, hatchery strategies, increased presence of transient killer whales and the presence/absence of forage fish or other fish that are staple food for pinnipeds. WDFW should receive state funding for coordination of this process and the governor should request the Washington federal delegation support funding capacity for NOAA to participate and review any resulting applications for management expediently. Once authorization is received for any management actions, those actions should be funded through state and federal funds.

Recommendation 13: Support authorization and other actions to more effectively manage pinniped predation of salmon in the Columbia River.

- Support efforts to enact a Columbia River-specific amendment to the Marine Mammal Protection Act enabling more effective management of pinniped (harbor seal and sea lion) predation of salmonids.

- Support MMPA authorization to add Steller sea lions to the list of pinnipeds managed in the lower Columbia River. Support increasing removal levels and altering removal requirements.
- Monitor Chinook survival and pinniped distribution in the Columbia River estuary to guide current and future management actions.
- WDFW should work with Oregon Department of Fish and Wildlife to pilot a project to remove artificial sea lion haul-out sites in the lower Columbia River and study the effectiveness of the action in reducing predation on Chinook.

Implementation details:

The governor should support efforts to amend the MMPA to more effectively manage pinniped predation of salmonids in the Columbia River through non-lethal and lethal methods. The task force should join the governor in expressing public support for a Columbia River-specific amendment to the MMPA, which is currently under consideration in Congress.

Alternatively, or in the meantime, the governor should support an application for MMPA authorization to increase effectiveness of the management program by allowing the management of Steller sea lions, increasing removal levels and altering removal requirements. In the case of an application for MMPA authorization, the governor should request the Washington federal delegation support funding for NOAA to review the application expediently. To implement increased management through either an MMPA amendment or additional MMPA authorization, the Legislature should provide additional funding to WDFW to work with partners to carry out the program.

To monitor the effectiveness of the management program, the governor should request that NOAA provide federal funding to monitor Chinook salmon survival from the Columbia River estuary to Bonneville Dam. The governor and Legislature should provide complementary state funding for WDFW to perform pinniped distribution surveys for this same area. In combination, these two analyses will greatly help to guide current and future management actions.

Recommendation 14: Reduce populations of nonnative predatory fish species that prey upon or compete with Chinook.

- Adjust game fish regulations and remove catch and size limits on nonnative predatory fish — including, but not limited to, walleye, bass and channel catfish — to encourage removal of these predatory fish, where appropriate.
- Evaluate predatory fish reduction options in McNary reservoir as the basis for further action to protect juvenile salmon.

Implementation details:

Request WDFW remove catch and size limits on nonnative predatory fish including, but not limited to, walleye, bass and channel catfish to encourage removal of these predatory fish, where appropriate, to protect salmon or other ESA-listed species. In addition, WDFW should adapt regulations to allow the disposal of these fish species because it is currently illegal to "waste" sport fish. Any increase in fishing for these species should be managed to minimize additional mortality or bycatch of salmonids.

The governor's budget should include funding for next three years as partial funding to support the proposed study to evaluate predatory fish population reductions through McNary Dam reservoir elevation management. The study would evaluate reservoir pool elevation levels that affect nonnative predatory fish spawning.

Forage fish: Increase the food available for Chinook

Recommendation 15: Monitor forage fish populations to inform decisions on harvest and management actions that provide for sufficient feedstocks to support increased abundance of Chinook.

- Complete Puget Sound-wide surveys of herring, smelt and sand lance to map spawning habitat and determine abundance of these food sources for Chinook.
- Surveys should be conducted in conjunction with restoration and protection of forage fish spawning habitat.
- Inventory existing and planned forage fish harvest levels to determine potential impact of forage fish harvest on Chinook.
- Provide funding to conduct these surveys and inventories.

Implementation details:

The governor and Legislature should continue to provide funding for forage fish surveys to identify and map the expansion or contraction of critical habitat used by three species of forage fish in Puget Sound: herring, surf smelt and sand lance. These surveys provide the only index of abundance currently available for any species of Puget Sound forage fish by estimating the spawning biomass of more than 20 Puget Sound herring stocks. Access to quality spawning habitat is critical to the health and persistence of forage fish stocks, so the results of forage fish surveys are updated annually and made available online to inform shoreline development, protection and restoration decisions that affect these species. The studies should be conducted in coordination with existing and ongoing efforts such as the Ocean Ecosystem Indicators work by National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center, the Puget Sound Ecosystem Monitoring Program and other regional ecosystem and forage fish efforts. Ongoing funding should be provided to the Washington Department of Natural

Resources' Puget Sound Corps Program and to Washington Department of Fish and Wildlife to implement the surveys.

The governor should provide ongoing funding for WDFW to inventory existing and future planned forage fish harvest levels in Puget Sound and to assess impacts to Puget Sound forage fish populations important to Chinook that would result from varying levels of harvest.

Recommendation 16: Support the Puget Sound zooplankton sampling program as a Chinook and forage fish management tool.

- Monitor zooplankton to better inform forage fish and Chinook conservation. Provide funding to DNR to coordinate this critical sampling program, leveraging the work of and funding from federal, state, tribal and academic partners.

Implementation details:

The governor should fund the Puget Sound zooplankton sampling program, which leverages the work of tribal, county, state, federal (including NOAA, the U.S. Coast Guard, the U.S. Army Corp of Engineers and the Environmental Protection Agency) and academic and non-academic entities, including the Northwest Indian Fisheries Commission, to sample and analyze the zooplankton community every two weeks at 16 sites. This program is essential to better manage Chinook and forage fish populations. These data help determine the role of our restoration actions versus marine drivers of productivity and aid in the forecasting of Chinook and forage fish abundance to help make continuous management decisions for whales and fisheries. Funding should be provided through the DNR, which will be leveraged with non-state partner funds to enable the continuation of the program.

Goal 2: Decrease disturbance of and risk to Southern Resident orcas from vessels and noise, and increase their access to prey

Reduce noise from small vessels operating near Southern Resident orcas

Recommendation 17: Establish a statewide "go-slow" bubble for small vessels and commercial whale watching vessels within half a nautical mile of Southern Resident orcas.

- Enact legislation in 2019 creating a half-mile "go-slow" zone, defined as speeds of seven knots over ground or less.
- Provide for discretion in enforcement and public outreach and education as needed.

- Encourage coordination among Washington state, federal and Canadian authorities to align regulations.

Implementation details:

In the 2019 legislative session, the Washington State Legislature and governor should update chapter 77.15.740 RCW to establish a statewide "go slow" bubble for small vessels operating within a half nautical mile of Southern Resident orcas. "Go slow" is defined as 7kt speed over ground, as measured using GPS. It is intended that fish and wildlife officers and other law enforcement officers will use discretion when enforcing this section and granting exceptions for safety reasons and provide public outreach and education when they determine it is appropriate.

Recommendation 18: Establish a limited-entry whale-watching permit system for commercial whale-watching vessels and commercial kayak groups in the inland waters of Washington state to increase acoustic and physical refuge opportunities for the orcas.

- Create a limited-entry permit system to manage commercial whale-watching in the inland waters of Washington state to reduce daily and cumulative impacts on Southern Residents.
- Washington Department of Fish and Wildlife should develop the permit system in consultation with the Pacific Whale Watch Association, orca conservation organizations and other stakeholders.
- The permitting system will consider limiting commercial whale-watching activities by: (1) number of boats that receive permits, (2) hours and duration spent in the vicinity of the Southern Resident orcas and (3) location. Development of the permit system will consider limiting the total number of boats that receive permits and help codify conservative and flexible measures, such as limiting the amount of time commercial whale-watching vessels may spend in the vicinity of a particular group of whales and limiting the number of commercial whale-watching vessels that may be in the vicinity of the whales at a given time. Permitting system must be in place by July 2019, including initial limits as described above.
- Consider implementing a buy-back program.
- Require the use of the Automatic Identification System to enable effective monitoring and compliance.
- Coordinate with Canadian authorities to develop and implement the permit system across boundaries.
- Formally apply standards from the Kayak Education and Leadership Program's "Code of Conduct" to the organized operation of kayaks and other human powered vessels near Southern Resident orcas (for example, practices such as "rafting up").

Implementation details:

By July 2019, the Legislature and governor should establish a Washington state commercial whale-watching license for whale watching in the inland waters (exempting the ocean) to be managed by WDFW. The fees for the license should be placed in a WDFW-dedicated account that could be used for the management and enforcement of whale-watching activities.

WDFW should also develop, assess and consider alternatives that restrict the number of Washington state whale-watching licenses and implement any restrictions by May 2020.

Recommendation 19: Create an annual Orca Protection endorsement for all recreational boaters to ensure all boaters are educated on how to limit boating impacts to orcas.

- Create a $10 statewide Orca Protection endorsement with an opt-out option for all registered recreational vessels.
- Provide education on Be Whale Wise guidelines, voluntary and regulatory measures and other information at the time the marine endorsement is purchased, so every boater has this basic information.
- Direct the resulting revenue to WDFW's new Marine Enforcement Division, to the Washington State Department of Licensing to cover costs of administering the program and to partners doing outreach and education.
- Work with trade associations and ports and through existing government programs and channels to provide additional education to commercial and recreational boaters.

Implementation details:

Establish a $10 endorsement on boater registration statewide to increase awareness and fund education and enforcement activities that promote recreational vessels' compliance with best boating practices near orcas. Boaters will be able to opt out of this fee. The DOL should also note Southern Resident orca regulations and guidelines on its website.

The governor should request that the Washington State Parks and Recreation Commission, Northwest Marine Trade Association and Recreational Boating Association of Washington work with the U.S. Coast Guard and National Association of State Boating Law Administrators to require the print and online curricula, testing and outreach for the mandatory Washington State Boater Education Card: (1) include Be Whale Wise guidelines, (2) include related updates to voluntary and regulatory measures by May 2019 and (3) include broader outreach to charter boat, boat rental companies and exempted audiences from outside Washington state (particularly in Canada) and those whose lifetime certification was obtained prior to the updated standards. Look at how to leverage Enhancing Cetacean Habitat and Observation Program's new online mariners training. Tribal governments will make their own decisions.

Recommendation 20: Increase enforcement capacity and fully enforce regulations on small vessels to provide protection to Southern Residents.

- Create a WDFW Marine Enforcement Division with four additional officer positions at WDFW focused on protection and enforcement in Puget Sound.

Implementation details:

In the 2019 legislative session, the Washington State Legislature and governor should provide proviso funding to WDFW to create at least four new fish and wildlife officer positions that will be dedicated to the goal of providing marine-based Southern Resident orca protection on every day of the whale-watching season and at other times of need. The proposed fish and wildlife officers will be based in northern Puget Sound in summer and be prepared to shift coverage southward to match the seasonal movements of Southern Residents to central Puget Sound. They will be strictly focused on protection of all marine resources when not engaged in priority Southern Resident orca protection activities (such as promoting compliance with chapter 77.15.740 RCW and any new regulations). To complement their priority Southern Resident orca protection activities on water, one or more of them will concentrate on enforcement of penalties for egregious noncompliance with regulations and develop strategies for the public to contribute photographic and video evidence of violations WDFW can pursue. Funding should be provided to WDFW to purchase an additional vessel and equipment, cover operations and maintenance and hire additional officers.

Reduce noise from the use of echo sounders near orcas

Recommendation 21: Discourage the use of echo sounders and underwater transducers within one kilometer of orcas.

- Establish a “standard of care” for small vessel operators limiting the use of echo sounders and other underwater transducers within a half nautical mile of Southern Resident orcas. Implement as a voluntary measure and provide exceptions for safe navigation.
- Conduct education and outreach.
- Consider phasing in mandatory equipment requirements and regulations.

Implementation details:

By December 2018, the Puget Sound Harbor Safety Committee should develop a “standard of care” for small vessel operators to turn off echo sounders and other underwater transducers when within a half nautical mile of orcas except when necessary for safe navigation. The adopted standard should be reported to the task force and communicated to registered vessel owners in Puget Sound counties through the Washington State Department of Licensing. The Southern Resident Orca Task Force Interagency Communicators Group should work immediately with maritime organizations with broad communications networks — such as the Northwest Marine Trade Association, Recreational Boating Association of Washington, U.S. Coast Guard Auxiliary and Boating Squadron, Washington State Ferries, State Parks, ports, marinas, Be Whale Wise.org — to develop and implement a complementary outreach campaign for voluntary compliance. In 2019, the task force should consult with the Legislature about opportunities to phase in mandatory equipment requirements (for whale-watching vessels in the recommended limited entry permit system, for example) and initiate a formal conversation with echo sounder manufacturers and suppliers.

Reduce noise from ships and ferries near Southern Resident orcas

Recommendation 22: Implement shipping noise-reduction initiatives and monitoring programs, coordinating with Canadian and U.S. authorities.

- Create a program similar to Enhancing Cetacean Habitat and Observation for Washington state, including participation by ports, whale watching operators, private vessel operators and Tribal governments as desired.
- Coordinate with the ECHO Program on transboundary efforts to reduce noise impacts to Southern Residents. Provide funding to complete an underwater acoustic monitoring network for Puget Sound, filling in gaps — such as on South San Juan Island — and supporting acoustic and visual mapping to improve the ability to identify when and where Southern Resident orcas are present.

Implementation details:

The governor should continue to encourage strategic U.S. and Washington state collaborations with ECHO — from the U.S. Coast Guard, Washington State Ferries, Puget Sound ports, the Pacific Merchants Shipping Association, the Puget Sound Pilots, OrcaSound, Tribal co-managers and others — that continue to support parallel and adaptive implementation of ECHO and related shipping noise-reduction initiatives while promoting safe, sustainable shipping practices.

Work with the Washington Public Ports Association to create a program similar to ECHO for Washington state. Gov. Inslee and the Legislature should fund the deployment of a permanent scientific grade hydrophone on South San Juan Island and fill in other key gaps in the underwater acoustic monitoring network of Puget Sound. Gov. Inslee and the Legislature should also support advancement of acoustic and visual mapping efforts by WSF and others, with the goal to share Washington data with the Southern Resident Killer Whale Report Alert System being developed in Canada by ECHO and the Vancouver Aquarium.

Recommendation 23: Reduce noise from the Washington state ferries by accelerating the transition to quieter and more fuel-efficient vessels and implementing other strategies to reduce ferry noise when Southern Residents are present.

- Conduct a ferry fleet noise baseline study as the basis for establishing noise reduction goals and developing plans.
- Based on the results of the baseline study, institute engineered or operational strategies to safely reduce noise from ferries when Southern Residents are present.
- Provide capital funding to accelerate the transition to quieter and more fuel-efficient ferry fleet.

Implementation details:

The governor and Legislature should support and accelerate transition of the WSF fleet to quieter, more fuel-efficient designs and technologies — while funding WSF's fleet noise baseline analysis project in 2019 — to achieve data-driven noise reduction goals.

WSF should institute engineered or operational strategies to safely reduce noise in the vicinity of the Southern Residents.

Increase protection of Southern Residents from the risk of a catastrophic oil spill

Recommendation 24: Reduce the threat of oil spills in Puget Sound to the survival of Southern Residents.

- Initiate zone-based rule making on tug escort requirements for oil laden tank vessels, including barges, more than 5,000 tons but less than 40,000 dead weight tons.
- Enact legislation disallowing any shoreline or seafloor infrastructure that would support offshore oil and gas development off the Washington coast.
- Update oil spill prevention and cleanup standards to address new types of oil and increased use of articulated tug-barges.
- Support the requirement for a stationed emergency response towing vessel (rescue tug) in a location to minimize response time in Haro Strait and other navigation lanes with the highest tank vessel traffic.

Implementation details:

Utilizing recommendations from the Department of Ecology's Strait of Juan de Fuca and Puget Sound Vessel Traffic Safety Report (2018), the 2019 Washington State Legislature should enact legislation to reduce the risk of oil spills in Puget Sound. The legislation should: (1) initiate zone-based rule making on tug escort requirements for oil laden tank vessels, including barges, more than 5,000 tons but less than 40,000 dead weight tons, including oil barges and articulated tug-barges, (2) support the requirement for a stationed emergency response towing vessel (rescue tug) in a location to minimize response time in Haro Strait and other navigation lanes with the highest tank vessel traffic and (3) require updated oil spill prevention and cleanup standards to address new types of oil (for example, diluted bitumen) and increased shipments by articulated tug-barges. The governor should meet with Canadian officials and seek involvement from the U.S, Coast Guard and the joint meetings of the Puget Sound Harbor Safety Committee and Canadian Pacific Coast Marine Advisory Review Panel and Navigation Aids and Navigation Services. The governor should direct Ecology and Washington Department of Fish and Wildlife to engage in Canadian environmental assessments of project-related shipping's cumulative effects on Southern Resident orcas (such as Roberts Bank Terminal 2).

Formalize or extend vessel protections for Southern Resident orcas

Recommendation 25: Coordinate with the Navy in 2019 to discuss reduction of noise and disturbance affecting Southern Resident orcas from military exercises and Navy aircraft.

- The U.S. Navy was not among the organizations that were initially asked to participate in the vessels working group during Year One. However, early in the task force process several task force members and the full vessels working group indicated the need for direct engagement with the Navy in Year Two, which was reinforced in hundreds of public comments on the draft report.

Implementation details:

The governor should meet with the U.S. Navy's Commanding Officer for the region that includes Washington state to address the acoustic and physical impacts to Southern Resident orcas from Naval exercises in waters and air of Washington state. The governor should request the Navy participate on the vessels working group in Year Two and identify actions to reduce the Navy's impacts to Southern Resident orcas.

Recommendation 26: Revise chapter 77.15.740 RCW to increase the buffer to 400 yards behind the orcas.

- The guidelines of the Pacific Whale Watch Association include this voluntary standard.
- By limiting the distance at which vessels can approach from behind (and their speed), the intent is to decrease the occurrence of chase-like situations that may adversely affect Southern Resident orcas.

- Encourage coordination among Washington state, federal and Canadian authorities to align regulations, which will foster clear communication and increase compliance.

Recommendation 27: Determine how permit applications in Washington state that could increase traffic and vessel impacts could be required to explicitly address potential impacts to orcas.

- State agencies should study potential requirements for relevant permit applications to explicitly address potential impacts to Southern Resident orcas and treat underwater noise as a "primary constituent element" of critical habitat and report to the task force by 2019.
- Coordinate with local governments and tribes and increase transboundary coordination with Canada.

Implementation details:

The governor should direct Ecology and request that DNR and WDFW work with the Governor's Office for Regulatory Innovation and Assistance to determine how applicable current and future permit applications in Washington state that could increase vessel traffic and vessel impacts (risk of oil spills, increased noise, threat of ship strikes) could be required to explicitly address potential impacts to Southern Resident orcas and treat underwater noise as a "primary constituent element" of critical habitat. This work must coordinate with local governments, tribes and others to identify authorities to issue permits, authorizations or mitigation measures related to any projects, and must increase transboundary coordination to address impacts from projects initiating in Canada (such as Roberts Bank Terminal 2). The agencies should report to the task force by April 2019.

Potential avenues for adding these requirements include:

- Updating the State Environmental Protection Act checklist.
- Updating the Joint Aquatic Resources Permit Application form.
- Updating the Prevention of Significant Deterioration Permit to Construct to specifically include potential vessel traffic impacts to Southern Resident orcas.
- Updating state regulations and Ecology's Shoreline Master Program Handbook to address vessel traffic impacts and require Southern Resident orca expertise for all state application submittals.

Recommendation 28: Suspend viewing of Southern Resident orcas

- Establish a whale watching regulation that precludes Southern Resident orca viewing by all boats in Puget Sound for the next three to five years. The governor should direct WDFW to begin rulemaking to define Washington whale watching in coordination with the commercial whale watching industry, kayak industry, local governments and interested nongovernment organizations.

- Report back to governor and Legislature after three to five years on the effectiveness of the suspension.

Goal 3: Reduce the exposure of Southern Resident orcas and their prey to contaminants

Prevent further use and release of toxics that could harm orcas and their prey

Recommendation 29: Accelerate the implementation of the ban on polychlorinated biphenyls in state-purchased products and make information available online for other purchasers.

- Direct the Department of Enterprise Services to accelerate implementation of the ban, enacted by the Legislature in 2014, on PCBs in products purchased by the state.
- This law includes a provision for suppliers to provide information on PCBs in products to the state, which should be shared publicly to facilitate PCB-free purchasing by other entities.

Implementation details:

The Department of Enterprise Services should immediately accelerate implementation of the ban on PCBs in state-purchased products and make information about PCB levels in state-purchased products and packaging available online to the public so other purchasers can access this information and make informed purchasing decisions.

Washington state adopted a procurement law in 2014 that states: “no agency may knowingly purchase products or products in packaging containing polychlorinated biphenyls above the practical quantification limit except when it is not cost-effective or technically feasible to do so” (chapter 39.26.280 RCW). Implementation of this law should be accelerated to reduce PCBs entering Puget Sound from products such as paints, hatchery fish feed, adhesives, electrical equipment, caulking, paper products and lubricants. Product suppliers to the state will provide information about PCBs in their products and this information can be shared with other purchasers that want to avoid products containing PCBs.

Recommendation 30: Identify, prioritize and take action on chemicals that impact orcas and their prey.

- By March 2019, the Department of Ecology should develop a prioritized list of chemicals of emerging concern that threaten the health of orcas and their prey and pursue policy and/or budget requests in the 2019 legislative session to prevent the use and release of chemicals of emerging concern7 into Puget Sound.
- Direct Ecology to convene discussions and develop a plan to address pharmaceuticals, identifying priorities, source control and wastewater treatment methods.
- Periodically review and update toxicological information as new science emerges and adaptively manage plans and programs.

Implementation details:

Ecology should develop a prioritized list of the chemicals of emerging concern based on greatest benefit to Southern Resident orcas and their prey if action is taken. Ecology, with input and review from regional experts, including Washington Department of Fish and Wildlife and National Oceanic and Atmospheric Administration, should begin this prioritization process in 2018 and complete the list in March 2019.

It is important to note toxicological information is limited on many chemicals of emerging concern. This list will need to be periodically revisited to ensure new chemicals and new research findings are incorporated into our efforts to decrease chemical exposure to Southern Residents and their prey.

Ecology should develop a plan and pursue agency request legislation and/or budget requests in the 2019 legislative session to address control of those chemicals of emerging concern based on greatest benefit to Southern Resident orcas and their prey if action is taken (informed by the prioritized list). This legislative request should include funding to implement existing policies as well as identify new policies and actions to decrease the load of priority chemicals of emerging concern to Puget Sound (for example, phaseouts, disclosure, assessment of safer alternatives and enhanced treatment). Given pharmaceuticals require a different control mechanism, Ecology should convene discussions about priority pharmaceuticals, source control and wastewater treatment options. The plan will identify the most effective actions to decrease loading of priority chemicals of emerging concern to Puget Sound and will be completed by 2025.

[7] The following groups of chemicals were identified as potentially important (in no particular order): flame retardants, per- and polyfluoroalkyl substances, phthalates, bisphenols, nonylphenols, medications, pesticides and chemical(s) in tires.

Recommendation 37: Protect against regulatory rollbacks at the federal and state level.

Implementation details:

The regulations that protect Southern Residents from contaminant threats are a mixture of state and federal laws and implementation. Historically, the relationship between state and federal regulators has been characterized by cooperative federalism and delegated authority. This historical precedent is being challenged through federal regulatory rollbacks to the Clean Water Act (including water quality standards and the definition of Waters of the U.S.), Endangered Species Act and other foundational laws. Given the current federal regulatory environment, the Governor and state agencies should ensure that state authority, rules and regulatory protections are sufficient to prevent moving backwards. The state should maintain and strengthen state authority, rules and regulatory protections.

Accelerate removal and clean-up of legacy sources of toxics harmful to orcas and their prey

Recommendation 31: Reduce stormwater threats and accelerate clean-up of toxics harmful to orcas.

- Provide funding to accelerate the clean-up and removal of legacy sources of polychlorinated biphenyls or PCBs, polycyclic aromatic hydrocarbons or PAHs, polybrominated diphenyl ether or PBDEs and per and polyfluoroalkyl substances present in Puget Sound.
- Prioritize and fund clean-up actions likely to have the greatest benefit to Southern Resident orcas.
- Identify toxic hotspots in the stormwater entering Puget Sound. Prioritize these for retrofits and/or redevelopment to meet current standards.
- Increase funding for the Stormwater Financial Assistance Program to incentivize immediate and accelerated retrofits and other source control actions.
- Prioritize and accelerate sediment remediation, nearshore restoration and clean-up of hotspots in forage fish and Chinook rearing habitats based on risk to Southern Resident orcas.

Implementation details:

The Legislature should fund the Department of Ecology in 2019 for a program that incentivizes the accelerated removal of primary legacy sources of PCBs, PAHs, PBDEs and per and polyfluoroalkyl substances present in the built environment in the central Puget Sound. In Phase I, Ecology should develop the program, to include: (1) prioritizing those legacy chemicals likely to have greatest impact on Southern Resident orcas, (2) coordinating with ongoing programs, (3) gathering stakeholder input and (4) undertaking targeted communications and outreach. In Phase II, the incentive program will be implemented.

Ecology should reduce stormwater threats in existing hotspots as soon as possible. In 2018-19, Ecology, in consultation with regional experts, should identify toxic stormwater hotspots and prioritize them for source control, stormwater retrofits and/or redevelopment projects to meet today's standards. Ecology should seek new funding in the 2019 Legislature through the Stormwater Financial Assistance Program to incentivize stormwater retrofits and source control to achieve goals faster. Programs such as the Stormwater Financial Assistance Program, retrofits through the Washington State Department of Transportation and federal funding through the Clean Water State Revolving Fund are in place to support this effort but they need substantially increased funding to increase the pace and provide the necessary pollutant removal.

Ecology and the Washington State Department of Natural Resources should immediately prioritize and accelerate sediment remediation and nearshore restoration and clean-up of hotspots in forage fish and juvenile Chinook rearing habitat in sensitive areas where toxics are known to impact prey survival. All prioritized cleanup actions should ensure "upstream" source control is also addressed. During the prioritization process, Ecology should coordinate with other agencies such as the Washington Department of Fish and Wildlife, Puget Sound Partnership and the National Oceanic Atmospheric Administration. Previously identified hotspots include the Duwamish Estuary and river, Commencement Bay, Hanford Reach, Sinclair and Dyes Inlets and Lake Union.

Improve pollution permitting and management to reduce contaminant exposure of orcas and their prey

Recommendation 32: Improve effectiveness, implementation and enforcement of National Pollutant Discharge Elimination System permits to address direct threats to Southern Resident orcas and their prey.

- Update aquatic life water quality standards focused on pollutants most harmful to Southern Residents and their prey.
- Direct the Department of Ecology to consider developing stronger pre-treatment standards for municipal and industrial wastewater discharges under NPDES.
- Provide funding for Ecology to increase inspections, assistance programs and enforcement to achieve water quality standards. Prioritize enforcement where limits are exceeded for pollutants known to be harmful to Southern Resident orcas.

Implementation details:

Ecology should report in 2019 on how to accelerate effectiveness, implementation and enforcement of NPDES permits. Using the existing regulatory framework and authority under the Clean Water Act and Water Pollution Control Act, Ecology should update aquatic life water quality standards focused on pollutants most harmful to Southern Resident orcas and their prey. To fill gaps, this will focus primarily on PBDEs, contaminants of emerging concern[8] and other chemicals based on greatest benefit to Southern Resident orcas and their prey. In addition, Ecology should consider developing stronger pre-treatment standards for municipal and industrial wastewater dischargers under NPDES.

Improved permit requirements would also result in increased innovation and source control for permitted dischargers and drive improved technology requirements under the existing "best available technology" standard. For municipal wastewater facilities this would combine improved industrial pretreatment and deployment of improved treatment technologies with already planned or required upgrades to wastewater treatment facilities. New standards could be implemented through renewals of the five-year NPDES permit cycle and could allow permittees the necessary time to fully implement solutions (ideally within one permit cycle).

To ensure new and existing NPDES permit conditions and water quality standards are met, Ecology should seek funding in the 2019 legislative session to conduct more robust inspections, assistance programs and enforcement. This funding should support field staff and data analysis and should include a clear directive to increase enforcement against entities that exceed limits for pollutants known to cause harm to the Southern Resident orcas and their prey.

Recommendation 33: Increase monitoring of toxic substances in marine waters; create and deploy adaptive management strategies to reduce threats to orcas and their prey.

- Expand and better coordinate existing toxic monitoring programs in Puget Sound focused on chemicals harmful to the Southern Resident orcas.
- Fund the development and implementation of a program to study and monitor the impact of CECs on Southern Resident orcas.

Implementation details:

The Legislature should fund Ecology, the Washington Department of Fish and Wildlife and the Puget Sound Ecosystem Monitoring Program managed by PSP, to expand and coordinate existing monitoring and new science programs in 2019. Funding is needed immediately to develop and support a robust toxic monitoring program as well as to conduct new science to

---

[8] The following groups of chemicals were identified as potentially important (in no particular order): flame retardants, per- and polyfluoroalkyl substances, phthalates, bisphenols, nonylphenols, medications, pesticides and chemical(s) in tires.

understand the effects of CEC exposure on Southern Resident orcas, their prey and other species in the lower trophic levels. This funding is critical to gain a more comprehensive understanding of CECs; to collect data to address critical uncertainties; to evaluate the impact of CECs on Southern Resident orcas to prioritize cleanups, phase outs and bans; to document whether the actions taken are effective; and to make changes to implemented actions/strategies if the data demonstrates no impact.

The task force requested that in Year Two, the contaminants working group look at issues associated with nutrient loading and water quality, as well as available ongoing work that is examining links between specific contaminants and health and reproductive challenges for the orcas.

Recommendation 38: Explore setting minimum standards for local stormwater funding to ensure that all programs have the resources necessary to protect water quality.

Implementation details:

A primary barrier to effectively managing stormwater is local government capacity to implement stormwater management programs. With too little staff capacity or limited capital funding, it is unlikely that jurisdictions will be capable of innovating, or even implementing requirements expected to be more stringent in the future. In many cases, local governments with the best, most intact natural resources often have the least capacity protect them.

Local government spending on stormwater programs varies from jurisdiction to jurisdiction, leaving some programs without adequate funding. Additionally, it can be problematic when stormwater funding is forced to compete with other “general fund” priorities. We should seek to better understand the varying funding streams, relative funding rates, and what can reasonably constitute adequate funding for different jurisdictions.

It would be beneficial for existing county and city organizations or workgroups to convene a meeting of jurisdictions in the Puget Sound region to identify what funding levels would be adequate to meet the need to control stormwater, explore funding alternatives, and discuss how to establish a “floor” for minimum investments. The Washington State Department of Commerce and Washington State Department of Ecology should participate in those discussions. With a better understanding, the state should explore legislation to set minimum standards for local stormwater funding, ensuring that all programs have the resources necessary to protect water quality.

Reduce human sources of nutrients in Puget Sound

Recommendation 39: Develop a National Pollutant Discharge Elimination System permit framework for advanced wastewater treatment in Puget Sound to reduce nutrients in wastewater discharges to Puget Sound by 2022.

Implementation details:

Discharges from wastewater treatment plants represent more than 50% of the human sources of nutrients into Puget Sound and contribute significantly to low dissolved oxygen levels. Ecology proposes developing a Puget Sound Nutrients General Permit to control nutrient discharges from domestic wastewater treatment plants (sewage treatment plants) through its National Pollutant Discharge Elimination System regulatory authority. The alternative to a general permit is to include nutrient control requirements in each wastewater treatment plant's individual permits, one by one, as they are reissued over the next five to 10 years.

Recommendation 40: Better align existing nonpoint programs with nutrient reduction activities and explore new ways to achieve the necessary nonpoint source nutrient reductions.

Implementation details:

Ecology should establish minimum requirements for nonpoint source best management practices to ensure they meet water quality standards. Existing nonpoint source programs can be expanded to address known problems related to nutrient runoff from agricultural, suburban/urban and rural land use activities. Many of these nonpoint source implementation actions have multiple benefits for water quality improvement, including nutrient reduction.

Recommendation 41: Collect high-quality nutrient data in watersheds to fill key knowledge gaps of baseline conditions.

Implementation details:

Making science-based nutrient management decisions depends on having the right tools and high-quality data. The Salish Sea Model is our best tool for understanding the marine waters of Puget Sound and evaluating the best suite of nutrient load reductions necessary to achieve water quality standards. Ecology should augment key watershed monitoring stations with continuous nutrient monitoring technology to improve our understanding of watershed nutrient loads and establish baseline conditions to measure future change.

Goal 4: Ensure funding, information and accountability mechanisms are in place to support effective implementation

Provide sustainable funding

Recommendation 34: Provide sustainable funding for implementation of all recommendations.

- Provide immediate capital and operating funds in the 2019-21 biennium budget to implement near-term high-priority actions.
- Request that the governor and Legislature establish a sustainable, durable funding source to implement these recommendations and meet needs as they arise.
- Include funding to state agencies for staffing, research and ongoing management needed to initiate and implement task force recommendations.

Conduct research, science and monitoring to enable adaptive management

Recommendation 35: Conduct research, science and monitoring to inform decision making, adaptive management and implementation of actions to recover Southern Residents.

- Request that National Oceanic and Atmospheric Administration Northwest Fisheries Science Center model the task force's Year One recommendations related to the three major threats to determine the degree of benefit to Southern Resident orcas that the recommended actions may produce under a reasonable range of future growth and development scenarios.
- Request that the zooplankton monitoring team engage with the Puget Sound Ecosystem Monitoring Program and the Department of Ecology to look at impacts associated with nutrient pollution.
- Request that the Regional Response Team and the Northwest Area Committee assess the connections to and impacts of oil spills on plankton.
- It will be important to use an adaptive management approach to track effectiveness of implemented recommendations, look for unintended consequences, monitor ongoing ecosystem change and adjust future investments based on our findings.

Track progress and address gaps in Year Two

Recommendation 36: Monitor progress of implementation and identify needed enhancements.

- Agencies shall report to the governor and the task force on progress implementing recommendations by May 1, 2019. These reports are to address progress, shortcomings, issues, barriers and gaps associated with initial implementation.
- The task force will identify changes needed, any new ideas and other actions needed to recover Southern Resident orcas.

Continuing the mission of Southern Resident orca recovery

Recommendation 42: Create one or more entities with authority and funding to recover and advocate for Southern Resident orcas by implementing task force recommendations, creating new recommendations as needed and reporting to the public, governor and tribal co-managers on status.

- Any oversight group must incorporate the following elements:
  - Is co-managed by the Governor's Office and tribes.
  - Coordinates with federal agencies in both the United States and Canada to stay connected to ongoing policies around species recovery.
  - Aligns with governor's priority on diversity, equity and inclusion and environmental justice.
  - Maintains some element of the working group structure and provides ongoing support and facilitation of working groups by state agencies.
  - Continues engagement from nonprofits, businesses and other stakeholders to monitor implementation of existing recommendations, consider new recommendations and recommend course corrections for continued recovery.
  - Maintains and enhances public visibility and interest in this crisis and facilitates a robust public engagement process.
  - Builds on ongoing monitoring and reporting to maintain accountability to the public.
  - Maximizes institutional durability, at least until the population reaches 84 whales by 2028.[9]

[9] In its 2018 report, the task force set forth the goal of increasing the Southern Resident population to 84 whales by 2028, or "10 more whales in 10 years."

Implementation Details

The task force has identified three general options (not listed in priority order) for moving this recommendation forward. By selecting one of the following options, the state can better ensure that between now and 2022, we witness evidence of consistently well-nourished whales, more live births and the survival of several thriving young orcas. With adequate consistency and attention, by 2028, we could see the primary indicator of body condition of the whales (the ratio of head width to body length in adults) remain high and stable between seasons and across years and finally see their population increase to 84 whales — an increase of 10 whales in 10 years. Options are summarized below:

- **Option 1: Expand existing agency capacity.** Expand the capacity and function of the Governor's Salmon Recovery Office to include orca recovery (e.g., Governor's Salmon and Orca Recovery Office). This option leverages existing agency infrastructure and is modeled after the Salmon Recovery Funding Board, with policy coordination and administration functions within the proposed Governor's Salmon and Orca Recovery Office and a policy board that includes governor-appointed members and agency heads.
- **Option 2: Create a new executive level team in Governor's Office.** Create an executive-level salmon and orca leadership team in the Governor's Office. This option includes explicit tribal co-manager engagement by the Governor's Office. This option houses the main functions of the policy leadership team within the Governor's Office and maintains an executive-level focus on recovery.
- **Option 3: Create a new orca recovery office.** Create an orca recovery office led by technical experts. This option creates a new office that is staffed to implement actions. This office can be located within the Governor's Office or within an existing agency. The key element of this option is that it is not a stakeholder-led process.

The task force also recommends incorporating PSP's recovery system into any of these options, as appropriate. PSP is well positioned to contribute to vessels recommendations, coordinate with Canadian representatives and actions, support scientific monitoring, advise on communications and track progress. Likewise, Salmon Recovery Councils on the Columbia River and Washington Coast could be useful partners.

Appendix 5 provides additional implementation details on the three options summarized above for the Governor's Office to consider. The task force has laid a foundation for Southern Resident recovery; strong governance will be necessary to build on this foundation with immediate, sustained and meaningful action.

Goal 5: Reduce the threat from climate change, including ocean acidification, to Southern Residents, the region's biodiversity, and ultimately, the well-being of Washington's people and economy

Reduce human-caused greenhouse gas emissions

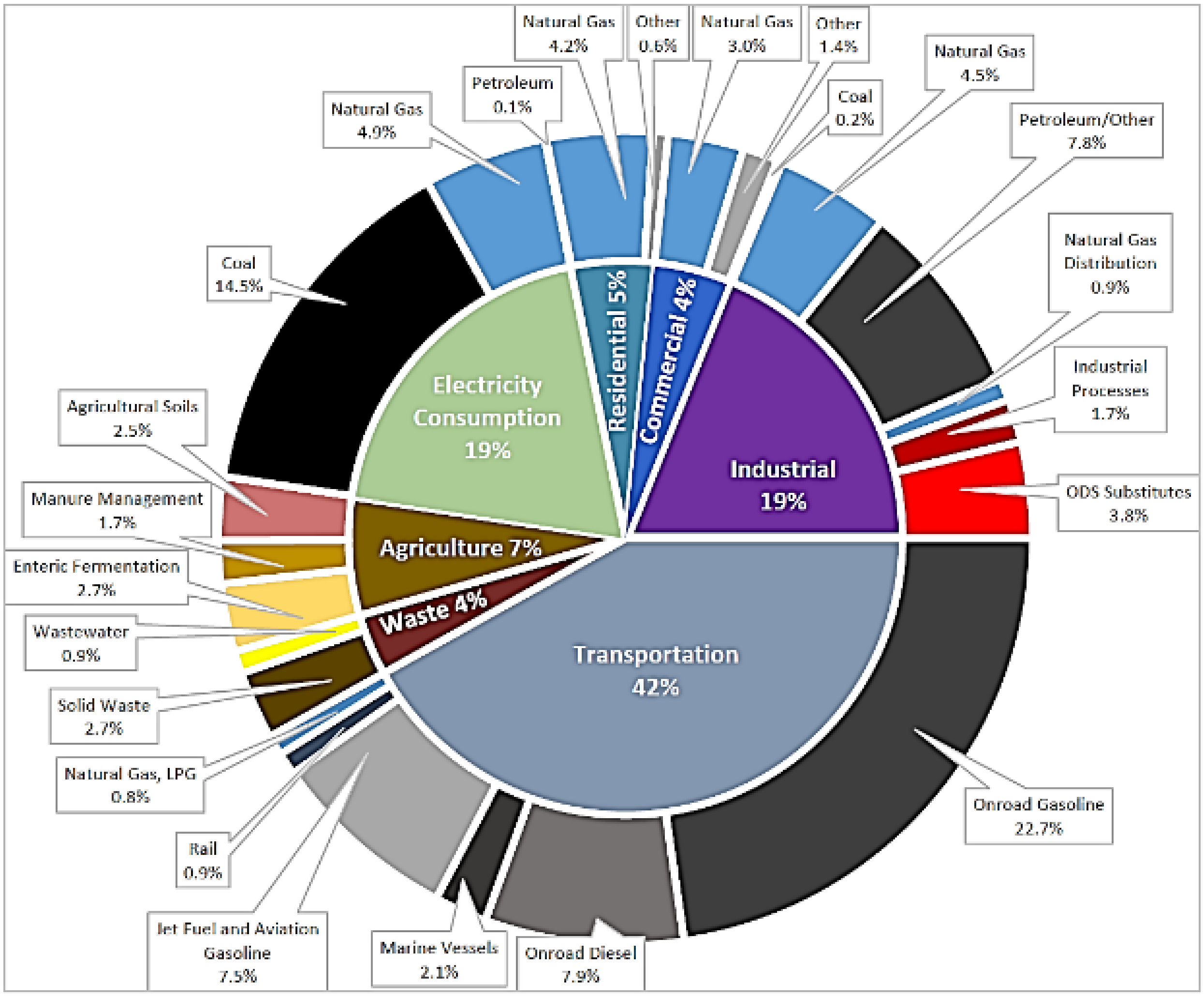
Recommendation 43: Take aggressive, comprehensive and sustained action to reduce human-caused greenhouse gas emissions, with the goal of achieving net zero emissions by 2050.

- At the individual, organizational and community levels and across the public, private and not-for-profit sectors, take immediate action to reduce greenhouse gas emissions.
- Build on existing policies and initiatives and advance policies at the state and local government levels to increase investments, regulatory frameworks and incentives that lead to a systematic and sustained reduction in emissions over the next 30 years.
- Monitor emissions reductions over time; take additional actions consistent with the goal of limiting planetary warming to 1.5-2°C.
- At the state level, provide leadership to reduce emissions in government operations and engage collectively with other states, the private sector and civil society to advance national and international solutions to reduce emissions.
- Inform and engage the public, stakeholders and decision makers on the connection between orcas, salmon, climate change and human well-being.
- Address equity issues associated with reducing human-caused emissions and transforming to a net zero carbon economy — by engaging and meeting the needs of disproportionately affected communities and workers, businesses and economic sectors that are adversely affected by the transition to low- or zero-carbon energy sources.

Implementation Details

With a focus on a vision of a thriving Southern Resident population, the task force supports immediate, aggressive and sustained action to reduce greenhouse gas emissions locally, regionally and globally. Actions can occur at all levels and be undertaken by individuals, organizations and governments across the public and private sectors and civil society. While it is beyond the task force's expertise to define specific policies and actions to reduce emissions, the science is clear that planetary warming must be stabilized at 1.5-2°C above preindustrial levels to limit the consequences of climate change [18, 42]. Most of the greenhouse gas emissions in Washington state are from transportation, electricity generation and residential, industrial, commercial and agricultural activities (**Figure 6**).

Figure 6. Washington greenhouse gas emissions, three-year average (2013–15) [43].



A sampling of actions that can be taken in Washington to reduce emissions are summarized in **Table 7** below. Although it does not endorse any specific activities or policies, the task force urges all members of the Washington community to examine their own contribution to the problem and both directly take, and advocate for, forceful action and policies to reduce emissions.

Table 7. Individual, organizational, and community action: methods for reducing carbon footprint [44, 45, 46].

Activity	Ways to reduce emissions
Transportation	• Walk, bike, bus, or use rail instead of driving • Use electric vehicles and vessels • Telecommute/teleconference • Carpool • Switch to low-carbon fuels (e.g. biodiesel)
Building heating and cooling	• Maximize use of efficient carbon-free energy (e.g., heat pumps) • Source clean, carbon-free electricity (e.g., wind, solar) • Reduce food waste • Reduce consumption of carbon-intensive food sources (e.g., meat)
Food consumption and waste	• Reduce overall consumption • Maximize reuse and recycling
Industrial	• Electrify energy sources • Maximize efficiency • Source lower carbon inputs
Agriculture and forestry	• Practice no-till agriculture and regenerative farming techniques • Improve soil health for carbon sequestration • Improve forest health to increase carbon sequestration and reduce emissions from wildland fires • Protect and restore seagrasses and other elements of coastal habitats for carbon sequestration and resilience

The Legislature — together with other local and regional governments and agencies — must continue to advance and adopt policies, investments, incentives and regulatory frameworks that can catalyze dramatic reduction in emissions generated in Washington over the next 30 years. In addition to individual actions, a policy framework and investment is needed to restructure the economy, ensure equity, address dislocations to workers and businesses and accelerate the transition to a low-carbon future. In 2018, the Washington State Legislature passed significant policies, such as SB 5116, the 100% Clean Electricity Bill, that will lead to clean energy investments and emission reductions over time. More action, however, is needed to establish policies and frameworks to: (1) reduce emissions in the transportation, building, commercial and industrial sectors, (2) encourage sequestration and emissions reduction in the agricultural and forestry sectors and in other terrestrial and coastal habitats and (3) incentivize innovations that will achieve deep de-carbonization over the longer term.

Table 8 presents an overview of alternative policy options, categorized into four broad types and linked to the major sources of emissions depicted in **Figure 6**.

Table 8. Government actions: Carbon emission reduction policy, regulatory and budget options [47].

Policy Type	Examples	Emissions & Sectors targeted
Performance standards – minimum requirements for energy efficiency, renewable energy uptake, or product performance	• Vehicle fuel economy standards • Low carbon fuel standard • Building codes for energy efficiency, fuel source, other carbon requirements • Renewable portfolio standards • Power plant emission limits	Transportation, residential and commercial, electricity
Economic signals – pricing designed to accelerate the adoption of low-carbon technologies and incorporate externalities into product costs	• Carbon fees or taxes • Cap & Trade • Subsidies, e.g. for clean energy production or efficiency upgrades	Transportation, residential and commercial, electricity, marine
Support for R&D – funding and incentives to accelerate innovation and create an enabling environment for innovation to thrive	• Funding for basic research • Shared technical expertise • Adopting intellectual property protections • Promoting STEM • Attracting STEM talent	Multiple – depending on the focus of efforts
Enabling Policies – those that enhance the functionality of the other policies	• Direct government expenditures • Information transparency • Reduction of barriers to better choices, e.g. energy use labels, good urban design providing transit options enabling a response to price signals such as a carbon tax	Multiple – depending on the focus of efforts

While broad consensus exists in Washington on the need for action to reduce emissions, each of the policy options has advantages and disadvantages in terms of efficacy, cost, equity and who is most impacted. They are supported, or opposed, to varying degrees by different constituencies, sectors and organizations. Experts have concluded that no single "silver bullet" policy will be the solution, but rather, a suite of complementary policies is necessary [47]. In this context, possible state actions include developing a comprehensive plan to achieve reductions across all major sectors of economy, prioritizing near-term actions that address the largest source of emissions (i.e., transportation) and having the Legislature create legal accountability to achieve the associated targets.

To benefit Southern Residents, actions that both reduce emissions and improve resiliency warrant priority consideration. Actions include investments in forest health, riparian and habitat restoration and agricultural practices that both sequester carbon and reduce runoff. In addition, many regulations and policies that serve to reduce emissions will also improve the health and well-being of the Salish Sea and its inhabitants including the orca, and vice versa. Education about the co-benefits of strong climate action may help build support for the policies and actions needed to address the problem at scale.

Within state and local government, actions that provide leadership in reducing emissions and have a nexus with the Southern Resident include Executive Order 18-01, which directs the WA State Ferries to move to a zero-emissions fleet. The task force endorses full and accelerated implementation of this Executive Order, while also addressing the associated noise issues that affect the orca. Other actions the state could take directly to reduce emissions include electrifying its vehicle fleets and providing support for local governments and school districts to electrify their fleets. Such leadership will help accelerate the transformation of the transportation sector from gas and diesel to electric-powered vehicles.

In addition to state and local action, Washington state should continue to work collectively with other states, the private sector and civil society to advance national and international solutions to reduce emissions to scientifically determined safe levels. State-level action is not enough. Washington state officials and leading Washington-based businesses and organizations must join together to advocate for and advance policies at the regional, national and international levels.

The successor to the task force should maintain a focus on the impact of climate change and ocean acidification on orcas and support the leadership of the governor, Legislature and state agencies to advance policies and solutions that reduce emissions. Support could include providing science-based information on the link between climate change and orca health, advocating for policy action to reduce emissions and educating the public about why reducing emissions is imperative to the survival of the orca.

Reduce, remediate, and adapt to ocean acidification

Recommendation 44: Increase Washington's ability to understand, reduce, remediate and adapt to the consequences of ocean acidification.

- Reduce local land-based contributions to ocean acidification. Reducing inputs of nutrients and organic carbon from local sources will decrease acidity in affected marine waters, decreasing the effects of ocean acidification on marine species in the area.
- Reduce Washington's carbon dioxide emissions quickly and aggressively. Reducing carbon dioxide emissions will decrease future acidification and help protect marine species (see Recommendation 3).
- Implement measures to adapt to, and remediate the impact of, ocean acidification.

- Continue to invest in Washington's ability to monitor ocean acidification and its effects. This investment will enable effective responses to ocean acidification.
- Inform, educate and engage stakeholders, decision makers and the public in addressing ocean acidification. Engagement and dialogue is essential to build support for investment in, and implementation of, effective actions.
- Maintain a sustainable and coordinated focus on ocean acidification.

Implementation Details

Washington was an early leader addressing ocean acidification and, in 2012, became the first state to develop a comprehensive plan for tackling ocean acidification through the Marine Resources Advisory Council. Since its inception, MRAC has provided a sustainable and coordinated focus on implementing the actions in the state's plan and updated it in 2017. The task force supports continued implementation of actions in the state's Ocean Acidification Action Plan and MRAC's recommended priorities, including:

- **Reducing local carbon dioxide emissions more aggressively**. Current projections indicate sharp declines in pH in Puget Sound over the next 30 years if we do not reverse course. Our local emissions contribute to local acidification and, therefore, must be part of the solutions advanced.
- **Accelerating actions that reduce human sources of nutrients**. Local human sources of nutrients are contributing significantly to ocean acidification, causing low dissolved oxygen levels and threatening marine life, particularly in parts of Puget Sound. Nutrients come from many sources, including wastewater treatment facilities, so reducing these discharges into Puget Sound is a priority. Management and policy actions that reduce nutrients from wastewater treatment plants, septic systems and other land-based sources will improve marine water quality for marine species. The Department of Ecology's Puget Sound Nutrient Reduction Project is evaluating and advancing such actions, including developing a general permit for wastewater treatment plants.
- **Improving resiliency of the ecosystem**. Protect and enhance kelp and eelgrass, which may reduce acidification locally and provide areas of refuge for marine species.
- **Continuing investments in science and collaboration** that underpin our actions and provide a sustainable and coordinated focus for our state to address and lead on this issue.
- **Updating communications materials and conducting strategic outreach** to increase understanding and connect with key audiences.

Beyond these actions at the state and local levels, Washington should continue leading, collaborating, advocating for and advancing policies at the regional, national and international levels in partnership with leading state-based businesses and organizations, elected officials and others.

Accelerate action to increase resiliency of salmon populations

Recommendation 45: Mitigate the impact of a changing climate by accelerating and increasing action to increase the resiliency and vitality of salmon populations and the ecosystems on which they depend.

- Fully implement and fund salmon recovery plans to improve climate resiliency against sea level rise, changes in precipitation, increased stream temperatures and ocean acidification. Where needed, adaptively manage and incorporate climate adaptation and resilience strategies in regional and watershed-scale recovery plans.
- Increase fish access to cold water habitats and refugia. Selectively remove, design and retrofit infrastructure (e.g., dams, culverts, dikes, rail lines, hatcheries, fish passage) to ensure long-term climate resiliency in the face of future changes in flows and water temperatures.
- Significantly increase the scale and scope of investment in habitat protection and restoration projects that focus on habitat diversity and complexity. Increase the diversity and resiliency of wild and hatchery salmon stocks.
- Ensure diverse wild and hatchery salmon populations to create more climate-resilient fish. Adaptively manage habitat restoration and hatcheries to account for and mitigate against climate change impacts such as water flow, water temperature and sea level rise. Changes may affect the location, type or operation of hatchery facilities.

Implementation details

In addition to the implementation details below, Year One Recommendations 1-9 address (1) preserving, restoring and protecting habitat, (2) expanding hatchery production, (3) re-establishing salmon runs above existing dams, (4) increasing spill over dams and (5) establishing a stakeholder process to examine the future of the Lower Snake River dams. These recommendations further the resiliency and productivity of the ecosystem and salmon populations, while providing a buffer against future adverse impacts of increased air and water temperatures, changing stream flows and sea level rise:

- Fully fund salmon recovery plans as written to ensure implementation. Increase funding as needed and look for opportunities to frontload investments to address the urgency of climate change, which exacerbates existing threats to salmon. Identify new funding sources in addition to WDFW funding. Prioritize restoration investments in (1) nearshore marine areas and estuaries, (2) floodplains and riparian areas, (3) culverts and infrastructure and (4) areas that increase access to cold water refugia. Assess which watersheds and estuaries will be most resistant to sea level rise and other impacts of climate change over time, such that they will support Chinook populations going forward. Prioritize investment in restoration and acquisition in these watersheds.

- Enhance existing efforts to increase access to cold water habitat and refugia. Identify opportunities to reintroduce species to habitats with cooler waters. Ensure that any losses in hydropower are replaced with other carbon-free sources and consider other potential conservation impacts.
- To buffer against climate change and increase stock resiliency, increase diversity and complexity of habitats throughout geographic range and restore associated life histories. While increasing stock diversity, identify resilient salmon species with sufficient populations throughout the state that have sufficient abundance and habitat diversity/complexity to adapt to climate change (also referred to as anchor populations or strongholds) — for example, unlisted species along the coast.
- Account for the impacts of sea level rise, increasing water temperatures and changes in streamflows when assessing upgrades and modifications to hatchery facilities. Consider facility water temperature and availability, river access and disease management. Hatchery managers should assess stock selection, growth rates, diversity and release timing as tools for reducing climate impacts to salmon. Ensure that these changes do not further exacerbate climate impacts on wild fish.

Pursue maritime innovations that benefit Southern Residents

Recommendation 46: Expand the Governor's Maritime Blue scope of work and provide funding to implement recommendations from the Southern Resident Orca Task Force and pursue shipping and other maritime innovations that benefit Southern Residents.

- Incentivize low-carbon or zero-emission, low-impact vessels in state waters. Target vessels with the greatest cumulative emissions impacts, based on vessel type and operational profile.
- Expand the scope of the Washington Maritime Blue initiative and the state's strategy for the "blue economy" to encompass relevant goals and recommendations from the task force. Provide additional resources as needed.

Implementation details

Vessels are a significant source of carbon dioxide emissions contributing directly to climate change and must be reduced over time to meet international and science-based goals to stabilize temperatures. The task force recommends a targeted approach to emissions reduction focused on reducing emissions from the vessels spending the most time and making the highest number of trips in local waters. As it applies to whale-watching vessels, one option to implement this recommendation could be to prioritize licensing for zero-emission or low-carbon vessels.

Although reducing emissions is a top priority, underwater noise and vessel disturbance is one of the three primary threats facing Southern Resident orcas. Ocean acidification extends the spatial spread of underwater noise (for frequencies up to 10kHz), making it more difficult for orcas to communicate. The task force recognizes that while some emerging vessel propeller technologies may reduce emissions, they can also increase underwater sounds at frequencies that interfere with orca communication and echolocation. Addressing this trade-off will require research, innovation and investment to develop and deploy technologies that reduce both noise and carbon emissions.

To catalyze this research and innovation, the task force recommends supporting Washington Maritime Blue, a strategic alliance for maritime innovation and sustainability. Maritime Blue is an independent, nonprofit partnership between industry, the public sector, research and training institutions and community organizations tasked with implementing Washington State's Strategy for the Blue Economy. The effort covers a number of potential strategies for innovation and sustainability in shipping that could benefit orcas (like sensor technologies, noise- and emissions-reduction efforts, propeller design and retrofits, etc.); however, in order to advance opportunities that provide mutual benefits for Washington's shipping industries and orcas, a clear governance mechanism within Maritime Blue is needed to incorporate priorities for orcas and sustain the effort over time.

To implement this recommendation, Maritime Blue should modify its governance structure (for example, by creating a dedicated board member seat or subgroup) to address Southern Resident orca issues and coordinate closely with the successor to this task force. Actions could include identifying and addressing shipping and other maritime impacts on orca prey, vessel noise and disturbance and emissions.

Mitigate increased threats from contaminants due to climate change and ocean acidification

Recommendation 47: Identify and mitigate increased threats to Southern Residents from contaminants due to climate change and ocean acidification. Prioritize actions that proactively reduce exposure where the increased impacts are expected to be most severe.

- Identify vulnerabilities of existing storm and wastewater infrastructure (stormwater management systems, CSO, WWTP, port and rail facilities) to sea level rise, flooding and other high-flow events. Retrofit or otherwise mitigate facilities at high risk.
- Identify and prioritize the timely clean-up and remediation of legacy toxics and waste sites that are likely to be exposed by sea level rise, flooding and high-flow events caused by climate change.

- Include the impacts of a changing climate and ocean acidification as criteria when developing a prioritized list of chemicals of concern for orcas.
- Address new contaminants entering marine and inland waters associated with the increase in wildland fires associated with climate change. These contaminants include PAHs (polycyclic aromatic hydrocarbons) from smoke, flame retardants and increased runoff from erosion.
- Ensure that the National Pollutant Discharge Elimination System permit processes are adaptable and responsive to climate-related impacts.
- Support the Department of Ecology's ongoing nutrients work and initiatives, recognizing the co-benefits of addressing nutrients to improve climate resiliency and mitigation efforts in Puget Sound and the Columbia Basin.
- Treat increased stream temperature resulting from climate change as a pollutant that creates potentially lethal conditions for juvenile salmon and returning adults. Mitigate the increase by expanding riparian vegetation and through other means to moderate temperatures.

Implementation details:

With runoff anticipated to increase as climate change drives increased precipitation, flooding and sea level rise, additional work is needed to address increasing levels of contaminants in the state's waters. Nutrient loadings will increase with these events and exposure to other toxics could increase as well. Increased bioavailability of toxics will accumulate up the food chain, ultimately threatening Chinook. In addition, the increased quantity and intensity of flows due to climate change are highly problematic, impacting the hydrology of basins and water systems and destroying forage fish and Chinook habitat.

In the near term, efforts to address this threat should focus on (1) identifying stormwater and wastewater infrastructure and other facilities — including legacy waste sites — most at risk and (2) taking action to mitigate those risks. Actions include prioritizing and adapting stormwater retrofits to account for the impacts of climate change, accelerating clean-up of toxics and waste sites, modifying or moving treatment facilities to withstand sea-level rise and increased flooding and increasing protection for low-lying infrastructure facilities (without hardening adjacent shorelines). Over time, responsible agencies and entities will need to monitor how increased intensity and duration of rainfall events, sea level rise and flooding, and warmer temperatures and ocean acidification affect toxics mobility and contaminants in the ecosystem, and proactively and adaptively manage to address expected future conditions.

To address PAHs and other contaminants associated with increased wildland fire, smoke and suppression, support the efforts of DNR, USFW and other agencies to identify and implement effective management and mitigation strategies. Accelerate investments and activities to improve forest health and reduce wildland fire risks currently being undertaken by DNR and USFW to ultimately reduce the intensity and extent of large catastrophic fires and associated smoke as well as the consequent need for flame retardants.

With disease susceptibility in salmonids, and other critical species likely to increase with warmer temperatures, targeted toxics reduction strategies should remain a focus for Southern Resident recovery. Additionally, the state should work to better understand emerging toxics threats to determine how effects might be amplified and synergized with changes in climate, water temperature and chemistry.

To include climate change considerations in the NPDES permit process, increase the resiliency of wastewater treatment plants, combined sewer overflows and stormwater facilities to maintain treatability in the event of sea level rise, extreme flooding and high-flow events.

Regarding nutrient management, Ecology recommends (1) developing a NPDES permit framework for wastewater treatment in Puget Sound, (2) developing a watershed nutrient management model and decision support tool and (3) collecting high-quality nutrient data in watersheds to fill key knowledge gaps related to baseline conditions. These actions will address current threats from nutrient loadings to the health of the Puget sound ecosystem, salmon and orcas, as well as future increases that will result from climate-driven impacts.

Goal 6: Reduce the threat that population growth and development pose to the critical habitat and sensitive ecosystems that Southern Residents and their food web they rely upon

Prevent further degradation of critical habitat and sensitive ecosystems associated with human population growth and development

Recommendation 48: Adopt and implement policies, incentives and regulations for future growth and development to prevent any further degradation of critical habitat and sensitive ecosystems; enable and channel population growth in ways that result in net ecological gain; evaluate and report outcomes for all jurisdictions at the state, county, tribal and municipal level.

- Net ecological gain in this context refers to taking actions through development and land management that result in improvement to the quality and quantity of the functions of the natural environment. Key elements include:

  - Following the mitigation sequence of (1) avoiding impacts, (2) minimizing impacts and (3) offsetting any impacts that cannot be avoided. Recognizing that mitigation efforts aimed at no net loss have not achieved (and are not likely to achieve) 100% success at offsetting impacts, additional mitigation should be required.
  - Establishing and defining the environmental baseline from which we are measuring improvements.
  - Consider local site-specific and a larger watershed scale.
- Revise statutes to shift from a “no net loss” standard to a “net ecological gain” standard to better protect salmon and orcas from population growth and development. Examples of statutes related to development include:
  - RCW 36.70A - Growth Management Act
  - RCW 90.58 - Shoreline Management Act
  - RCW 77.55 - Construction Projects in State Waters
  - RCW 80.50 - Energy Facilities – Site Locations
- Provide adequate funding and support to both state natural resource agencies and local governments to engage with communities, improve guidelines, align policies and regulations and effectively enforce statutes that protect habitat, while funding restoration efforts.
- Disincentivize growth along priority marine and freshwater shorelines and in sensitive riparian and forest areas by requiring mitigation ratios greater than 1:1 while incentivizing infill and development in brown fields that would not impact critical habitats.
- Implement regulations that preclude new development if existing stormwater and wastewater infrastructure are within a percentage of their thresholds.
- Consider equity across rural and urban areas, incentivizing growth in areas that need it to support their economies while ensuring that economic development does not come at the cost of the environment.
- Increase affordable housing and reduce urban sprawl by growing “up instead of out.”
- Promote “live where you work” to reduce commutes while improving public transportation infrastructure.

Implementation details:

In order to prevent further loss of critical habitat and restore what has already been lost, the task force urges Washington state and local jurisdictions to shift their growth standards from “no net loss” to “net ecological gain.” The GMA should be more responsive to the needs of the ecosystem, treating habitat as critical public infrastructure and emphasizing protection over mitigation. The environmental baseline from which we are measuring improvements must be established and defined. This recommendation and the actions identified are closely linked to existing recommendations:

- Strengthen agency rules, regulations and policies. Enforce habitat protection laws and increase incentives for landowners (**Recommendations 3, 4 and 5**).
- Invest in and fully implement salmon recovery plans (**Recommendations 1 and 2**).
- Focus "Be Whale Wise" outreach around boating regulations in the Seattle area on new residents (**Recommendation 19**).
- Expand the governor's Maritime Blue scope of work to implement recommendations from the task force and pursue shipping and other maritime innovations that benefit Southern Residents **(Recommendation 46**).
- Fund local governments to conduct facilities planning through 2070 that looks at population growth through a wastewater, centralized and onsite sewage and stormwater lens to ensure increased contaminant loads do not impact salmon and orcas (**Recommendation 32**).

Minimize whale-strike risk and underwater noise from fast-ferries and water taxis

Recommendation 49: Conduct a comprehensive environmental review and take action to minimize potential whale-strike risk and underwater noise posed by the growing number and distribution of fast ferries and water taxis in Southern Resident critical habitat.

- Federal and state agencies with the appropriate jurisdiction should coordinate and conduct the comprehensive environmental review.
- Washington State Ferries should work with operators of fast ferries and water taxis to determine and implement effective actions.
- Engage Washington Maritime Blue in technology and innovation solutions.

Implementation details:

According to Puget Sound Harbor Safety Committee bi-monthly report summaries, the volume of fast ferry and water taxi traffic has risen dramatically in recent years, and the levels rank near the top of all vessel classes in Puget Sound (but are far exceeded by Washington State Ferries and tugs and barges). Based on the Puget Sound Partnership's assessment of automatic identification system information, such vessels travel over 300,000 miles (in more than 10,000 hours) annually in Puget Sound.

Since issuing its recommendations in 2018, the vessels working group and task force became aware of the development of several new fast ferry and water taxi operations in Puget Sound. Kitsap Transit and King County currently operate fast ferries, with other communities planning similar operations to the south and north. These ferries make multiple roundtrips in the morning and afternoon, traveling at relatively high speeds in an area frequented by Southern Residents (especially in the fall).

The vessels working group expressed concerns about the elevated risk of collisions with Southern Residents as some of these vessels can travel faster than the top speed of orcas. The emergence of similar fast ferry networks elsewhere in the world (e.g., the Canary Islands and Korea) has led to more ship strikes with whales and dolphins. The International Whaling Commission has recommended several precautionary measures to mitigate related risks [41].

The task force urgently recommends working with the fast ferry and water taxi sector on potential bridge lookout policies and technological mitigations due to (1) the small size of the Southern Resident population, (2) evidence of collisions leading to the injury or death of Southern Residents and (3) the comparatively high vulnerability of calves and other young whales to this potential threat.

Appendix 2. Dashboard of progress made on Year One recommendations

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
Goal 1: Increase Chinook abundance.				
	Recommendation 1: Significantly increase investment in restoration and acquisition of habitat in areas where Chinook stocks most benefit Southern Resident orcas.			
1a	Provide capital budget funding to support the existing lists of projects and Salmon Recovery Funding Board (SRFB) requests intended to improve Chinook and forage fish habitat.	Recommendation called for "fully funding" of Salmon Recovery Funding Board, Puget Sound Acquisition and Restoration (PSAR), Estuary and Salmon Restoration Program (ESRP), Fish Passage Barrier Removal, and Washington Coast Restoration and Resilience Initiative. Also called for "support" for Floodplains by Design, Puget Sound Nearshore Ecosystem Restoration Project (PSNERP), Chehalis Basin Strategy, and Yakima Basin Integrated Plan.	Legislature, state agencies	Capital funding in the final budget for habitat restoration totals $435 million including: – $75M ($25M state, $75M in federal authority) for SRFB grants – $73M for the Chehalis Basin Strategy – $49.5M for PSAR – $50.4M for Floodplain by Design – $12M ESRP – State’s PSNERP match – $12.0M Coastal Restoration Grants – $40M for Columbia River Water Supply – $40M for Yakima River Water Supply – $40M for Streamflow restoration – $26M for Fish Passage Barrier Removal Board While significant progress was made this year, the task force was explicit that full funding was
1b	Accelerate the implementation of currently funded Chinook restoration projects known to provide survival benefits to Southern Resident orcas.			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				needed for all of these programs. That goal was not achieved. **Washington Department of Fish and Wildlife:** ESRP appropriated $10M below Gov budget. PSNERP is advancing Duckabush project and has received some federal funding in addition to state match. SRFB recently approved some additional state SRFB funding for Duckabush to fill current status funding gap for this year. PSNERP continues to work with local communities to set up future PSNERP projects.
1c	Significantly increase funding for a minimum of 10 years for high-priority actions or projects targeted to benefit Chinook stocks.	Additional state funding should be provided for at least 10 years (five biennia) to focus specifically on high-priority actions for the stocks that most benefit Southern Residents.	Legislature, state agencies	There was no discussion in the legislature about establishing a long-term funding plan for salmon habitat restoration
1d	Emphasize large-scale estuary restoration programs and prioritize grant making for restoration that increases Chinook recovery in the short term.	Should be evaluated and prioritized where juvenile Chinook production could be increased in the very near term. Estuaries called out include Nooksack, Skagit, Stillaguamish, Elwha, Dungeness, Snohomish, Green-Duwamish, Puyallup, Nisqually,	Washington State Recreation and Conservation Office; Washington State Department of Ecology, the Puget Sound Partnership, and WDFW	Due to the complexity and size of estuary projects, it often takes many years to plan and coordinate the restoration. Thus, the key estuary efforts are already in the queue for funding. The best way to prioritize the efforts is to increase funding per the above recommendations. **RCO**: Several RCO programs address estuary restoration including: SRFB, Pacific Coastal Salmon Recovery Fund, and PSAR.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
		Skokomish, Snohomish, Columbia, and Chehalis		**Ecology** Several of ECY's grant programs directly address this recommendation and are included in the budget as passed. **PSP** The potential for dam removal in the Middle Fork Nooksack to ultimately produce high numbers of returning spring Chinook for Southern Resident Orcas helped justify the project's case for PSAR funding. – The final capital budget funds RCO to provide grants to fund the top three PSAR large capital projects, along with 66 smaller-scale projects. – The final capital budget also Ecology to fund nine Floodplains by Design projects. – The Environmental Protection Agency is working with state partners to award National Estuary Program funding to habitat and other projects proposed in the 2018-2022 Action Agenda. – PSP led its annual trip to Washington, DC, May 14-16. For the first time, we combined this trip with the annual Salmon Days on the Hill. Over 70 leaders from Washington State, and salmon recovery leaders from 4 other western states, attended this event to encourage our delegations to increase funding for the Pacific Coastal Salmon Recovery Fund and the National Estuary Program.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				– PSP's operating budget includes funding to coordinate some updating of the Puget Sound Salmon Recovery Plan. – PSP will continue to work, in coordination with the Governor's Office and Office of Financial Management, to seek alternate sources of funding for these important projects. – PSP will continue to advocate for increased federal funding for orca recovery actions, including restoration and acquisition of habitat.
1e	To complement forest Road Maintenance and Abandonment Plans and Washington State Department of Transportation fish passage improvement efforts, continue to use a strategic approach for using RCO-administered programs to remove barriers (for example, culverts and small dams) where removal would provide a high benefit to Chinook.	Draft list identifying barriers to priority chinook runs should be developed by March 2019. Phase II (further assessment and next steps) due by June 2020. Middle Fork Nooksack and Pilchuck dams specifically called out for removal.	Governor's Salmon Recovery Office, WDFW, Fish Barrier Removal Board, regional salmon recovery orgs, and partners	**WDFW**: This task is currently behind the requested timeline because funding was not available until the current biennium (2019-21). WDFW received 2019-21 Biennial funding in their Fish Passage Division to compile existing information on high-priority barriers to Chinook during Phase I and to assist in the development of a strategic approach to prioritization and refinements to the list for Phase II. Refinements may include verification of the extent of Chinook distribution, identification of data gaps in the inventory of barriers to Chinook, and subsequent barrier and habitat data analysis, among others. **GSRO** is coordinating the WDFW efforts with the recovery regions and the watersheds.
1f	Create a new funding source to support the significant increases in investments in the	The Legislature should provide funding via the	Legislature	The Legislature did not discuss creating a new funding source specifically for salmon habitat restoration.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	habitat protection and restoration programs. This should be done in conjunction with the development of a sustainable funding source for the implementation of all task force recommendations.	capital budget for removal of barriers identified.		
1g	The Legislature should fully fund payment in lieu of taxes to counties to compensate for the loss of revenue associated with the land that is acquired by the state for habitat protection and restoration projects.	Consistent with restoration programs to date, projects on private lands will be limited to high priority habitat areas with willing sellers.	Legislature, state agencies	The Governor's 2019-21 operating budget proposal provided full funding for payment in lieu of taxes at the WDFW. The final legislative budget did not fully fund payment in lieu of taxes (PILT). HB 1662/SB 5696 which would have fully funded PILT on an ongoing basis were introduced but did not pass the legislature.
1h	The Legislature should ensure adequate funding for the operations and maintenance of lands acquired by the state for habitat protection and restoration projects.	Natural resource managers should be adequately funded for operations and maintenance of lands acquired.	Legislature, state agencies	Given funding shortfalls for many natural resource agencies (particularly WDFW) it is unclear if the agencies acquiring land through easements/incentive programs will have the staffing capacity/resources needed to steward the lands to obtain maximum conservation benefits.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
1i	Support a more robust monitoring and adaptive management system to better ascertain restoration project compliance and measurable ecological benefits.	Support for comprehensive and systematic evaluation of fish / habitat response / interactions to restoration.	Legislature, state agencies	ESRP program supports monitoring and adaptive management but receives opportunistic funding below levels needed for this recommendation.
1j	Support funding for completion of Chinook recovery plan updates for 14 of 16 remaining Puget Sound watersheds.		Legislature, state agencies	The Governor's 2019-21 operating budget provided $977,000 to PSP to update Chinook Recovery plans in Puget Sound. The enacted budget only provided $500,000 for this effort.
	Recommendation 2: Immediately fund acquisition and restoration of nearshore habitat to increase the abundance of forage fish for salmon sustenance.			
2a	Provide funding for the immediate implementation of nearshore habitat restoration projects.	Fully fund PSAR, Washington Coast Restoration Initiative, SRFB, and ESRP	Legislature, state agencies	Copied from above for grant programs focused on nearshore marine habitats: – $49.5M for PSAR – $10M ESRP – $12.0M Coastal Restoration Grants – PSNERP federal funding **Ecology**: – Based on immediate Executive Order actions, Ecology has identified criteria for existing grant programs to prioritize projects that benefit Southern Resident orcas.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				– Several of Ecology's ongoing grant programs directly address this recommendation and are included in the budget (See Rec.31)
	Recommendation 3: Apply and enforce laws that protect habitat.			
3a	WDFW, Washington Department of National Resources (DNR) and ECY must strongly apply and enforce existing habitat protection and water quality regulations. Provide WDFW, DNR and ECY with the capacity for implementation and enforcement of violations.	The number of WDFW and Ecology staff should be increased to improve implementation, compliance and civil enforcement.	Legislature, state agencies	**Ecology**: Additional staff to support enforcement of the: – Clean Water Act (Approx. 5 FTEs) – Shoreline Management Act (2 FTEs) – Instream-flow ($4.7M, FTEs and other work) – Ecology will devote one FTE to collaborate with WDFW in reviewing compliance with armoring priorities identified by the PSP. This position has been filled, effective November 2019. – Ecology will also provide one FTE for specialized geotechnical review of shoreline armoring proposals and conducting training for geotechnical consultants and local governments to ensure adequate demonstration of need when shoreline-armoring projects are approved. This position is in the recruitment process as of November 2019. **WDFW**: The Legislature did not fund the administrative compliance positions that were requested to implement the recommendation. WDFW is requesting funding for the positions in the 2020 supplemental legislative session. The Legislature did fund two new Fish and Wildlife Officer

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				positions to focus on habitat-related criminal enforcement.
3b	Direct DNR, WDFW and ECY to identify and report to the task force before July 2019 on approaches using existing habitat, instream flow and water quality regulations to improve prey availability.		Washington State Department of Natural Resources, WDFW, Ecology	The three agencies did not produce the report by July 2019. Ideally, this report would identify existing authorities among the agencies that (if fully enforced) would contribute to salmon recovery/restoration. This report would also help identify gaps where the agencies' authorities are constrained, resources are inadequate, or rules require clarification. **WDFW**: The Legislature did not direct or fund WDFW with capacity to develop the report.
3c	Coordinate state and local enforcement efforts.	WDFW and Ecology should work with the Attorney General's Office and local prosecutors to increase compliance with habitat protection and water quality regulations.	WDFW, Ecology	Unclear if coordination with the Attorney General's office is occurring. **WDFW**: No new action is planned because the Legislature did not direct or fund WDFW to implement this recommendation. However, the Enforcement Program recently did extensive outreach and education to local prosecutors on Fish and Wildlife related crimes.
3d	Develop and adopt rules to implement and enforce the Fishway, Flow and Screening statute.	WDFW - rules for RCW 77.57, Fishway, Flow, and Screening.	WDFW	**WDFW**: Funding was appropriated to complete this work. The department will need to develop new rules for implementation. The Fish Passage Division has been ramping up around the rulemaking process. A consultation with the Attorney General's Office is being set up to consult on the

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				process. A staff person will soon be hired to oversee this rulemaking process.
3e	Enhance penalties and WDFW's enforcement of the state Hydraulic Code and fish passage regulations.	Amend RCW 77.55.29 to give WDFW enforcement tools	Legislature, state agencies	**WDFW**: The Hydraulic Project Approval bill [HB 1579 (Bill Chapter 290, Laws of 2019)] was enacted to provide enforcement tools for the HPA. WDFW will need to develop rules to implement the new statute and increase WDFW Officer staffing for implementation. The HPA bill increased WDFW's civil enforcement authority and removed key exemptions. Increased fines are still undetermined. Governor Inslee requested WDFW to establish a $10K fine per violation via rulemaking. The agency is going through the rulemaking process to implement 2SHB1579 and anticipates that the Fish and Wildlife Commission will adopt the rule changes in March 2020.
3f	Increase prosecution of violations of state and local habitat protection and water quality regulations, including seeking to hold both property owners and contractors accountable, when appropriate.	WDFW and Ecology to work with Attorney General on increasing compliance.	WDFW, Ecology	Unclear if coordination with Attorney General's office is occurring. In addition, only Ecology got increased staff to increase prosecution of habitat violations. **WDFW**: The Legislature did not direct or fund WDFW with capacity to implement this recommendation. However, WDFW engages the Attorney General's Environmental Protection Unit when appropriate. In addition, the Enforcement Program recently did extensive outreach and education to local prosecutors on Fish and Wildlife related crimes.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 4: Immediately strengthen protection of Chinook and forage fish habitat through legislation that amends existing statutes, agency rule making and/or agency policy.			
4a	Strengthen legislation, agency rules, or agency internal policies, where appropriate, for ECY and WDFW to better protect Chinook and forage fish.	Meet regularly with the goal of developing a habitat protection/regulatory reform legislature packages for 2019 and subsequent legislative sessions and rulemaking.	Governor's Office, legislators, tribes, DNR, WDFW, Ecology, salmon recovery regional reps, and other partners	A lot of progress was made this year, but a part of this effort (regularly convening a group to constantly be developing priorities and identifying policy challenges to advancing salmon restoration) does not appear to be occurring yet. **Ecology:** Under current law, Ecology is completing a 15-year long effort to overhaul all local Shoreline Master Programs across the state to ensure no net loss of ecological functions, which includes stringent protections for Chinook and forage fish habitat. Ecology assumes that no new statutory authorizations will be needed to the Shoreline Management Act to meet the objectives to strengthen protection of Chinook and forage fish. **WDWF**: See 4b
4b	Direct WDFW to develop a plan with local governments for analyzing cumulative impacts and amend existing authority to allow WDFW to require mitigation for cumulative impacts over time under the	Add cumulative impacts and remove single-family exemption	Legislature, WDFW	**WDFW** is going through the rulemaking process to implement 2SHB1579. We anticipate the Fish and Wildlife Commission will adopt the rule changes in March 2020. WDFW authority was amended, but unclear if agencies plan to "develop a plan with local governments for analyzing cumulative impacts " as requested. The HPA bill was amended so that cumulative impacts did not have to be included.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Hydraulic Project Approval authority.			**WDFW**: HB 1579 (Chapter 290, Laws of 2019), requested by the Governor was enacted and removed the single-family bulkhead exemption. The department will need to develop rules to implement the new statute and increase staffing for implementation. The first step is to amend the rules to reflect the statutory changes and then the department can file for expedited or standard rulemaking. The Legislature did not direct or fund WDFW to develop the plan around cumulative impacts with local governments. Currently, WDFW does not have statutory authority to require compensatory mitigation for cumulative impacts.
4c	Provide agencies with clear authority to prohibit or mitigate certain actions.		Governor's Office/Legislature, state agencies	**WDFW**: The Legislature did rescind RCW 77.55.141. This allows WDFW to require compensatory mitigation for the construction of single-family bulkheads.
	Recommendation 5: Develop incentives to encourage voluntary actions to protect habitat.			
5a	State agencies should identify and implement incentives for landowners to voluntarily protect shorelines and habitats to benefit salmon and Southern Resident orcas.		WDFW	The existing Shore Friendly Program is an example of an incentives program that has led to several thousands of feet of armoring removed and a program that local governments support. There may be options to codify and expand this program.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
5b	Increase funding for existing and seek to develop additional cooperative conservation programs.	Develop a 10-year funding proposal for incentives by June 2020" and funding for programs like Floodplains by Design, Shore Friendly Program, Forest Riparian Easement Program, Rivers Habitat Open Space Program, and Conservation Reserve and Enhancement Program.	Legislature, federal agencies, state agencies	Funding was decreased for several incentive programs, nor did the legislature discus funding needs/plans over a 10-year period as was requested. **Washington State Conservation Commission**: Funding for the Conservation Reserve Enhancement Program supports incentive-based riparian restoration and enhancement projects supporting Chinook riparian habitat. The 2019-21 capital budget significantly reduced available funding for this program, risking the ability to increase needed riparian habitat. WSCC will consider whether to pursue a supplemental budget request to increase support for CREP. **WDFW**: Three habitat staff are participating in the Puget Sound Task Force Multi-Agency Review Team. The purpose of the MART is to streamline the federal permitting process for soft-shore protection projects. WDFW-ESRP Shore Friendly Program was only partially funded due to below-request ESRP appropriation. EPA federal funding has provided a 1-time support for Shore Friendly for this biennium. A future funding gap exists for Shore Friendly for capital and non-capital funding at current ESRP appropriation levels.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
➕	**Recommendation 6**: Significantly increase hatchery production and programs to benefit Southern Resident orcas consistent with sustainable fisheries and stock management, available habitat, recovery plans and the Endangered Species Act. Hatchery increases need to be done in concert with significantly increased habitat protection and restoration measures.			
6a	Authorize/provide funding for WDFW and co-managers to significantly increase hatchery production at facilities in Puget Sound, on the Washington Coast and in the Columbia River basin in a manner consistent with sustainable fisheries and stock management and the Endangered Species Act (ESA). Decisions on hatchery production are made by WDFW and tribal co-managers, with ESA consultation from the NOAA and the U.S. Fish and Wildlife Service where appropriate. The Washington Fish and Wildlife Commission adopted a policy statement in 2018		Governor's Office/Legislature, WDFW	**WDFW**: – An additional $13.5 million was provided to WDFW and tribal co-managers for increasing hatchery production in Puget Sound, Washington Coast and the Columbia River. – WDFW is working with National Oceanic and Atmospheric Administration Fisheries and United States Fish and Wildlife Service on implementing new production in FY20 and FY21. – Ongoing work to implement increased production was funded in FY19. – Releases of increased production began in May/June of 2019.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	indicating support for hatchery increases of approximately 50 million smolts beyond 2018 levels to produce more Southern Resident orca prey and fisheries benefits; the task force supports significant increases in hatchery production and habitat protection and restoration.			
6b	In 2019, undertake hatchery pilots to test and refine methods and practices (location, timing of release, age, size) that maximize production of Chinook for the benefit of Southern Resident orcas while minimizing competition with wild stocks.	Pilots should aim to (1) increase marine survival, (2) adjust return timing and locations, (3) increase size and age of returns, and (4) reduce competition with wild fish. Effectiveness would be assessed with five-year review of hatchery increases	WDFW, co-managers, NOAA, and Long Live the Kings	**WDFW**: Coordination with Puget Sound tribes and LLTK on size and age of returns and increasing smolt to adult survival. Legislative funding was provided for this action. Approximately 7.5 million additional fish were released in spring of 2019. Quarterly meetings are being held to coordinate the hatchery pilot studies. 2019 brood year production proposals for WDFW, Co-manager and Douglas Public Utility District total 26.8 million. Continuing to work with NOAA and USFWS on consultation for increased production.
6c	Manage the increase in hatchery production consistent with available and improved habitat to enable survival of both hatchery and wild fish stocks.		WDFW, co-managers	The Prey Working Group expressed that it is unclear if the increases in hatchery production are being coordinated with investment in habitat restoration or are occurring in areas where the habitat can accept/support additional fish. Without additional restoration resources this is unlikely to be successful.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
6d	Provide increased funding to cover the operational, infrastructure, management and monitoring costs associated with increased hatchery production.		Governor's Office, Legislature, WDFW	Funds for monitoring and management costs associated with increased production were not yet provided to WDFW.
6e	Conduct ongoing adaptive management, five-year comprehensive reviews and the science needed to support a sustained increase in hatchery production.	Reviews should consider stray rates, juvenile rearing carrying capacity, density dependence, smolt-to-adult ratios, genetic fitness"	WDFW, co-managers	No funding has yet been obtained for this purpose.
	Recommendation 7: Prepare an implementation strategy to reestablish salmon runs above existing dams, increasing prey availability for Southern Resident orcas.			
7a	Provide funding to WDFW and regional salmon organizations to coordinate with partners to determine how to reestablish sustainable salmon runs above dams including, but not limited to, the Chief Joseph and Grand Coulee Dams on the		WDFW, regional salmon recovery orgs, tribes, local governments, NOAA	**WDFW**: The legislature provided $524,000 to WDFW for enhanced engagement on this issue. WDFW staff have been coordinating with the Upper Columbia United Tribes to develop a strategy to amend existing Hatchery Genetic Management Plans in the upper Columbia. The HGMPs are attached to multiple tribes, public utility districts and WDFW. Amending these permits requires extensive coordination amongst managers and the utilities and coordination and approval with NOAA. The HGMPs dictate to the fishery

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Columbia River and the Tacoma Diversion, Howard Hanson and Mud Mountain dams in the Puget Sound. Provide policy support for actions needed. Prioritize projects that produce downstream adult Chinook.			managers the number of hatchery origin salmon and steelhead that can be released into the upper Columbia River and tributaries. Reintroduction of salmon and steelhead above Chief Joseph and Grand Coulee Dams will require a substantial increase in the number of smolts released into the upper Columbia and tributaries. The current HGMP's do not consider the impacts of these increased stocking events. With these increased stocking numbers, these HGMPs will have to be renegotiated with NOAA to ensure that programs are within the bounds of ESA impacts to existing wild salmon and steelhead populations. WDFW's Hatchery Evaluation and Assessment Team will take the lead in working with the multiple parties involved to amend these permits. WDFW and UCUT will work with NOAA over the coming 2 years to scope out the increases in smolt release programs and how these will fit into the existing HGMPs to be protective of wild salmon and steelhead while allowing the release of adequate numbers of smolts to effectively test reintroduction efforts above Chief Joseph and Grand Coulee Dams. WDFW has also been working with UCUT staff on outreach and communication to decision-makers regarding reintroduction. In August, WDFW helped staff a tour of sites relevant to reintroduction by the Northwest Power and Conservation Council's (NPCC) Independent Scientific Advisory Board (ISAB), as part of the ISAB's review of the UCUT's Phase I report to the NPCC on reintroduction. The Phase I report,

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				with which WDFW assisted UCUT, looks at habitat potential, disease risk, and stock selection issues. Once approved by the NPCC, Phase II will begin, which will be focused on using modelled and real-world testing to assess the best locations and technologies for reintroduction. WDFW recently submitted comments reinforcing the value of this phased process and encouraged the NPCC to move forward with it as it amends its Fish and Wildlife Program. Finally, WDFW staff attended one of the Colville Tribe's "cultural releases" of small numbers of trucked salmon into Lake Roosevelt in August. These releases mark the first time that the waters above Chief Joseph and Grand Coulee dams have seen salmon since the construction of those dams.
✓	**Recommendation 8**: Increase spill to benefit Chinook for Southern Residents by adjusting total dissolved gas allowances at the Snake and Columbia River dams.			
8a	Direct the ECY to increase the standard for dissolved gas allowances from 115 percent to up to 125 percent, to allow use of the best available science to determine spill levels over these dams to benefit Chinook and other		Ecology	Ecology started the rule process in the summer of 2019. A draft rule was out for public review and the agency is currently reviewing all comments. A final rule is expected by the end of December 2019.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	salmonids for Southern Residents.			
8b	Coordinate with the Oregon Department of Environmental Quality to align standards across the two states.		Ecology	Ecology has stayed in constant communication and connection with our counterparts at the Department of Environmental Quality in Oregon. We are working on making sure the two standards are similar across both states.
8c	Maintain rigorous monitoring of impacts to juvenile Chinook and resident fish to ensure any changes in spill levels do not negatively impact salmon or other aquatic species.		Ecology	As part of the rule that Ecology proposed there is a requirement for biological monitoring to track spill impacts on aquatic species.
8d	Work with tribes, salmon recovery regions, ECY and WDFW to minimize revenue losses and impacts to other fish and wildlife program funds.		WDFW, NPCC	NPCC is amending its current Fish and Wildlife Program through the use of an addendum. Comments period closed on Oct 18, 2019. Washington state is working on a long-term funding agreement for fish and wildlife programs with Bonneville Power Administration.
	Recommendation 9: Establish a stakeholder process to discuss potential breaching or removal of the lower Snake River Dams for the benefit of Southern Resident orcas.			
9a	In conjunction with the states of Idaho and Oregon, Washington should act quickly to hire a neutral third party		Governor's Office	$750,000 ($375,000 per fiscal year) was appropriated in the 2019-21 biennial operating budget to the Governor's office for a neutral third-party contractor.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	to establish a tribal and stakeholder process for local, state, tribal and federal leaders to address issues associated with the possible breaching or removal of the four lower Snake River dams.			A consultant was hired in July 2019. Interviews with stakeholders, tribes and impacted states are underway. Draft report is to be released in December 2019. Public meetings are to be held in Vancouver, Clarkston and Tri-Cities in early January 2020. The report is scheduled to be completed by early March 2020.
	Recommendation 10: Support full implementation and funding of the 2019–28 Pacific Salmon Treaty.			
10a	Washington's congressional delegation should prioritize securing appropriations to implement this treaty. Delegation members, the governor, task force members and others should advocate for these appropriations.		Governor's Office, WDFW	This work is ongoing. While several Prey Work Group members expressed disappointment that the orcas are not considered a 'user group' in the treaty negotiations, that was not indicated in the task force recommendation. The recommendation was solely to express support for implementation of Pacific Salmon Treaty. **Pacific Salmon Commission**: – Met with Congressional staff and federal agency representatives in Washington, D.C., November 2018. Received a generally positive response accompanied by a request for supplementary information. – A summary document for each component of one-time and annual funding request was developed and shared in conjunction with 26 follow-up visits in Washington D.C. that included west coast congressional members and/or their staff, key staff associated with
10b	The treaty and its appropriations will result in harvest reductions, reduced bycatch, increased hatchery production and investments in habitat restoration,			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	which are crucial to reducing harvest thereby increasing Chinook for the benefit of Southern Resident orcas.			appropriations, and NOAA DC staff in March 2019. – Several letters of support have been sent to key congressional members including one from Phil Anderson that included 25 individuals or organizations signing on in support, one from the PSP, and one from the WFWC. **WDFW**: – Congress is continuing work on FFY 20 appropriations. – Senate committee reports and House appropriations are encouraging but less than the full request. – Senate includes an additional $23.7M; House an additional $30M. – US section is now preparing to seek remainder of funding request in FFY 21.
	Recommendation 11: Reduce Chinook bycatch in west coast commercial fisheries.			
11a	WDFW should work with regional councils and stakeholders to implement practices and regulations in west coast fisheries that further reduce bycatch of Chinook – allowing more of these Chinook to reach Southern Residents.	Via Pacific Fishery Management Council and North Pacific Fishery Management Council (NPFMC)	WDFW	**WDFW**: Ongoing efforts to avoid and minimize Chinook bycatch through the Pacific and NPFMC. National Marine Fisheries Service West Coast Region has informed the Pacific Fishery Management Council that they are reinitiating consultation under the ESA for 2019 ocean salmon fisheries. PFMC will work with NMFS through the re-consultation and Biological Opinion process.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				The NPFMC meets five times annually and is updated on current levels of chinook bycatch at each meeting. The NPFMC receives annual updates from Groundfish industry on their efforts to minimize chinook bycatch. The PFMC also meets five times annually, and chinook bycatch is monitored year-round. All catch, including bycatch, is tracked and provided as an in-season report at each meeting. NMFS also provides an annual report on all catch, including chinook salmon bycatch, in the groundfish fisheries every March. WDFW will continue to work within the councils to seek further reductions when and where possible, as new technology and research becomes available.
	Recommendation 12: Direct the appropriate agencies to work with tribes and National Oceanic and Atmospheric Administration to determine if pinniped (harbor seal and sea lion) predation is a limiting factor for Chinook in Puget Sound and along Washington's outer coast and evaluate potential management actions.			
12a	Conduct a pilot project for the removal or alteration of artificial haul out sites where sites are associated with significant outmigration and predation of Chinook smolts. Fund a study to determine if pilot removal accomplishes the goal of significantly		WDFW, NOAA, Tribes	**WDFW**: – The Governor requested $1.2 million in the 2019-21 operating budget to conduct research on the impact of pinnipeds in Puget Sound. WDFW did not receive funding for this work from the legislature in 2019. – WDFW coordinated with Canada and our partners on a science workshop in May 2019 at the University of British Columbia to work towards a shared understanding of the latest

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	reducing Chinook smolt predation.			information available among scientists closest to the topic. – WDFW and tribal co-managers are working to complete processing and analysis of harbor seal and sea lion diet in Puget Sound from 2017 and 2018 within existing resources as possible. – WDFW and several tribal co-managers collaborated to conduct pinniped surveys of the Salish Sea in August 2019. The surveys were done in coordination with Canada to allow for a cross-border assessment of pinniped populations. – WDFW and tribal co-managers are meeting in early November 2019 to further discuss the state of the science around pinnipeds and salmonid predation. WDFW and Fisheries and Oceans Canada, with tribes, first nations, and other partners are conducting additional transboundary workshop on pinnipeds in late November 2019. – WDFW is requesting additional funding in the supplemental 2020 legislative session to further the work outlined in the recommendation. **PSP (12d):** Convening of a management panel should wait until the science work group has compiled its comprehensive report. In the meantime, the Partnership worked with the Northwest Indian Fisheries Commission to host a panel discussion
12b	Complete ongoing regional research and coordinate an independent science panel (Washington Academy of Sciences or National Academy of Sciences) to review and evaluate research needed to determine the extent of pinniped predation on Chinook salmon in Puget Sound and Washington's outer coast. The ongoing and new work should include an assessment of factors that may exacerbate or ameliorate predation such as infrastructure haul-outs, hatchery strategies, the increased presence and impact of transient killer whales and the presence/absence of forage fish or other fish that are staple food for pinnipeds.		Gov, Legislature, and NOAA	

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
12c	Engage NOAA to determine the optimal sustainable populations of harbor seal stocks in Puget Sound.		WDFW, NOAA, Tribes	on pinniped management options with Congressman Derek Kilmer on October 8, 2019.
12d	Convene a management panel of state, tribal and federal agencies to communicate with the independent science panel, review the results of the ongoing regional research and independent scientific review and assess appropriate management actions. Citizen stakeholders should also be engaged in the process. If pinniped removal is identified as a management option, secure authorization through the Marine Mammal Protection Act.		PSP, NOAA	
12e	Provide funding for the science, research, coordination, decision making and, if deemed necessary, removal.		Gov, Leg	

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 13: Support authorization and other actions to more effectively manage pinniped predation of salmon in the Columbia River.			
13a	Support efforts to enact a Columbia River-specific amendment to the Marine Mammal Protection Act enabling more effective management of pinniped (harbor seal and sea lion) predation of salmonids.		Governor's Office, WDFW	**WDFW**: – In December 2018, President Trump signed into law S. 3119 – the Endangered Salmon Predation Prevention Act – which gives state and tribal resource managers more flexibility to manage sea lion predation in the Columbia River. – S. 3119 allows NMFS to approve permits for Washington, Oregon, Idaho, and several area tribes that will streamline the removal process of a designated number of sea lions from a portion of the Columbia River and adjacent tributaries each year.
13b	Support Marine Mammal Protection Act (MMPA) authorization to add Steller sea lions to the list of pinnipeds managed in the lower Columbia River. Support increasing removal levels and altering removal requirements.		Governor's Office, WDFW	**WDFW**: The states and eligible treaty tribes have initiated the process to obtain a joint permit for removal of California and Steller sea lions in the Columbia River's mainstem between River Mile 112 and the McNary Dam, and Washington tributaries. WDFW, Idaho Fish and Game, Oregon Department of Fish and Wildlife, and Columbia River Inter-tribal Fish Commission submitted an application in May 2019 under the new MMPA Section 120(f) to increase removals of Steller and California sea lions in the Columbia River and tributaries. NMFS has determined that the co-managers' application was sufficient and is accepting public comment on the application through the end of October 2019. WDFW has nominated a staff person to represent agency on

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				the pinniped task force. WDFW submitted a 2020 supplemental operating budget request for $924K in September to the Governor's Office for consideration in the 2020 legislative session.
13c	Monitor Chinook survival and pinniped distribution in the Columbia River estuary to guide current and future management actions.		WDFW	Some Prey Working Group members expressed that they were unclear if monitoring protocols are in place to assess the impact of lethally removing pinnipeds and if this action contributes to salmon recovery (and if it is an efficient use of limited resources). **WDFW**: WDFW did not receive additional funding for this work from the legislature in 2019.
13d	WDFW should work with Oregon Department of Fish and Wildlife to pilot a project to remove artificial sea lion haul-out sites in the lower Columbia River and study the effectiveness of the action in reducing predation on Chinook.		WDFW	Some Prey Working Group members expressed that it was unclear if this is being explored, which is unfortunate because it is an important non-lethal piece of this recommendation. **WDFW**: WDFW did not receive additional funding for this work from the legislature in 2019.
	Recommendation 14: Reduce populations of nonnative predatory fish species that prey upon or compete with Chinook.			
14a	Adjust game fish regulations and remove catch and size limits on		WDFW	**WDFW**:

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	nonnative predatory fish — including, but not limited to, walleye, bass and channel catfish — to encourage removal of these predatory fish, where appropriate.			2SHB 1579 (Chapter 290, Laws of 2019) included direction to liberalize bag limits for non-native predatory fish in all anadromous waters of the state (i.e., consider expanding rules that currently apply to the Columbia River to other anadromous systems, as appropriate). WDFW is conducting rulemaking to implement section 2 of 2SHB 1579. Section 2 states "The commission shall adopt rules to liberalize bag limits for bass, walleye, and channel catfish in all anadromous waters of the state in order to reduce the predation risk to salmon smolts." Department staff held five public meeting throughout the state and collected public comment via an online commenting tool through October 17th. Staff presented the proposed rule changes to the WFWC on October 19th and the Commission held a public hearing on that date. Department staff will be analyzing the public comment received and will be providing options for WFWC decision making at the December 2019 meeting. Any rule changes will take effect 31 days after filing with the Office of the Code Reviser. Some of the funding is also being used in Eastern Washington to fill some short-term needs around northern pike removal. Removal efforts will begin in February of 2020. WDFW will be hiring a crew of temporary technicians and using gill nets for removal efforts for three months to reduce the overall abundance of northern pike in Lake Roosevelt. The intent is to prevent Northern Pike from progressing further

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				downriver into the anadromous portions of the Columbia River.
14b	Evaluate predatory fish reduction options in McNary reservoir as the basis for further action to protect juvenile salmon.	Gov's budget should include "funding for the next three years" to support student of reservoir elevation management at McNary Dam	WDFW	**WDFW:** Continuing McNary assessment to determine solutions- to look at bass and walleye reduction through reservoir management
	Recommendation 15: Monitor forage fish populations to inform decisions on harvest and management actions that provide for sufficient feedstocks to support increased abundance of Chinook.			
15a	Complete Puget Sound-wide surveys of herring, smelt, and sand lance to map spawning habitat and determine abundance of these food sources for Chinook.		DNR, WDFW	**WDFW**: WDFW received funding in the biennial budget ($743K) to support this Recommendation. A new forage fish Washington Conservation Corps crew (funded by DNR) has been recruited, and they will be trained for and begin smelt and sand lance habitat surveys and mapping in October. Herring surveys will resume in January 2020. Habitat surveys will provide updates of spawning distribution and timing for all 3 species, and spawning biomass estimates for herring.
15b	Surveys should be conducted in conjunction with restoration and protection of forage fish spawning habitat.		DNR, WDFW	Unclear if sampling will be done in conjunction with habitat restoration efforts. This should be a priority as it will help agencies assess the impact of these restoration projects on target species of forage fish.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				WDFW: WDFW has met with North West Straits Initiative staff and County Marine Resource Committee volunteers who are involved in shoreline restoration projects. We have identified restoration projects that these groups will be monitoring, and WDFW and the forage fish Washington Conservation Corps crew (funded by DNR) will be assisting these groups by analyzing and providing quality control and quality assurance review of the beach spawning forage fish samples collected at these project sites.
15c	Inventory existing and planned forage fish harvest levels to determine potential impact of forage fish harvest on Chinook.		WDFW	**WDFW**: 2SHB 1579 (Chapter 290, Laws of 2019) includes a license requirement for smelt fishing in marine waters. WDFW has developed outreach materials to inform anglers of the new license requirement for smelt. We've learned that genetic analysis needed to assess the stock structure of herring encountered in the commercial fishery will not be completed in time for use in this project. We are proceeding with studies to assess smelt and herring harvest in areas where high fishing effort is reported. WDFW has begun staff recruitment and training, as well as gear testing and exploratory surveys in preparation for studies of surf smelt and herring fisheries. Surveys are planned to begin in 2020. These first phase studies will assess exploitation of herring and smelt in areas where fishing efforts are currently concentrated.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
15d	Provide funding to conduct these surveys and inventories.		Governor's Office, Leg, WDFW	**WDFW**: WDFW received funding in the biennial budget ($743K) to support this recommendation. Funding for this was received, but unclear if it's adequate for long-term monitoring. In addition to $743K, WDFW is leveraging WDFW, DNR, and Federal resources to address this recommendation. Funding beyond the current biennium will be required to continue progress.
	Recommendation 16: Support the Puget Sound zooplankton sampling program as a Chinook and forage fish management tool.			
16a	Monitor zooplankton to better inform forage fish and Chinook conservation. Provide funding to DNR to coordinate this critical sampling program, leveraging the work of and funding from federal, state, tribal and academic partners.		DNR, WDFW	**DNR:** DNR received funding in the biennial budget and $500K was moved to DFW to support zooplankton monitoring (original request was $720k). **WDFW**: The Zooplankton Monitoring Program Steering Committee had its first meeting to discuss priorities. There is strong support for the program from the sampling partners, and all indicated that they would endeavor to continue sampling despite the budget shortfall, however, some groups indicated that they would not be able to afford to sample as frequently or as many areas as they had previously. The Steering Committee identified minimizing data gaps and maintaining sampling capacity near 2018 levels as a top priority. Sampling has continued while WDFW is working with DNR, University of Washington and the sampling partners to finalize contracts.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
Goal 2: Decrease disturbance of and risk to Southern Resident orcas from vessels and noise, and increase their access to prey.				
	Recommendation 17: Establish a statewide “go-slow” bubble for small vessels and commercial whale watching vessels within half a nautical mile of Southern Resident orcas.			
17a	Enact legislation in 2019 creating a half-mile “go-slow” zone, defined as speeds of seven knots over ground or less.		WDFW	**WDFW:** SSB 5577 (Chapter 291, Laws of 2019), which includes this action, was passed by the legislature and then signed by Governor Inslee. Funding of $1.36 M was provided to WDFW to implement the new laws. As a result of increased funding to WDFW Enforcement, the following results were achieved: 1.) Three FTE's were funded and staffed by new or existing Enforcement Officers in the North Puget Sound area. One additional FTE will be funded in January 2020. 2.) At least 105 SRKW patrols were conducted. (Number is lower than projected due to a protracted absence of SRKW's in U.S. waters during the 2019 season) 3.) The associated costs of vessel maintenance and operations are funded through state and federal SRKW appropriations. WDFW, along with our partners in Be Whale Wise and others have ramped up outreach and education around the new regulations.
17b	Provide for discretion in enforcement and public outreach and education as needed.			
17c	Encourage coordination among Washington state, federal and Canadian authorities to align regulations.			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 18: Establish a limited-entry whale-watching permit system for commercial whale-watching vessels and commercial kayak groups in the inland waters of Washington state to increase acoustic and physical refuge opportunities for the orcas.			
18a	Create a limited-entry permit system to manage commercial whale-watching in the inland waters of Washington state to reduce daily and cumulative impacts on Southern Residents.		WDFW	**WDFW:** SSB 5577 (Chapter 291, Laws of 2019), which includes this action, was passed by the legislature and then signed by Governor Inslee on 5/8/2019. Funding was provided to WDFW to implement the new laws. WDFW must adopt rules for the commercial whale watching license system by January 1, 2021--based on best available science. WDFW hired a staff person to manage the rulemaking process directed via SSB 5577. An application/nomination period for members of an advisory committee closed on 10/25/19. The advisory committee will meet through spring 2020 to initiate development of the commercial whale watching licensing program. A co-manager/partner group will meet in parallel to discuss implementation details, and an independent science panel will examine the body of research to produce a summary of agreed-upon best available science. Proposed rules will be reviewed in fall 2020 for prospective adoption by January 1, 2021.
18b	WDFW should develop the permit system in consultation with the Pacific Whale Watch Association, orca conservation organizations and other stakeholders.			
18c	The permitting system will consider limiting commercial whale-watching activities by: (1) number of boats that receive permits, (2) hours and duration spent in the vicinity of the Southern Resident orcas and (3) location. Development of the			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	permit system will consider limiting the total number of boats that receive permits and help codify conservative and flexible measures, such as limiting the amount of time commercial whale-watching vessels may spend in the vicinity of a particular group of whales and limiting the number of commercial whale-watching vessels that may be in the vicinity of the whales at a given time. Permitting system must be in place by July 2019, including initial limits as described above.			
18d	Consider implementing a buy-back program.			
18e	Require the use of the Automatic Identification System to enable effective monitoring and compliance.			
18f	Coordinate with Canadian authorities to			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	develop and implement the permit system across boundaries.			
18g	Formally apply standards from the Kayak Education and Leadership Program's "Code of Conduct" to the organized operation of kayaks and other human powered vessels near Southern Resident orcas (for example, practices such as "rafting up").			
	Recommendation 19: Create an annual Orca Protection endorsement for all recreational boaters to ensure all boaters are educated on how to limit boating impacts to orcas.			
19a	Create a $10 statewide Orca Protection endorsement with an opt-out option for all registered recreational vessels.		Washington State Parks and Recreation Commission	Not included in Governors policy or budget priorities for legislative session. In 2019, vessels working group and task force urged shift in emphasis to: – Close the education loophole for visiting (charter and rental users) and Canadian boaters who are not required to get a Boating Education card because they are here less than 90 days. – Make more use of Be Whale Wise platform and mass media tools (like videos that kayak companies use).
19b	Provide education on Be Whale Wise guidelines, voluntary and regulatory measures and other information at the time the marine			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	endorsement is purchased, so every boater has this basic information.			**State Parks:** State Parks is updating marine law enforcement training manuals to reflect new laws. State Parks IT worked with Washington State Patrol to code new laws for citations for ticketing and collect data. Recreational Boater Safety questions around the new laws have been created and are in the queue to be added to the online Mandatory Boater Education Card exam. State Parks' Communications Consultant is engaging with WDFW to reproduce the Be Whale Wise stickers and handouts reflecting new laws.
19c	Direct the resulting revenue to WDFW's new Marine Enforcement Division, to the Washington State Department of Licensing to cover costs of administering the program and to partners doing outreach and education. Make more use of Be Whale Wise platform and mass media tools (like videos that kayak companies use).			
19d	Work with trade associations and ports and through existing government programs and channels to provide additional education to commercial and recreational boaters.			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 20: Increase enforcement capacity and fully enforce regulations on small vessels to provide protection to Southern Residents.			
20a	Create a WDFW Marine Enforcement Division with four additional officer positions at WDFW focused on protection and enforcement in Puget Sound.		WDFW	Funding for SSB 5577 (Chapter 291, Laws of 2019) was provided to WDFW to implement the new laws and will result in increased officer presence/number of patrols. As a result of increased funding to WDFW Enforcement, the following results were achieved: 1.) Three FTE's were funded and staffed by new or existing Enforcement Officers in the North Puget Sound area. One additional FTE will be funded in January 2020. 2.) At least 105 SRKW patrols were conducted. (Number is lower than projected due to a protracted absence of SRKW's in U.S. waters during the 2019 season) 3.) The associated costs of vessel maintenance and operations are funded through state and federal SRKW appropriations.
	Recommendation 21: Discourage the use of echo sounders and underwater transducers within one kilometer of orcas.			
21a	Establish a “standard of care” for small vessel operators limiting the use of echo sounders and other underwater transducers within a half nautical mile of Southern Resident orcas. Implement as a voluntary measure and	– Continue coordination with Canada – Keep message simple – Consider “Notice to Mariners” from USCG – Blend the messaging: balance need for safety while discouraging use	PSP	– Puget Sound Harbor Safety Committee adopted a voluntary Standard of Care for Puget Sound in June. Canada adopted a similar interim voluntary standard in their waters in June. – PSP, WDFW and Transport Canada are working with Be Whale Wise to help unify standard in US and Canadian waters and

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	provide exceptions for safe navigation.	– Future evaluation could explore strategies for discouraging use of other transducer types like “chirp” units that emit pulses over a broader frequency range. – Working Group strongly encouraged near-immediate development and implementation of a communications campaign/roll out – to maximize potential effectiveness in 2019 season.		disseminate consistent, simple communications materials.
21b	Conduct education and outreach.			
21c	Consider phasing in mandatory equipment requirements and regulations.			
	Recommendation 22: Implement shipping noise-reduction initiatives and monitoring programs, coordinating with Canadian and U.S. authorities.			
22a	Create a program similar to Enhancing Cetacean Habitat and Observation for Washington state, including participation by ports, whale watching operators, private vessel operators and Tribal governments as desired.	– Group has met three times – appetite for coordination – early in process so too early to tell – Important to look at emerging technologies and provide funding to support this	Northwest Seaport Alliance, Port of Seattle, Port of Tacoma, PSP	The Ports of Seattle and Tacoma, as well as the Northwest Seaport Alliance (with support WSF, NOAA, ECHO and PSP) convened a stakeholder and tribal meeting with more than 50 participants in October 2019. PSP, Port of Seattle, Port of Tacoma and the Northwest Seaport Alliance plan to lead the next phase of the Planning Committee and coordinate potential future development of a pilot program starting with dialogue at a Partnership/Tribal Co-Management Council meeting in December. The pending USCG Authorization Act in Congress could

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
22b	Coordinate with the ECHO Program on transboundary efforts to reduce noise impacts to Southern Residents. Provide funding to complete an underwater acoustic monitoring network for Puget Sound, filling in gaps — such as on South San Juan Island — and supporting acoustic and visual mapping to improve the ability to identify when and where Southern Resident orcas are present.	– Quiet Seas award program – Data gaps that need to be filled – acoustic monitoring; speed by ship type; mix of ships and profiling them by sector and by vessel – coordination needed b/c this is ECHOs work – Need to find problem statement – categorizing waterway is a good first step – Assumes that we know what initiatives are – need to fill gaps – Needs tribal engagement – invites are out – Measure noise levels in habitat of orcas – need to measure the source levels of a particular vessel versus the received level at particular locations – Need coordination with Navy – Which vessel types is this going to apply to? Important to think about this. Mix of		promote and potentially expand Federal involvement.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
		traffic is important to think about. Application of any initiative can have different impacts based on type of traffic. – Need to include navigational strategies and best practices for when SRKW are present – ECHO includes this. – Are decreased noise levels helpful to SRKW – we need to know this. – Work Group wants report-outs about how it is going.		
	Recommendation 23: Reduce noise from the Washington state ferries by accelerating the transition to quieter and more fuel-efficient vessels and implementing other strategies to reduce ferry noise when Southern Residents are present.			
23a	Conduct a ferry fleet noise baseline study as the basis for establishing noise reduction goals and developing plans.	– Funding received doesn't include shoreside infrastructure to support this, don't have funding for shoreside charges – Technology still needs to be developed	Washington State Ferries	**WSF:** Legislature funded a new electric hybrid ferry and retrofit of an existing ferry to an electric hybrid. Legislature also provided funding for WSF's fleetwide noise baseline study, which will have its fieldwork complete by the time of this final report (including testing of a Kitsap Transit fast ferry) and will have the study complete most likely by the end of the year. The Whale Report Alert System developed in Canada has
23b	Based on the results of the baseline study, institute engineered or			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	operational strategies to safely reduce noise from ferries when Southern Residents are present.	around the charging mechanism – Emissions reduction effort – great- but may not be a noise reduction effort – don't have data that cavitation is main source from ferry side – this is coupled with study to determine impact of cavitation – Noise Control Engineering under contract and will start this study starting July – all noise emanating from ferries is focus of study – Funding for one vessel retrofit and one new vessel (language says up to two) – Potential opportunity to collaborate around study – Want more funding to support long-range plan – the funding is drop in bucket – acceleration element important – Will learn something from first one and then will apply to others		expanded and is being used in Puget Sound by WSF and other maritime operators.
23c	Provide capital funding to accelerate the transition to quieter and more fuel-efficient ferry fleet.			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
		– Whale Report Alert System needs to be implemented beyond the ferry system – Work Group would like to get updates but do not need to roll up sleeves.		
	Recommendation 24: Reduce the threat of oil spills in Puget Sound to the survival of Southern Residents.			
24a	Initiate zone-based rule making on tug escort requirements for oil laden tank vessels, including barges, more than 5,000 tons but less than 40,000 dead weight tons.	– Not all elements from original bill made it into law – (1) ECY rulemaking for emergency response towing vessels – additional legislation would be needed to authorize them to conduct rulemaking – this still important piece – A lot more to do outside of ESHB 1578 around oil spills recognizing that ESHB 1578 is important piece of legislation – Potential additional noise – needs to be direction/funding to	Washington Board of Pilotage Commissioners, Ecology	**Ecology:** In March 2018, the governor signed Exec. Order 18-02 directing state agencies to take several immediate actions to benefit SRKWs. Ecology was directed to create a curriculum to improve and increase the number of trainings for vessels in the whale watching industry to assist in the event of an oil spill. Ecology requires funding to implement the Curriculum Plan for a Killer Whale Deterrence Program Report published in April 2018. – Ecology will work with WDFW to develop and deploy a whale deterrence program within the waters of the Salish Sea, Strait of Juan de Fuca, and Puget Sound. – Ecology will assist the Board of Pilotage Commissioners with adopting rules for tug requirements for oil tankers and safety measures when dealing with oil tankers in Washington waters (similar to the approach in 2SHB 1611 in the 2017 session).
24b	Enact legislation disallowing any shoreline or seafloor infrastructure that would support offshore oil and gas development off the Washington coast.			
24c	Update oil spill prevention and cleanup standards to address new types of oil and			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	increased use of articulated tug-barges.	help monitor this change/impacts – before and after before rule goes into place.		– Standards for articulated tug barges will be covered under the Rules for Tug Escorts item also noted under this recommendation. – ESHB 1578 (Chapter 289, Laws of 2019), passed by the 2019 Legislature and signed by Governor Inslee, requires smaller oil vessels that can carry up to 7 million gallons of oil to have tug escorts in the busy shipping lanes of Rosario Strait and waters to the east by Sept. 1, 2020. The new law brings the smaller oil vessels in line with the long-standing escort requirements for the large, loaded oil tankers traversing the Salish Sea. (recruiting for risk modeling team) (identifying zones then modeling) (shipping synopsis) (Host Salish Sea Forums) – 5-year effort. Agency is funded for the 2019-21 biennium at $1.37 M for implementation. – Per ESHB 1578 (Chapter 289, Laws of 2019), the Board of Pilotage Commissioners will initiate rulemaking in December 2019 to work with us to adopt rules for tug escorts in all of Puget Sound for the smaller oil vessels by 2025. It requires us to work with the U.S. Coast Guard, tribes, and stakeholders to develop and maintain an internal computer modeling capability that uses data to predict vessel risk to inform the rulemaking. – Ecology must assess by September 2023 if an emergency response towing vessel stationed in the San Juan Islands — similar to the emergency response towing vessel currently stationed at Neah Bay — would reduce oil spill risks. This will be a topic of discussion at the 2019 Salish Sea Shared
24d	Support the requirement for a stationed emergency response towing vessel (rescue tug) in a location to minimize response time in Haro Strait and other navigation lanes with the highest tank vessel traffic.			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
				Waters Forum to be held Nov. 14, 2019, in Bellingham.
	Recommendation 25: Coordinate with the Navy in 2019 to discuss reduction of noise and disturbance affecting Southern Resident orcas from military exercises and Navy aircraft.			
25a	The U.S. Navy was not among the organizations that were initially asked to participate in the Vessels working group during Year One. However, early in the task force process several task force members and the full Vessels working group indicated the need for direct engagement with the Navy in Year Two, which was reinforced in hundreds of public comments on the draft report.	• Interest in maintaining and restoring institutional knowledge within the Navy on this topic • For detailed information and to comment on proposed future Navy testing and training activities in the northwest, use the portal provided in the Draft Supplemental EIS/OEIS • The spatial scale and effectiveness of current SRKW deterrence strategies in the event of an spill in the Northwest Area Contingency plan are limited; there was broad interest in exploring the unconventional idea of whether/how deployment of Navy mid frequency sonar during an oil spill response could be applied, among other alternatives. • Vessels Work Group involvement likely needed as part of follow up to the	PSP	The US Navy joined the vessels working group in 2019 and at least five experts participated. The Navy also participated in the ECHO South meeting in September 2019 (Recommendation 22). The Navy met with WRAS in September to discuss potential use of Whale Report Alert System. Many organizations from the Task Force submitted public comment on the Navy's Draft Supplemental EIS/OEIS in June 2019. NMFS has proposed expanding SRKW critical habitat beyond Puget Sound to the outer coast of Washington. The comment deadline is in mid-December 2019. The State of Washington and other organizations plan to submit comments and note concerns with the geographic exemption for military activities off the north coast which overlaps with the distribution of the Southern Resident orcas.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
		updated SRKW hazing plan outlined in the Governor's Executive Order in 2018.		
	Recommendation 26: Revise chapter 77.15.740 RCW to increase the buffer to 400 yards behind the orcas.			
26a	The guidelines of the Pacific Whale Watch Association include this voluntary standard.		WDFW	SSB 5577 (Chapter 291, Laws of 2019), which includes this action, was passed by the legislature and then signed by Governor Inslee. Funding was provided to WDFW to implement the new laws. **WDFW:** As a result of increased funding to WDFW Enforcement, the following results were achieved: 1.) Three FTE's were funded and staffed by new or existing Enforcement Officers in the North Puget Sound area. One additional FTE will be funded in January 2020. 2.) At least 105 SRKW patrols were conducted. (Number is lower than projected due to a protracted absence of SRKW's in U.S. waters during the 2019 season) 3.) The associated costs of vessel maintenance and operations are funded through state and federal SRKW appropriations. WDFW, along with our partners in Be Whale Wise and others have ramped up outreach and education around the new regulations.
26b	By limiting the distance at which vessels can approach from behind (and their speed), the intent is to decrease the occurrence of chase-like situations that may adversely affect Southern Resident orcas.			
26c	Encourage coordination among Washington state, federal and Canadian authorities to align regulations, which will foster clear communication and increase compliance.			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 27: Determine how permit applications in Washington state that could increase traffic and vessel impacts could be required to explicitly address potential impacts to orcas.			
27a	State agencies should study potential requirements for relevant permit applications to explicitly address potential impacts to Southern Resident orcas and treat underwater noise as a “primary constituent element” of critical habitat and report to the task force by 2019.	– Need more direction from Governor’s Office – agencies are waiting for Governor’s Office for Regulatory Innovation and Assistance to schedule a meeting-needs to be agency meetings to figure out what to do together. – No discussions between permitting world at state level – Loophole is new use to existing facilities – Loophole – high-speed ferries (what regulations are they working under – do they have to abide by same laws/regulations as other operators, ferries, etc.)	DNR, Ecology	As requested by ORIA, members of the Vessels Working Group developed clearer statement of the key two problems this recommendation sought to address. Accordingly, the next steps are: (1) for the next phase of the Vessels Working Group to develop additional technical resources that can be consulted by coastal planners and environmental staff to identify and suggest mitigation options for potential impacts of increased vessel traffic and associated with facilities; and (2) for Ecology to update the State Environmental Protection Act checklist to include a vessel traffic question and specifically require that potential impacts to SRKW be addressed. Because this by itself does not seem to warrant legislative attention, Ecology is inclined to make such modifications to the SEPA checklist whenever they next conduct rulemaking on SEPA for other purposes (i.e., rather than as a standalone effort). Before potentially updating the state JARPA (Joint Aquatic Resources Permit Application), the willingness and timeline for DNR, WDFW and Ecology to provide expertise on interpreting data and impacts must be determined.
27b	Coordinate with local governments and tribes and increase transboundary coordination with Canada.			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 28: Suspend viewing of Southern Resident orcas.			
28a	Establish a whale watching regulation that precludes Southern Resident orca viewing by all boats in Puget Sound for the next three to five years. The governor should direct WDFW to begin rulemaking to define Washington whale watching in coordination with the commercial whale watching industry, kayak industry, local governments and interested nongovernment organizations.			This component was removed from the Governor's request legislation. – Task Force and Working Group viewpoints strongly split on this recommendation – If a suspension were to be required, there would need to be much greater funding and capacity provided for enforcement to be effective – In contrast to Washington, commercial whale watchers in Canada agreed to not watch the Southern Resident orcas for the upcoming year – A new ballot initiative in San Juan County seeks to restrict vessels from watching the Southern Resident orcas within 650 yards in San Juan County waters; an oppositional lawsuit from commercial operators has been filed against the proponent and the County. – San Juan County is advancing a marine spatial planning process which will more definitively identify the Southern Resident orcas foraging hotspots and patterns in commercial and recreational fishing use.
28b	Report back to governor and Legislature after three to five years on the effectiveness of the suspension.			

Goal 3: Reduce the exposure of Southern Resident orcas and their prey to contaminants.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 29: Accelerate the implementation of the ban on polychlorinated biphenyls in state purchased products and make information available online for other purchasers.			
29a	Direct the Department of Enterprise Services to accelerate implementation of the ban, enacted by the Legislature in 2014, on PCBs in products purchased by the state.	DES does not currently have authority to require disclosure, but should create strong disclosure incentives, and/or work to make low or no PCB purchasing decisions the norm.	Governor's Office, DES	**DES:** DES published the Purchasing Preference Policy, provided a training for DES contracting staff, and is currently adding new language to master contracts as the old versions expire and the new 6-10-year contract is developed.
29b	This law includes a provision for suppliers to provide information on PCBs in products to the state, which should be shared publicly to facilitate PCB-free purchasing by other entities.	Scope and assess resource needs to develop legislative request.	DES	DES has completed guidance for state agencies.
	Recommendation 30: Identify, prioritize and take action on chemicals that impact orcas and their prey.			
30a	By March 2019, ECY should develop a prioritized list of chemicals of emerging concern that threaten the health of orcas and their prey and pursue	Identify chemicals most likely to have the largest impact on Southern Resident orcas, directly, or to their prey, or to the	Ecology, Puget Sound Institute with support from PSMP Toxics WG	**Ecology:** Ecology, in collaboration with the PSEMP Toxics work group, is working with regional partners to conduct a risk-based CEC prioritization. This work is currently under-funded, with a small grant from PSP.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	policy and/or budget requests in the 2019 legislative session to prevent the use and release of chemicals of emerging concern into Puget Sound.	ecosystem that supports both.		Ecology is implementing the Safer Product for Washington program (SSB 5135) to address five priority chemical classes and products, including PFAS, phthalates, phenolic compounds, flame retardants and PCBs. Ecology also received funding to accelerate the development and implementation of Chemical Action Plans and conduct product testing to address these chemical classes that impact the heath of orcas and their prey. Ecology is seeking supplemental funding for enhancing the Local Source Control Partnership to address local sources of toxics and support local government efforts for source control.
30b	Direct ECY to convene discussions and develop a plan to address pharmaceuticals, identifying priorities, source control and wastewater treatment methods.	Undertake CAPs for prioritized chemicals. And, update CAP rules to accommodate CECs. The Legislature could ban or give ECY necessary authority to ban or phase-out chemicals. Implement pollution prevention actions around problem chemicals. Implement treatment, management, or cleanup actions around problem chemicals. Reallocate, or allocate new funding, to reduce toxics loading, and exposure. Direct ECY to	Ecology, Legislature	**Ecology:** Ecology has hired part-time staff to convene discussions and access CECs and pharmaceuticals for treatment approaches and source control.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
		convene discussions and develop a plan to address pharmaceuticals, identifying priorities, source control and wastewater treatment methods.		
	Recommendation 31: Reduce stormwater threats and accelerate clean-up of toxics that are harmful to orcas.			
31a	Provide funding to accelerate the clean-up and removal of legacy sources of polychlorinated biphenyls or PCBs, polycyclic aromatic hydrocarbons or PAHs, polybrominated diphenyl ether or PBDEs and per and polyfluoroalkyl substances present in Puget Sound.	Reallocate, reprioritize, or allocate new funding, to accelerate cleanup and threat reduction.	Legislature	Funding available, comparable with past funding. Not enough. Questions about how 'targeted', or 'prioritized'.
31b	Prioritize and fund clean-up actions likely to have the greatest benefit to Southern Resident orcas.	Fund partners to remove toxic materials	Ecology	**Ecology:** Pilot project ($3.7m). Funding available. Not enough--just pilot funding. Questions about how 'targeted', or 'prioritized'.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
31c	Identify toxic hotspots in the stormwater entering Puget Sound. Prioritize these for retrofits and/or redevelopment to meet current standards.	Provide pass through funding to local entities to identify sources of toxics in known hot spots	Ecology	**ECY:** The Governor's 2019-21 operating budget included $3 million for local source control programs. No funding for local source control programs was provided in the enacted budget. Funding for ECY to identify sources in the Snohomish Basin ($490k).
31d	Increase funding for the Stormwater Financial Assistance Program to incentivize immediate and accelerated retrofits and other source control actions.	Fund and implement stormwater retrofits to reduce threats from stormwater hot spots. Create incentives to redevelop stormwater problem areas to increase treatment and remove toxic materials	Ecology	**Ecology:** Fund and implement stormwater retrofits to reduce threats from stormwater hot spots. 2019-21 Centennial Clean Water ($20m). 2019-21 Stormwater Financial Assistance ($30m). 2019-21 Water Pollution Control Revolving Program ($12m). Funding available. Not enough. Questions about how 'targeted', or 'prioritized'.
31e	Prioritize and accelerate sediment remediation, nearshore restoration and clean-up of hotspots in forage fish and Chinook rearing habitats based on risk to Southern Resident orcas.	Accelerate cleanups in areas where toxic contamination is threatening juvenile salmon and forage	Ecology	**Ecology:** Environmental Resilience - Creosote Piling Removal ($1.89m). Expanded Cleanup Site Capacity ($1.5m). Support Voluntary Cleanups ($800k). Derelict Vessel Removal ($5m). 2019-21 Clean Up Toxic Sites - Puget Sound ($10.5m). Funding available. Not enough. Questions about how 'targeted', or 'prioritized'.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 32: Improve effectiveness, implementation and enforcement of National Pollutant Discharge Elimination System permits to address direct threats to Southern Resident orcas and their prey.			
32a	Update aquatic life water quality standards focused on pollutants most harmful to Southern Resident orcas and their prey.	Focus on PBDEs, contaminants of emerging concern. Explore setting more protective aquatic life criteria. Report on findings.	Ecology	Contaminants of Emerging Concern (CEC) prioritization will inform this step. Assess results of CEC prioritization.
32b	Direct ECY to consider developing stronger pre-treatment standards for municipal and industrial wastewater discharges under NPDES.	Consider enhanced permits to benefit the Southern Resident orcas.	Ecology; Local Operators	No funding is available to complete work beyond implementing existing standards.
32c	Provide funding for ECY to increase inspections, assistance programs and enforcement to achieve water quality standards. Prioritize enforcement where limits are exceeded for pollutants known to be harmful to Southern Resident orcas.		Legislature; Ecology	At the request of the Governor, $490,000 was provided for point source water pollution Inspection Staff, and $707,000 was provided for water quality specialists to work with landowners and local governments on nonpoint water pollution source issues. ($490k pt. source, $707k non-pt.)

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	Recommendation 33: Increase monitoring of toxic substances in marine waters; create and deploy adaptive management strategies to reduce threats to orcas and their prey.			
33a	Expand and better coordinate existing toxic monitoring programs in Puget Sound focused on chemicals harmful to the Southern Resident orcas.	Monitor air quality. Monitor volatilization of chemicals on water surface	Legislature (Fund)	Not clear on any progress on these recommendations. Some additional funding for PSEMP last session.
33b	Fund the development and implementation of a program to study and monitor the impact of CECs on Southern Resident orcas.	Monitor CECs in PS—via freshwater inputs. Monitor CECs in prey and forage fish. Establish thresholds for CECs that are protective for whales and prey	Legislature (Fund)	Not clear on any progress on these recommendations
Goal 4: Ensure funding, information and accountability mechanisms are in place to support effective implementation.				
	Recommendation 34: Provide sustainable funding for implementation of all recommendations.			
34a	Provide immediate capital and operating funds in the 2019-21 biennium budget to implement near-term high-priority actions.		Governor's Office; Legislature	The enacted 2019-21 operating, and capital budgets included $676 million to implement near-term high-priority actions.

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
34b	Request that the governor and Legislature establish a sustainable, durable funding source to implement these recommendations and meet needs as they arise.			
34c	Include funding to state agencies for staffing, research and ongoing management needed to initiate and implement task force recommendations.			
	Recommendation 35: Conduct research, science and monitoring to inform decision making, adaptive management and implementation of actions to recover Southern Residents.			
35a	Request that NOAA's Northwest Fisheries Science Center model the task force's Year One recommendations related to the three major threats to determine the degree of benefit to Southern Resident		PSP, WDFW, RCO, Ecology, and other agencies	In the options the Task Force outlined for "Life After the Task Force," the importance of the emphasis in 35d was well recognized. All options seek to complement any future governance body with relevant regional or statewide forums and networks to conduct monitoring and adaptive management (as emphasized in the joint letter from the Puget Sound Partnership's Science Panel and Puget Sound Ecosystem Monitoring Program). Agencies agree that any future governing body should recognize that developing

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	orcas that the recommended actions may produce under a reasonable range of future growth and development scenarios.			a monitoring and adaptive management framework with clear objectives is a necessary next step.
35b	Request that the zooplankton monitoring team engage with the PSEMP and ECY to look at impacts associated with nutrient pollution.			
35c	Request that the Regional Response Team and the Northwest Area Committee assess the connections to and impacts of oil spills on plankton.			
35d	It will be important to use an adaptive management approach to track effectiveness of implemented recommendations, look for unintended consequences, monitor			

Recommendation		Notes	Implementor(s)	Progress as of Nov. 2019
	ongoing ecosystem change and adjust future investments based on our findings.			
	Recommendation 36: Monitor progress of implementation and identify needed enhancements.			
36a	Agencies shall report to the governor and the task force on progress implementing recommendations by May 1, 2019. These reports are to address progress, shortcomings, issues, barriers and gaps associated with initial implementation.		Agencies	Completed as of March/June 2019 task force meetings.
36b	The task force will identify changes needed, any new ideas and other actions needed to recover Southern Resident orcas.		Task force	Completed as of Year Two report date (November 8, 2019).

Appendix 3. Task force, working group, steering committee and consulting team members

Task force

Co-Chairs

Dr. Les Purce
Stephanie Solien

Observer

Bryce Campbell, Global Affairs Canada

Tribal representatives

Confederated Tribes of the Colville Reservation

Karen Condon, PhD
Casey Baldwin
Councilwoman Norma Sanchez

Lummi Nation

Chairman Jay Julius
G.I. James
Lisa Wilson
Councilman Nikolaus Lewis
Kurt Russo

Makah Tribe

Councilman Nate Tyler
Chad Bowechop
Katie Wrubel
Haley Kennard
Scott McCreery

Northwest Indian Fisheries Commission

Cecilia Gobin

Port Gamble S'Klallam Tribe

Paul McCollum

Samish Indian Nation

Chairman Tom Wooten

Skokomish Indian Tribe

Dave Herrera

Spokane Tribe of Indians

B.J. Kieffer
Conor Giorgi
Brent Nichols, PhD

Squaxin Island Tribe

Jeff Dickison
Chairman Arnold Cooper

Suquamish Tribe

Chairman Leonard Forsman
Bardow Lewis

Tulalip Tribes

Commissioner Terry Williams
Daryl Williams

Task force members

Association of Washington Businesses
Gary Chandler

Center for Whale Research
Ken Balcomb

City of Shoreline Mayor
Will Hall

Commercial fisherman
Brendan Flynn

Ilwaco Charters
Butch Smith

Long Live the Kings
Jacques White, PhD

National Oceanic and Atmospheric Administration
Lynne Barre
Teresa Mongillo

Northern Economics, Inc.
Katharine Wellman, PhD

Northwest Marine Trade Association
George Harris

Office of Gov. Inslee
JT Austin

Okanogan County
Commissioner Andy Hover

Pacific Salmon Commission
Phil Anderson

Pacific Whale Watch Association
Jeff Friedman
Kelly Balcomb-Bartok
Brian Goodremont

Puget Sound Anglers
Ron Garner

Puget Sound Partnership
Laura Blackmore

San Juan County
Council Member Jamie Stephens

The SeaDoc Society
Joe Gaydos, VMD, PhD

The Whale Trail
Donna Sandstrom

Washington Department of Fish and Wildlife
Amy Windrope
Kelly Susewind

Washington Environmental Council
Mindy Roberts, PhD
Washington Farm Bureau
Tom Davis

Washington Fish and Wildlife Commission
Brad Smith, PhD

Washington Forest Protection Association
Mark Doumit

Washington House of Representatives
Representative Brian Blake (D)
Representative Debra Lekanoff (D)
Representative Drew MacEwen (R)

Washington Public Ports Association
Commissioner Steve Johnston
Commissioner Kathy Pittis

Washington State Senate
Senator Kevin Van De Wege (D)
Senator Doug Ericksen (R)

Washington State Conservation Commission
Ron Shultz
Brian Cochrane
Alison Halpern, PhD

Washington State Department of Agriculture
Kelly McLain
Brian Joseph, DVM

Washington State Department of Ecology
Maia Bellon

Washington State Department of Natural Resources
Kristin Swenddal

Washington State Department of Transportation
Amy Scarton
Kevin Bartoy
Nicole McIntosh
Philip Narte

Washington State Parks and Recreation Commission
Lisa Lantz
Virginia Painter
Owen Rowe

Washington State Recreation and Conservation Office
Kaleen Cottingham

Prey working group

Co-Chairs

Penny Becker, PhD, Washington Department of Fish and Wildlife
Erik Neatherlin (Year Two) & Steve Martin (Year One) - Washington State Recreation and Conservation Office/Governor's Salmon Recovery Office

Tribal representatives

Confederated Tribes of the Colville Reservation

Casey Baldwin

Lummi Nation

Lisa Wilson
Tom Chance

Makah Tribe

Tiffany Petersen
Katie Wrubel

Nisqually Indian Tribe

David Troutt

Spokane Tribe of Indians

Brent Nichols, PhD

Squaxin Island Tribe

Jeff Dickison

Confederated Tribes and Bands of the Yakama Nation

Bill Sharp
Paul Ward

Working group members

Bonneville Power Administration

Liz Klumpp

Department of Fisheries and Oceans (Canada)

Lisa Jones

Chelan County Public Utility District

Alene Underwood
Bill Towey

Commercial fishing

Skip Anderson

Washington State Dairy Federation

Jay Gordon

Defenders of Wildlife

Robb Krehbiel

Hatchery and Science Review Group

Lee Blankenship

Hood Canal Coordinating Council Lead Entity

Alicia Olivas

Humane Society of the United States

Dan Paul

Long Live the Kings

Michael Schmidt

National Oceanic and Atmospheric Administration

Mike Ford, PhD

Natural Resources Defense Council

Giulia Good Stefani

Northwest Power and Conservation Council

Guy Norman

Oregon Department of Fish and Wildlife

Chris Kern
Shaun Clements, PhD

Puget Sound Partnership

Amber Moore

Recreational fishing industry

Dave Croonquist
Liz Hamilton

Council of Regions

Steve Manlow

Roza Irrigation District

Scott Revell

San Juan County Public Works

Kendra Smith

Sound Action

Amy Carey

University of Washington Friday Harbor Labs

Deborah Giles, PhD

U.S. Navy

Andrea Balla-Holden
Chris Hunt
Mary Anderson

Washington Department of Fish and Wildlife

Michele Culver
Kirt Hughes

Washington State Department of Natural Resources

Dave Palazzi

Vessels working group

Chair

Todd Hass, PhD – Puget Sound Partnership

Tribal representatives

Lummi Nation

Kurt Russo

Makah Tribe

Chad Bowechop
Haley Kennard

Working group members

Chamber of Shipping of British Columbia

Denien Ford
Robert Lewis-Manning

Friends of the San Juans

Lovel Pratt

National Oceanic and Atmospheric Administration

Marla Holt, PhD
Grace Ferrara

Oceans Initiative

Erin Ashe, PhD
Rob Williams, PhD

Orca Conservancy

David Bain, PhD

Pacific Merchant Shipping Association

Captain Mike Moore

Pacific Whale Watch Association

Jeff Friedman

Port of Seattle

Commissioner Fred Felleman

Vancouver Fraser Port Authority

Orla Robinson

Puget Sound Pilots

Captain Eric Von Brandenfels

Recreational Boating Association of Washington

Steve Finney
Wayne Reinholt

San Juan County Public Works

Frances Robertson, PhD

The Whale Museum

Rich Osborne, PhD

The Whale Trail

Donna Sandstrom

Transport Canada

Jeff Pelton

U.S. Coast Guard

Lieutenant Scott McGrew
Captain Laird Hail
Brian Corrigan

U.S. Navy

Commander Craig Thedwall
Dawn Grebner
Lieutenant Eilas Boddy
Christopher Hunt
Mary Anderson
Margaret Moran Dour
Heather Parker
Lynn Wall
Andrea Balla-Holden
Lieutenant Commander Allen Agor

University of British Columbia

Chris McKesson, PhD

University of Washington Friday Harbor Labs

Deborah Giles, PhD

Washington Department of Fish and Wildlife

Captain Alan Myers
Sergeant Russ Mullins

Washington State Department of Commerce

Joshua Berger
J.B. Bennis

Washington State Department of Ecology

Captain Scott Ferguson
Sara Thompson

Washington State Department of Natural Resources

Cyrilla Cook

Washington State Ferries

Kevin Bartoy

Washington State Parks

Derek VanDyke
Amos Almy

Contaminants working group

Chair

Derek Day – Washington State Department of Ecology

Working group members

Center for Urban Waters, Puget Sound Institute

Andy James, PhD

City of Tacoma

Dana DeLeon

Eco-Tec

Herb Pearse

Environment and Climate Change Canada

Cecilia Wong
Chris Marshall

Geosyntec

Christian Nilsen
Eric Strecker

King County Department of Natural Resources

Deborah Lester

National Oceanic and Atmospheric Administration

Jessica Lundin, PhD

Northwest Seaport Alliance

Deanna Seaman

Office of Gov. Inslee

Rob Duff

Puget Sound Partnership

Mike Johnson

Puget Soundkeeper

Alyssa Barton
Retired
Lincoln Loehr

The Nature Conservancy

Emily Howe, PhD

Toxic Free Future

Laurie Valeriano

Washington Environmental Council

Mindy Roberts, PhD

Washington State Department of Commerce

Linda Bentley

Washington State Department of Ecology

Chris Dudenhoeffer
Jeff Killelea
Ken Zarker
Rachel McCrea
Will Hobbs, PhD

Washington State Department of Fish and Wildlife

Sandra M O'Neill
Jim West

Washington State Department of Natural Resources

Abby Barnes

Washington Stormwater Center

Jen McIntyre, PhD
John Stark, PhD

Zero Waste Washington

Heather Trim, PhD

Steering committee

Co-chairs

Dr. Les Purce
Stephanie Solien

Steering committee members:

Office of Financial Management

Jim Cahill
Leslie Connelly

Office of Gov. Inslee

JT Austin

Puget Sound Partnership

Todd Hass, PhD
Cathy Cochrane
Laura Blackmore
Jon Bridgman

Washington State Recreation and Conservation Office, Governor's Salmon Recovery Office

Erik Neatherlin
Steve Martin

Washington Department of Fish and Wildlife

Penny Becker, PhD

Washington State Department of Ecology

Derek Day
Heather Bartlett
Tom Laurie

Consultants

Cascadia Consulting Group (Project Management)

Gretchen Muller
Angela Pietschmann

Sound Resolutions (Facilitation)

Susan Gulick

The Caspian Group (Strategic Advisory)

Marc Daudon

Appendix 4. Impacts of human sources of nutrients on marine water quality

The following memo was prepared by the Washington State Department of Ecology, Water Quality Program on September 18, 2019:

Introduction

Productivity in Puget Sound is affected by many factors including: the upwelled waters of the Pacific Ocean importing nitrogen and low dissolved oxygen, water temperature, biogeochemical activity in marine sediments and the water column, atmospheric deposition of nitrogen, circulation and exchange of waters between the ocean and watersheds, and nutrient flux from watersheds to marine waters. Healthy nearshore eelgrass and kelp habitats, robust fish communities and diverse macroinvertebrate communities depend on a natural cycle of productivity to create sustainable populations of forage fish, salmonids and orcas.

Climate change is creating warmer temperatures and reduced circulation in Puget Sound degrading water quality and producing conditions that create stress on Puget Sound marine ecology. Deep ocean water entering the Salish Sea is expected to continue to decline in dissolved oxygen levels and increase in the concentration of nitrogen [48, 49]. Excess nutrients from human activities exacerbate the stress on Puget Sound water quality.

When a waterbody has excess nutrients, such as nitrogen and carbon, it can cause excessive plant and algae growth, which ultimately depletes the DO levels in the water. Many parts of Puget Sound have DO levels that fall below the concentrations needed for marine life to thrive and fail to meet our state's water quality standards.

Human sources of nutrients

The Salish Sea Model characterizes human-source inputs as: municipal and industrial wastewater facilities that discharge directly to Puget Sound, and watershed inflows that include both point and nonpoint source nutrient loads. Human sources in watersheds include municipal wastewater, agriculture, forestry and other land use activities that potentially discharge nutrients in diffuse or direct discharges.

The 2019 Salish Sea modeling report [50] evaluated the impact of human-sources on Puget Sound water quality and found that the sum of human sources in Puget Sound are causing violations of state water quality criteria for DO because of excess nutrients from human-sources. Ecology is obligated under the federal Clean Water Act and the State Water Pollution Control Act to take action in order to reduce nutrient loading from human sources that cause or contribute to DO water quality impairments.

Figure 7. Two indicators of eutrophication (dinoflagellate and jellyfish blooms) at Butler Cover near Budd Inlet. Aerial image taken September 26, 2016.

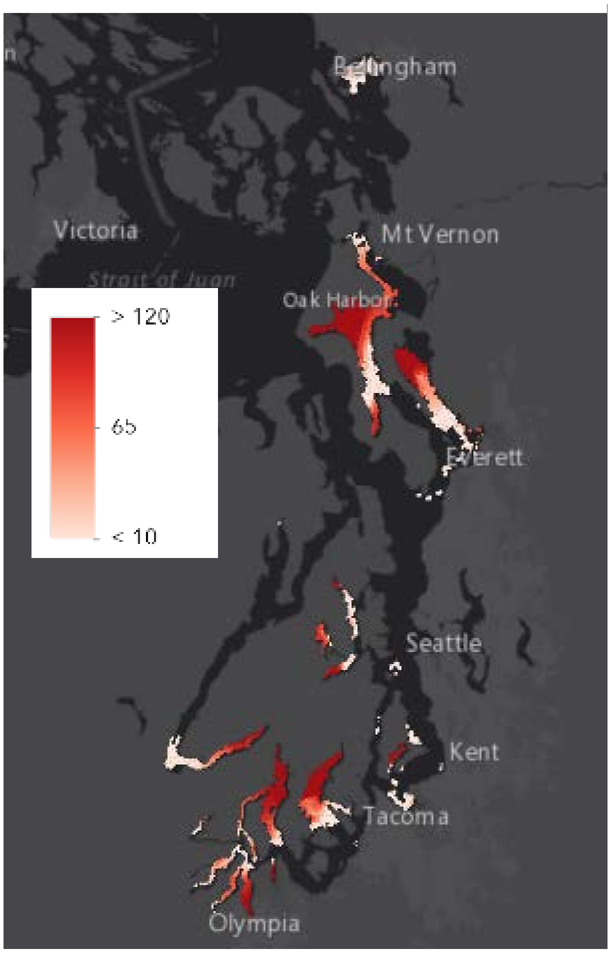
Imbalance of nutrients effects on Southern Residents

In addition to the effect of lowering dissolved oxygen, excess nutrients is also connected to other negative responses in the chemical and biological elements of the marine environment, including:

- Production of carbon dioxide from remineralization of organic carbon, which lowers the pH, contributing to acidification of the water column [51, 52, 53]. As water becomes acidic, less calcium carbonate is available for marine organisms to form shells [54].
- Changes to the benthic (bottom-dwelling) macroinvertebrate community structure and species diversity, habitat compression and shifts to microbial-dominated energy flow, resulting in changes to the food chain [55].
- Changes to micronutrient availability that can lead to increased incidence and duration of harmful algal blooms [56].
- Increased growth and abundance of opportunistic and ephemeral macroalgae, in particular, species of *Ulva* [57].
- Deleterious effects to eelgrass meadows [58, 59]. Declines in eelgrass shoot density with increasing macroalgal abundance have been demonstrated [60, 61].

These ecological effects can reduce the foundations of the marine food web by reducing the habitat and water quality conditions conducive to healthy and robust populations of marine species. Reducing human nutrient inputs to Puget Sound will improve water quality, support diverse nearshore habitats and create a healthy, nutritious marine food web to support forage fish, salmon and orcas. We have the science that confirms human impacts on DO and emerging science points to these other indicators manifesting in Puget Sound.

Figure 8. Duration of days not in compliance with DO criteria caused by human-sources of nutrients.



Ecology's Actions to Reduce Human-sources of Nutrients to Puget Sound

Beginning in 2018, the Department of Ecology initiated the Puget Sound Nutrient Source Reduction Project to use state of the art science and tools to inform policy and regulatory discussions about nutrient management in Puget Sound. We are in a multi-year process meant to inform future decision-making at the local and state levels. Recent Salish Sea modeling results [50] established that human sources of nutrients are causing or contributing to low dissolved oxygen in many sensitive inlets and bays within Puget Sound.

Ecology has been working with federal, state and local partners to develop the tools and data to understand how human sources of nutrients (i.e. wastewater, agriculture, stormwater and others) affects water quality in Puget Sound. We have looked at other U.S. coastal estuaries experiencing similar excess nutrient problems and identified clear lessons from those states, including:

- Engagement and collaboration between stakeholders and regulatory authorities is key to implementing actions to better manage or reduce nutrient discharges to waterbodies.
- General permits are an efficient and effective way to manage changes at wastewater treatment plants that contribute to excess nutrients.
- Nutrient reduction solutions touch on a wide-range of point and nonpoint source human land-use activities.

There has been more than a decade of implementing activities to reduce nutrients in watersheds draining to these other U.S. coastal estuaries. They have had the most success with nutrient reductions from advanced wastewater treatment to reduce nitrogen loads, while also reducing nonpoint sources in watersheds. Marine water quality has improved in Long Island Sound [62] and Chesapeake Bay [63, 64], and aquatic species that depend on healthy nearshore eelgrass habitats are on the rebound [65] because of those actions. We need to take similar actions to protect and restore Puget Sound water quality and populations of iconic species like Chinook salmon and the Southern Resident orcas.

Ecology is continuing to use the Salish Sea Model to understand the significance of watersheds, potential improvement from advanced wastewater treatment technology, and the combined effect of various nonpoint source reduction strategies to improve Puget Sound DO. Recommended improvements to watershed water quality data collection will further increase our understanding of watershed nutrient loads to Puget Sound and help inform potential next steps for further reductions of human sources of nutrients in watersheds in order to protect Puget Sound.

Over the next several years, Ecology will develop a Puget Sound Nutrient Management Plan that will include the regulatory approaches for point and nonpoint sources of nutrient loading to Puget Sound. In addition to human-source nutrient reductions, the natural function for nitrogen to attenuate in watersheds needs to be restored and protected [66]. Ecology is confident that technology exists to reduce nitrogen from Puget Sound WWTPs and advanced treatment can significantly improve marine water quality. But, the science is also clear that watershed reductions (including point and nonpoint sources) are necessary.

Reducing human nutrients in Puget Sound builds resiliency to Climate Change

Khangaonkar et al (2019) used the Salish Sea Model to evaluate the impacts of climate change over the next 100 years and estimated that water temperatures will increase, DO and pH will decrease, with the area of annually recurring hypoxia could increase 16% relative to Y2000. They also suggest a species shift from diatoms toward dinoflagellates which would further decrease the quality of the marine food web. The predicted response to climate change may be less severe than predicted change to the ocean boundary, and we can create more resiliency to climate change impacts by reducing our burden of nutrients on Puget Sound [67].

As we continue to grow in population, our wastewater infrastructure and land-use activities must adapt to accommodate that growth while further reducing our impact on water quality and ecological resources. Strategically reducing human sources of nutrients now allows more growth without commensurate environmental degradation and is cheaper and more efficient in the long run. As a region, we need to start now on improvements that will take a decade or more to build and implement.

As we reduce human sources of nutrients, we will improve the overall water quality of the Puget Sound affording increased resiliency to the marine environment that will hedge against increased ocean temperatures and climate change.

Recommendations

Given our region's growing population and our current science on excess nutrients in Puget Sound, Ecology believes now is the time to start the process. Infrastructure investments take time and money, and collaboration with communities to plan for these investments.

Through discussions the Marine Water Quality Implementation Strategy working group and the Puget Sound Nutrient Reduction Forum advisory group led by Ecology, three specific recommendations have been identified by Ecology to support this.

Begin addressing human sources of nutrients

Recommendation 39: Develop a National Pollutant Discharge Elimination System permit framework for wastewater treatment in Puget Sound to reduce nutrients in wastewater discharges to Puget Sound by 2022.

- Ecology should explore ways to use its NPDES regulatory authority to address point sources of nutrients. Significant nutrient reductions can be achieved with implementing advanced wastewater technology.

Implementation Details

Ecology is proposing to develop a Puget Sound Nutrients General Permit to control nutrient discharges from domestic wastewater treatment plants (or sewage treatment plants). The Department issued a public notice for a Preliminary Determination to develop a Puget Sound Nutrients General Permit on August 21, 2019. The purpose of this comment period is to obtain feedback about whether or not a general permit is the right NPDES permit framework for this purpose.

The alternative to a general permit is to include nutrient control requirements in each of the WWTP's individual permits, one by one, as they are reissued over the next five to 10 years. Discharges of excess nutrients to Puget Sound from WWTPs represent more than 50% of the human sources of nutrients into Puget Sound and significantly contribute to low oxygen levels. Given this, Ecology must require WWTPs to control nutrients consistent with the Clean Water Act and Washington's Water Pollution Control Act.

More information is available: https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-quality-permits/Water-Quality-general-permits.

Recommendation 40: Better align existing nonpoint programs with nutrient reduction activities and explore new ways to achieve the necessary nonpoint source nutrient reductions.

- Establish minimum requirements for nonpoint BMPs to ensure they meet water quality standards.
- Expand existing state and local nonpoint programs to include nutrient reduction best management practices (BMPs) to begin correcting known land use problems in watersheds.

Implementation Details

There are existing nonpoint programs that can be expanded to address known problems from nutrient runoff from agricultural, suburban/urban, and rural land use activities. Many of these nonpoint implementation actions have multiple benefits for water quality improvement including nutrient reduction.

Ecology is developing minimum performance requirements for agricultural nutrient reduction BMPs that will meet water quality standards. Continuing that process and beginning to explore other ways to achieve meaningful nonpoint nutrient reductions will occur over the next few years as Ecology continues working with stakeholders using state-of-the-art modeling to develop an integrated Puget Sound nutrient management plan for point source and nonpoint source nutrient reductions.

Modernize watershed data collection for nutrients

Recommendation 41: Collect high-quality nutrient data in watersheds to fill key knowledge gaps of baseline conditions.

- Augment key watershed monitoring stations with continuous nutrient monitoring technology to improve our understanding of watershed nutrient loads and establish baseline conditions to measure future change.
- Explore potential tools to quantify human sources in watersheds and evaluate nutrient management actions to meet total watershed nutrient reduction goals.

Implementation Details

Making science-based nutrient management decisions depends on having the right tools and high-quality data. The Salish Sea Model[10] is our best tool for understanding the marine waters of

[10] https://ecology.wa.gov/Research-Data/Data-resources/Models-spreadsheets/Modeling-the-environment/Salish-Sea-modeling

Puget Sound, and evaluating the best suite of nutrient load reductions necessary to achieve water quality standards.

We can improve our understanding of the timing, and magnitude of nutrient discharges from watersheds with modest enhancements to existing long-term watershed monitoring networks. Monitoring is critical to establish a strong scientific basis to characterize both baseline conditions and to measure progress as nutrient reduction actions are implemented on the landscape. Nutrient management decisions in watersheds depend on quality science and data to understand complex interactions between human sources and freshwater and marine water quality.

Appendix 5. Continuing the mission of Southern Resident orca recovery

As noted in **Chapter 4**, the Southern Resident Orca Task Force will sunset on November 8, 2019. The task force recommends that an oversight group continues this important work, incorporating the following elements:

- Is co-managed by the Governor's Office and tribes.
- Coordinates with federal agencies in both the United States and Canada to stay connected to ongoing policies around species recovery.
- Aligns with governor's priority on diversity, equity and inclusion and environmental justice.
- Maintains some element of the working group structure and provides ongoing support and facilitation of working groups by state agencies.
- Continues engagement from non-profits, businesses and other stakeholders to monitor implementation of existing recommendations, consider new recommendations and recommend course corrections for continued recovery.
- Maintains and enhances public visibility and interest in this crisis and facilitates a robust public engagement process.
- Builds on ongoing monitoring and reporting to maintain accountability to the public.
- Maximizes institutional durability, at least until the population reaches 84 whales by 2028.[11]

The task force recommends the following path forward:

NEW Recommendation 42: Create one or more entities with authority and funding to recover and advocate for Southern Resident orcas by implementing task force recommendations, creating new recommendations as needed and reporting to the public, governor and tribal co-managers on status.

- ➲ Requires legislative funding.
- ➲ Refer to **Appendix 1** for related actions and implementation details.

The task force proposed the following options for the Governor's Office to consider:

[11] In its 2018 report, the task force set forth the goal of increasing the Southern Resident population to 84 whales by 2028, or "10 more whales in 10 years."

- **Option 1: Expand existing agency capacity.** Expand the capacity and function of the Governor's Salmon Recovery Office to include orca recovery (e.g., Governor's Salmon and Orca Recovery Office). This option leverages existing agency infrastructure and is modeled after the Salmon Recovery Funding Board with policy coordination and administration functions within the proposed Governor's Salmon and Orca Recovery Office and a policy board comprising governor-appointed members and agency heads.
- **Option 2: Create a new executive level team in Governor's Office.** Create an executive-level salmon and orca leadership team in the Governor's Office. This option includes explicit tribal co-manager engagement by the Governor's Office. This option houses the main functions of the policy leadership team within the Governor's Office and maintains an executive-level focus on recovery.
- **Option 3: Create a new orca recovery office.** Create an orca recovery office led by technical experts. This option creates a new office that is staffed to implement actions. This office can be located within the Governor's Office or within an existing agency. The key element of this option is that it is not a stakeholder-led process.

The task force also recommends incorporating PSP's recovery system into any of these options, as appropriate. PSP is well-positioned to contribute to vessels recommendations, coordinate with Canadian representatives and actions, support scientific monitoring, advise on communications and track progress. Likewise, Salmon Recovery Councils on the Columbia River and Washington Coast could be useful partners.

Refer to the sections below for additional detail on the structure, partnerships, implementation details, benefits and barriers of each option described above.

Structure

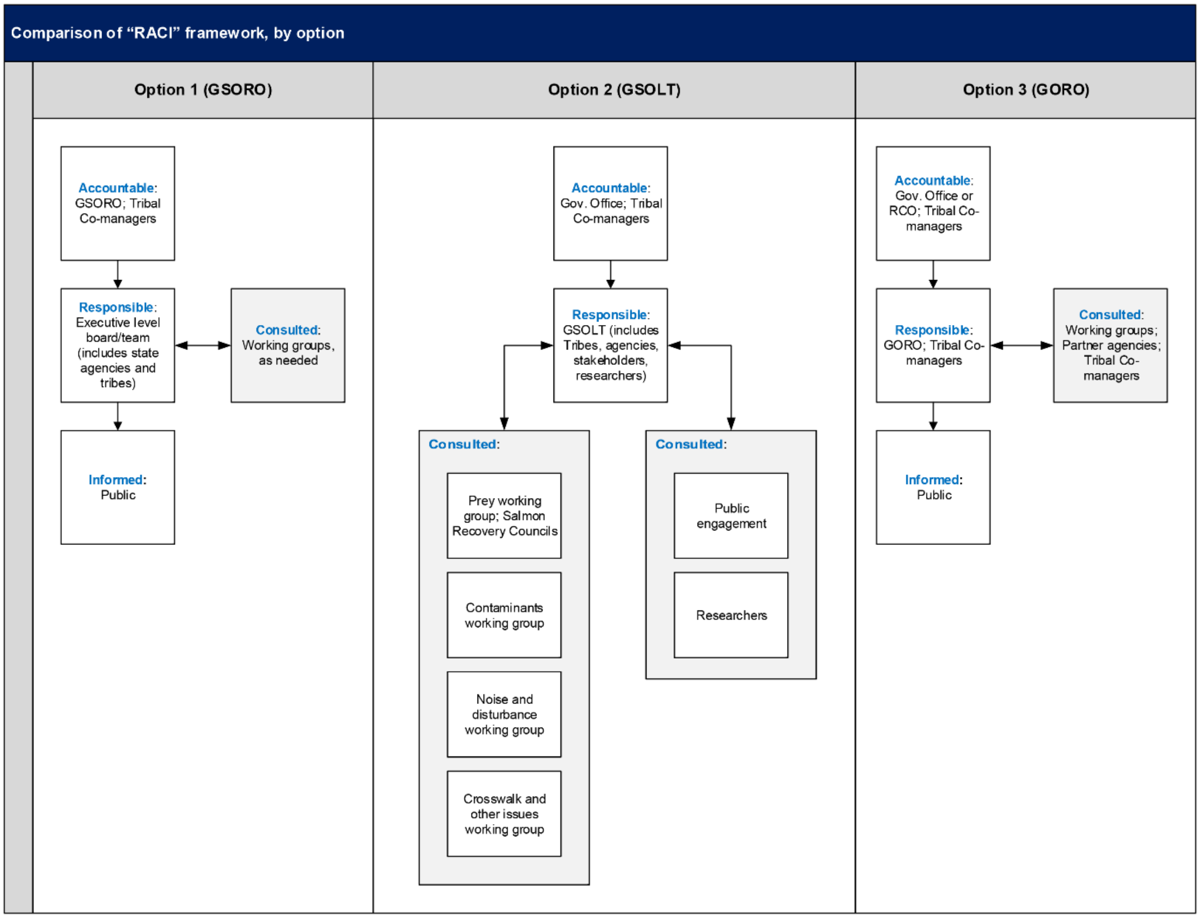
Responsible-Accountable-Consulted-Informed Framework

The terminology used throughout this section draws from the "RACI" framework.[12] The framework is summarized as follows:

- **Responsible**: those who do the work to complete the task. At least one individual must be "responsible," although others can be delegated to assist in the work required.
- **Accountable**: the individual ultimately answerable for the correct and thorough completion of the deliverable or task. The one who ensures the prerequisites of the task are met and who delegates the work to those responsible. The accountable individual must approve work that the responsible individual(s) provides. There must be only one accountable specified for each task or deliverable.

[12] https://web.archive.org/web/20180822181406/https://pmicie.org/images/downloads/raci_r_web3_1.pdf

- **Consulted**: those whose opinions are sought (typically subject matter experts) and with whom there is two-way communication.
- **Informed**: individuals who need to be informed after a decision or action is taken and may be required to take action as a result of the outcome (one-way communication).



Leadership and representation

Option 1: Governor's Salmon and Orca Recovery Office

- Establish executive-level board, or council to oversee orca recovery.
- GSRO provides policy support in coordination with the Governor's Office.
- Executive-level membership to be determined – some appointed by the Governor, some ex-officio state agency representatives.
- Staffed by designated agency representatives.

Option 2: Governor's Salmon and Orca Leadership Team

- Governor's Office leadership as Chief Executive in co-management role with tribes accountable for orca and salmon recovery, drawing from recommendations from the Salmon and Orca Leadership Team. This option depends on the Governor's Office and tribes agreeing to how the co-management roles will cover salmon and orcas.
- Salmon and Orca Leadership Team (similar concept to current task force) responsible for monitoring implementation of existing recommendations, considering new recommendations coming from working groups and recommending course corrections for continued recovery. Representative composition with the same sectors as current Southern Resident Orca Task Force (e.g., tribes, elected officials, state agencies, fishing interests, non-government organizations, business, federal agencies and Canada). Appointed by the governor, balancing the need to be small and nimble yet representative.

Option 3: Governor's Orca Recovery Office

- Executive team chaired or co-chaired by technical experts with experience in recovering marine mammal populations. Leadership should not be a stakeholder group.
- Team size should be lean and nimble to facilitate effective, responsive analysis and decision-making.
- One or two leads for each threat area (prey abundance, contaminants, vessel impacts, climate change and population growth, new/emerging). Could be working group leads.
- Tribal representatives as tribes see fit.
- Stakeholder interests represented in working groups, not at the leadership level.

Reporting structure

Option 1: Governor's Salmon and Orca Recovery Office

- Expand GSRO statutory authority to include orca recovery.

Option 2: Governor's Salmon and Orca Leadership Team

- Salmon and Orca Leadership Team holds twice-yearly public meetings to monitor progress on implementing recommendations, consider new information sourced from expanded working groups, take public input and identify necessary course corrections.
- This group must answer to the public and to the governor and tribes as co-managers, possibly through a Results Washington dashboard/accountability structure, subcabinet, or initiatives similar to Washington Maritime Blue 2050 or U.S.-Canada Maritime Commerce Resilience.
- Biennial comprehensive reviews due beginning November 2021, with brief annual updates.

Option 3: Governor's Orca Recovery Office

- Report to the governor or Washington State Recreation and Conservation Office; analogous to the Salmon Recovery Office. Goal of structure is to provide executive support as well as continuity between administrations.

Key goals and actions

Option 1: Governor's Salmon and Orca Recovery Office

- Maintain momentum and focus on orca recovery.
- Coordinate policy and budget initiatives specific to orca recovery.
- Coordinate the actions, science and progress through individual agencies.

Option 2: Governor's Salmon and Orca Leadership Team

- Maintain executive-level attention on salmon and orca recovery.
- Track progress on Southern Resident Orca Task Force actions, recommend new actions based on information from working groups, identify course corrections and maintain the broad coalition of voices working together toward recovery.

Option 3: Governor's Orca Recovery Office

- Drive and synchronize state actions toward achieving Southern Resident population recovery goals.
- Prioritize existing recommendations and work with governor and Legislature to implement.
- Evaluate, update and add new recommendations in response to population status.
- Identify roles and schedules for implementation of each recommendation, especially where authorities or actions overlap. Recommendations treated like projects to be acted on (or not) with roles, schedules, accountabilities and outcomes clearly defined.
- Measure and track progress towards goals, provide transparency and accountability and a mechanism for public engagement.

Partners and stakeholders

Tribal co-managers

Option 1: Governor's Salmon and Orca Recovery Office

- Tribal treaty rights – tribes will engage on multiple fronts as appropriate, including appointments to the board or council.

Option 2: Governor's Salmon and Orca Leadership Team

- Accountable/approver in co-manager role.
- Responsible for developing Salmon and Orca Leadership Team recommendations with stakeholders, agencies and others.
- Consulted as working group members, clarifying new work needed.

Option 3: Governor's Orca Recovery Office

- Co-managers with seats on council and working groups.
- Additional roles, depending on tribal input.

State, federal and international partner agencies

Option 1: Governor's Salmon and Orca Recovery Office

- Hybrid executive-level and GSRO structure offers a statewide and transboundary perspective.

Option 2: Governor's Salmon and Orca Leadership Team

- Responsible for developing Salmon and Orca Leadership Team recommendations with tribes, stakeholders and others.
- Responsible for facilitating working groups.
- Consult role with transboundary organizations.

Option 3: Governor's Orca Recovery Office

- Serve as collaborators and implementers.

Working groups

Option 1: Governor's Salmon and Orca Recovery Office

- Use existing working groups on as-needed basis to address specific topics as they arise.
- Do not have standing meetings but may hold periodic check ins to keep the teams intact.

- Each working group would continue to be led by staff from the Washington State Department of Ecology, Washington Department of Fish and Wildlife, and Puget Sound Partnership. These three staff leads would be ex-officio members of the Governor's Salmon and Orca Recovery Office.
- One new staff to coordinate with the working groups and organize the logistics and reporting of the board or council, these staff would report to the executive coordinator.

Option 2: Governor's Salmon and Orca Leadership Team

- Existing prey and contaminants working groups continue to source information to the Leadership Team.
- Reframe the vessels working group to "noise and disturbance working group" (not limited to just vessels).
- Use existing structures to the maximum extent with plenty of expertise; these groups are skilled and should not be recreated.
- Add a new working group that addresses crosswalk and "none-of-the-above" issues (i.e., climate change, population growth, synergy across working group silos and gaps in that structure).
- Agency-led technical expertise and facilitation are critical. Detailed quarterly updates on progress. Produce annual course-correction recommendations that are written and reviewed by the working groups and provided to the Leadership Team and the public.

Option 3: Governor's Orca Recovery Office

- Led (or co-led) by members of the Governor's Orca Recovery Office.
- Lead is responsible for the work products and driving the process to answer key scientific questions.
- Working groups should be representative and diverse (tribal/public/private).
- Current members should be included for continuity and efficiency. Others may be added.

Public

Option 1: Governor's Salmon and Orca Recovery Office

- The public will remain engaged through multiple pathways; public engagement brought these issues to the forefront and remains critical.

Option 2: Governor's Salmon and Orca Leadership Team

- Consulted: Public engagement brought these issues to the forefront and remains critical; public pressure reminds elected officials and pushes government structures forward.

Option 3: Governor's Orca Recovery Office

- Provide feedback.

Implementation

Level of effort and funding

Option 1: Governor's Salmon and Orca Recovery Office

- GSRO Staffing (1 FTE).
- Operational costs for the executive level policy board (Approximate = $200,000/biennium).
- Agency staff support for PSP, WDFW, ECY (3 FTE or in-kind).
- Plus additional contracted consulting services if required as start up.

Option 2: Governor's Salmon and Orca Leadership Team

- Results WA-style meetings with the governor, tribes
- Salmon and Orca Leadership Team – Facilitate twice-annual, all-day public meetings. Meeting packets with outputs from working groups. Manage public comment process and compile results.
- Facilitate quarterly or twice-annual meetings for four working groups (the three existing, plus a new one). Half day.
- Manage website communication tools
- Produce more detailed biennial report beginning November 2021, continuing until the population reaches 84 whales by 2028.

Option 3: Governor's Orca Recovery Office

- Office would be 5 to 7 FTEs (Exec director, leads for each area, public engagement/communications and support).
- Quarterly reports on progress towards goals.
- Technology: Dashboard to show status of recommendations and progress towards goals, provide transparency and accountability.
- Communication and public engagement through dashboard, quarterly reports and quarterly public meetings.
- Stipend for working group member travel.

Timeline

Option 1: Governor's Salmon and Orca Recovery Office

- Could be implemented relatively quickly.

Option 2: Governor's Salmon and Orca Leadership Team

- November 2019 – January 2020 – transition plan from Orca Recovery Task Force into an interim structure.
- Winter/spring 2020 – form new oversight and accountability Leadership Team. Secure funding through the Legislature.

Option 3: Governor's Orca Recovery Office

- Executive order to start ASAP, should be in place by end of legislative session or sooner.

Benefits and barriers

Benefits

Option 1: Governor's Salmon and Orca Recovery Office

- The Governor's Salmon and Orca Recovery Office would provide statewide consistency, coordination and accountability for salmon and orca recovery:
- Governor's Office or RCO can coordinate executive engagement with additional resources.
- GSRO can work with RCO to manage associated grants and contracts.
- GSRO could leverage its existing role in coordinating among the tribes, state and federal agencies, regional salmon recovery organizations, local partners and jurisdictions, and federal and state legislative activities.

Option 2: Governor's Salmon and Orca Leadership Team

- Oversight and accountability – Executive-level attention and engagement are crucial to address this crisis, implement the remaining recommendations, develop new recommendations, monitor progress and adjust tactics. Without executive-level leadership, resident orcas and Chinook salmon are doomed to extinction. Salmon and orcas have been listed for 20 and 15 years, respectively, but we did not galvanize this much action without the leaders in our region setting the table and the public applying pressure.
- Power – It took the breadth of the current task force table to compel actions. Tribes, fishing interests and non-governmental organizations make sure government processes do not revert to business as usual, and agencies bring expertise and structure from existing programs.
- Structure – Hybrid executive and working group structure offers a statewide and transboundary perspective and reflects the importance of salmon runs throughout the state and transboundary issues with Canada.

- Efficiency – Agency-led working group processes continue through existing and refined structures.

Option 3: Governor's Orca Recovery Office

- Focus on orcas is championed and maintained. (Orca recovery includes, but is not the same thing as, salmon recovery.)
- Tribal representation as recommended by tribes.
- Gold star and accountable guidance for decision-makers.
- Task force work recommendations are implemented and evolve.
- Continued engagement by diverse stakeholders with deep knowledge and experience.
- Informed think tank to brainstorm, create and evaluate solutions.
- Goal is not to duplicate efforts within agencies, but to synchronize towards orca recovery – identify gaps and priorities.
- Serve as the gold standard for non-biased information about the orcas.

Barriers

Option 1: Governor's Salmon and Orca Recovery Office

- Would require additional funding.
- May require statutory changes.

Option 2: Governor's Salmon and Orca Leadership Team

- Identifying and maintaining durable funding and attention.

Option 3: Governor's Orca Recovery Office

- Funding.
- Time to implement.

Appendix 6. Public comments

Public comments were welcomed throughout 2019 and considered in the final drafting of this report. All public comments received in 2019 are available in the following folder and its sub-folders: https://pspwa.box.com/s/vdg8outmj17ccras2oj70yd43s75rve1

This appendix summarizes input received during the official public comment period (October 14–25, 2019) on the October 2019 draft report. The task force received 953 public comments on this report and its recommendations.

Individual comments

Habitat

The task force received 486 comments related to salmon habitat, with the following key themes:

Themes	Comments	% of total
Human population growth and net ecological gain	478	98%
Restore critical habitat and sensitive ecosystems	71	15%
Funding restoration projects	6	1%

Life After Task Force

The task force received 470 comments related to continuing orca recovery work after the task force sunsets in 2019, with the following key themes:

Themes	Comments	% of total
Support for Option 2	444	95%
Support for continuing long-term orca recovery efforts	24	5%
Include tribes as co-managers	20	4%
Role of stakeholders and the public	5	1%

Hydropower

The task force received 268 comments related to hydropower, with the following key themes:

Themes	Comments	% of total
Breach the lower Snake River dams	217	81%
Breach dams (specific dams not identified)	49	23%
Do not breach the lower Snake River dams	1	<1%
Howard Hanson dam fish passage	1	<1%

Urgent action

The task force received 229 comments urging them to take immediate action to recover Southern Residents.

Vessels

The task force received 131 comments related to vessels, with the following key themes:

Themes	Comments	% of total
Research vessels	111	85%
Impacts of cruise ship, whale watching and general vessel traffic	9	7%
U.S. Navy testing	8	6%
Fast ferries and water taxis	7	5%
Oil spills	6	5%
Maritime Blue	3	2%

Research impacts

The task force received 125 comments with concerns around the impacts of research on Southern Residents. The majority of these comments were based on a form letter containing the following key themes:

- Define and implement a moratorium on research.
- Ban captures and captivity.
- Determine ways to include unbiased, nonaffiliated public review.
- Stop any funding by the aquarium industry such as SeaWorld.
- Enacting Emergency Orders under the Species at Risk Act.

Additional public comments

The following themes received less than 10% each of the total number of public comments:

Themes	Comments
Forage Fish	62
Progress Report	58
Harvest	22
Contaminants	20
Text Edits	16
Climate Change	15
Funding	14
Co-management	9
Public engagement	8

Predation	7
Prey	7
Enforcement & Regulation	6
Hatchery	5

Organization/coalition comments

The task force also received formal comment letters from the agencies, organizations and coalitions listed below. Letters in full are available in the following folder:

https://pspwa.box.com/s/vdg8outmj17ccras2oj70yd43s75rve1

- City of Shoreline
- Friends of the San Juans
- King County Department of Natural Resources and Parks
- Lifeforce Foundation
- National Oceanic and Atmospheric Administration Fisheries West Coast Region and Northwest Fisheries Science Center.
- Northwest Environmental Advocates
- Oceana
- Orca Conservancy
- Orca Network
- Port of Seattle, Port of Tacoma and the Northwest Seaport Alliance
- Roza Irrigation District
- San Juan County Council
- Seattle Aquarium
- Skagit County
- United States Navy
- Washington Environmental Council
- Washington Public Ports Association
- Washington State Association of Counties
- Washington State Ferries
- Washington State Recreation and Conservation Office
- Whale and Dolphin Conservation
- Whale Trail

Works cited:

[1] Indian Country Today's Press Pool, "Southern Resident Killer Whales given Lummi name in traditio ceremony," *Indian Country Today*, pp. https://newsmaven.io/indiancountrytoday/the-press-pool/sout resident-killer-whales-given-lummi-name-in-traditional-ceremony-IzXRGRz8NEKgdX28pQcK2g/, August 2019.

[2] G. J. Wiles, "Periodic status review for the killer whale in Washington," Washington Department of and Wildlife, Olympia, WA, 2016.

[3] United States Environmental Protection Agency, "Southern Resident Killer Whales," United States Environmental Protection Agency, July 2017. [Online]. Available: https://www.epa.gov/salish-sea/southern-resident-killer-whales. [Accessed 5 November 2019].

[4] Center for Whale Research, "Southern Resident Killer Whale Population," Center for Whale Researc July 2019. [Online]. Available: https://www.whaleresearch.com/orca-population. [Accessed 17 Octo 2019].

[5] B. R. Scheffers and G. Pecl, "Persecuting, protecting or ignoring biodiversity under climate change," *Nature Climate Change*, vol. 9, no. 8, pp. 581-586, 2019.

[6] M. J. Ford, J. Hempelmann, M. B. Hanson, K. L. Ayres, R. W. Baird, C. K. Emmons, J. I. Lundin, G Schorr, S. K. Wasser and L. K. Park, "Estimation of a Killer Whale (Orcinus orca) Population's Diet Using Sequencing Analysis of DNA from Feces," *PLoS ONE*, p. 11(1):e0144956. Doi:10.1371/journal.pone.0144956, 2016.

[7] D. Canty, "Funding for Salmon Recovery in Washington State," Governor's Salmon Recovery Office the Council of Regional Salmon Recovery Organizations, Olympia, WA, 2011.

[8] M. White, K. Mueller, R. Millar and K. Metcalf, *Restoring Fish Passage at WSDOT Stream Crossin Joint Transportation Committee Work Session*, Washington State Department of Transportation, 201

[9] J. Wall, "Fish-Barriers: A Comprehensive Approach," Washington State Association of Counties, Olympia, WA, 2019.

[10] E. Johnson, *Fish Passage Barrier Removal: A County Perspective*, Olympia, WA: Washington State Association of Counties, 2019.

[11] C. Schroeder and S. McClelland, "Culverts & salmon recovery," Association of Washington Cities, Olympia, WA, 2019.

[12] Puget Sound Partnership, "2018 Action Agenda NTA Funding Status," Puget Sound Partnership, 10 September 2019. [Online]. Available: https://actionagenda.pugetsoundinfo.wa.gov/Results/FundingStatus. [Accessed 1 October 2019].

[13] Puget Sound Partnership, "Action Agenda Priority Focus Area: Chinook Salmon," Puget Sound Partnership, 10 September 2019. [Online]. Available: https://actionagenda.pugetsoundinfo.wa.gov/TaxonomyTrunk/Detail/25. [Accessed 1 October 2019].

[14] D. Lusseau, D. E. Bain, R. Williams and J. C. Smith, "Vessel traffic disrupts the foraging behavior of southern resident killer whales Orcinus orca," *Endangered Species Research*, vol. 6, pp. 211-221, 20(

[15] D. Tollit, R. Joy and J. Wood, "Estimating the effects of noise from commercial vessels and whale w boats on Southern Resident Killer Whales," Port of Vancouver, Vancouver, B.C., 2017.

[16] M. J. A. Durkan, "2019 Draft Navy Northwest Training and Testing Supplemental Environmental Im Statement," City of Seattle, Seattle, WA, 2019.

[17] G. J. Inslee, "Comments regarding Northwest Training and Testing Activities Draft Supplemental Environmental Impact Statement/Overseas Environmental Impact Statement," State of Washington, Olympia, WA, 2019.

[18] A. K. Snover, C. L. Raymond, H. A. Roop and H. Morgan, "No Time to Waste. The Intergovernmen Panel on Climate Change's Special Report on Global Warming of 1.5C and Implications for Washing State.," University of Washington Climate Impacts Group, Seattle, WA, 2019.

[19] G. Vaidyanathan, "How Bad of a Greenhouse Gas Is Methane?," Scientific American, 22 December 2015. [Online]. Available: https://www.scientificamerican.com/article/how-bad-of-a-greenhouse-gas-methane/. [Accessed 1 October 2019].

[20] Governor's Salmon Recovery Office, "State of Salmon in Watersheds 2019," Governor's Salmon Recovery Office, Olympia, WA, 2019.

[21] G. M. a. J. Casola, "State of Knowledge, Climate Change in Puget Sound," Climate Impacts Group, 2

[22] V. A. Guinder and J. C. Molinero, "Climate Change Effects on Marine Phytoplankton," in *Marine Ecology in a Changing World*, Boca Raton, FL, CRC Press, 2013, pp. 68-90.

[23] W. T. Peterson and B. B. Burke, "Oceanographic and ecological indicators for Salmon Returns in the Northern California Current," *North Pacific Anadramous Fish Comm. Tech. Rep.*, pp. 71-75, 2013.

[24] F.-X. Fu, Y. Zhang, M. E. Warner, Y. Feng, J. Sun and D. A. Hutchins, "A comparison of future increased CO2 and temperature effects on sympatric Heterosigma akashiwo and Prorocentrum minimum," *Harmful Algae*, vol. 7, no. 1, pp. 76-90, 2008.

[25] L. Brotz, W. W. Cheung, K. Kleisner, E. Pakhomov and D. Pauly, "Increasing jellyfish populations: trends in Large Marine Ecosystems," *Hydrobiologia*, vol. 690, no. 1, pp. 3-20, 2012.

[26] R. J. Beamish, B. E. Riddell, K. L. Lange, E. Farley Jr., S. Kang, T. Nagasawa, V. Radchenko, O. Temnykh and S. Urawa, "The Effects of Climate on Pacific Salmon: A Summary of Published Literature," North Pacific Anadramous Fish Commission, Vancouver, B.C., 2009.

[27] I. O. A. R. A. M. L. S. V. R. e. a. C. Provost, "Ocean currents: RDI Long Ranger acoustic Doppler current profiler [Data set].," Norwegian Polar Institute, 2016.

[28] T. Klinger, "Potential effects of warming and acidification on Southern Resident Killer Whales.," in *Southern Resident Killer Whale Task Force Meeting*, Lacey, WA, 2019.

[29] K. Garner, M. Y. Chang, T. M. Fulda, J. A. Berlin, R. E. Freed, M. M. Soo-Hoo, D. L. Revell, M. Ikegami, F. E. Lorraine, A. L. Flint and B. E. Kendall, "Impacts of sea level rise and climate change o coastal plant species in the central California coast," *PeerJ*, vol. 3, no. 958, 2015.

[30] C. L. Sabine, "FAQs about Ocean Acidification," Woods Hole Oceanographic Institution, 19 March 2010. [Online]. Available: https://www.whoi.edu/know-your-ocean/ocean-topics/ocean-chemistry/oc acidification/faqs-about-ocean-acidification/. [Accessed 24 October 2019].

[31] J. Barry, J. Bijima, K. Caldeira, A. Cohen and S. Cooley, "Frequently asked questions about ocean acidification," U.S. Ocean Carbon and Biogeochemistry Program, 2019.

[32] S. C. S. R. F. A. S. S. M. A. D. W. R. J. N. a. J. M. Alin, "Puget Sound marine waters: 2015 overview PSEMP Marine Waters Workgroup, 2016.

[33] S. B. R. P. o. O. A. Washington, "Ocean Acidification: From Knowledge to Action, Washington Stat Strategic Response," Washington Department of Ecology, Olympia, Washington, 2012.

[34] C. R. Williams, A. H. Dittman, P. McElhany, D. S. Busch, M. Maher, T. K. Bammler, J. W. MacDor and E. P. Gallagher, "Elevated CO2 impairs olfactory-mediated neural and behavioral responses and expression in ocean-phase coho salmon (Oncorhynchus kisutch)," *Global Change Biology: In review* 2018.

[35] R. Haigh, D. Janson, C. A. Hold, H. E. Neate and A. M. Edwards, "Effects of ocean acidification on temperate coastal marine ecosystems and fisheries in the northeast Pacific," *PLos ONE*, vol. 10, no. 2 2015.

[36] G. E. Nilsson, D. L. Dixson, P. Domenici, M. I. McCormick, C. Sorenson, S.-A. Watson and P. L. Munday, "Near-future carbon dioxide levels alter fish behaviour by interfering with neurotransmitter function," Nature, Climate Change Letters, 2012.

[37] P. G. Brewer and K. Hester, "Ocean acidification and the increasing transparency of the ocean to low frequency sound," *Oceanography*, vol. 22, no. 4, pp. 86-93, 2009.

[38] Y. Zhao, "Strong population growth in Washington continues," Washington Office of Financial Management, 26 June 2018. [Online]. Available: https://www.ofm.wa.gov/about/news/2018/06/stron population-growth-washington-continues. [Accessed 1 October 2019].

[39] Washington Office of Financial Management, "Total population and percent change," Washington O of Financial Management, [Online]. Available: https://www.ofm.wa.gov/washington-data-research/statewide-data/washington-trends/population-changes/total-population-and-percent-change. [Accessed 1 October 2019].

[40] Municipal Research Services Center, "Growth Management Act," Municipal Research Services Cent 27 September 2019. [Online]. Available: http://mrsc.org/Home/Explore-Topics/Planning/General-Planning-and-Growth-Management/Comprehensive-Planning-Growth-Management.aspx. [Accessed October 2019].

[41] Carillo and Ritter, "Increasing numbers of ship strikes in the Canary Islands: Proposals for immediate action to reduce risk of vessel-whale collisions," *Journal of Cetacean Research and Management*, vo no. 2, pp. 131-138, 2010.

[42] IPCC, "Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5° above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change," 2018.

[43] Washington State Department of Ecology, "Washington State Greenhouse Gas Emissions Inventory: 1990-2015 (Report to the Legislature)," Washington State Department of Ecology, Olympia, WA, 20

[44] M. Chadsey, "Ocean Acidification Action Page: What Can You Do About OA?," University of Washington College of the Environment Sea Grant, Seattle, WA.

[45] R. Cho, "The 35 Easiest Ways to Reduce Your Carbon Footprint," Columbia University Earth Institu New York, NY, 2018.

[46] Clean Energy Transition Institute, "Meeting the Challenge of Our Time: Pathways for a Clean Energ Future for the Northwest," 2019.

[47] H. Harvey, "Designing Climate Solutions: A Policy Guide for Low-Carbon Energy," 2018.

[48] F. A. Whitney, H. J. Freeland and M. Robert, "Persistently declining oxygen levels in the interior wa of the eastern subarctic Pacific.," *Progress in Oceanography,* vol. 75, pp. 179-199, 2007.

[49] S. D. Pierce, J. A. Barth, R. K. Shearman and A. Y. Erofeey, "Declining oxygen in the Northeast Pac *Journal of Physical Oceanography*, vol. 42, pp. 495-501, 2011.

[50] A. Ahmed, C. Figueroa-Kaminsky, J. Gala, T. Mohamedali, G. Pelletier and S. McCarthy, "Puget So Nutrient Source Reduction Project. Volume 1: Model Updates and Bounding Scenarios.," Washingto Department of Ecology, Publication 19-03-001, Olympia, WA, 2019.

[51] R. B. Wallace, H. Baumann, J. S. Grear, R. C. Aller and C. J. Gobler, "Coastal ocean acidification: th other eutrophication problem.," *Estuarine, Coastal, and Shelf Science,* vol. 148, pp. 1-13, 2014.

[52] R. A. Feely, S. R. Alin, J. Newton, C. L. Sabine, M. Warner, A. Devol, C. Krembs and C. Maloy, "Th combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary.," *Estuarine, Coastal, and Shelf Science,* vol. 88, pp. 442-449, 2010.

[53] G. Pelletier, L. Bianucci, W. Long, T. Khangaonkar, T. Mohamedali, A. Ahmed and C. Figueroa-Kaminsky, "Salish Sea Model Ocean Acidification Module and the Response to Regional Anthropog Nutrient Sources. Publication 17-03-009," Washington State Department of Ecology, Olympia, WA, 2017.

[54] N. Bednarsek, T. Klinger, C. J. Harvey, S. Weisberg, R. M. McCabe, R. A. Feely, J. Newton and N. Tolimieri, "New ocean, new needs: Application of pteropod shell dissolution as a biological indicator marine resource management.," *Ecological Indicators,* vol. 76, pp. 240-244, 2017.

[55] R. Diaz and R. Rosenberg, "Spreading Dead Zones and Consequences for Marine Ecosystems," *Scien* vol. 321, pp. 926-929, 2008.

[56] R. Howarth, F. Chan, D. Conley, J. Garnier, S. Doney, R. Marino and G. Billen, "Coupled biogeochemical cycles: Eutrophication and hypoxia in temperate estuaries and coastal marine ecosystems.," *Frontiers in Ecology and the Environment,* vol. 9, no. 1, pp. 18-26, 2011.

[57] M. Teichberg, S. E. Fox, Y. S. Olsen, I. Valiela, P. Martinetto and O. Irbarne, "Eutrophication and macroalgal blooms in temperate and tropical coastal waters: Nutrient enrichment experiments with U spp..," *Global Change Biology,* vol. 16, pp. 2624-2637, 2010.

[58] J. Burkholder, D. Tomasko and B. Touchette, "Seagrasses and eutrophication.," *Journal of Experime Marine Biology and Ecology,* vol. 350, pp. 46-72, 2007.

[59] M. Hessing-Lewis, S. Hacker, B. Menge and S. Rumrill, "Context-dependent eelgrass-macroalgae interactions along an estuarine gradient in the Pacific Northwest, USA," *Estuaries and Coasts,* vol. 3 pp. 1169-1181, 2011.

[60] S. Bittick, M. Sutula and P. Fong, "A tale of two algal blooms: Negative and predictable effects of tw common bloom-forming macroalgae on seagrass and epiphytes.," *Marine Environmental Research,* v 140, pp. 1-9, 2018.

[61] T. Nelson and A. Lee, "A manipulative experiment demonstrates that blooms of the macroalga Ulvar obscura can reduce eelgrass shoot density.," *Aquatic Botany,* vol. 71, pp. 149-154, 2001.

[62] New York City Department of Environmental Protection, "$1 Billion Nitrogen Reduction Project Improves the Health of the East River and Long Island Sound," 5 January 2017. [Online]. Available: https://www1.nyc.gov/html/dep/html/press_releases/17-001pr.shtml#.XZPGh0ZKhaR. [Accessed 1 October 2019].

[63] University of Maryland Center for Environmental Science, "Chesapeake Bay Report Card Shows Ste Bay Health Recovery," 8 May 2017. [Online]. Available: https://www.umces.edu/content/chesapeake bay-report-card-shows-steady-bay-health-recovery. [Accessed 1 October 2019].

[64] S. Dance, "Scientists say they're confident Chesapeake Bay health is 'significantly improving'," The Baltimore Sun, 15 June 2018. [Online]. Available: https://www.baltimoresun.com/news/environment md-chesapeake-bay-improving-20180612-story.html. [Accessed 1 October 2019].

[65] D. Charles, "Grass is Back in the Chesapeake, and Crabs Will Follow," Oregon Public Broadcasting, March 2018. [Online]. Available: https://www.opb.org/news/article/npr-grass-is-back-in-the-chesape and-crabs-will-follow/. [Accessed 1 October 2019].

[66] R. W. Sheibley, C. P. Konrad and R. W. Black, "Nutrient attenuation in rivers and streams, Puget Sou Basin, Washington," U.S. Geological Survey Scientific Investigations Report 2015-5074, 2015.

[67] T. Khangaonkar, A. Nugraha, W. Xu and K. Balaguru, "Salish Sea response to global climate change level rise, and future nutrient loads.," *Journal of Geophysical Research: Oceans,* vol. 124, 2019.

[68] Washington State Department of Ecology, "Salish Sea Model," [Online]. Available: https://ecology.wa.gov/Research-Data/Data-resources/Models-spreadsheets/Modeling-the-environment/Salish-Sea-modeling. [Accessed 1 October 2019].

[69] A. Selk, "Update: Orca abandons body of her dead calf after a heartbreaking, weeks-long journey," *T Washington Post,* pp. https://www.washingtonpost.com/news/animalia/wp/2018/08/10/the-stunning-devastating-weeks-long-journey-of-an-orca-and-her-dead-calf/, 12 August 2018.

[70] R. Williams, D. Lusseau and P. Hammond, "Estimating relative energetic costs of human disturbance killer whales (Orcinus orca)," *Biological Conservation,* pp. 301-311, 2006.

[71] R. Williams, E. Ashe and D. Sandilands, "Stimulus-dependent response to disturbance affecting the activity of killer whales," in *Report SC/63/WW5 presented to the 63rd International Whaling Commi Scientific Committee Meeting,* Tromso, Norway, 2011.

[72] NOAA Fisheries, "Special Report: Southern Resident Killer Whales 10 Years of Research and Conservation," NOAA Fisheries, Seattle, 2014.

[73] A. Freedman and L. Tierney, "The ‘Blob’ is surging back in the Pacific, leading to fears of mass die- of marine life and unusual weather patterns," The Washington Post, 21 September 2019. [Online].

Available: https://www.washingtonpost.com/weather/2019/09/21/blob-is-surging-back-pacific-leadir fears-mass-die-offs-marine-life-unusual-weather-patterns/. [Accessed 1 October 2019].

[74] NOAA Fisheries, "Special Report: Southern Resident Killer Whales 10 Years of Research and Conservation," NOAA Fisheries, Seattle, WA, 2014.

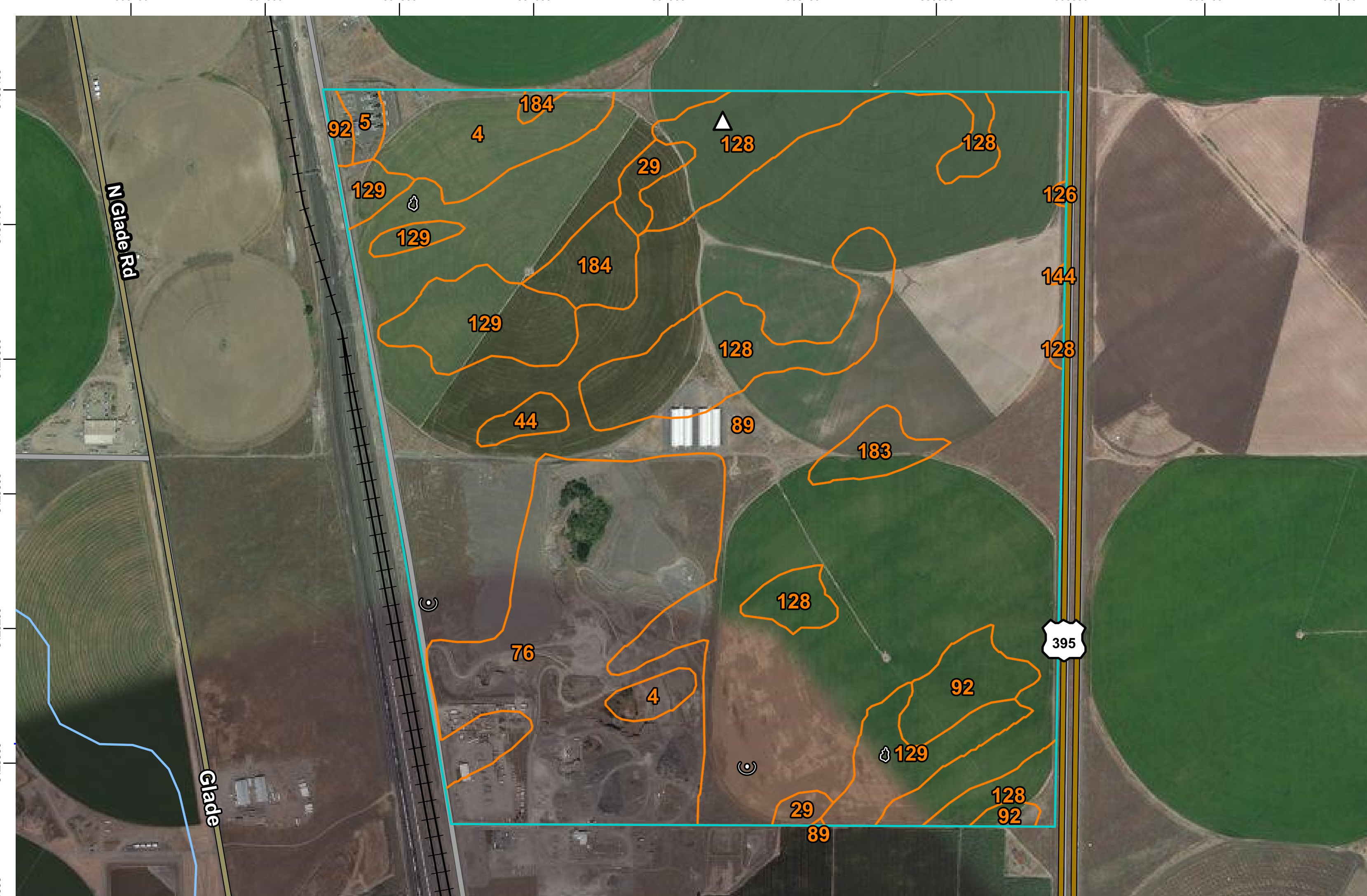
[75] NOAA Fisheries, "Species Directory: Killer Whale," NOAA, [Online]. Available: https://www.fisheries.noaa.gov/species/killer-whale. [Accessed 1 October 2019].

[76] Federal Transit Administration, "Monthly Module Adjusted Data Release," United States Departmen Transporation, July 2019. [Online]. Available: https://www.transit.dot.gov/ntd/data-product/monthly-module-adjusted-data-release. [Accessed 1 October 2019].

[77] U.S. Environmental Protection Agency, "National Pollutant Discharge Elimination System (NPDES) U.S. Environmental Protection Agency, [Online]. Available: https://www.epa.gov/npdes/about-npdes [Accessed 13 October 2019].

[78] NOAA Fisheries, "Critical Habitat for Southern Resident Killer Whales," NOAA Fisheries, 18 Septe 2019. [Online]. Available: https://archive.fisheries.noaa.gov/wcr/protected_species/marine_mammals/killer_whale/critical_habi ml. [Accessed 13 October 2019].

Soil Map—Franklin County, Washington
(Pasco UGA Expansion NE Part)



Map Scale: 1:13,900 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 200, 400, 800, 1200

Feet: 0, 500, 1000, 2000, 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 28, 2014—Jul 31, 2018

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
4	Burbank loamy fine sand, 0 to 5 percent slopes	24.6	4.0%
5	Burbank loamy fine sand, 5 to 10 percent slopes	2.9	0.5%
29	Hezel loamy fine sand, 0 to 15 percent slopes	6.0	1.0%
44	Kennewick silt loam, 2 to 5 percent slopes	3.4	0.6%
76	Pits	91.5	14.9%
89	Quincy loamy fine sand, 0 to 15 percent slopes	356.4	58.2%
92	Quincy loamy fine sand, loamy substratum, 0 to 10 percent slopes	13.5	2.2%
126	Royal loamy fine sand, 0 to 10 percent slopes	0.4	0.1%
128	Royal fine sandy loam, 0 to 2 percent slopes	60.6	9.9%
129	Royal fine sandy loam, 2 to 5 percent slopes	36.3	5.9%
144	Sagemoor very fine sandy loam, 0 to 2 percent slopes	0.3	0.0%
183	Timmerman fine sandy loam, 0 to 2 percent slopes	6.5	1.1%
184	Timmerman fine sandy loam, 2 to 5 percent slopes	10.0	1.6%
Totals for Area of Interest		**612.2**	**100.0%**

Franklin County, Washington

4—Burbank loamy fine sand, 0 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2dn2
Elevation: 350 to 950 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Burbank and similar soils: 80 percent
Minor components: 16 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Burbank

Setting

Landform: Terraces
Parent material: Glaciofluvial deposits

Typical profile

H1 - 0 to 3 inches: loamy fine sand
H2 - 3 to 24 inches: loamy fine sand
H3 - 24 to 27 inches: very gravelly loamy fine sand
H4 - 27 to 60 inches: extremely gravelly sand

Properties and qualities

Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Available water storage in profile: Very low (about 3.0 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Royal

Percent of map unit: 8 percent

Landform: Terraces
Hydric soil rating: No

Sagehill

Percent of map unit: 8 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

5—Burbank loamy fine sand, 5 to 10 percent slopes

Map Unit Setting

National map unit symbol: 2dp2
Elevation: 350 to 950 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Burbank and similar soils: 80 percent
Minor components: 16 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Burbank

Setting

Landform: Terraces
Parent material: Glaciofluvial deposits

Typical profile

H1 - 0 to 3 inches: loamy fine sand
H2 - 3 to 24 inches: loamy fine sand
H3 - 24 to 27 inches: very gravelly loamy fine sand
H4 - 27 to 60 inches: extremely gravelly sand

Properties and qualities

Slope: 5 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Available water storage in profile: Very low (about 3.0 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Royal

Percent of map unit: 8 percent

Landform: Terraces
Hydric soil rating: No

Sagehill

Percent of map unit: 8 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

29—Hezel loamy fine sand, 0 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2dm1
Elevation: 400 to 2,500 feet
Mean annual precipitation: 6 to 10 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 150 to 200 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Hezel and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hezel

Setting

Landform: Terraces
Parent material: Glaciofluvial deposits with a mantle of eolian sands

Typical profile

H1 - 0 to 7 inches: loamy fine sand
H2 - 7 to 18 inches: loamy sand
H3 - 18 to 27 inches: fine sandy loam
H4 - 27 to 60 inches: stratified fine sandy loam to silt loam

Properties and qualities

Slope: 0 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 9.0 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Quincy

Percent of map unit: 10 percent
Landform: Terraces
Hydric soil rating: No

Sagehill

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

44—Kennewick silt loam, 2 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2dnj
Elevation: 300 to 1,500 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 130 to 210 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Kennewick and similar soils: 85 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Kennewick

Setting

Landform: Terraces
Parent material: Lacustrine deposits

Typical profile

H1 - 0 to 8 inches: silt loam
H2 - 8 to 60 inches: silt loam

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)
Available water storage in profile: High (about 12.0 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C
Ecological site: CALCAREOUS LOAM 6-10 PZ (R007XY701WA)
Hydric soil rating: No

Minor Components

Royal

Percent of map unit: 5 percent

Landform: Terraces
Hydric soil rating: No

Warden

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

76—Pits

Map Unit Composition

Pits: 100 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pits

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

89—Quincy loamy fine sand, 0 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2dtt
Elevation: 350 to 1,200 feet
Mean annual precipitation: 6 to 12 inches
Mean annual air temperature: 48 to 54 degrees F
Frost-free period: 150 to 200 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Quincy and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quincy

Setting

Landform: Terraces
Parent material: Mixed eolian sands

Typical profile

H1 - 0 to 4 inches: loamy fine sand
H2 - 4 to 60 inches: fine sand

Properties and qualities

Slope: 0 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Available water storage in profile: Low (about 4.9 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 15 percent
Landform: Terraces, dunes

Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

92—Quincy loamy fine sand, loamy substratum, 0 to 10 percent slopes

Map Unit Setting

National map unit symbol: 2dv6
Elevation: 350 to 1,000 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Quincy and similar soils: 85 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quincy

Setting

Landform: Terraces
Parent material: Mixed eolian sands

Typical profile

H1 - 0 to 3 inches: loamy fine sand
H2 - 3 to 52 inches: loamy fine sand
H3 - 52 to 60 inches: silt loam

Properties and qualities

Slope: 0 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 5.0
Available water storage in profile: Moderate (about 6.5 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)

Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

126—Royal loamy fine sand, 0 to 10 percent slopes

Map Unit Setting

National map unit symbol: 2df7
Elevation: 400 to 1,400 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Royal and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Royal

Setting

Landform: Terraces
Parent material: Sandy alluvium

Typical profile

H1 - 0 to 6 inches: loamy fine sand
H2 - 6 to 19 inches: fine sandy loam
H3 - 19 to 60 inches: stratified fine sand to very fine sandy loam

Properties and qualities

Slope: 0 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 7.5 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 15 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

128—Royal fine sandy loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 2dfc
Elevation: 400 to 1,400 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Royal and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Royal

Setting

Landform: Terraces
Parent material: Sandy alluvium

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 15 inches: fine sandy loam
H3 - 15 to 60 inches: stratified fine sand to very fine sandy loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 7.6 inches)

Interpretive groups

Land capability classification (irrigated): 1
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 15 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

129—Royal fine sandy loam, 2 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2dff
Elevation: 400 to 1,400 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Royal and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Royal

Setting

Landform: Terraces
Parent material: Sandy alluvium

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 15 inches: fine sandy loam
H3 - 15 to 60 inches: stratified fine sand to very fine sandy loam

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 7.6 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 15 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

144—Sagemoor very fine sandy loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 2dgj
Elevation: 400 to 1,000 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Sagemoor and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Sagemoor

Setting

Landform: Terraces
Parent material: Loess over layered lacustrine deposits

Typical profile

H1 - 0 to 4 inches: very fine sandy loam
H2 - 4 to 9 inches: silt loam
H3 - 9 to 18 inches: silt loam
H4 - 18 to 60 inches: silt loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 11.7 inches)

Interpretive groups

Land capability classification (irrigated): 1
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: LOAMY 6-10 PZ (R007XY102WA)
Hydric soil rating: No

Minor Components

Kennewick

Percent of map unit: 10 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

183—Timmerman fine sandy loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 2djn
Elevation: 350 to 1,000 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Timmerman and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Timmerman

Setting

Landform: Terraces
Parent material: Glacial outwash and alluvium mixed with loess in the upper part

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 19 inches: sandy loam
H3 - 19 to 60 inches: loamy coarse sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 13 to 30 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Royal

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Winchester

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

184—Timmerman fine sandy loam, 2 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2djq
Elevation: 350 to 1,000 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Timmerman and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Timmerman

Setting

Landform: Terraces
Parent material: Glacial outwash and alluvium mixed with loess in the upper part

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 19 inches: sandy loam
H3 - 19 to 60 inches: loamy coarse sand

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: 13 to 30 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Royal

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Sagehill

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

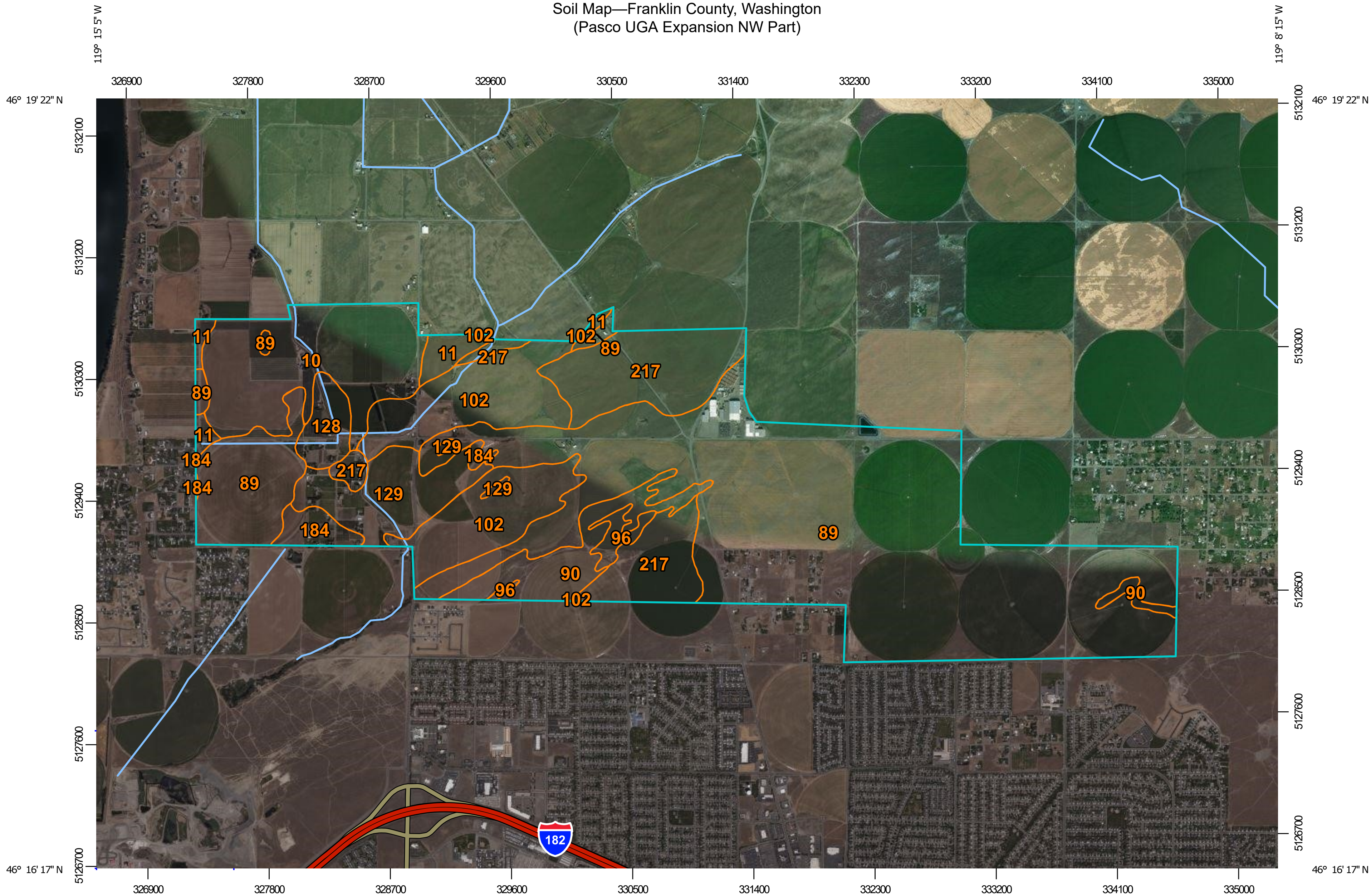
Winchester

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Soil Map—Franklin County, Washington
(Pasco UGA Expansion NW Part)



Map Scale: 1:40,100 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 500, 1000, 2000, 3000

Feet: 0, 1500, 3000, 6000, 9000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 11N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 28, 2014—Jul 31, 2018

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
10	Chedehap fine sandy loam, 0 to 2 percent slopes	297.1	10.4%
11	Chedehap fine sandy loam, 2 to 5 percent slopes	45.5	1.6%
89	Quincy loamy fine sand, 0 to 15 percent slopes	1,509.6	52.8%
90	Quincy loamy fine sand, 15 to 30 percent slopes	126.1	4.4%
96	Quincy-Dune land complex, 5 to 40 percent slopes	23.7	0.8%
102	Quincy-Timmerman complex, 0 to 15 percent slopes	318.0	11.1%
128	Royal fine sandy loam, 0 to 2 percent slopes	49.6	1.7%
129	Royal fine sandy loam, 2 to 5 percent slopes	145.4	5.1%
184	Timmerman fine sandy loam, 2 to 5 percent slopes	40.0	1.4%
217	Winchester loamy coarse sand, 2 to 5 percent slopes	305.2	10.7%
Totals for Area of Interest		**2,860.3**	**100.0%**

Franklin County, Washington

10—Chedehap fine sandy loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 2dcv
Elevation: 400 to 1,100 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Chedehap and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Chedehap

Setting

Landform: Terraces
Parent material: Glaciofluvial deposits

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 18 inches: sandy loam
H3 - 18 to 31 inches: sandy loam
H4 - 31 to 60 inches: coarse sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 26 to 40 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 20.0
Available water storage in profile: Low (about 4.3 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Quincy

Percent of map unit: 15 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

11—Chedehap fine sandy loam, 2 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2ddc
Elevation: 400 to 1,100 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Chedehap and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Chedehap

Setting

Landform: Terraces
Parent material: Glaciofluvial deposits

Typical profile

H1 - 0 to 4 inches: fine sandy loam
H2 - 4 to 18 inches: sandy loam
H3 - 18 to 31 inches: sandy loam
H4 - 31 to 60 inches: coarse sand

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: 26 to 40 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 20.0
Available water storage in profile: Low (about 4.3 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Quincy

Percent of map unit: 15 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

89—Quincy loamy fine sand, 0 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2dtt
Elevation: 350 to 1,200 feet
Mean annual precipitation: 6 to 12 inches
Mean annual air temperature: 48 to 54 degrees F
Frost-free period: 150 to 200 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Quincy and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quincy

Setting

Landform: Terraces
Parent material: Mixed eolian sands

Typical profile

H1 - 0 to 4 inches: loamy fine sand
H2 - 4 to 60 inches: fine sand

Properties and qualities

Slope: 0 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Available water storage in profile: Low (about 4.9 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 15 percent
Landform: Terraces, dunes

Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

90—Quincy loamy fine sand, 15 to 30 percent slopes

Map Unit Setting

National map unit symbol: 2dv0
Elevation: 350 to 1,200 feet
Mean annual precipitation: 6 to 12 inches
Mean annual air temperature: 48 to 54 degrees F
Frost-free period: 150 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Quincy and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quincy

Setting

Landform: Terraces
Parent material: Mixed eolian sands

Typical profile

H1 - 0 to 4 inches: loamy fine sand
H2 - 4 to 60 inches: fine sand

Properties and qualities

Slope: 15 to 30 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Available water storage in profile: Low (about 4.9 inches)

Interpretive groups

Land capability classification (irrigated): 6e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 10 percent
Landform: Dunes, terraces
Hydric soil rating: No

Royal

Percent of map unit: 5 percent
Landform: Terraces, dunes
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

96—Quincy-Dune land complex, 5 to 40 percent slopes

Map Unit Setting

National map unit symbol: 2dvr
Elevation: 350 to 1,200 feet
Mean annual precipitation: 6 to 12 inches
Mean annual air temperature: 48 to 54 degrees F
Frost-free period: 150 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Quincy and similar soils: 55 percent
Dune land: 35 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quincy

Setting

Landform: Terraces
Parent material: Mixed eolian sands

Typical profile

H1 - 0 to 11 inches: fine sand
H2 - 11 to 60 inches: fine sand

Properties and qualities

Slope: 5 to 40 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Available water storage in profile: Low (about 4.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Description of Dune Land

Setting

Landform: Dunes
Parent material: Unstratified fine sand and sand

Typical profile

C - 0 to 60 inches: fine sand

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 10 percent
Landform: Dunes, terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

102—Quincy-Timmerman complex, 0 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2dd1
Elevation: 350 to 1,200 feet
Mean annual precipitation: 6 to 12 inches
Mean annual air temperature: 48 to 54 degrees F
Frost-free period: 150 to 200 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Quincy and similar soils: 60 percent
Timmerman and similar soils: 35 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quincy

Setting

Landform: Terraces
Parent material: Mixed eolian sands

Typical profile

H1 - 0 to 4 inches: loamy fine sand
H2 - 4 to 60 inches: fine sand

Properties and qualities

Slope: 0 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Available water storage in profile: Low (about 4.9 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Description of Timmerman

Setting

Landform: Terraces

Parent material: Glacial outwash and alluvium mixed with loess in the upper part

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 19 inches: sandy loam
H3 - 19 to 60 inches: loamy coarse sand

Properties and qualities

Slope: 0 to 15 percent
Depth to restrictive feature: 13 to 30 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 3 percent
Landform: Dunes
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

128—Royal fine sandy loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 2dfc
Elevation: 400 to 1,400 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Royal and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Royal

Setting

Landform: Terraces
Parent material: Sandy alluvium

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 15 inches: fine sandy loam
H3 - 15 to 60 inches: stratified fine sand to very fine sandy loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 7.6 inches)

Interpretive groups

Land capability classification (irrigated): 1
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 15 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

129—Royal fine sandy loam, 2 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2dff
Elevation: 400 to 1,400 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Royal and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Royal

Setting

Landform: Terraces
Parent material: Sandy alluvium

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 15 inches: fine sandy loam
H3 - 15 to 60 inches: stratified fine sand to very fine sandy loam

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 7.6 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Sagehill

Percent of map unit: 15 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

184—Timmerman fine sandy loam, 2 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2djq
Elevation: 350 to 1,000 feet
Mean annual precipitation: 6 to 9 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 180 to 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Timmerman and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Timmerman

Setting

Landform: Terraces
Parent material: Glacial outwash and alluvium mixed with loess in the upper part

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 19 inches: sandy loam
H3 - 19 to 60 inches: loamy coarse sand

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: 13 to 30 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: A
Ecological site: SANDY 6-10 PZ (R007XY501WA)
Hydric soil rating: No

Minor Components

Royal

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Sagehill

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Winchester

Percent of map unit: 5 percent
Landform: Terraces
Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

217—Winchester loamy coarse sand, 2 to 5 percent slopes

Map Unit Setting

National map unit symbol: 2dlb
Elevation: 350 to 1,800 feet
Mean annual precipitation: 4 to 12 inches
Mean annual air temperature: 48 to 54 degrees F
Frost-free period: 110 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Winchester and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Winchester

Setting

Landform: Terraces
Parent material: Sandy alluvium and eolian sands

Typical profile

H1 - 0 to 15 inches: loamy coarse sand
H2 - 15 to 60 inches: coarse sand

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Available water storage in profile: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: A
Ecological site: SANDS 6-10 PZ (R007XY502WA)
Hydric soil rating: No

Minor Components

Burbank

Percent of map unit: 10 percent
Landform: Terraces

Hydric soil rating: No

Data Source Information

Soil Survey Area: Franklin County, Washington
Survey Area Data: Version 17, Sep 16, 2019

Franklin County, Washington

Community Wildfire Protection Plan

Approved by the

Franklin County Commissioners

2014

This plan was developed by the Franklin County Community Wildfire Protection Plan steering committee.

Acknowledgements

This Community Wildfire Protection Plan represents the efforts and cooperation of a number of organizations and agencies working together to improve preparedness for wildfire events while reducing factors of risk.

F.C.F.P.D.s #1, #2, #4, & #5

Pasco Fire Department

Franklin County Weed Board

To obtain copies of this plan contact:

Franklin County Emergency Management
502 Boeing St.
Pasco, WA 99301
509-545-3546

Table of Contents

[This page intentionally left blank.]

Foreword

The process of developing a Community Wildfire Protection Plan (CWPP) can help a community clarify and refine its priorities for the protection of life, property, and critical infrastructure in the wildland–urban interface on both public and private land. It also can lead community members through valuable discussions regarding management options and implications for the surrounding land base. Local fire service organizations help define issues that may place the county, communities, and/or individual homes at risk. Through the collaboration process, the CWPP steering committee discusses potential solutions, funding opportunities, and regulatory concerns and documents their resulting recommendations in the CWPP. The CWPP planning process also incorporates an element for public outreach. Public involvement in the development of the document not only facilitates public input and recommendations, but also provides an educational opportunity through interaction of local wildfire specialists and an interested public.

The idea for community-based forest planning and prioritization is neither novel nor new. However, the incentive for communities to engage in comprehensive forest planning and prioritization was given new and unprecedented impetus with the enactment of the Healthy Forests Restoration Act (HFRA) in 2003. This landmark legislation includes the first meaningful statutory incentives for the US Forest Service (USFS) and the Bureau of Land Management (BLM) to give consideration to the priorities of local communities as they develop and implement forest management and hazardous fuel reduction projects. In order for a community to take full advantage of this new opportunity, it must first prepare a Community Wildfire Protection Plan (CWPP).

A countywide CWPP steering committee generally makes project recommendations based on the issue causing the wildfire risk, rather than focusing on individual landowners or organizations. Thus, projects are mapped and evaluated without regard for property boundaries, ownership, or current management. Once the CWPP is approved by the Franklin County Commissioners, the steering committee will begin further refining proposed project boundaries, feasibility, and public outreach as well as seeking funding opportunities.

The ***Franklin County Community Wildfire Protection Plan*** *expands on the wildfire chapter of the Franklin County Hazard Mitigation Plan updated in 2011. This project was funded by the Franklin County Emergency Management, Franklin County Fire Protection Districts, City of Connell Fire Department, City of Pasco Fire Department, and the Bureau of Land Management.*

[This page intentionally left blank.]

Chapter 1

Overview of this Plan and its Development

In 2011, the Bureau of Land Management contracted with Northwest Management Inc. to conduct an in-depth risk assessment for the hazards of wildland fire. Wildfire events occur almost annually in Franklin County; thus, programs and projects that mitigate the impacts of this hazard is a benefit to the local residents, property, infrastructure, and the economy. In May of 2013, the Bureau of Land Management met with the newly formed planning committee to introduce their plans in developing a wildland fire risk assessment and the opportunity to meld that plan into a Community Wildfire Protection Plan.

This Community Wildfire Protection Plan for Franklin County, Washington, is the result of analyses, professional collaboration, and assessments of wildfire risks and other factors focused on reducing wildfire threats to people, structures, infrastructure, and unique ecosystems in Franklin County. Agencies and organizations that participated in the planning process included:

- City of Connell Fire Department
- City of Pasco Fire Department
- Franklin County Fire District #1
- Franklin County Fire District #2
- Franklin County Fire District #3
- Franklin County Fire District #4
- Franklin County Fire District #5
- Franklin County Department of Emergency Management
- Franklin County Noxious Weed Board
- Washington Department of Fish and Wildlife
- Washington Department of Natural Resources
- U.S. Bureau of Reclamation
- Bureau of Land Management
- U.S. Fish and Wildlife Service

Northwest Management, Inc. of Moscow, Idaho was selected to assist the planning committee by facilitating meetings, leading the assessments, and authoring the document. The project lead from Northwest Management, Inc. was Brad Tucker.

Goals and Guiding Principles

Planning Philosophy and Goals

The goals of the planning process include integration with the National Fire Plan, the Healthy Forests Restoration Act, and the Disaster Mitigation Act. The plan utilizes the best and most appropriate science from all partners as well as local and regional knowledge about wildfire risks and fire behavior while meeting the needs of local citizens and recognizing the significance wildfire can have to the regional economy.

Mission Statement

To make Franklin County residents, communities, state agencies, local and federal governments, and businesses less vulnerable to the negative effects of wildland fires through the effective administration of wildfire hazard mitigation grant programs, hazard risk assessments, wise and efficient fuels treatments, and a coordinated approach to mitigation policy through federal, state, regional, and local planning efforts. To also provide a plan that will not diminish the Private Property Rights of land/asset owners within Franklin County.

Vision Statement

Our combined focus will be the protection of people, structures, infrastructure, livestock, state and federally listed species, and unique ecosystems that contribute to our way of life and the growth and sustainability of the local and regional economy through education, training, support, and planning.

Goals

1. To protect people, structures, assets, critical infrastructure, state and federally listed species, and unique ecosystems that contribute to our way of life and the sustainability of the local and regional economy.
2. Identify and map Wildland Urban Interface (WUI) boundaries.
3. Provide a plan that balances private property rights of landowners in Franklin County with personal safety and responsibility
4. Educate citizens about the unique challenges of wildfire preparedness and reclamation in the County through the introduction of the Firewise program and encourage homeowners to manage their property accordingly.
5. Develop regulatory measures such as building codes and road standards specifically targeted to reduce the wildland fire potential and reduce the potential for loss of life and property.
6. Determine areas at risk of wildfire and establish/prioritize mitigation projects, without regard to ownership, and recommend both conventional and alternative treatment methods to protect people, homes, infrastructure, state and federal listed species, and natural resources throughout Franklin County.
7. Improve county and local fire agency eligibility for funding assistance (National Fire Plan, Healthy Forest Restoration Act, FEMA, and other sources) to reduce wildfire

hazards, prepare residents for wildfire situations, and enhance fire agency response capabilities.

8. Improve emergency response times through enhanced radio communications and greater road signage throughout the County.
9. Improve the ability of the County Fire Districts to provide fire protection for the residents of Franklin County through improved resources, recruitment and retention of volunteers, and training.

United States Government Accountability Office (GAO)

Since 1984, wildland fires have burned an average of 850 homes each year in the United States and, because more people are moving into fire-prone areas bordering wildlands, the number of homes at risk is likely to grow. The primary responsibility for ensuring that preventative steps are taken to protect homes lies with homeowners. Although losses from fires made up only 2 percent of all insured catastrophic losses from 1983 to 2002, fires can result in billions of dollars in damages.

GAO was asked to assess, among other issues, (1) measures that can help protect structures from wildland fires, (2) factors affecting use of protective measures, and (3) the role technology plays in improving firefighting agencies' ability to communicate during wildland fires.

The two most effective measures for protecting structures from wildland fires are: (1) creating and maintaining a buffer, called defensible space, from 30 to 100 feet wide around a structure, where flammable vegetation and other objects are reduced; and (2) using fire-resistant roofs and vents. In addition to roofs and vents, other technologies – such as fire-resistant windows and building materials, surface treatments, sprinklers, and geographic information systems mapping – can help in protecting structures and communities, but they play a secondary role.

Although protective measures are available, many property owners have not adopted them because of the time or expense involved, competing concerns such as aesthetics or privacy, misperceptions about wildland fire risks, and lack of awareness of their shared responsibility for fire protection. Federal, state, and local governments, as well as other organizations, are attempting to increase property owners' use of protective measures through education, direct monetary assistance, and laws requiring such measures. In addition, some insurance companies have begun to direct property owners in high risk areas to take protective steps[1].

State and Federal CWPP Guidelines

This Community Wildfire Protection Plan includes compatibility with FEMA requirements for a Hazard Mitigation Plan, while also adhering to the guidelines proposed in the National Fire Plan, and the Healthy Forests Restoration Act (2003). This Community Wildfire Protection Plan has been prepared in compliance with:

---

[1] United States Government Accountability Office. Technology Assessment – Protecting Structures and Improving Communications during Wildland Fires. Report to Congressional Requesters. GAO-05-380. April 2005.

- The National Fire Plan: A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment 10-Year Comprehensive Strategy Implementation Plan (December 2006).
- Healthy Forests Restoration Act (2003).
- National Cohesive Wildland Fire Management Strategy (March 2011). The Cohesive Strategy is a collaborative process with active involvement of all levels of government and non-governmental organizations, as well as the public, to seek national, all-lands solutions to wildland fire management issues.
- The Federal Emergency Management Agency's Region 10 guidelines for a Local Hazard Mitigation Plan as defined in 44 CFR parts 201 and 206, and as related to a fire mitigation plan chapter of a Multi-Hazard Mitigation Plan.
- National Association of State Foresters – guidance on identification and prioritizing of treatments between communities (2003).

The objective of combining these complementary guidelines is to facilitate an integrated Community Wildfire Protection Plan, identify pre-hazard mitigation activities, and prioritize activities and efforts to achieve the protection of people, structures, the environment, and significant infrastructure in Franklin County while facilitating new opportunities for pre-disaster mitigation funding and cooperation.

Additional information detailing the state and federal guidelines used in the development of the Franklin County Community Wildfire Protection Plan is included in Appendix 5.

Integration with other Local Planning Documents

During development of this Community Wildfire Protection Plan, several planning and management documents were reviewed in order to avoid conflicting goals and objectives. Existing programs and policies were reviewed in order to identify those that may weaken or enhance the mitigation objectives outlined in this document. The following sections identify and briefly describe some of the existing Franklin County planning documents and ordinances considered during development of this plan.

Franklin County Hazard Mitigation Plan

As a requirement to receive certain types of federal non-emergency disaster assistance, including funding for hazard mitigation projects, Franklin County and the cities and towns of Pasco, Connell, Mesa, and Kahlotus are required to develop and maintain an up-to-date local hazard mitigation plan. The jointly developed Franklin County Hazard Mitigation Plan was approved on December 27th, 2011. The Federal government requires that hazard mitigation plans be updated every five years.

Franklin County Comprehensive Plan

The Countywide Comprehensive Plan is the guiding document that establishes the vision for growth and development in the County. The goals and policies of the plan create the framework for designating properties into comprehensive plan map designations and their correlating zoning districts.

This Community Wildfire Protection Plan will “dove-tail” with the County’s Comprehensive Plan during its development and implementation to ensure that the goals and objectives of each are integrated. This planning effort is intended to be compatible with the goals and objectives of the County’s Comprehensive Plan.

[This page intentionally left blank.]

Chapter 2

Documenting the Planning Process

Documentation of the planning process, including public involvement, is necessary to meet FEMA's DMA 2000 requirements (44CFR§201.4(c)(1) and §201.6(c)(1)). This section includes a description of the planning process used to develop the plan, including how it was prepared, who was involved in the process, and how all of the involved agencies participated.

Description of the Planning Process

The Franklin County Community Wildfire Protection Plan was developed through a collaborative process involving all of the organizations and agencies detailed in Chapter 1 of this document. The planning process included five distinct phases which were in some cases sequential (step 1 then step 2) and in some cases intermixed (step 4 completed throughout the process):

1. **Collection of Data** about the extent and periodicity of the wildfire hazard in and around Franklin County.
2. **Field Observations and Estimations** about risks, location of structures and infrastructure relative to risk areas, access, and potential treatments.
3. **Mapping** of data relevant to pre-wildfire mitigation and treatments, structures, resource values, infrastructure, risk assessments, and related data.
4. **Facilitation of Public Involvement** from the formation of the planning committee to news releases, public meetings, public review of draft documents, and acknowledgement of the final plan by the signatory representatives.
5. **Analysis and Drafting of the Report** to integrate the results of the planning process, provide ample review and integration of committee and public input, and signing of the final document.

The Planning Team

Northwest Management facilitated the Community Wildfire Protection Plan meetings. Stakeholders involved in the meetings included representatives from local communities, fire districts, municipal fire departments, federal and state agencies, and local organizations with an interest in the county's fire safety.

The planning philosophy employed in this project included the open and free sharing of information with interested parties. Information from federal, state, and local agencies was integrated into the database of knowledge used in this project. Meetings with the committee were held throughout the planning process to facilitate a sharing of information between participants. When the public meetings were held, many of the committee members were in attendance and shared their support and experiences and their interpretations of the results.

Multi-Jurisdictional Participation

44 CFR §201.6(a)(3) calls for multi-jurisdictional planning in the development of Hazard Mitigation Plans which impact multiple jurisdictions. In addition to the participation of federal agencies and other organizations, the following local jurisdictions were actively involved in the development of this Community Wildfire Protection Plan:

- City of Pasco
- City of Connell
- Franklin Co. Emergency Management
- Franklin County Weed Board
- Franklin County F.D. #1
- Franklin County F.D. #2
- Franklin County F.D. #3
- Franklin County F.D. #4
- Franklin County F.D. #5
- Washington Department of Fish and Wildlife
- Washington Department of Natural Resources
- Bureau of Land Management
- Bureau of Reclamation
- U.S. Fish and Wildlife Service

These jurisdictions were represented on the planning committee and in public meetings either directly or through their servicing fire department or district. They participated in the development of hazard profiles, risk assessments, and mitigation measures. The planning committee meetings were the primary venue for authenticating the planning record. However, additional input was gathered from each jurisdiction in the following ways:

- Planning committee leadership visits to local group meetings where planning updates were provided and information was exchanged.
- One-on-one visits between the planning committee leadership and representatives of the participating jurisdictions (e.g. meetings with county councilors, city councilors and mayor, fire district commissioners, and community leaders).
- Written correspondence between the planning committee leadership and each jurisdiction updating the participating representatives on the planning process, making requests for information, and facilitating feedback.

Like other areas of Washington and the United States, Franklin County's human resources have many demands placed on them in terms of time and availability. In Franklin County, elected officials (county and town councilors and mayor) do not serve in a full-time capacity; some of them have other employment and serve the community through a convention of public service. Recognizing this and other time constraints, many of the jurisdictions decided to identify a representative to cooperate on the planning committee and then report back to the remainder of their organization on the process and serve as a conduit between the planning committee and the jurisdiction.

Planning Committee Meetings

The following people participated in planning committee meetings, volunteered time, or responded to elements of the Franklin County Community Wildfire Protection Plan's preparation.

NAME	ORGANIZATION
Bob Gear	Pasco Fire Department
Dave Hare	Pasco Fire Department
Marvin Leonard	Kennewick Fire
Chris Schulte	Connell Fire Department
Eric Mauseth	Franklin County F.P.D. #1
Les Litzenberger	Franklin County F.P.D. #3
Mike Harris	Franklin County F.P.D. #3
Tom Hughes	Franklin County F.P.D. #3
Bryan Thornhill	Franklin County Emergency Management
Jacque Cook	Franklin County Emergency Management
Sean Davis	Franklin County Emergency Management
Todd Harris	Franklin County Weed Board
Vic Reeve	Franklin County Weed Board
Joe Weeks	Washington Department of Natural Resources
Chuck Wytko	Washington Department of Natural Resources
Joe Blazek	Washington Department of Natural Resources
Greg Bjornstrom	Washington Department of Fish & Wildlife
Phillip Buser	Washington Department of Fish & Wildlife
Thomas Skinner	U.S. Fish & Wildlife Service
Brandon Lewis	U.S. Fish & Wildlife Service
Jacob Gear	U.S. Fish & Wildlife Service
Richard Parrish	Bureau of Land Management
Michael Solheim	Bureau of Land Management
Dennis Strange	Bureau of Land Management
Jonathan Brooks	U.S. Bureau of Reclamation
Michael S. Lesky	U.S. Bureau of Reclamation
Brad Tucker	Northwest Management, Inc.
Vaiden Bloch	Northwest Management, Inc.
Tera King	Northwest Management, Inc.

Committee Meeting Minutes

Committee meetings were scheduled and held from May, 2013 through January, 2014. These meetings served to facilitate the sharing of information and to lay the groundwork for the Franklin County Community Wildfire Protection Plan. Northwest Management, Inc. as well as other planning committee leadership attended the meetings to provide the group with regular updates on the progress of the document and gather any additional information needed to complete the Plan.

Planning committee meeting minutes are included in Appendix 2.

Public Involvement

Public involvement was made a priority from the inception of the project. There were a number of ways that public involvement was sought and facilitated. The idea is to allow members of the public to provide information and seek an active role in protecting their own homes and businesses, and in some cases it may lead to the public becoming more aware of the process without becoming directly involved in the planning.

News Releases

Under the auspices of the planning committee, periodic press releases were submitted to the various print and online news outlets that serve Franklin County residents. Informative flyers were also distributed around town and to local offices within the communities by the committee members.

Print Media	Other Media
Tri-City Herald	Local Fire Districts
Franklin County Graphic	KEPR news station
	KNDU news station
	KONA radio station

Figure 2.1. Sample Press Release, April, 2013.

Franklin County Press Release

April 23, 2013

Franklin County Plans to Assess Wildfire Risk

Working in conjunction with Franklin County, the Bureau of Land Management (BLM) has launched the process of developing a county-level wildland fire risk assessment. Local agencies and organizations in Franklin County have initiated a planning committee to complete the risk assessment as the first step in the ultimate development of a Franklin County Wildfire Protection Plan as part of the National Fire Plan and Healthy Forests Restoration Act. The Franklin County Wildland Fire Risk Assessment will include risk analyses with predictive models indicating where fires are likely to ignite and how they may impact local communities and the environment. The first meeting is scheduled for May 2nd, 2013 and will be the first of several monthly meetings.

Northwest Management, Inc. has been retained by the Bureau of Land Management to facilitate meetings, conduct field inspections and interviews, develop vulnerability assessments, and collaborate with the committee to delineate mitigation projects. The planning committee includes representatives from local fire districts, Franklin County, Washington Department of Natural Resources, Bureau of Land Management, and others.

The intention of the project is to conduct an assessment of wildland fire risk in Franklin County and the local communities, then make mitigation recommendations that will not only help prevent wildfire ignitions from occurring, but will also guide decision-makers towards creating a more fire-resistant Franklin County and provide for public wildfire education. Some of the goals of this project are to improve awareness of wildland fire issues locally, identify high fire risk areas and develop strategies to reduce this risk, and improve accessibility of funding assistance to achieve these goals.

The planning committee will be conducting public meetings to discuss preliminary findings and to seek public involvement in the planning process in the fall of 2013. A notice of the dates and locations of these meetings will be posted in local news outlets. For more information on the Franklin County Wildland Fire Risk Assessment or if you're interested in participating on the planning committee, please contact Brad Tucker, Northwest Management, Inc., at 208-883-4488 ext 123 or Richard Parrish, Bureau of Land Management, at 509-536-1226.

Public Meetings

Public meetings were scheduled in strategic locations during the wildfire risk assessment phase of the planning process to share information on the Plan, obtain input on the details of the wildfire risk assessments, and discuss potential mitigation treatments. Attendees at the public meetings were asked to give their impressions of the accuracy of the information generated and provide their opinions of potential treatments.

The schedule of public meetings in Franklin County included 2 locations; the first was held in Pasco, WA and the second in Connell, WA. The first public meeting was attended by a number of individuals on the committee and one from the general public. The second public meeting was attended by a number of individuals on the committee and one from the general public. The public meeting announcement sent to the local newspapers, two television stations, county departments, fire district representatives, and distributed by committee members, is included below in Figure 2.2.

Figure 2.2. Public Meeting Flyer.

Franklin County Community Wildfire Protection Plan

Public Meeting Announcement

NORTHWEST MANAGEMENT, INC.

Franklin Co. Fire Station #3 7809 Road 36, Pasco, **Nov. 20th at 6:00 pm**

Connell Fire Station 605 S Columbia, Connell, **Nov. 21st at 6:00 pm**

These public meetings will address the Community Wildfire Protection Plan being developed for Franklin County. Public input is being sought to better understand the vulnerability of County residents, businesses, and resources to wildfire. The purpose of this plan is to promote awareness of the countywide wildland fire hazard and propose workable solutions to reduce the wildfire risk.

The planning committee is working on:

- **Mapping the Wildland Urban Interface in Franklin County.**
- **Improving public awareness and educating the public about wildfire risk.**
- **Evaluating strategies for landowners to lessen wildfire potential.**
- **Addressing areas of inadequate fire protection.**
- **Recommending risk mitigation projects.**

These meetings are open to the public and will include slideshow presentation by wildfire specialists and local personnel working to develop these plans.

Learn about the assessments of wildfire risk and the wildland urban interface of Franklin County. Discuss *YOUR* priorities for how our community can best mitigate these risks.

Figure 2.3. Local News Article.

Franklin County residents can review preliminary wildfire protection proposal

By Tyler Richardson, Tri-City Herald November 19, 2013

Franklin County residents will get the chance this week to review a preliminary plan to keep people safe in case a major wildfire breaks out.

Northwest Management, a natural resource consulting firm based in Moscow, Idaho, was hired to identify areas in Franklin County most susceptible to wildfires, plan how to fight them, educate residents about the dangers of wildfires and help fire districts work together.

The firm will present its findings to residents in Pasco and Connell. The Pasco meeting is scheduled for today at fire station 36 at 7809 Road 36. The Connell meeting is Thursday at the fire station at 605 S. Columbia Ave. Both start at 6 p.m.

"It's mostly a chance for folks to become familiar with the plan," said Brad Tucker, a wildlife biologist with Northwest Management. "People can ask questions of committee members and voice any concerns they might have."

The plan costs around $25,000, with the county putting up $6,400 and the Bureau of Land Management covering the rest, Tucker said. Officials hope to present a first draft to a committee, which will review the plan, in about three weeks.

The committee comprises federal, local fire and county officials, Tucker said.

Northwest Management used fire behavioral models, conducted field assessments and spoke with fire officials to develop the plan.

"We really identify areas within the county that are more at risk for wildfires and come up with projects to mitigate the risk," Tucker said. "The idea is to try and get everybody on the same page with what they have resource-wise."

Benton County has had a wildfire protection plan for a number of years and Franklin County just now found the funds to partner with BLM to develop a plan, said Les Litzenberger, chief of Franklin Fire District 3.

The plan should keep everyone safer should a wildfire start, Litzenberger said.

"This is a scientific-based analysis of the issues, the fuel types, the fire history and the threats to the people in Franklin County," he said. "It's definitely more scientific than me just standing up there. This gives us a document that proves I know what I am talking about."

-- Tyler Richardson: 582-1556; trichardson@tricityherald.com; Twitter: @Ty_richardson

Documented Review Process

Review and comment on this plan has been provided through a number of avenues for the committee members as well as members of the general public.

During regularly scheduled committee meetings in the summer and fall of 2013, the committee met to discuss findings, review mapping and analysis, and provide written comments on draft sections of the document. During the public meetings, attendees observed map analyses and photographic collections, discussed general findings from the community assessments, and made recommendations on potential project areas.

The first draft of the document was prepared after the public meetings and presented to the committee in December for a full committee review. The committee was given two weeks to provide comments to the plan.

Public Comment Period

A public comment period was conducted from February 7th – 28th, 2014 to allow members of the general public an opportunity to view the full draft plan and submit comments and any other input to the committee for consideration. A press release was submitted to the local media outlets announcing the comment period, the location of Plan for review, and instructions on how to submit comments. Hardcopy drafts were printed and made available at Pasco library, Mid-Columbia library (Kahlotus), Basin City library, Connell library, West Pasco library, and Merrill's Corner library (Eltopia). Each hardcopy was accompanied by a letter of instruction for submitting comments to the planning committee. The press release used to announce the public review period is shown in Figure 2.4. A list of comments that were not incorporated into the plan can be found in Appendix 2. Each public comment is followed by a brief explanation, given by the committee, as to why that comment was not incorporated into the document.

Continued Public Involvement

Franklin County is dedicated to involving the public directly in review and updates of the Community Wildfire Protection Plan. The Franklin County Commissioners, working through the planning committee, are responsible for review and update of the Plan as recommended in chapter 6 of this document.

The public will have the opportunity to provide feedback annually on the anniversary of the adoption of this plan, at an open meeting of the planning committee. Copies of the Plan will be catalogued and kept at all of the appropriate agencies in the county. The Plan also includes the address and phone number of Franklin County Emergency Management, who is responsible for keeping track of public comments on the Plan.

A public meeting will also be held as part of each annual evaluation or when deemed necessary by the planning committee. The meetings will provide the public a forum for which they can express its concerns, opinions, or ideas about the Plan. The County Department of Emergency Management will be responsible for using county resources to publicize the annual public meetings and maintain public involvement through the webpage and various print and online media outlets.

Figure 2.4. Press Release #3 – Public Comment Period.

Franklin County

Media Release

From: Sean Davis, Franklin County Emergency Management
Date: January 27, 2014
RE: Franklin County Community Wildfire Protection Plan

Franklin County Community Wildfire Protection Plan Available for Public Review

The Franklin County Community Wildfire Protection Plan has been completed in draft form and is available to the public for review and comment at the locations listed below. Electronic copies may be viewed in pdf format at www.franklinem.org and www.fcfd3.org. The public review phase of the planning process will be open from February 3rd, 2014 thru February 28th, 2014.

Pasco Library
1320 W Hopkins St.
Pasco, Washington 99301

West Pasco Library
7525 Wrigley Drive
Pasco, Washington 99301

Basin City Library
50-A N. Canal Blvd.
Basin City, Washington 99343

Mid-Columbia Library
225 E Weston St.
Kahlotus, WA 99335

Connell Library
118 N. Columbia
Connell, Washington 99326

Merrill's Corner
5240 Eltopia West
Eltopia, Washington 99330

The purpose of the Franklin County Community Wildfire Protection Plan (CWPP) is to reduce the impact of wildfire on Franklin County residents, landowners, businesses, communities, local governments, and state and federal agencies while maintaining appropriate emergency response capabilities and sustainable natural resource management policies. The CWPP identifies high risk areas as well as recommend specific projects that may help prevent wildland fires from occurring altogether or, at the least, lessen their impact on residents and property. The CWPP is being developed by a committee of city and county elected officials and departments, local and state emergency response representatives, land managers, highway district representatives, and others.

The Franklin County CWPP includes a risk analysis at the community level with predictive models for where disasters are likely to occur. This Plan will enable Franklin County and its communities to be eligible for grant dollars to implement the projects and mitigation actions identified by the committee. Although not regulatory, the CWPP will provide valuable information as we plan for the future.

Comments on the CWPP must be submitted to the attention of Brad Tucker, Northwest Management, Inc. at tucker@nmi2.com or mailed to Northwest Management, Inc., PO Box 9748, Moscow, Idaho 83843 by close of business on February 28th, 2014. For more information on the Franklin County CWPP update process, contact Brad Tucker at 208-883-4488 ext. 123.

[This page intentionally left blank.]

Chapter 3

Franklin County Characteristics

Franklin County was created in 1883 and named after Benjamin Franklin. Pasco is the County seat and the Courthouse has been listed as a Washington State National Historic Building.

Franklin County is located in the south central part of the State of Washington. It is bounded on the west and separated from Benton County by the Columbia River. On the south and east the Snake River and its tributary, the Palouse River, separate it from Walla Walla County. On the north, Grant and Adams Counties bound it. The area is arid to semiarid, receiving an average rainfall of about six to seven inches per year[2] .

With an area of 1,242 square miles, Franklin County is the fastest growing county (in terms of percentage of population change) of Washington's 39 counties. The estimated 2012 population is 85,845 providing a population density of 69.1 persons per square mile.

Description

Three major rivers dominate the geography of Franklin County: the Columbia, Snake and Palouse. The cities of Pasco, Connell, Mesa and Kahlotus are located within Franklin County. The rivers provide a sharp contrast to the warm, dry surrounding landscape, the majority of which is either under irrigation or dry-land cultivation. The rivers give the region its most enduring character, providing abundant water for both irrigation and energy, a major transportation intersection (water, rail, air, and road), and a major recreational resource[3].

Elevations range from about 345 feet above sea level at the lower points to over 1,600 feet in the higher points. The terrain is generally basin and valley bottomland interspersed with upland plateaus[3].

Geography and Climate

Franklin County is part of what is referred to as the Columbia Basin Province. The County contains many canyon and cliff features such as Palouse Canyon and Devils Canyon, as well as unique rock formations. Some of the most interesting geographical features are the sand dunes located north of Interstate 82 and the Juniper Dunes area northeast of Pasco off the Pasco-Kahlotus Highway[2].

The County lies at the south end of the Channeled Scablands. The geology of Franklin County was formed by alternate volcanism and flooding. Three of the five geological formations, which characterize the entire Columbia River Basalt Group, occur in Franklin County[2].

---

[2] Franklin County Comprehensive Plan. 2008. http://www.co.franklin.wa.us/planning/documents/2008ComprehensivePlan-Entirepdfwebsite_000.pdf. Accessed August, 2013.

[3] Franklin County Economic Plan. 2009. http://www.co.franklin.wa.us/planning/documents/EconomicPlan-complete2009update.pdf. Accessed August, 2013.

The climate of the region is described as mild and dry. Throughout the year the region averages 280 days of sunshine. During the summer the maximum temperatures exceed 90°F on about half of the days in July and August. The average night temperature in July and August is 59°F. In the winter, the daily maximum temperatures average 40.5°F in January and 48.8°F in February. The daily minimums average 24.5°F in January and 30.1°F in February. The average yearly temperature is 55°F. The growing season in the region varies from 152 to 194 frost-free days. The northerly latitude of our area means long hours of daylight and an abundance of sunshine during the growing season[3].

Population and Demographics

The 2010 Census established the Franklin County population at 78,163, which is up from 49,347 in 2000. Table 3.1 shows historical changes in population in Franklin County.

Table 3.1. Historical and Current Population by Community.

1960	1970	1980	1990	2000	2010
23,342	25,816	35,025	37,473	49,347	78,163

Since 1890, Franklin County has had some significant jumps in population including a 960% increase in 1910 and another large increase in 1950 of 115%. Since the 1960's, the county's population has grown, by 36% on average[4].

Of the county's residents, about 76% (59,781) live in Pasco. Connell has 4,209 residents, Kahlotus has 193 residents, Mesa has 489 residents, West Pasco has 3,739 residents, and Basin City had 968 residents (2000 census data)[5]. The majority of the remaining residents (8,752) are concentrated in unincorporated parts of Franklin.

The 2010 Census reported that ethnicity in Franklin County is comprised of 91.3%, 1.3% American Indian, 2.6% African American, 2.1% Asian, and 2.3% people reporting two or more races. 50.9% of residents report a Hispanic or Latino heritage. Residents that identify their origin as Spanish, Hispanic, or Latino may be of any race, thus should not be added to percentages for racial categories. Approximately 52.2% of residents are male. There are 25,120 occupied housing units (67.2% homeownership rate) in Franklin County.[5] In 2007-2011, there were an estimated 3.36 persons per household in Franklin County with a median household income of $50,731[6].

Land Ownership

The majority of ownership within Franklin County is private. Federal ownerships account for 7% of the land base with the Bureau of Land Management contributing the largest federal

[4] Wikipedia website. http://en.wikipedia.org/wiki/Franklin_County,_Washington. Accessed August, 2013.

[5] US Census Bureau. State & County QuickFacts. Available online at http://quickfacts.census.gov/qfd/states/53/53017.html. Accessed August,2013.

[6] U.S. Census Bureau, State & County QuickFacts. http://quickfacts.census.gov/qfd/states/53/53021.html. Accessed August, 2013.

portion with over 23,000 acres and the U.S. Fish & Wildlife Service closely behind with over 22,500 acres. Approximately 4% of Franklin County is State-owned land.

Table 3.2. Land Ownership Categories in Franklin County		
Entity	**Acres**	**Percent of Total Area**
Private	709,673	88%
State	29,927	4%
BLM	23,834	3%
FWS	22,509	3%
Federal	11,342	1%
Water	5,780	1%
State Parks	2,326	<1%
State Fish & WL	2,025	<1%
NIPF	1,377	<1%
Undetermined	676	<1%
Total	**809,467**	**100%**

The data used to develop this table was provided by the 2010 BLM database. Local government property (i.e. County) is likely included in the Private ownership category. There may be more accurate information, but this table shows general trends, which is sufficient for the purpose of this plan.

The predominant land use in Franklin County is agriculture in the form of dryland grain crops (including some in CRP) and irrigated agriculture. Irrigated agriculture activities are located primarily in the western half of the County. Dryland wheat and other grain crops are primarily located in the eastern half of the County.

Development Trends

Because Franklin County is one of the fastest growing counties in Washington, agricultural lands are frequently converted to housing developments. This is especially true around the perimeter of Pasco (project areas 1 & 2) where numerous developments have sprung up in recent years. Many of the towns and cities in Franklin County have witnessed some level of expansion. Because much of the County is agriculture, the space is limited for major expansion. However, as the demand increases for potential building sites, land may become more valuable as residential property than agriculture.

Natural Resources

Franklin County is a diverse ecosystem with a complex array of vegetation, wildlife, and fisheries that have developed with, and adapted to fire as a natural/man-induced disturbance process. Nearly a century of wildland fire suppression coupled with past land-use practices (primarily agriculture and grazing) has altered plant community succession and has resulted in dramatic shifts in the fire regimes and species composition. As a result, some areas of Franklin County have become more susceptible to large-scale, high-intensity fires posing a threat to life, property, and natural resources including wildlife and plant populations. High-intensity, stand-replacing fires have the potential to seriously damage soils, native vegetation, and fish and wildlife populations. In addition, an increase in the number of large, high-intensity fires throughout the nation's forest and rangelands has resulted in significant safety risks to firefighters and higher costs for fire suppression.

Fish and Wildlife

There are many species of wildlife that inhabit the shrub / steppe region of central Washington. Some of the species present even rely on this type of ecosystem to survive. Sage grouse (*Centrocercus urophasianus*), Ferruginous hawk (*Buteo regalis*), and Burrowing owl (*Athene cunicularia*) once heavily populated this region of Washington; however due to habitat loss (among other reasons); these populations have been drastically reduced in numbers and in some instances genetically isolated from other populations. There has been a significant effort by federal, state, and private landowners in recent years to increase the availability of preferred habitat through the Conservation Reserve Program and incorporating higher grazing standards throughout the region.[7]

Vegetation

The Columbia Basin supports a complex landscape composed of native shrubsteppe vegetation, scablands, and agriculture or rangeland. Areas that have not been converted to agriculture typically exhibit scattered sagebrush or bitterbrush with a bunchgrass understory. The understory usually consists of bluebunch wheatgrass (*Psuedoroegneria spicata*), Idaho fescue (*Festuca idahoensis*)or various needlegrass (*Achnatherum sp.*) species. Areas in Franklin County that have shallow rocky soils are considered scablands. These shallow soils support specialized vegetation dominated by stiff sagebrush (*Artemisia rigida*), bushy buckwheats (*Eriogonum sp.*), and short bunchgrasses (e.g. *Poa secunda*). Land largely converted to agricultural use or rangeland are often dominated by exotic plants or native vegetation tolerant of persistent land use.[8]

Table 3.3. Vegetative Cover Types in Franklin County.

Land Cover	Acres	Percent of Total Area
Agriculture	422,560	52%
Shrubland	281,002	35%
Developed	39,937	5%
Exotic Grassland	35,282	4%
Water	15,845	2%
Riparian	6,723	1%

[7] Washington Department of Fish and Wildlife. 2008. Priority Habitat and Species List. Olympia, Washington. 174 pp.

[8] A Riparian Vegetation Classification of the Columbia Basin, Washington. http://www1.dnr.wa.gov/nhp/refdesk/pubs/columbiarip.pdf Accessed May, 2013

Table 3.3. Vegetative Cover Types in Franklin County.		
Land Cover	**Acres**	**Percent of Total Area**
Grassland	6,446	1%
Mixed Conifer	1,326	<1%
Barren	257	<1%
Sparsely Vegetated	89	<1%
Total	**809,467**	**100**

Vegetation in Franklin County is a mix of shrubland, grassland, agricultural, and some riparian ecosystems. An evaluation of satellite imagery of the region provides some insight to the composition of the vegetation of the area. Agriculture and shrubland account for nearly 90% of the cover in Franklin County. It should be noted that the exotic grasses contribute to 4% of the total cover in the County.

Hydrology

The Washington Department of Ecology, Water Resources Program is charged with the development of the Washington State Water Plan. Included in the State Water Plan are the statewide water policy plan and component basin and water body plans, which cover specific geographic areas of the state (WDOE 2005). The Washington Department of Ecology has prepared general lithologies of the major ground water flow systems in Washington.

The State may assign or designate beneficial uses for particular Washington water bodies to support. These beneficial uses are identified in section WAC 173-201A-200 of the Washington Surface Water Quality Standards (WQS). These uses include:

- ***Aquatic Life Uses:*** char; salmonid and trout spawning, rearing, and migration; nonanadromous interior redband trout, and indigenous warm water species
- ***Recreational Uses:*** primary (swimming) and secondary (boating) contact recreation
- ***Water Supply Uses:*** domestic, agricultural, and industrial; and stock watering

While there may be competing beneficial uses in streams, federal law requires protection of the most sensitive of these beneficial uses.

A correlation to mass wasting due to the removal of vegetation caused by high intensity wildland fire has been documented. Burned vegetation can result in changes in soil moisture and loss of rooting strength that can result in slope instability, especially on slopes greater than 30%. The greatest watershed impacts from increased sediment will be in the lower gradient, depositional stream reaches.

Of critical importance to Franklin County will be the maintenance of the domestic watershed supplies in the Alkali-Squilchuck (WRIA 40), Esquatzel Coulee (WRIA 36), Lower Snake (WRIA 33), Lower Yakima (WRIA 37), and Rock-Glade (WRIA 31)[9].

[9] Washington Department of Ecology, Water Resources Program website. http://www.ecy.wa.gov/watershed/index.html. Accessed August, 2013.

Air Quality

The primary means by which the protection and enhancement of air quality is accomplished is through implementation of National Ambient Air Quality Standards (NAAQS). These standards address six pollutants known to harm human health including ozone, carbon monoxide, particulate matter, sulfur dioxide, lead, and nitrogen oxides.[10]

The Clean Air Act, passed in 1963 and amended in 1977, is the primary legal authority of the U.S. Environmental Protection Agency. The Clean Air Act provides the principal framework for national, state, and local efforts to protect air quality. Under the Clean Air Act, the Organization for Air Quality Protection Standards (OAQPS) is responsible for setting the NAAQS standards for pollutants which are considered harmful to people and the environment. OAQPS is also responsible for ensuring these air quality standards are met, or attained (in cooperation with state, Tribal, and local governments) through national standards and strategies to control pollutant emissions from automobiles, factories, and other sources.[11]

Smoke emissions from fires potentially affect an area and the airsheds that surround it. Climatic conditions affecting air quality in Washington are governed by a combination of factors. Large-scale influences include latitude, altitude, prevailing hemispheric wind patterns, and mountain barriers. At a smaller scale, topography and vegetation cover also affect air movement patterns. Locally adverse conditions can result from occasional wildland fires in the summer and fall, and prescribed fire and agricultural burning in the spring and fall.

Due principally to local wind patterns, air quality in Franklin County is generally good to excellent, rarely falling below Washington Department of Ecology pollution standards.

Washington Department of Ecology

The Washington Department of Ecology Air Quality Program protects public health and the environment from pollutants caused by vehicles, outdoor and indoor burning, and industry. The DOE oversees permitting for non-forested (i.e. agriculture and rangeland) burning. Franklin County falls under the jurisdiction of the Eastern Regional Office (ERO). The ERO can be reached at: 509-329-3400.

Washington State Smoke Management Plan

The Department of Natural Resources (DNR), Department of Ecology (DOE), U.S. Forest Service (USDA), National Park Service (NPS), Bureau of Land Management (BLM), U.S Fish and Wildlife Service (USDI), participating Indian nations, military installations (DOD), and small and large forest landowners have worked together to deal with the effect of outdoor burning on air.

---

[10] USDA-Forest Service (United States Department of Agriculture, Forest Service). 2000. Incorporating Air Quality Effects of Wildland Fire Management into Forest Plan Revisions – A Desk Guide. April 2000. – Draft.

[11] Louks, B. 2001. Air Quality PM 10 Air Quality Monitoring Point Source Emissions; Point site locations of DEQ/EPA Air monitoring locations with Monitoring type and Pollutant. Idaho Department of Environmental Quality. Feb. 2001. As GIS Data set. Boise, Idaho.

Protection of public health and preservation of the natural attractions of the state are high priorities and can be accomplished along with a limited, but necessary, outdoor burning program. Public health, public safety, and forest health can all be served through the application of the provisions of Washington State law and this plan, and with the willingness of those who do outdoor burning on forest lands to further reduce the negative effects of their burning.

The Washington State Smoke Management Plan pertains to DNR-regulated silvicultural outdoor burning only and does not include agricultural outdoor burning or outdoor burning that occurs on improved property. Although the portion of total outdoor burning covered by this plan is less than 10 percent of the total air pollution in Washington, it remains a significant and visible source.

The purpose of the Washington State Smoke Management Plan is to coordinate and facilitate the statewide regulation of prescribed outdoor burning on lands protected by the DNR and on unimproved, federally-managed forest lands and participating tribal lands. The plan is designed to meet the requirements of the Washington Clean Air Act.

The plan provides regulatory direction, operating procedures, and advisory information regarding the management of smoke and fuels on the forest lands of Washington State. It applies to all persons, landowners, companies, state and federal land management agencies, and others who do outdoor burning in Washington State on lands where the DNR provides fire protection, or where such burning occurs on federally-managed, unimproved forest lands and tribal lands of participating Indian nations in the state.

The plan does not apply to agricultural outdoor burning and open burning as defined by Washington Administrative Code (WAC) 173-425-030 (1) and (2), nor to burning done "by rule" under WAC 332-24 or on non-forested wildlands (e.g., rangelands).

[This page intentionally left blank.]

Chapter 4

Risk and Preparedness Assessments

Wildland Fire Characteristics

An informed discussion of fire mitigation is not complete until basic concepts that govern fire behavior are understood. In the broadest sense, wildland fire behavior describes how fires burn; the manner in which fuels ignite, how flames develop and how fire spreads across the landscape. The three major physical components that determine fire behavior are the fuels supporting the fire, the topography in which the fire is burning, and the weather and atmospheric conditions during a fire event. At the landscape level, both topography and weather are beyond our control. We are powerless to control winds, temperature, relative humidity, atmospheric instability, slope, aspect, elevation, and landforms. It is beyond our control to alter these conditions, and thus impossible to alter fire behavior through their manipulation. When we attempt to alter how fires burn, we are left with manipulating the third component of the fire environment; fuels which support the fire. By altering fuel loading and fuel continuity across the landscape, we have the best opportunity to control or affect how fires burn.

A brief description of each of the fire environment elements follows in order to illustrate their effect on fire behavior.

Weather

Weather conditions contribute significantly to determining fire behavior. Wind, moisture, temperature, and relative humidity ultimately determine the rates at which fuels dry and vegetation cures, and whether fuel conditions become dry enough to sustain an ignition[12]. Once conditions are capable of sustaining a fire, atmospheric stability and wind speed and direction can have a significant effect on fire behavior. Winds fan fires with oxygen, increasing the rate at which fire spreads across the landscape. Weather is the most unpredictable component governing fire behavior, constantly changing in time and across the landscape.

Topography

Fires burning in similar fuel types, will burn differently under varying topographic conditions. Topography alters heat transfer and localized weather conditions, which in turn influences vegetative growth and resulting fuels. Changes in slope and aspect can have significant influences on how fires burn. Generally speaking, north slopes tend to be cooler, wetter, more productive sites. This can lead to heavy fuel accumulations, with high fuel moistures, later curing of fuels, and lower rates of spread. In contrast, south and west slopes tend to receive more direct sun, and thus have the highest temperatures, lowest soil and fuel moistures, and lightest fuels. The combination of light fuels and dry sites leads to fires that typically display the highest

[12] NOAA website http://www.nws.noaa.gov/om/wfire.shtml. Accessed on July 30, 2012.

rates of spread. These slopes also tend to be on the windward side of mountains. Thus, these slopes tend to be "available to burn" a greater portion of the year.

Slope also plays a significant role in fire spread, by allowing preheating of fuels upslope of the burning fire. As slope increases, rate of spread and flame lengths tend to increase. Therefore, we can expect the fastest rates of spread on steep, warm south and west slopes with fuels that are exposed to the wind.[13]

Fuels

Fuel is any material that can ignite and burn. Fuels describe any organic material, dead or alive, found in the fire environment. Grasses, brush, branches, logs, logging slash, forest floor litter, conifer needles, and buildings are all examples. The physical properties and characteristics of fuels govern how fires burn. Fuel loading, size and shape, moisture content, and continuity and arrangement all have an effect on fire behavior. Generally speaking, the smaller and finer the fuels, the faster the potential rate of fire spread. Small fuels such as grass, needle litter and other fuels less than a quarter inch in diameter are most responsible for fire spread. In fact, "fine" fuels, with high surface to volume ratios, are considered the primary carriers of surface fire. This is apparent to anyone who has ever witnessed the speed at which grass fires burn. As fuel size increases, the rate of spread tends to decrease due to a decrease in the surface to volume ratio. Fires in large fuels generally burn at a slower rate, but release much more energy and burn with much greater intensity. This increased energy release, or intensity, makes these fires more difficult to control. Thus, it is much easier to control a fire burning in grass than to control a fire burning in timber.[14]

The study of fire behavior recognizes the dramatic and often-unexpected effect small changes in any single component have on how fires burn. It is impossible to speak in specific terms when predicting how a fire will burn under any given set of conditions. However, through countless observations and repeated research, some of the principles that govern fire behavior have been identified and are recognized.

Wildfire Hazards

In the 1930s, wildfires consumed an average of 40 to 50 million acres per year in the contiguous United States, according to US Forest Service estimates. By the 1970s, the average acreage burned had been reduced to about 5 million acres per year. Over this time period, fire suppression efforts were dramatically increased and firefighting tactics and equipment became more sophisticated and effective. For the 11 western states, the average acreage burned per year since 1970 has remained relatively constant at about 3.5 million acres per year.

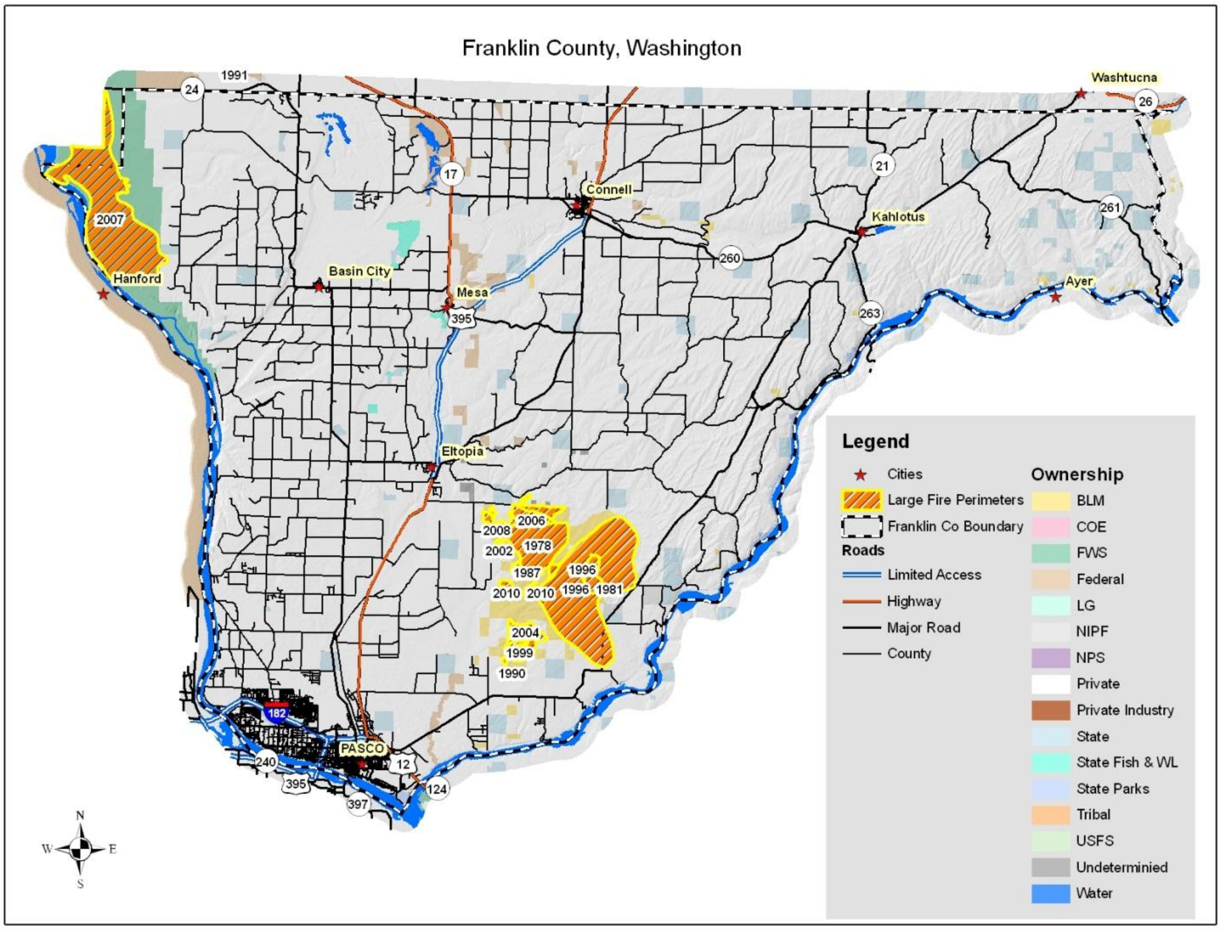
The severity of a fire season can usually be determined in the spring by how much precipitation is received, which in turn determines how much fine fuel growth there is and how long it takes

[13] Auburn University website https://fp.auburn.edu/fire/topos_effect.htm. Accessed on July 30,2012.

[14] Gorte, R. 2009. Congressional Research Service, Wildfire Fuels and Fuel Reduction.

this growth to dry. These factors, combined with annual wind events can drastically increase the chance a fire start will grow and resist suppression activities. Furthermore, recreational activities are typically occurring throughout the months of July, August, and September. Occasionally, these types of human activities cause an ignition that could spread into populated areas and timberlands.

Figure 4.1. Ignition History in Franklin County.



It should be noted that this map is not entirely accurate as many Franklin County Fire Protection Districts do not report fires because of limited record keeping resources.

Fire History

Fire was once an integral function within the majority of ecosystems in Washington. The seasonal cycling of fire across most landscapes was as regular as the July, August and September lightning storms plying across eastern Washington. Depending on the plant community composition, structural configuration, and buildup of plant biomass, fire resulted from ignitions with varying intensities and extent across the landscape. Shorter return intervals between fire events often resulted in less dramatic changes in plant composition.[15] These fires burned from 1

[15] Johnson, C.G. 1998. Vegetation Response after Wildfires in National Forests of Northeastern Oregon. 128 pp.

to 47 years apart, with most at 5- to 20-year intervals.[16] With infrequent return intervals, plant communities tended to burn more severely and be replaced by vegetation different in composition, structure, and age.[17] Native plant communities in this region developed under the influence of fire, and adaptations to fire are evident at the species, community, and ecosystem levels.

Fire history data for Franklin County is largely unknown. Local knowledge suggests that Native Americans did frequently burn which played an important role in shaping the vegetation throughout County. The Bureau of Land Management is helping to fund future research targeted at identifying the fire history in central Washington through fire scars and charcoal deposits. Although this data is not available for the development of this document, it should be available for the five year update of this plan.

Figure 4.2. News Article About Recent Fire Activity18.

Acres of wheat burned in fire near Burbank

Published: August 9, 2013

Tri-City Herald

Around 35 acres of standing wheat was burned in a Friday evening farmland fire near Burbank, officials said.

The fire at State Route 124 and Walkley Road was reported at 6:13 p.m., said Walla Walla Fire 5 spokeswoman Maria Kennedy. No one was injured in the fire and no buildings were damaged.

Firefighters were called in from the city of Pasco, Franklin Fire 3, Walla Walla Fire 3 and Walla Walla Fire 5, Kennedy said.

The fire took about an hour and 20 minutes to get under control, Kennedy said. The cause is still under investigation, but firefighters say it could have started from a combine on the farm.

Kennedy warns residents to be careful with dry weather this weekend.

---

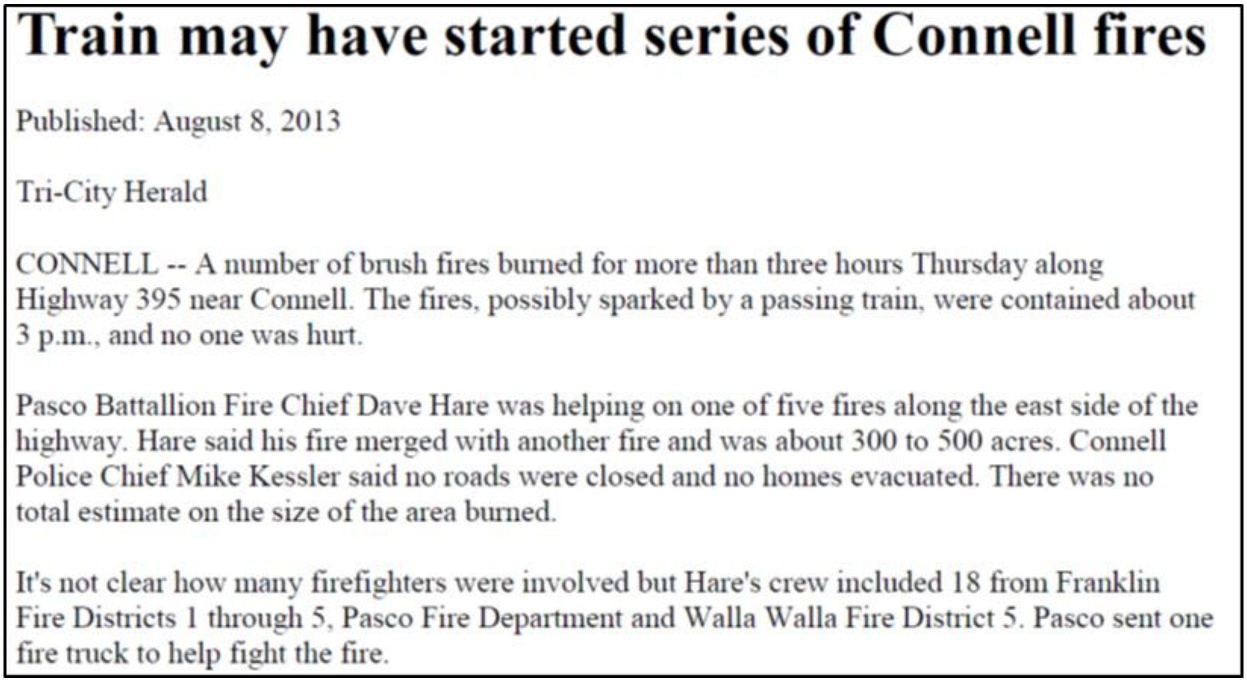
[16] Barrett, J.W. 1979. Silviculture of ponderosa pine in the Pacific Northwest: the state of our knowledge. USDA Forest Service, General Technical Report PNW-97. Pacific Northwest Forest and Range Experiment Station, Portland, OR. 106 p.

[17] Johnson, C.G.; Clausnitzer, R.R.; Mehringer, P.J.; Oliver, C.D. 1994. Biotic and Abiotic Processes of Eastside Ecosytems: the Effects of Management on Plant and Community Ecology, and on Stand and Landscape Vegetation Dynamics. Gen. Tech. Report PNW-GTR-322. USDA-Forest Service. PNW Research Station. Portland, Oregon. 722pp.

[18] Tri City Herald Newspaper Online. http://www.tri-cityherald.com/2013/08/09/2513865/acres-of-wheat-burned-in-fire.html

Accessed September, 2013.

Figure 4.3. News Article About Recent Fire Activity[19].



Train may have started series of Connell fires

Published: August 8, 2013

Tri-City Herald

CONNELL -- A number of brush fires burned for more than three hours Thursday along Highway 395 near Connell. The fires, possibly sparked by a passing train, were contained about 3 p.m., and no one was hurt.

Pasco Battallion Fire Chief Dave Hare was helping on one of five fires along the east side of the highway. Hare said his fire merged with another fire and was about 300 to 500 acres. Connell Police Chief Mike Kessler said no roads were closed and no homes evacuated. There was no total estimate on the size of the area burned.

It's not clear how many firefighters were involved but Hare's crew included 18 from Franklin Fire Districts 1 through 5, Pasco Fire Department and Walla Walla Fire District 5. Pasco sent one fire truck to help fight the fire.

Wildfire Ignition Profile

Detailed records of wildfire ignitions and extents from the Washington Department of Natural Resources (DNR) and Bureau of Land Management (BLM) have been analyzed. In interpreting these data, it is important to keep in mind that the information represents only the lands protected by the agency specified and may not include all fires in areas covered only by local fire departments or other agencies.

The DNR and BLM (1994-2013) database of wildfire ignitions used in this analysis includes ignition and extent data within their jurisdictions. During this period, the agencies recorded an average of 1.5 wildfire ignitions per year resulting in an average total burn area of 1,815 acres per year. According to this dataset, the vast majority of fires occurring in Franklin County are human caused; however, naturally ignited and fires with unknown causes do occur.

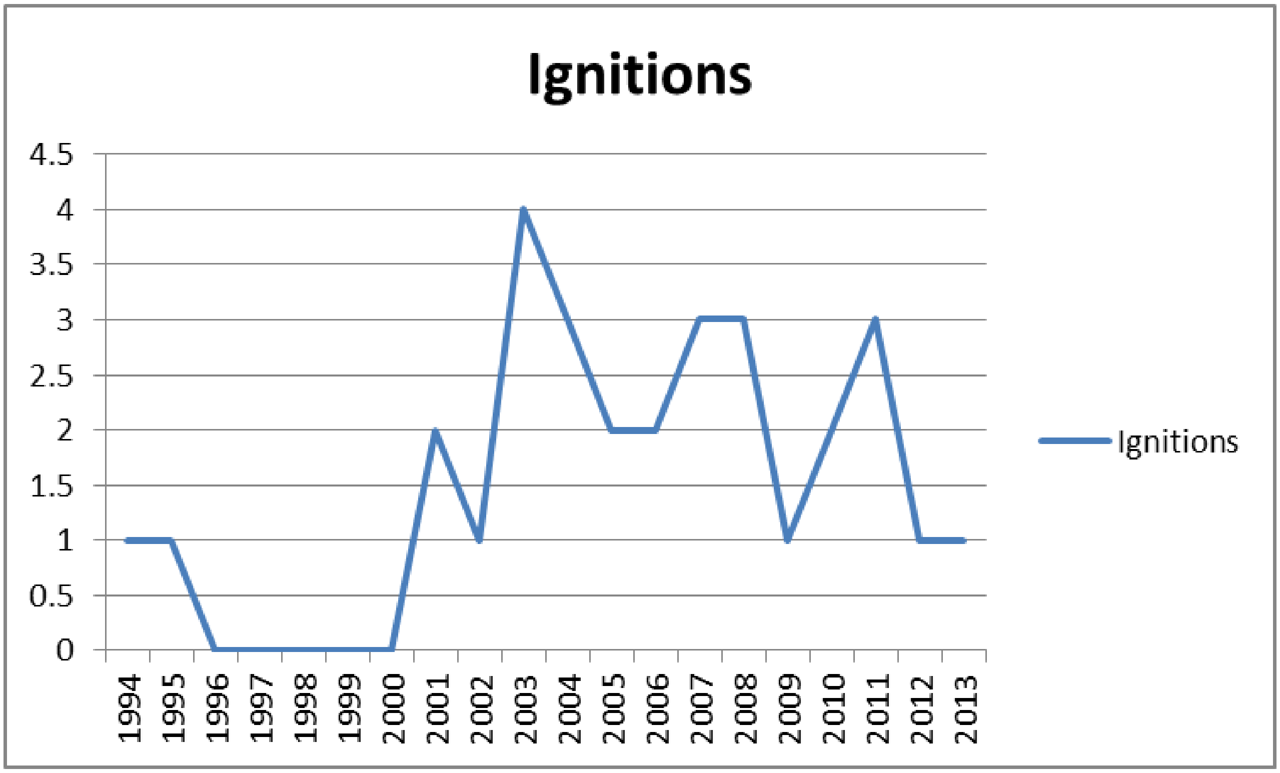
The highest number of ignitions in Franklin County was witnessed in 2003 with 4 separate ignitions. However, the greatest number of acres burned in a single year occurred in 2007 with over 18,000 acres being burned.

[19] Tri City Herald Newspaper Online. http://www.tri-cityherald.com/2013/08/08/2512308/train-may-have-started-series.html Accessed September, 2013.

Table 4.1. Summary of Cause from State and BLM databases 1994-2013.				
General Cause	**Number of Ignitions**	**Percent of Total Ignitions**	**Acres Burned**	**Percent of Total Acres**
Human-Caused	20	67%	15,453	42%
Natural Ignition	3	10%	18,092	50%
Unknown	7	23%	2,763	8%
Total	**30**	**100%**	**36,308**	**100%**

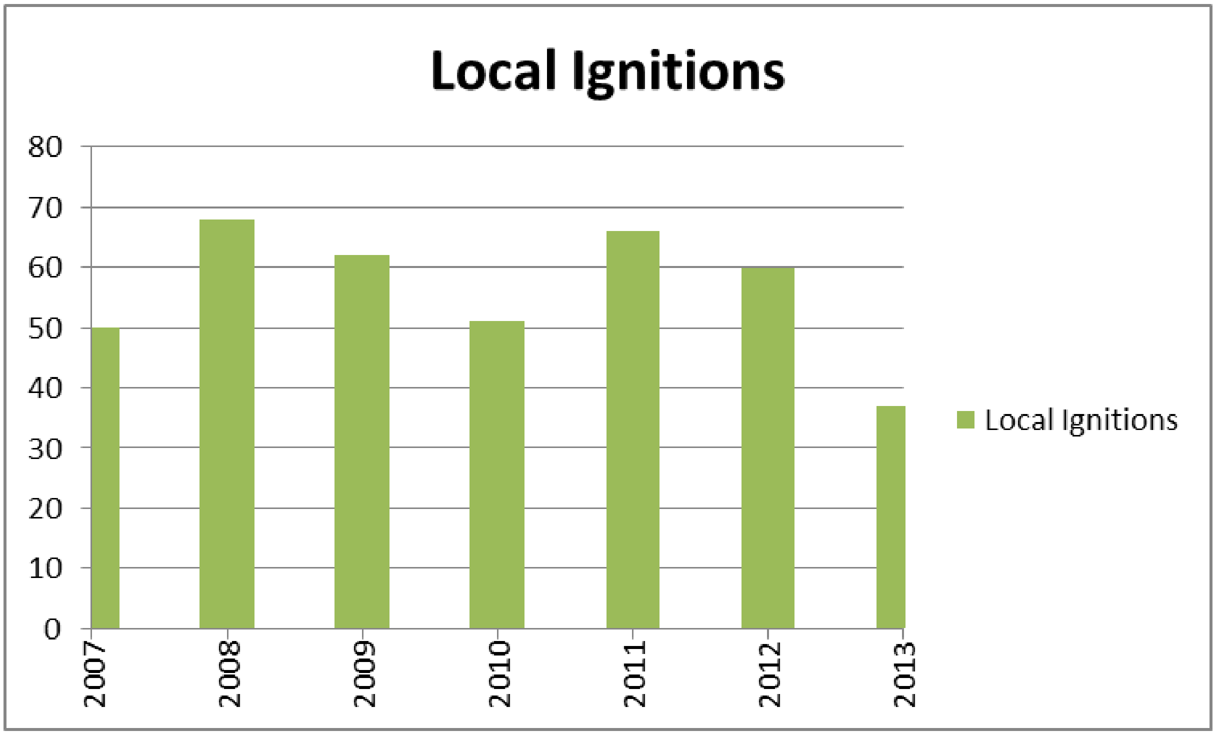
Based on the agencies' combined datasets specific to Franklin County, there is an upward trend in both the number of ignitions/year and acres burned per year since 1994. There are however, occasional spikes in the total acres burned in any given year and appear to generally be located in the more remote parts of the County. The average number of ignitions since 1994 that were reported by State or Federal agencies was approximately 1.5 starts annually. Over 18,000 acres are burned annually on average in Franklin County. Over the previous twenty years, only 50% of the total acres burned (36,308) have been the result of natural causes.

Figure 4.4. Summary of Franklin County Ignitions



Ignitions reported by local fire districts have been summarized in Figure 4.5. Total acres, location, and cause were not provided, but it is assumed that a majority of these fires were kept to less than one acre in size. Local fire districts respond to approximately 56 ignitions annually. When combined with the statistics in Figure 4.4, it only takes less than 3% of ignitions to burn large amounts of acreages within Franklin County.

Figure 4.5. Summary of Fires Reported by Local Fire Protection Districts.



The data reviewed above provides a general picture regarding the level of wildland-urban interface fire risk within Franklin County. There are several reasons why the fire risk may be even higher than suggested above, especially in developing wildland urban interface areas.

1) Large fires may occur infrequently, but statistically they will occur. One large fire could significantly change the statistics. In other words, 40 years of historical data may be too short to capture large, infrequent wildland fire events.

2) The level of fire hazard depends profoundly on weather patterns. A several year drought period would substantially increase the probability of large wildland fires in Franklin County. For smaller vegetation areas, with grass, brush and small trees, a much shorter drought period of a few months or less would substantially increase the fire hazard.

3) The level of fire hazard in wildland urban interface areas is likely significantly higher than for wildland areas as a whole due to the greater risk to life and property. The probability of fires starting in interface areas is much higher than in wildland areas because of the higher population density and increased activities. Many fires in the wildland urban interface are not recorded in agency datasets because the local fire department responded and successfully suppressed the ignition without mutual aid assistance from the state or federal agencies.

Wildfire Extent Profile

Across the west, wildfires have been increasing in extent and cost of control. Data summaries for 2003 through 2012 are provided and demonstrate the variability of the frequency and extent of wildfires nationally.

Table 4.2. Statistical Highlights

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Number of Fires	85,943	77,534	66,753	96,385	85,705	78,979	78,792	71,971	74,126	67,315
10-year Average ending with indicated year	101,575	100,466	89,859	87,788	80,125	79,918	78,549	76,521	80,465	74,912
Acres Burned (million acres)	4.9	6.8	8.7	9.9	9.3	5.3	5.9	3.4	8.7	9.2
10-year Average ending with indicated year (million acres)	4.7	4.9	6.1	6.5	7.0	6.9	6.9	6.5	7.0	7.3
Structures Burned	5,781	1,095	--	--	--	--	--	--	--	--
Estimated Cost of Fire Suppression (Federal agencies only)	$1.3 billion	$1.0 billion	$1.0 billion	$1.93 billion	$1.84 billion	$1.85 billion	$1.24 billion	$1.13 billion	$1.73 billion	$1.9 billion

The National Interagency Fire Center maintains records of fire costs, extent, and related data for the entire nation. Tables 4.2 and 4.3 summarize some of the relevant wildland fire data for the nation and some trends that are likely to continue into the future unless targeted fire mitigation efforts are implemented and maintained. According to these data, the total number of fires is trending downward while the total number of acres burned is trending upward. Since 1980 there has been a significant increase in the number of acres burned.[20]

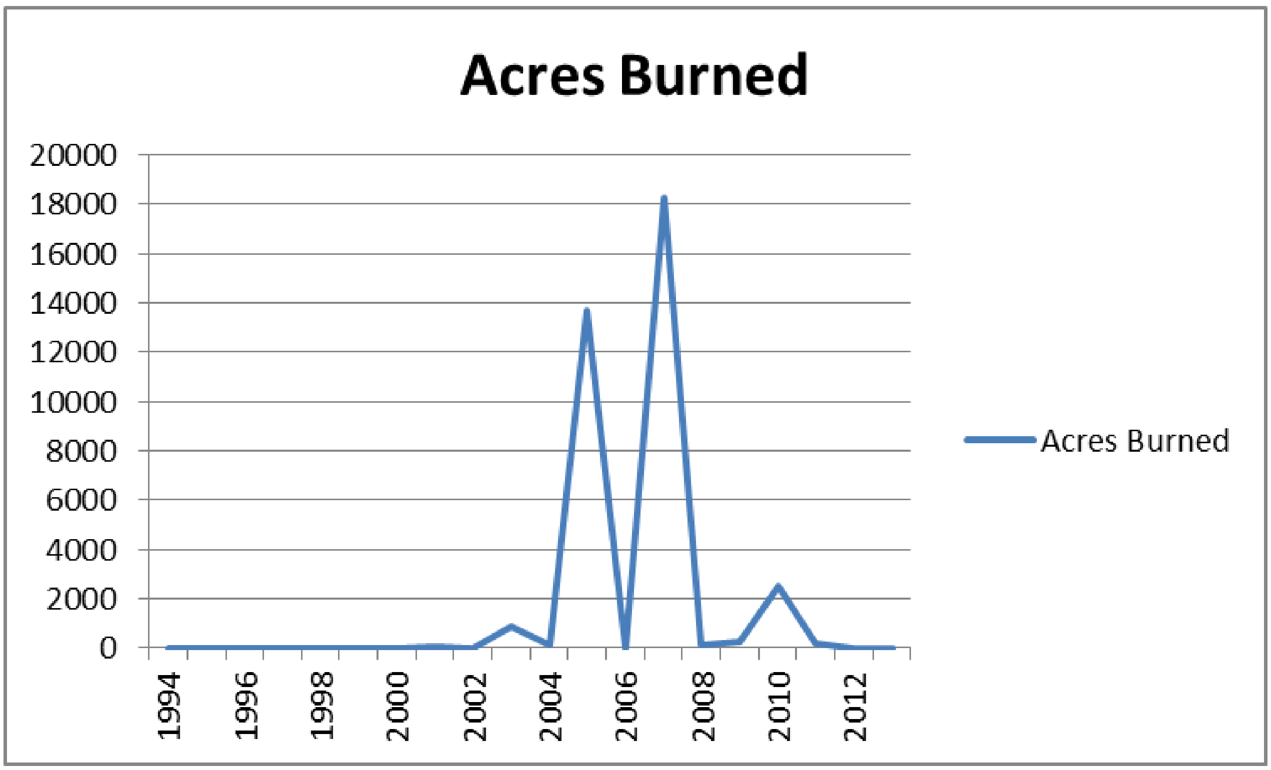
[20] National Interagency Fire Center. 2008. Available online at http://www.nifc.gov/.

Table 4.3. Total Fires and Acres 1980 - 2011 Nationally.

Year	Fires	Acres	Year	Fires	Acres
2011	74,126	8,711,367	**1995**	130,019	2,315,730
2010	71,971	3,422,724	**1994**	114,049	4,724,014
2009	78,792	5,921,786	**1993**	97,031	2,310,420
2008	68,594	4,723,810	**1992**	103,830	2,457,665
2007	85,822	9,321,326	**1991**	116,953	2,237,714
2006	96,385	9,873,745	**1990**	122,763	5,452,874
2005	66,753	8,689,389	**1989**	121,714	3,261,732
2004	77,534	6,790,692	**1988**	154,573	7,398,889
2003	85,943	4,918,088	**1987**	143,877	4,152,575
2002	88,458	6,937,584	**1986**	139,980	3,308,133
2001	84,079	3,555,138	**1985**	133,840	4,434,748
2000	122,827	8,422,237	**1984**	118,636	2,266,134
1999	93,702	5,661,976	**1983**	161,649	5,080,553
1998	81,043	2,329,709	**1982**	174,755	2,382,036
1997	89,517	3,672,616	**1981**	249,370	4,814,206
1996	115,025	6,701,390	**1980**	234,892	5,260,825

These statistics are based on end-of-year reports compiled by all wildland fire agencies after each fire season. The agencies include: Bureau of Land Management, Bureau of Indian Affairs, National Park Service, US Fish and Wildlife Service, Forest Service, and all state agencies.

Figure 4.6. Summary of Franklin County Acres Burned.



The fire suppression agencies in Franklin County respond to numerous wildland fires each year, but few of those fires grow to a significant size. According to national statistics, only 2% of all wildland fires escape initial attack. However, that 2% accounts for the majority of fire suppression expenditures and threatens lives, properties, and natural resources. These large fires are characterized by a size and complexity that require special management organizations drawing suppression resources from across the nation. These fires create unique challenges to local communities by their quick development and the scale of their footprint.

Franklin County has experienced high impact wildland fires that have burned structures or infrastructure within their wildland urban interface. Based on field assessments by experts, the fuels for potentially catastrophic fires are present and given an extremely dry summer, it is not unimaginable that significant fires will continue to occur. It is important that regional planners as well as local residents understand that threat in order to more effectively prepare for potential wildfire events.

Wildfire Hazard Assessment

Franklin County was analyzed using a variety of models managed on a Geographic Information System (GIS) system. Physical features of the region including roads, streams, soils, elevation, and remotely sensed images were represented by data layers. Field visits were conducted by specialists from Northwest Management, Inc. and others. Discussions with area residents and local fire suppression professionals augmented field visits and provided insights into forest health issues and treatment options. This information was analyzed and combined to develop an objective assessment of wildland fire risk in the region.

Historic Fire Regime

Historical variability in fire regime is a conservative indicator of ecosystem sustainability, and thus, understanding the natural role of fire in ecosystems is necessary for proper fire management. Fire is one of the dominant processes in terrestrial systems that constrain vegetation patterns, habitats, and ultimately, species composition. Land managers need to understand historical fire regimes, the fire return interval (frequency) and fire severity prior to settlement by Euro-Americans, to be able to define ecologically appropriate goals and objectives for an area. Moreover, managers need spatially explicit knowledge of how historical fire regimes vary across the landscape.

“Natural” fires in Franklin County would have been disproportionately caused by Native Americans. Aboriginal peoples intentionally set fires throughout the region for the purposes of controlling tree and shrub expansion and for the cultivation of select plants. When we describe “natural” in the Range of Natural Variability we are including indigenous peoples as natural disturbance agents and contributors to perceptions of what is “natural”.

A primary goal in ecological restoration is often to return an ecosystem to a previously existing condition that no longer is present at the site given the assumption that the site’s current condition is somehow degraded or less desirable than the previous condition and needs improvement

Land managers in Franklin County must determine if the past, Native American-influenced condition of the County was necessarily healthier, had a higher level of integrity, and was more sustainable than the current condition. In other words, is “restoration” an appropriate course of action? After a prolonged absence, if fire is reintroduced to these ecosystems the result could be damaging. Fuel loads throughout most of the County today are quite high and most of the County is inhabited by people, homes, and infrastructure. The ecosystem was adapted to fire in the past, but is no longer adapted today, especially in light of the human component.

In the absence of intensive Native American burning, a condition has developed where fire could/should not be reintroduced without some significant alteration of the current ecosystem structure. This would also require a significant assessment of social acceptance and financial contribution.

Many ecological assessments are enhanced by the characterization of the historical range of variability which helps managers understand: (1) how the driving ecosystem processes vary from site to site; (2) how these processes affected ecosystems in the past; and (3) how these processes might affect the ecosystems of today and the future. Historical fire regimes are a critical component for characterizing the historical range of variability in fire-adapted ecosystems. Furthermore, understanding ecosystem departures provides the necessary context for managing sustainable ecosystems. Land managers need to understand how ecosystem processes and functions have changed prior to developing strategies to maintain or restore sustainable systems. In addition, the concept of departure is a key factor for assessing risks to ecosystem components. For example, the departure from historical fire regimes may serve as a useful proxy for the potential of severe fire effects from an ecological perspective.

Table 4.4. Historic Fire Regimes in Franklin County.

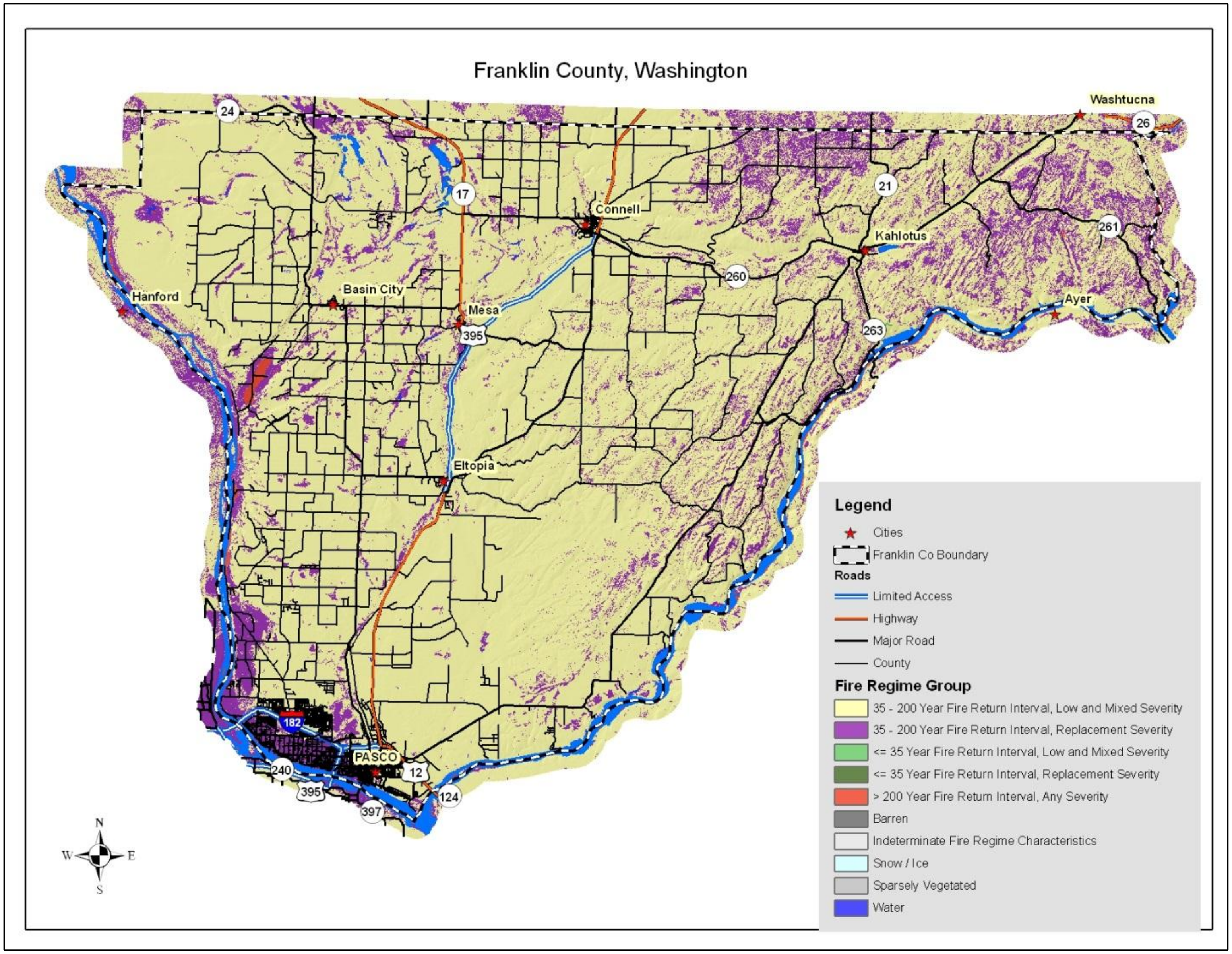
Historic Fire Regime	Description	Acres	Percent of Total
Fire Regime Group I	<= 35 Year Fire Return Interval, Low and Mixed Severity	30	<1%
Fire Regime Group II	<= 35 Year Fire Return Interval, Replacement Severity	0	0%
Fire Regime Group III	35 - 200 Year Fire Return Interval, Low and Mixed Severity	687,378	85%
Fire Regime Group IV	35 - 200 Year Fire Return Interval, Replacement Severity	103,654	13%
Fire Regime Group V	> 200 Year Fire Return Interval, Any Severity	2,228	<1%
Water	Water	15,829	2%
Barren	Barren	252	<1%
Sparsely Vegetated	Sparsely Vegetated	91	<1%
Indeterminate Fire Regime Characteristics	Indeterminate Fire Regime Characteristics	5	<1%
	Total	**809,467**	**100%**

This model only uses the historic vegetation types to determine the historic fire regime. Native Americans reportedly burned throughout the county on a regular basis. The vegetation types were much different pre Euro-American settlement than they are today and believed to be a more grassland-dominated landscape. The Historic Fire Regime model suggests that fires in Franklin

County historically burned with mixed severity fires on a longer return interval. The dry climate of this region likely contributed to sparse vegetation which would not have frequently carried fire.[21] The longer time between fires may allow fuels to build-up, which can burn very intensely when conditions are dry. For this reason, it may be reasonable to assume that a majority of the areas in the County that have been categorized as having a 35 to 200 year historical return interval with mixed severity fires, could likely be stand replacing fires with the current accumulation of fuels.

[21] Guyette, R.A.; Stambaugh, M.C.; Marschall J. M. 2010. Quantitative Analysis of Fire History at National Parks in the Great Plains. Final Report for: USGS – NRPP (06-3255-0205Guyette). Missouri Tree-Ring Laboratory, Department of Forestry, University of Missouri-Columbia. 138pp.

Figure 4.7. Historic Fire Regime for Franklin County.



Vegetation Condition Class

A natural fire regime is a general classification of the role fire would play across a landscape in the absence of modern human mechanical intervention, but including the influence of aboriginal burning.[22, 23] Coarse scale definitions for historic fire regimes have been developed by Hardy et al[24] and Schmidt et al[25] and interpreted for fire and fuels management by Hann and Bunnell.

A vegetation condition class (VCC) is a classification of the amount of departure from the historic regime. [26] The three classes are based on low (VCC 1), moderate (VCC 2), and high (VCC 3) departure from the central tendency of the natural (historical) regime.[27,28] The central tendency is a composite estimate of vegetation characteristics (species composition, structural stages, stand age, canopy closure, and mosaic pattern); fuel composition; fire frequency, severity, and pattern; and other associated natural disturbances. Low departure is considered to be within the natural (historical) range of variability, while moderate and high departures are outside.

An analysis of Vegetation Condition Classes in Franklin County shows that the majority of land in the county that has not been converted to agriculture (52%) is considered highly departed (38%) from its historic fire regime and associated vegetation and fuel characteristics. Approximately 2% has a low departure and less than 1% is considered moderately departed.

---

[22] Agee, J. K. Fire Ecology of the Pacific Northwest forests. Oregon: Island Press. 1993.

[23] Brown. J. K. "Fire regimes and their relevance to ecosystem management." *Proceedings of Society of American Foresters National Convention*. Society of American Foresters. Washington, D.C. 1995. Pp 171-178.

[24] Hardy, C. C., et al. *"Spatial data for national fire planning and fuel management."* International Journal of Wildland Fire. 2001. Pp 353-372.

[25] Schmidt, K. M., et al. *"Development of coarse scale spatial data for wildland fire and fuel management."* General Technical Report, RMRS-GTR-87. U.S. Department of Agriculture, Forest Service. Rocky Mountain Research Station. Fort Collins, Colorado. 2002.

[26] Hann, W. J. and D. L. Bunnell. "Fire and land management planning and implementation across multiple scales." International Journal of Wildland Fire. 2001. Pp 389-403.

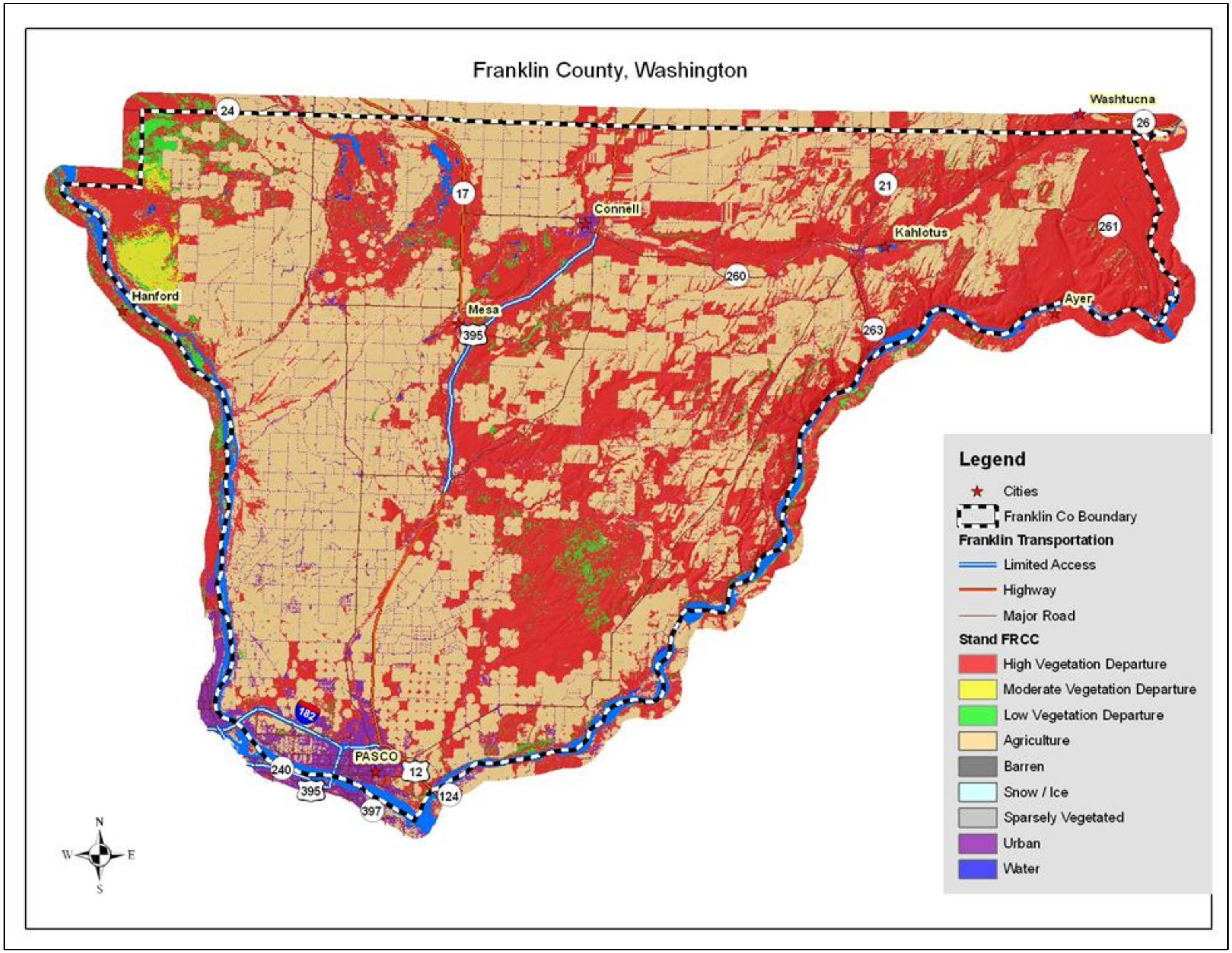
[27] Hardy, C. C., et al. *"Spatial data for national fire planning and fuel management."* International Journal of Wildland Fire. 2001. Pp 353-372.

[28] Schmidt, K. M., et al. *"Development of coarse scale spatial data for wildland fire and fuel management."* General Technical Report, RMRS-GTR-87. U.S. Department of Agriculture, Forest Service. Rocky Mountain Research Station. Fort Collins, Colorado. 2002.

Table 4.5. Vegetation Condition Class in Franklin County.			
Vegetation Condition Class	**Description**	**Acres**	**Percent of Total**
Vegetation Condition Class I	Low Vegetation Departure	17,107	2%
Vegetation Condition Class II	Moderate Vegetation Departure	6,614	<1%
Vegetation Condition Class III	High Vegetation Departure	307,001	38%
Agriculture	Agriculture	422,650	52%
Water	Water	15,829	2%
Urban	Urban	39,924	5%
Barren	Barren	252	<1%
Sparsely Vegetated	Sparsely Vegetated	91	<1%
	Total	809,467	100%

The current Vegetation Condition Class model shows that much of Franklin County is considered to be highly departed. A majority of the County is dominated by various shrub species with a grass understory consisting of bluebunch wheatgrass, Idaho fescue, and many other grass species. The current structure and density of the shrublands in many areas makes it susceptible to health issues from competition, insects, and disease. The current fire severity model suggests that a higher severity fire than historical norms would be expected in these areas.

Figure 4.8. Vegetation Condition Class Map for Franklin County.



Franklin County's Wildland Urban Interface

The wildland urban interface (WUI) has gained attention through efforts targeted at wildfire mitigation; however, this analysis technique is also useful when considering other hazards because the concept looks at where people and structures are concentrated in any particular region.

A key component in meeting the underlying need for protection of people and structures is the protection and treatment of hazards in the wildland urban interface. The wildland-urban interface refers to areas where wildland vegetation meets urban developments or where forest fuels meet urban fuels such as houses. The WUI encompasses not only the interface (areas immediately adjacent to urban development), but also the surrounding vegetation and topography. Reducing the hazard in the wildland-urban interface requires the efforts of federal, state, and local agencies and private individuals.[29] "The role of [most] federal agencies in the wildland-urban interface includes wildland firefighting, hazard fuels reduction, cooperative prevention and education, and technical experience. Structural fire protection [during a wildfire] in the wildland-urban interface is [largely] the responsibility of Tribal, state, and local governments".[30] The role of the federal agencies in Franklin County is and will be much more limited. Property owners share a responsibility to protect their residences and businesses and minimize danger by creating defensible areas around them and taking other measures to minimize the risks to their structures.[31] With treatment, a wildland urban interface can provide firefighters a defensible area from which to suppress wildland fires or defend communities against other hazard risks. In addition, a wildland urban interface that is properly treated will be less likely to sustain a crown fire that enters or originates within it. [32]

By reducing hazardous fuel loads, ladder fuels, and tree densities, and creating new and reinforcing existing defensible space, landowners can protect the wildland-urban interface, the biological resources of the management area, and adjacent property owners by:

- Minimizing the potential of high-severity ground or crown fires entering or leaving the area;
- Reducing the potential for firebrands (embers carried by the wind in front of the wildfire) impacting the WUI. Research indicates that flying sparks and embers (firebrands) from a

---

[29] Norton, P. Bear Valley National Wildlife Refuge Fire Hazard Reduction Project: Final Environmental Assessment. Fish and Wildlife Services, Bear Valley Wildlife Refuge. June 20, 2002.

[30] USFS. 2001. United States Department of Agriculture, Forest Service. Wildland Urban Interface. Web page. Date accessed: 25 September 2001. Accessed at: http://www.fs.fed.us/r3/sfe/fire/urbanint.html

[31] USFS. 2001. United States Department of Agriculture, Forest Service. Wildland Urban Interface. Web page. Date accessed: 25 September 2001. Accessed at: http://www.fs.fed.us/r3/sfe/fire/urbanint.html

[32] Norton, P. Bear Valley National Wildlife Refuge Fire Hazard Reduction Project: Final Environmental Assessment. Fish and Wildlife Services, Bear Valley Wildlife Refuge. June 20, 2002.

crown fire can ignite additional wildfires as far as 1¼ miles away during periods of extreme fire weather and fire behavior;[33]

- Improving defensible space in the immediate areas for suppression efforts in the event of wildland fire.

Three wildland-urban interface conditions have been identified (Federal Register 66(3), January 4, 2001) for use in wildfire control efforts. These include the Interface Condition, Intermix Condition, and Occluded Condition. Descriptions of each are as follows:

- **Interface Condition** – a situation where structures abut wildland fuels. There is a clear line of demarcation between the structures and the wildland fuels along roads or back fences. The development density for an interface condition is usually 3+ structures per acre;
- **Intermix Condition** – a situation where structures are scattered throughout a wildland area. There is no clear line of demarcation; the wildland fuels are continuous outside of and within the developed area. The development density in the intermix ranges from structures very close together to one structure per 40 acres; and
- **Occluded Condition** – a situation, normally within a city, where structures abut an island of wildland fuels (park or open space). There is a clear line of demarcation between the structures and the wildland fuels along roads and fences. The development density for an occluded condition is usually similar to that found in the interface condition and the occluded area is usually less than 1,000 acres in size.

In addition to these classifications detailed in the Federal Register, Franklin County has included two additional classifications to augment these categories:

- **Low Density Rural Areas** – a situation where the scattered small clusters of structures (ranches, farms, resorts, or summer cabins) are exposed to wildland fuels. There may be miles between these clusters.
- **High Density Urban Areas** – those areas generally identified by the population density consistent with the location of incorporated cities, however, the boundary is not necessarily set by the location of city boundaries or urban growth boundaries; it is set by very high population densities (more than 7-10 structures per acre).

In summary, the designation of areas by the Franklin County planning committee includes:

- Interface Condition: WUI
- Intermix Condition: WUI
- Occluded Condition: WUI
- Low Density Rural Areas: WUI

[33] McCoy, L. K., et all. Cerro Grand Fire Behavior Narrative. 2001.

- High Density Urban Areas: WUI

Franklin County's WUI is mostly based on population density. Relative population density across the county was estimated using a GIS-based kernel density population model that uses object locations to produce, through statistical analysis, concentric rings or areas of consistent density. To graphically identify relative population density across the county, structure locations are used as an estimate of population density. Aerial photography was used to identify structure locations in 2013 using 2009 and 2011 NAIP imagery and Franklin County's cadastral data. The resulting output identified the extent and level of population density throughout the county.

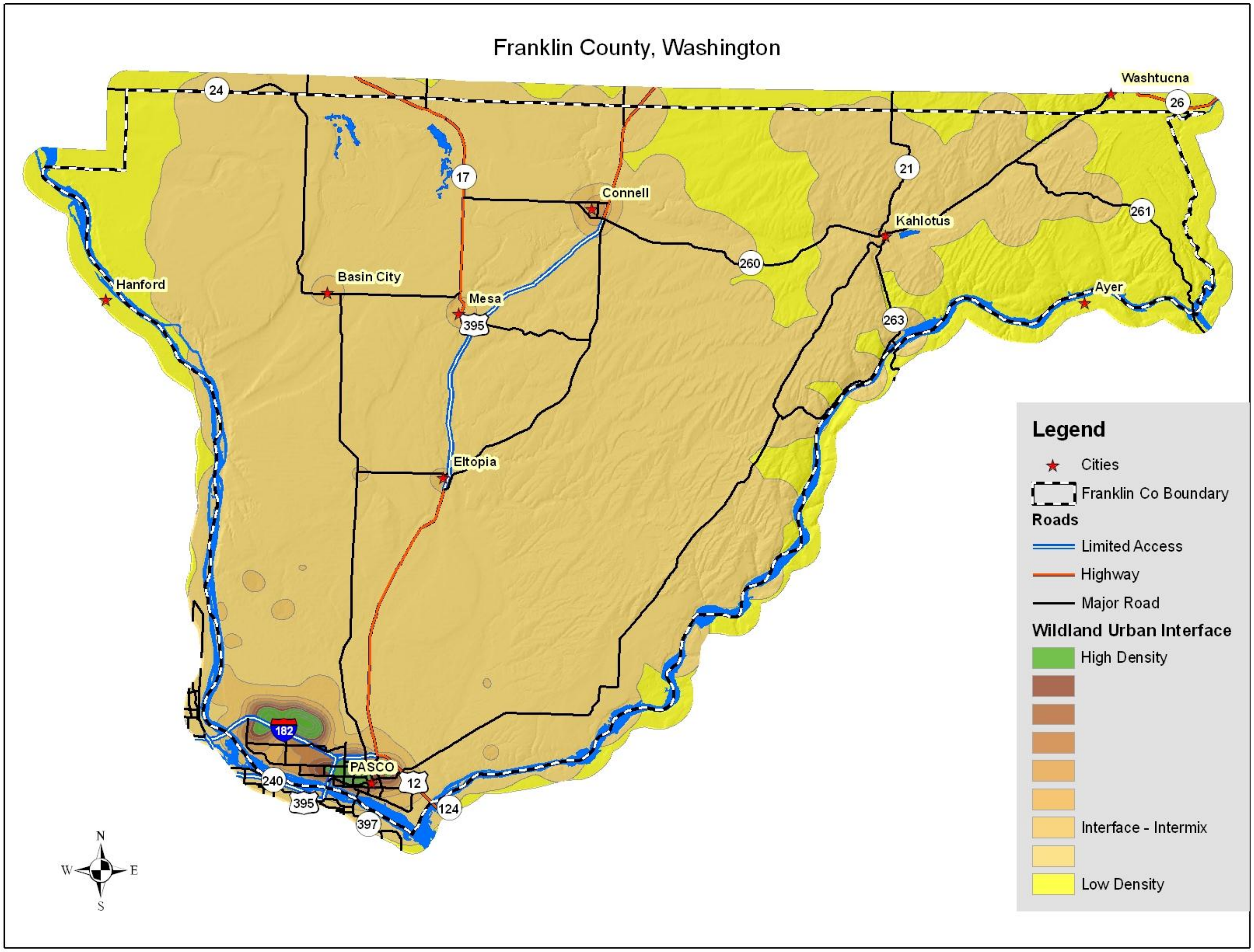
In addition, the Franklin County planning committee determined that the entire County should be classified under WUI designation due to the rapid rates of spread that commonly occur within the County.

By evaluating structure density in this way, WUI areas can be identified on maps by using mathematical formulae and population density indexes. The resulting population density indexes create concentric circles showing high density areas, interface, and intermix condition WUI, as well as low density WUI (as defined above). This portion of the analysis allows us to "see" where the highest concentrations of structures are located in reference to relatively high risk landscapes, limiting infrastructure, and other points of concern.

The WUI, as defined here, is unbiased and consistent and most importantly – it addresses all of the county, not just federally identified communities at risk. It is a planning tool showing where homes and businesses are located and the density of those structures leading to identified WUI categories. It can be determined again in the future, using the same criteria, to show how the WUI has changed in response to increasing population densities. It uses a repeatable and reliable analysis process that is unbiased.

The Healthy Forests Restoration Act makes a clear designation that the location of the WUI is at the determination of the county or reservation when a formal and adopted Community Wildfire Protection Plan is in place. It further states that the federal agencies are obligated to use this WUI designation for all Healthy Forests Restoration Act purposes. The Franklin County Community Wildfire Protection Plan steering committee evaluated a variety of different approaches to determining the WUI for the county and selected this approach and has adopted it for these purposes. In addition to a formal WUI map for use with the federal agencies, it is hoped that it will serve as a planning tool for the county, state and federal agencies, and local fire districts.

Figure 4.9. Wildland Urban Interface in Franklin County, Washington.



Potential WUI Treatments

The definition and mapping of the WUI is the creation of a planning tool to identify where structures, people, and infrastructure are located in reference to each other. This analysis tool does not include a component of fuels risk. There are a number of reasons to map and analyze these two components separately (population density vs. fire risk analysis). Primary among these reasons is the fact that population growth often occurs independent from changes in fire risk, fuel loading, and infrastructure development. Thus, making the definition of the WUI dependent on all of them would eliminate populated places with a perceived low level of fire risk today, which may in a year become an area at high risk due to forest health issues or other concerns.

By examining these two tools separately, the planner is able to evaluate these layers of information to see where the combination of population density overlays areas of high current relative fire risk and then take mitigative actions to reduce the fuels, improve readiness, directly address factors of structural ignitability, improve initial attack success, mitigate resistance to control factors, or (more often) a combination of many approaches.

It should not be assumed that just because an area is identified as being within the WUI, that it will therefore receive treatments because of this identification alone. Nor should it be implicit that all WUI treatments will be the application of the same prescription. Instead, each location targeted for treatments must be evaluated on its own merits: factors of structural ignitability, access, resistance to control, population density, resources and capabilities of firefighting personnel, and other site specific factors.

It should also not be assumed that WUI designation on national or state forest lands automatically equates to a treatment area. The Forest Service, Bureau of Land Management, and Washington Department of Natural Resources are still obligated to manage lands under their control according to the standards and guides listed in their respective forest plans (or other management plans). The adopted forest plan has legal precedence over the WUI designation until such a time as the forest plan is revised to reflect updated priorities.

Most treatments may begin with a home evaluation, and the implicit factors of structural ignitability (roofing, siding, deck materials) and vegetation within the treatment area of the structure. However, treatments in the low population areas of rural lands (mapped as yellow) may look closely at access (two ways in and out) and communications through means other than land-based telephones. On the other hand, a subdivision with densely packed homes (mapped as brown – interface areas) surrounded by forests and dense underbrush, may receive more time and effort implementing fuels treatments beyond the immediate home site to reduce the probability of a crown fire entering the subdivision.

Relative Threat Level Mapping

Franklin County recognizes that certain regions of the County have unique risk factors that increase their vulnerability to wildland fire. In an effort to demonstrate these risk factors, the planning committee developed a threat level model analyzing various risk factors on a scale relative to Franklin County specifically.

Risk Categories

Based on analysis of the various modeling tools, existing historical information, and local knowledge, a preliminary assessment of potentially high wildfire risk areas was completed. This assessment prioritized areas that may be at higher risk due to non-native or high fire risk vegetation, fire history profile, high risk fuel models, and/or limited suppression capabilities. This assessment also considered areas that had a high population or other valuable assets requiring protection from the impacts of wildland fires.

Non-native or High Fire Risk Vegetation

Fuel type, or vegetation, plays an important role in determining wildland fire danger. All fuel types can and will burn under the right conditions; however, some fuel types pose more danger than others due to the intensity at which they burn, the horizontal and vertical continuity of burnable material, and firefighters' ability to modify the fuel complex in front of an approaching wildfire. While rangeland or grass fires often spread rapidly, they burn quickly and at a lower intensity than forest fires. Additionally, local farmers and firefighters can often construct fuel breaks with dozers and other equipment relatively quickly. These tactics are not as effective in forested areas or on steep terrain.

Vegetation types that lead to increased wildfire intensity or severity were given a higher threat level rating.

High Risk Fire Behavior

Due to heavy fuel loads, much of the County could experience extreme wildfire behavior characteristics that result in very intense, stand replacing fires. The agriculture/grassland areas will likely experience lower intensity fires with rapid rates of spread, particularly under the influence of wind.

One of the factors contributing to potentially dangerous fire behavior is the preheating of fuels on steep slopes ahead of the actual flame front. Typically, fires spread very rapidly uphill, particularly in grass fuel types. Hot gases rise in front of the fire along the slope face preheating the upslope vegetation and moving a grass fire up to four times faster with flames twice as long as a fire on level ground. This preheating of fuels, or radiant heat, is capable of igniting combustible materials from distances of 100 feet or more.[34]

Areas with a high potential for extreme fire behavior based on Fire Behavior Analysis Tool modeling and local knowledge were given a higher threat level rating. Based on local knowledge, the grass fuel model was given a higher intensity level than it normally would receive due to the vast amounts of available fuel. Although grass fires can generally be controlled relatively easily, fires burning in this fuel type can spread rapidly. Extreme rates of

[34] "Wildfires and Schools". 2008. National Clearinghouse for Educational Facilities. National Institute of Building Sciences. Available online at http://www.ncef.org/pubs/wildfires.pdf.

spread coupled with the remote nature of much of the County, can cause significant control issues for local fire districts.

Suppression Capabilities

Fire protection in each district in Franklin County is essentially the responsibility of the local fire district. The County has five active fire districts and two municipalities with resources available for fire suppression. However, each district is limited to the resources at hand until help from other districts or state or federal agencies can arrive.

Some parts of the County fall under Washington DNR or BLM fire protection responsibility. The Washington DNR and BLM have cooperative agreements with Franklin County Fire Districts to provide initial attack on their respective districts. The response times for the DNR and BLM can be several hours or longer due to the logistical challenge of mobilizing both crews and equipment from their respective duty stations.

Population Centers and Developing Areas

Due to the increased human activity within and surrounding Franklin County communities, these areas are inherently at a higher risk of ignitions.

The perimeter and outskirts of population centers and known developing areas were given a high threat level rating.

High Protection Value

There are several areas in Franklin County that constitute protection due to their high conservation value such as tribal and other culturally or historically significant sites, recreational areas, and critical infrastructure. Watersheds were included in this risk category due to the limited supply of this natural resource within the County. Communication towers and State Parks are other examples of "High Protection Value" assets that were ranked with a high threat level.

Field Assessments

Based on the preliminary review of the risk categories, high risk areas were identified and mapped. Field assessment of these areas were conducted in October and included visits to U.S. Fish & Wildlife property, Smith Canyon, Juniper Dunes, subdivisions north of Pasco, and agriculture/canyon area in the northeast corner of the County as well as tours of several of the communities in combination with interviews with local residents in identified high risk areas. Fire control and mitigation specialists conducted thorough field assessment to evaluate the accuracy of the models and other data, assess the extent of risk and hazardous fuels, and develop specific hazardous fuels treatment project plans. Additionally, experts from the local fire districts, the Bureau of Land Management, and Franklin County were consulted in order to address specific areas of concern and document local wildfire suppression operational tactics.

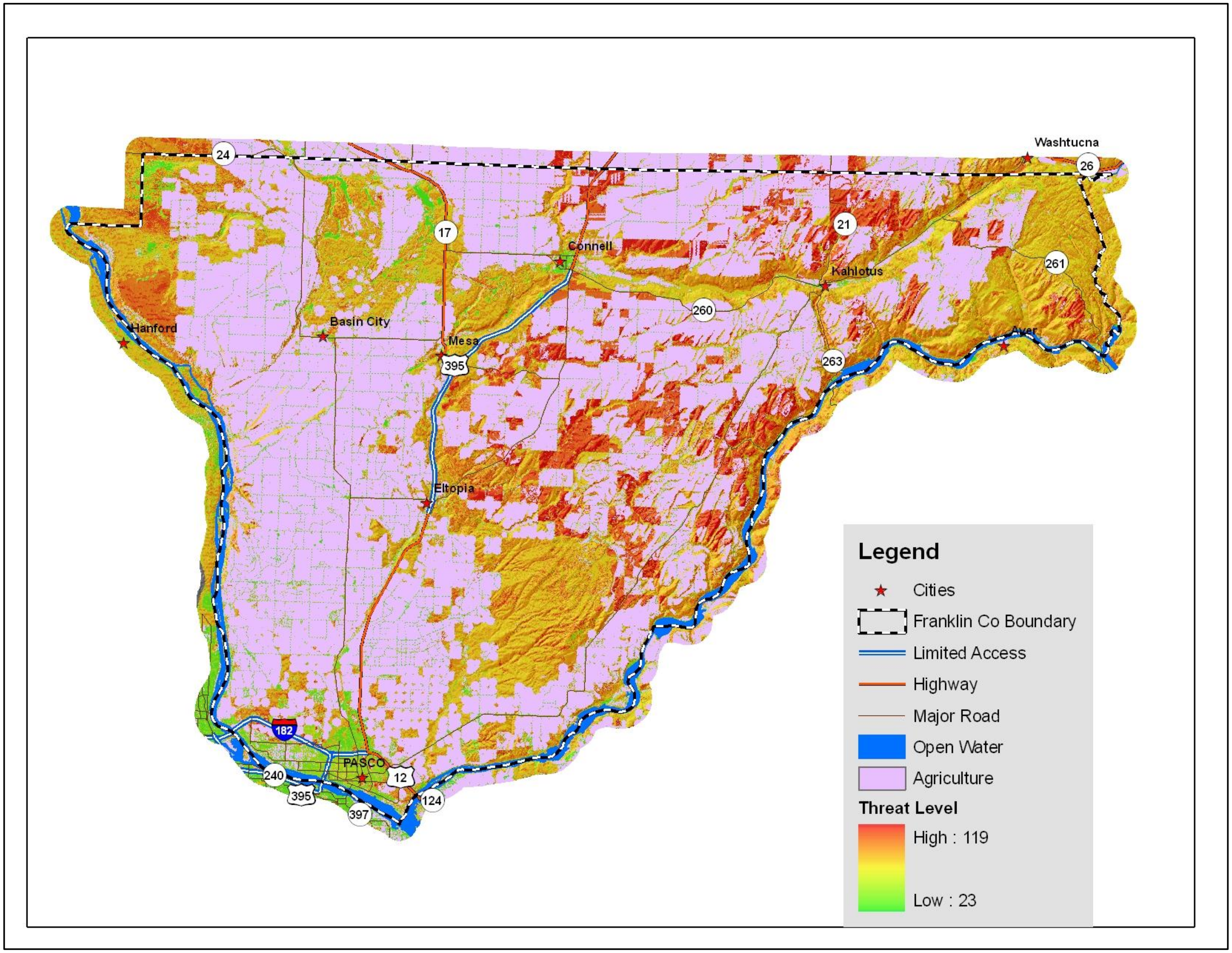
Determination of Relative Threat Level

Following the field assessments, the planning committee began development of the Relative Threat Level model. Risk categories included in the final analysis were slope, aspect, precipitation, fuel models, rate of spread, fire intensity, and population density. The various categories, or layers, were ranked by the committee based on their significance pertaining to causal factors of high wildland fire risk conditions or protection significance. The ranked layers were then analyzed in a geographical information system to produce a cumulative effects map based on the ranking. Following is a brief explanation of the various categories used in the analysis and the general ranking scheme used for each.

- Environmental Factors – slope, aspect and precipitation all can have an enormous impact on the intensity of a wildfire. Therefore, areas with steep slopes, dry aspects, or lesser amounts of precipitation, relative to Franklin County, were given higher threat rankings.
- Vegetation Cover Types – certain vegetation types are known to carry and produce more intense fires than other fuel types. For Franklin County, shrub and grass fuel models were given the higher rankings followed by short grass / agriculture, and forest types (shrub understory) fuel models.
- Fire Behavior – areas identified by fire behavior modeling as having high rate of spread potential or high fire intensity were given a higher threat level ranking.
- Populated Areas – these areas were ranked higher due to the presence of human populations, structures, and infrastructure requiring protection from fire.

Each data layer was developed, ranked, and converted to a raster format using ArcGIS 9.3. The data layers were then analyzed in ArcGIS using the Spatial Analyst extension to calculate the cumulative effects of the various threats. This process sums the ranked overlaid values geographically to produce the final map layer. The ranked values were then color coded to show areas of highest threat (red) to lowest threat (green) relative to Franklin County.

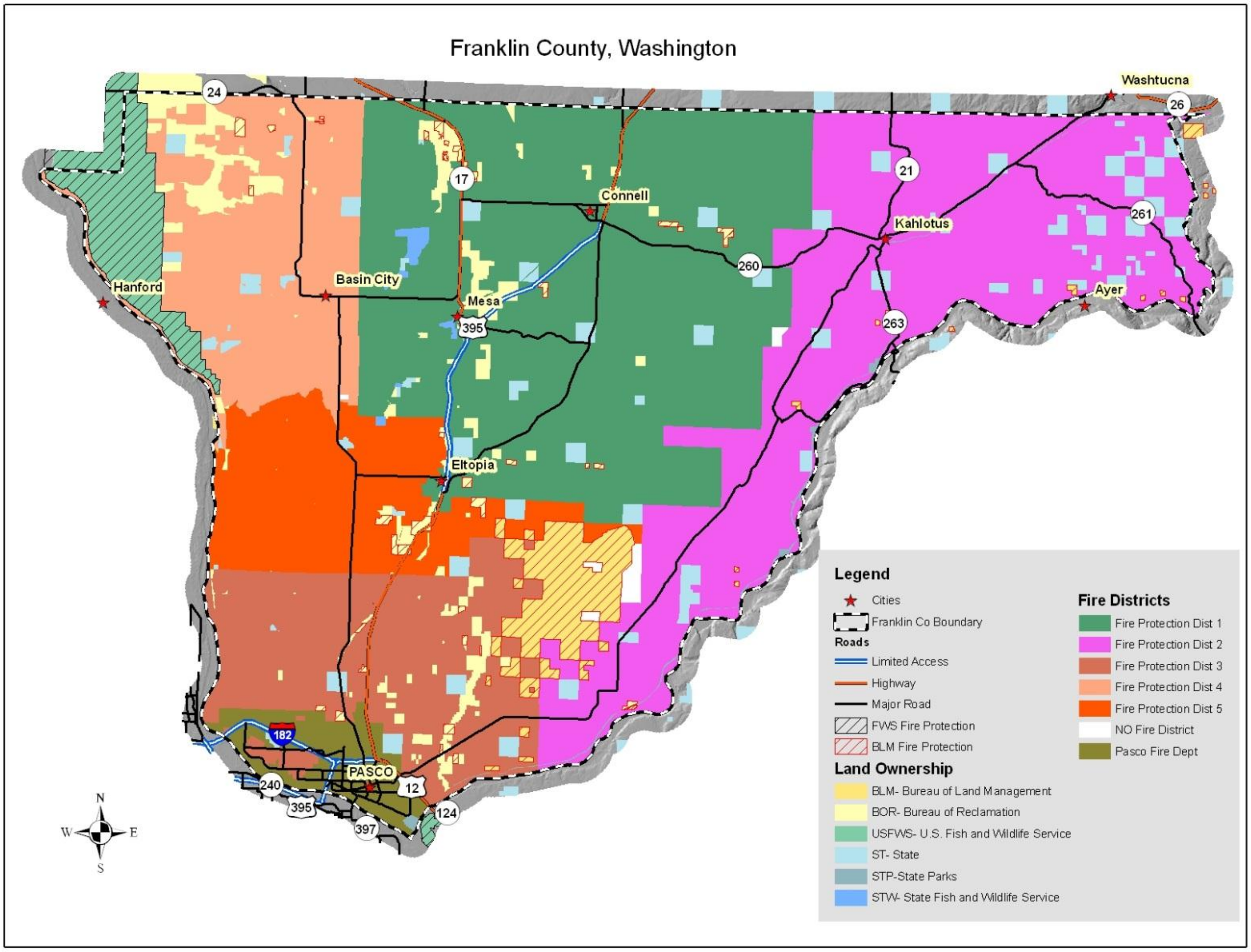
Figure 4.10. Franklin County Relative Threat Level Map.



Overview of Fire Protection System

A majority of the County has a local fire protection district that covers both structural and wildland fire response. The Washington DNR is responsible for wildland fire protection outside of fire district jurisdictions. Due to the lack of DNR resources in Franklin County, the DNR maintains an agreement with Franklin County to provide initial attack for the first 12 hours of the operational period.

Figure 4.11. Wildfire Protection Responsibility Map.



****NOTE: Washington DNR does not respond to structure fires.****

Local Fire Department and District Summaries

The firefighting resources and capabilities information provided in this section is a summary of information provided by the fire chiefs or representatives of the wildland firefighting agencies listed. Each organization completed a survey with written responses. Their answers to a variety of questions are summarized here. These synopses indicate their perceptions and information summaries.

Appendix 4 contains contact information and a complete available resource list for each of the following fire service organizations.

City of Pasco Fire Department

District Summary: The City of Pasco Fire Department is primarily an urban/suburban fire agency that provides primary fire, EMS, hazardous materials, and technical rescue services to the residents of the City of Pasco. The fire department operates out of three stations utilizing 52 career firefighters divided into three 24 hour shifts and covers an area of approximately 32 square miles.

Issues of Concern: As mentioned earlier, the PFD is primarily an urban/suburban fire department that deals with urban issues (structural fires, etc.). The areas of concern are:

Residential Growth: The City of Pasco has seen significant residential growth over the last 10 years. The population has doubled to approximately 66,000 residents. Single and multi-family residential structures account for most of the growth. As a result, our exposure to the WUI zones within the city and on the edge of the city boundaries has increased significantly.

Communications: The City of Pasco is located in the extreme southern portion of Franklin County and has direct line of sight with the highest repeaters in the area. We have the capability to utilize/share other frequencies with Benton County agencies. The rest of Franklin County does not share these benefits largely due to budgetary and geography related issues.

Policy development and dispatcher training continue to be a major issue of concern. The Franklin County Communications Center (FCCC) reports to the Franklin County Sheriff and is primarily designed around the needs of local law enforcement. Training and policies for fire/EMS dispatching is minimal.

The current dispatching configuration within the Tri-County area utilizes three separate and distinctive centers, CAD (Computer Aided Dispatch) and PSAP's (Public Safety Answering Points). Often, communications between communications centers is done via phone. The CAD systems are not interlinked and therefore requests for resources are often unfilled or filled incorrectly. None of the CAD systems have been upgraded within the last 10 years and are no longer able to be supported by the vendor(s).

Burn Permit Regulations: Outdoor burning permissions within the City of Pasco UGA (urban growth area) are determined based upon the Benton County burning regulations. The

City of Pasco does not allow any outdoor burning (other than blown tumbleweeds) within the UGA. The Code Enforcement Officer for the City of Pasco is charged with enforcing burning regulations.

Other: The PFD is heavily reliant on the neighboring fire districts for sustained wildfire operations. Most of our wildland fire exposure, to date, has been residential or commercial lots. A wildland fire and increased populations within could potentially overwhelm initial responders. The need to have better access to equipment such as tenders, Type 3 engines, etc. that can be successfully utilized in both the rural and suburban area is apparent and should be addressed.

Franklin County and the City of Pasco should adopt a regulation requiring "defensible space" for all existing and new construction within the WUI. This process will require a two-fold approach. First, public education through a collaborative partnership with the media, fire departments, and emergency management, and second development and adoption of county ordinances requiring the improvement and maintenance of defensible spaces.

Last, the county fire agencies should explore the development of a "MIST" (minimum incident support team – Type 4) in which qualified command/overhead positions are filled at a wildfire incident within Franklin County. There are times when agencies are responding together for fires when command and control are not clearly established or known. This issue creates confusion on fire scenes and is a major safety concern for responders.

Cooperative Agreements: The City of Pasco Fire Department is a co-signer and participant in the Franklin County Mutual Aid agreement as well as the Tri-County Master Mutual Aid agreement which includes Franklin, Benton and Walla Walla counties. The City of Pasco also has a cooperative agreement with the USFWS.

District Needs/Wish List: The members of the City of Pasco Fire Department are well-versed, trained and experienced in structural firefighting techniques and skills. They are not as comfortable or qualified to manage a large wildland fire scenario. Conversely, the fire districts are more comfortable and experienced dealing with wildland fires than with structural fires. Collaborative opportunities should be explored to provide the needed experience and training to the firefighting community of Franklin County.

An integrated and focused public education program dedicated to wildland fire prevention and protection needs to be developed and implemented throughout the county. This program should include consistent and enforceable burning regulations, information on defensible spaces, and outreach programs through the use of all facets of media, including social media.

Encourage County-wide support of Emergency Management Department for activation of the Emergency Operations Center in the event of a large wildfire incident within Franklin County.

City of Connell Fire Department

District Summary: The City of Connell Fire Department has served the folks in historic Connell, Washington for around 73 years. The Fire Department is now classified as a 'Combination' department. In February of 2011, the City of Connell hired a full time Fire Chief. There have been numerous volunteer chiefs in years past. The Fire Department has 20 volunteers that are all very devoted contributors. There is a long standing tradition of volunteer fire fighters that have served. The majority of the volunteers have been on board for over 10 years but there is also a half a dozen that have only served since the spring of 2011. It is an exciting time to be a part of this new developing program. The department has only one station, but it has just completed a significant remodel. The 'new' station houses two apparatus (E2011 - 1998 Freightliner Pumper and L2021 - 2009 Rosenbauer Aerial), a newly renovated training room, and the three older bay areas.

The volunteers that serve the City of Connell Fire Department are also members of the volunteer program of Franklin County Fire District 1 (FCFD1). FCFD1 responds to an average of 85 to 100 natural cover fires annually. FCFD1 response originates from the county vehicles that are stationed just down the street from the City of Connell Fire Station. The county and city programs are tightly interwoven. The leadership and members are common to both departments. The spirit of teamwork and progress is contagious. With the arrival of the new chief, the City of Connell Fire Department has solidified the cooperative spirit with FCFD1 and the neighboring Fire Districts to the east, west and south as well as a number of much larger municipalities in the Tri-Cities (Kennewick Pasco, Richland), the US Fish and Wildlife Service, and numerous fire districts in Benton County.

In May of 2011, the new chief assembled an interagency cadre and launched, for the first time, a NWCG approved Wildland Fire School. This Wildland Fire School presented S-110 (Introduction to Wildland Fire), S-190 (Introduction to Wildland Fire Behavior), S-134 (LCES), I-100 (Introduction to Incident Command System), L-180 (Human Factors in the Wildland Fire Services), and S-130 (Firefighter Training) for more than 30 volunteers, 20 of which were from the City of Connell Fire Department.

The department has received some structural training over the years, but with the current momentum, new organization, and positive direction gained from the recent Wildland Fire training the City of Connell Fire Department is excited about gearing up our structural protection program with some sorely needed equipment upgrades and additional training for all personnel.

Issues of Concern:

Residential Growth: The City of Connell is well poised for continued growth. Water systems and infrastructure are in place that will provide for numerous opportunities for the city to continue to develop and expand. The schools have all been recently remodeled or constructed and are ready for decades of K-12 educational opportunities.

Communications: The emergency response communications network is managed out of the County Seat of Pasco. There is currently a restructuring effort in place that is being designed to provide coverage for years to come. Franklin County infrastructure for communications is current and has excellent technicians maintaining the system. The topography of the area promotes effective communications and very few areas exist without adequate coverage.

Burn Permit Regulations: There is only limited burning allowed within the city limits of Connell. Burning is limited to windblown tumbleweeds only. Burning is often restricted during hot and dry conditions.

Other: The City of Connell Fire Department is a 'Combination' department. The budget is effective but the department is challenged to replace apparatus and some of the higher priced equipment within the confines of the current budget.

Cooperative Agreements: City of Connell is a signatory member of the Franklin County Master Mutual Aid Agreement. It has also provided requested information to the U.S. Fish and Wildlife Services to participate in a Cooperative Agreement with the Mid-Columbia River National Wildlife Refuge Complex, based out of the city of Burbank.

District Needs/Wish List: Continued cooperation with the Fire District and municipal fire department partners. Replace the aging apparatus and some of the higher priced equipment. Continue to seek community and volunteer support to maintain and improve the effectiveness of the Fire Department.

Franklin County Fire Protection District #2

No information was available at the time this document was developed.

Franklin County Fire Protection District #3

District Summary: Franklin County Fire Protection District #3 currently provides fire and BLS ambulance service to approximately 6000 residents in 150 square miles in the southern portion of Franklin County in Washington State. The nearest city is the City of Pasco. The district is made up of a mix of suburban residential and irrigated and dry land agriculture with some agricultural-based industrial facilities. Franklin County F.P.D. #3 is a combination district staffed with five career employees and approximately 50 volunteer responders.

Issues of Concern:

Residential Growth: Residential growth in the WUI areas, particularly the Martindale and Haugen/Kepps Road areas, continues to be of high concern. Any fire that starts in these areas has high potential of affecting properties within these developments.

Communications: Franklin County F.P.D. #3 is situated fairly well in the southern portion of the County having direct line of sight to one of the highest repeater sites in the area plus being able to utilize other frequencies with Benton County agencies. However, the rest of the County does not share these benefits with budget and geography issues hampering Countywide use of a single frequency for dispatching.

Assistance with training and policy development on utilization of geographic and tactical frequencies would be beneficial for all agencies especially as we are moving more towards working together on incidents.

Burn Permit Regulations: The County takes precious little responsibility for burn permitting, leaving it to the State Department of Ecology. Lack of a full time Fire Marshall and short staffing in the Code Enforcement officer portion of the Building Department hampers investigation and enforcement of burn regulation infractions. Public education with regard to fire safety and burning conditions can prove beneficial but they need to be ongoing and well organized. Franklin County F.P.D. #3 has a public education program which we are very proud of, but without outside funding, we are unable to extend this beyond the borders of District #3. Currently, the majority of our public education is rightfully directed towards school-aged children. With additional funding and some type of assistance, it is hoped that we would be able to extend this to other parts of the community.

Other: Like all districts, Franklin County F.P.D. #3 is dependent upon volunteers for the bulk of firefighting duties. We are fortunate to be situated near and surrounded by a major population center in the City of Pasco from where many of our volunteers are recruited and reside.

This is not the case for the rest of the County which has a much more limited and predominately agriculture based population. Education and incentives may assist with keeping these volunteers involved particularly since the call volume is not very high.

There are times when we are brought together for fires when we do not know who is in charge or where to find them for assignments and accountability. This creates considerable discomfort at minimum and definite safety concerns for responders who are used to more closely run incidents.

Cooperative Agreements: Franklin County F.P.D. #3 is a signer and participant in the Franklin County Mutual Aid Agreement as well as the Tri-County Mutual Aid Agreement which includes Franklin, Benton, and Walla Walla Counties. Franklin County F.P.D. #3 also has a cooperative agreement with the US Fish and Wildlife Service and is working toward an agreement with the BLM.

District Needs/Wish List: While the mutual aid and cooperative agreements are beneficial, training together and knowledge of each other's district and operations would be of great benefit for the times we work together on fires. In the last few years we have had better communication with quarterly meetings. This needs to continue and perhaps include tours of each other's district for some institutional knowledge of the threats we each have.

Of course we all want to replace engines and water tenders on a more frequent basis but that hopefully will be easier to do with our needs better defined by this document.

On the short term basis, help with expansion of our public education program and participation by other departments spreading the word to their constituents should help with minimizing the effects of accidental fires. Intentional starts are a completely different issue and help from the law enforcement agencies are needed for that.

Regarding some of the residential concerns, help with getting permissions to do fuels mitigation efforts near these properties reducing the threat of these fires progressing onto their property.

Franklin County Fire Protection District #4

No information was available at the time this document was developed.

Franklin County Fire Protection District #5

No information was available at the time this document was developed.

U.S. Fish & Wildlife Service

District Summary: The mission of the National Wildlife Refuge System is to preserve a national network of lands and waters for the conservation and management of fish, wildlife and plant resources of the United States for the benefit of present and future generations.

The Mid-Columbia River NWRC lies in the heart of the Columbia Basin with must Refuge lands in close proximity to the Columbia River (hence the name). The Complex is comprised of 8 Refuges and 1 National Monument covering over 265,000 acres: Columbia NWR, Hanford Reach National Monument/Saddle Mountain NWR, McNary NWR, Umatilla NWR, Cold Springs NWR, McKay NWR, Conboy NWR and Toppenish NWR.

The Mid-Columbia River NWRC shares common ecological elements between the different refuges. Vegetation, wildlife and wildland fuels are generally very similar between the refuges with the exception of Conboy NWR.

The Mid-Columbia River NWRC fire program serves the 8 refuges (Columbia NWR, Toppenish NWR, Cold Springs NWR, McKay NWR, Umatilla NWR, McNary NWR, Hanford NWR and Conboy NWR). The Mid-Columbia River NWRC consists of one Type 4 Engine (8oo gallons), one Type 5 Engine (500 gallons), one Type 6 Engine (300 gallons), and one Type 3 Fire Boat. The staffing consists of a Fire Management Officer (FMO), an Assistant Fire Management Officer (AFMO), 2 Fire Operations Specialist (FOS), 3 Engine Captains and a seasonal staff of 9. One FOS and Type 5 Engine is stationed at Columbia NWR in Othello, WA, along with 3 seasonal firefighters. The rest of the staff (FMO, AFMO, FOS and 6 seasonals) is stationed at McNary NWR. The complex responds to an average of 70 fires a year and burns approximately 1000 – 2000 acres a year in both mechanical and prescribed fire treatment.

Cooperative Agreements: The Mid - Columbia River NWRC has cooperative agreements with Franklin County Fire Districts 3 and 4 and City of Pasco Fire Department. Pending and proposed Memorandums of Understanding's with Franklin County Fire Districts 1 and 5, Franklin County Emergency Services and City of Connell are in the works. The Mid-Columbia River NWRC also has cooperative agreements with: Adams County District 5; Benton County Districts 1, 2, 3, 4, and 6; Cities of College Place, Kennewick and Richland; Grant County Districts 4, 8, 10 and 11; the Hanford Fire Department; and Walla Walla County Districts 5 and 6.

Washington Department of Natural Resources

District Summary: The Washington Department of Natural Resources (DNR) is the largest on-call fire department in the State with 1,200 permanent and temporary employees that fight fire on more than 12 million acres of private and state-owned forest lands. The DNR's fire protection and safety equipment requirements help local fire districts respond to wildfires. The DNR also works with the National Weather Service to provide the fire weather forecasts and fire precaution levels that firefighters, landowners, and forest industry rely on.

The Washington DNR does not have resources directly assigned to Franklin County. The DNR's Northwest Region has 8-10 Type 5 and 6 initial attack engines staffed and available during the fire season in addition to air resources. These resources as well as others statewide are available to Franklin County as they are available.

Cooperative Agreements in Franklin County: Unknown.

****NOTE: Washington DNR does not respond to structure fires.****

Bureau of Land Management

Spokane District Mission Statement: The mission of the Spokane District is to share our unique capability and interest in sustaining the full diversity of natural and cultural landscapes across Washington State and invite their discovery and use. This includes protecting the natural resources, such as water for fish and wildlife; preserving environmental and cultural values on the lands they manage; providing for multiple uses including some commercial activities; and enhancing opportunities for safe and enjoyable outdoor recreation. The Spokane District also assesses energy and mineral resources and works to ensure that their development is in the best interest of the public. Another major responsibility is to ensure consideration of Tribal interests and administration the Department of Interior's trust responsibilities for American Indian Reservation communities.

District Summary: Up through the 1970's, BLM's policy was to divest ownership of all federal public (BLM) lands in the state of Washington. But in 1980, at the height of the Sage Brush Rebellion (a social movement to give control over federal lands to the states and local authorities), Washington voted to have the public lands remain under federal ownership and management. In the 1980 general election, the state put a measure on the ballot asking voters if the state constitution should "be amended to provide that the state no longer disclaim all rights to unappropriated federal public lands." Approximately 60% of the people and the majority in every county voted no, signaling to BLM that there was strong support for continued federal management of the public lands in the state.

In response to this vote, the Director of BLM approved a proposal by the District to begin a process of consolidating the scattered BLM lands around the state. Today the Spokane District BLM manages nearly 24,000 acres in Franklin County for multiple uses, providing wildfire protection, suppression, support, and training for the BLM managed lands and other federal/state/county agencies.

The Spokane District Fire Management Program currently consists of two type six wildland engines (300 gallons) with two full time Engine Captains, four engine crew members, one ten person hand crew, one Fuels Technician, Seasonal Dispatcher, Assistant Fire Management Officer (AFMO), and a Fire Management Officer (FMO). The hand crew and one engine is stationed in Spokane at the District office and the other in Wenatchee at the field office. There are approximately 16 other specialist (staff) from across the district that assist the Fire Management Program in wildland and/or prescribed fire efforts. With the District's scattered ownership pattern, the engines are usually on scene after initial attack forces have arrived. Our engines and personnel are available for off District and out of state fire assignments that aide in support, training, and experience.

Fire Protection Issues

The following sections provide a brief overview of the many difficult issues currently challenging Franklin County in providing wildland fire safety to citizens. These issues were discussed at length both during the committee process and at the public meetings.

Address Signage

The ability to quickly locate a physical address is critical in providing services in any type of emergency response. Accurate road address and address signage is fundamental to ensuring the safety and security of Franklin County residents. Currently, there are numerous areas throughout the county lacking road signs, address markers, or both. Signage throughout the County needs to be updated in order to assure visibility and quick location by emergency responders.

Coordination with State and Federal Agencies

Efforts are being created to improve communication between local fire departments and the federal agencies through agreements and sharing communication plans. This presents a problem when there is confusion on who has initial attack responsibilities on federal lands and what restrictions are imposed by the jurisdictional agency responsible for fire protection.

Urban and Suburban Growth

One challenge Franklin County faces is the large number of houses in the urban/rural fringe. Since the 1970s, a segment of Washington's growing population has expanded further into traditional rural or resource lands. The “interface” between urban and suburban areas and the resource lands created by this expansion has produced a significant increase in threats to life and property from fires and has pushed existing fire protection systems beyond original or current design or capability. Franklin County has a low number of Firewise Communities; therefore, there are many property owners within the interface that are not aware of the problems and threats they face. Furthermore, human activities increase the incidence of fire ignition and potential damage.

Rural Fire Protection

People moving from mainland urban areas to the more rural parts of Franklin County, frequently have high expectations for structural fire protection services. Often, new residents do not realize that the services provided are not the same as in an urban area. The diversity and amount of equipment and the number of personnel can be substantially limited in rural areas. Fire protection may rely more on the landowner’s personal initiative to take measures to protect his or her property. Furthermore, subdivisions on steep slopes and the greater number of homes exceeding 3,000 square feet are also factors challenging fire service organizations. In the future, public education and awareness may play a greater role in rural or interface areas. Great improvements in fire protection techniques are being made to adapt to large, rapidly spreading fires that threaten large numbers of homes in interface areas.

Debris Burning

Local burning of yard debris is highly regulated in Franklin County. Permit burns in Franklin County are based on the DNR cycle, while burn bans are a locally-based decision determined by fuel moistures (see Fire District Summaries for more information on burning). Some people still burn outside of the designated time frame, and escaped debris fires impose a very high fire risk to neighboring properties and residents. It is likely that regulating this type of burning will always be a challenge for local authorities and fire departments; however, improved public education regarding the County's burning regulations and permit system as well as potential risk factors would be beneficial.

Pre-planning in High Risk Areas

Although conducting home, community, and road defensible space projects is a very effective way to reduce the fire risk to communities in Franklin County, recommended projects cannot all occur immediately and many will take several years to complete. Thus, developing pre-planning guidelines specifying which and how local fire agencies and departments will respond to specific areas is very beneficial. These response plans should include assessments of the structures, topography, fuels, available evacuation routes, available resources, response times, communications, water resource availability, and any other factors specific to an area. All of these plans should be available to the local fire departments as well as dispatch personnel.

Conservation Reserve Program Fields

Since the introduction of the CRP by the federal government, many formerly crop producing fields have been allowed to return to native grasses. CRP fields are creating a new fire concern all over the west. As thick grasses are allowed to grow naturally year after year, dense mats of dead plant material begin to buildup. Due to the availability of a continuous fuel bed, fires in CRP fields tend to burn very intensely with large flame lengths that often jump roads or other barriers, particularly under the influence of wind. Many landowners and fire personnel are researching allowable management techniques to deal with this increasing problem.

Currently, large blocks of land as well as scattered parcels in Franklin County are enrolled in the CRP program. Hundreds of acres of continuous higher fuel concentrations as well as limited access to these areas have significantly increased the potential wildfire risk in these areas. Many CRP landowners are willing to conduct hazardous fuel reduction treatments to lessen the fire risk; however, they are often limited by the regulations of the CRP program.

Due to the difficulties involved with conducting fuel reduction projects on CRP land as well as the enormity of the task in Franklin County, the Community Wildfire Protection Plan steering committee has recommended disking fuel breaks adjacent to CRP land wherever possible. The goal is to lower the intensity of a wind-driven CRP fire before it threatens homes and other resources.

Volunteer Firefighter Recruitment

The rural fire departments in Franklin County are predominantly dependent on volunteer firefighters. Each district spends a considerable amount of time and resources training and equipping each volunteer, with the hope that they will continue to volunteer their services to the department for at least several years. One problem that all volunteer-based departments encounter is the diminishing number of new recruits. As populations continue to rise and more and more people build homes in high fire risk areas, the number of capable volunteers has gone down. In particular, many departments have difficulty maintaining volunteers available during regular work day hours (8am to 5pm).

One of the goals of this CWPP is to assist local fire departments and districts with the recruitment of new volunteers and retention of trained firefighters. This is a very difficult task, particularly in small, rural communities that have a limited pool; however, providing departments with funding for training, safety equipment, advertising, and possibly incentive programs will help draw more local citizens into the fire organizations.

Communication

There are several communication issues being addressed in Franklin County. Many of the emergency responders have identified areas of poor reception for both radios and cell phones. The lack of communication between responders as well as with central dispatch significantly impairs responders' ability to effectively and efficiently do their job as well as lessens their safety. The conversion to a narrow band communication system exacerbated these issues and require numerous additional repeaters to be installed.

On a smaller scale, many subdivisions or unincorporated population centers have identified the need to improve emergency communication between residents. In an emergency situation, there is no existing way of notifying each resident in an area of the potential danger, the need for evacuation, etc. Many groups of homeowners have begun to establish phone trees and contact lists in order to communicate information at the individual scale; however, this is not being done in all of the high wildfire risk areas within the County.

Communication is a central issue for the planning committee; thus, numerous recommendations targeting the improvement of communications infrastructure, equipment, and pre-planning have been made.

Water Resources

Nearly every fire district involved in this planning process indicated the need to develop additional water resources in several rural areas. Developing water supply resources such as cisterns, dry hydrants, drafting sites, and/or dipping locations ahead of an incident is considered a force multiplier and can be critical for successful suppression of fires. Pre-developed water resources can be strategically located to cut refilling turnaround times in half or more, which saves valuable time for both structural and wildland fire suppression efforts.

Invasive Species

Fire behavior and fire regimes have been altered due to the proliferation of cheatgrass (*Bromus tectorum*) and other invasive species. Cheatgrass has a very fine structure, tends to accumulate litter, and dries completely in early summer, thus becoming a highly flammable, often continuous fuel.[35]

Public Wildfire Awareness

As the potential fire risk in the wildland urban interface continues to increase, it is clear that fire service organizations cannot be solely responsible for protection of lives, structures, infrastructure, ecosystems, and all of the intrinsic values that go along with living in rural areas. Public awareness of the wildland fire risks as well as homeowner accountability for the risk on their own property is paramount to protection of all the resources in the wildland urban interface.

The continued development of mechanisms and partnerships to increase public awareness regarding wildfire risks and promoting "do it yourself" mitigation actions is a primary goal of the planning committee as well as many of the individual organizations participating on the committee.

Current Wildfire Mitigation Activities

Many of the county's fire departments and agencies are actively working on public education and homeowner responsibility by visiting neighborhoods and schools to explain fire hazards to citizens. Often, they hand deliver informative brochures and encourage homeowners to have their driveways clearly marked with their addresses to ensure more rapid and accurate response to calls and better access.

Firewise

"Over the past century, America's population has nearly tripled, with much of the growth flowing into traditionally natural areas. These natural, unprotected settings are attracting more residents every year. This trend has created an extremely complex landscape that has come to be known as the wildland urban interface: a set of conditions under which a wildland fire reaches beyond trees, brush, and other natural fuels to ignite homes and their immediate surroundings. Consequently, in nearly all areas of the country, the wildland urban interface can provide conditions favorable for the spread of wildfires and ongoing threats to homes and people. Many individuals move into these landscapes with urban expectations. They may not recognize wildfire hazards or might assume that the fire department will be able to save their home if a

[35] USDA online database. http://www.fs.fed.us/database/feis/plants/graminoid/brotec/all.html#REFERENCES Accessed December, 2013.

wildfire ignites. However, when an extreme wildfire spreads, it can simultaneously expose dozens — sometimes hundreds — of homes to potential ignition. In cases such as this, firefighters do not have the resources to defend every home. Homeowners who take proactive steps to reduce their homes' vulnerability have a far greater chance of having their homes withstand a wildfire. The nation's federal and state land management agencies and local fire departments have joined together to empower homeowners with the knowledge and tools to protect their homes through the National Firewise Communities Program. Firewise Communities is designed to encourage local solutions for wildfire safety by involving firefighters, homeowners, community leaders, planners, developers, and others in efforts to design, build, and maintain homes and properties that are safely compatible with the natural environment. The best Firewise approach involves a series of practical steps that help individuals and community groups work together to protect themselves and their properties from the hazard of wildfire. Using at least one element of a Firewise program and adding other elements over time will reduce a homeowner's and a community's vulnerability to fire in the wildland/urban interface. Wildland fires are a natural process. Making your home compatible with nature can help save your home and, ultimately, your entire community during a wildfire."[36]

Fire Adapted Communities (FAC)

"Fire Adapted Communities are neighborhoods located in wildfire-prone areas that can survive wildfire with little or no assistance from firefighters. During a wildfire, FACs reduce the potential for loss of human life and injury, minimize damage to homes and infrastructure and reduce firefighting costs. This program offers information, promotional materials and articles that can be customized for your area. This program also offers videos and a display system that is available for use at community events, meetings, etc."[37]

---

[36] http://www.firewise.org/Information/Who-is-this-or/Homeowners/~/media/Firewise/Files/Pdfs/Booklets%20and%20Brochures/BrochureCommunitiesCompatibleNature.pdf. Accessed June, 2012.

[37] Living with Fire website available at: http://www.livingwithfire.info/fire-adapted-communities. Accessed May, 2014.

[This page intentionally left blank.]

Chapter 5

Landscape Risk Assessments

The following description was taken out of the 2008 Franklin County Growth Management Comprehensive Plan.

Franklin County is located in the south central part of the State of Washington. It is bounded on the west and separated from Benton County by the Columbia River. On the south and east the Snake River and its tributary, the Palouse River, separate it from Walla Walla County. On the north Grant and Adams Counties bound it. The area is arid to semiarid, receiving an average rainfall of about six to seven inches per year.

The area averages about 10.3 days of snowfall and 7.5 days of rainfall annually. The median monthly temperature ranges from a low of 30.6 degrees Fahrenheit in January to a July high of 75.7 degrees Fahrenheit. High wind velocities, with peak gusts as high as 70 mph or higher, can be expected at any time of the year.

Franklin County is part of what is referred to as the Columbia Basin Province. The County contains many canyon and cliff features such as Palouse Canyon, Juniper Dunes wilderness, and Devils Canyon as well as unique rock formations.

The County lies at the south end of the Channel Scablands. The geology of Franklin County was formed by alternate volcanism and flooding. Three of the five geological formations, which characterize the entire Columbia River Basalt Group, occur in Franklin County.

Franklin County can be characterized as a level to steep loessial upland steppe zone. Elevations range from about 345 feet above sea level at the southernmost part of the County to over 1,600 feet in the northeastern part.

Even though rainfall amounts are small, the moisture that does fall escapes evaporation during winter months and seeps deeply into the soil. This provides water to sustain vigorous growth in the spring. The upland loams are dominated by bluebunch wheatgrass, Idaho fescue, and Sandberg's bluegrass (*Poa Secunda*). The sand soils support Indian ricegrass (*Achnatherum hymenoides*) and sand dropseed (*Sporobolus cryptandrus*).

The remainder of the area is classified as “shrubsteppe” and is characterized by various sagebrush species. Dominance over much of the region is by nonnative cheatgrass. Because of the turbulent floods that inundated the area, the soils tend to be thin and stony.

The varied terrain and major river environments that cut through the steppe region of Franklin County create many unique habitats for wildlife. Areas such as Scooteney Lake, Eagle Lake, the Lower Palouse, and the Snake River and Snake River Island are some of those. The Washington Environment Atlas lists over 35 important species of birds and five species of mammals, which range over the area. These include sage grouse, scaled quail, peregrine falcon, and coyote, among others.

The Columbia and Snake Rivers are an important ecosystem for Franklin County. The Columbia River between McNary Pool and Priest Rapids Dam is the only remaining free flowing segment in Washington, and the last spawning grounds of the fall Chinook salmon (*Oncorhynchus tshawytscha*). About 80 percent of the Great Basin Canada goose (*Branta canadensis*) population nest and live most of the year in the Columbia River region, which also provide wintering grounds for the rare giant Canada goose (*Branta canadensis maxima*).

Cover vegetation and wildland fuels exhibited across the county have been influenced by massive geologic events during the Pleistocene era that scoured and shifted the earth's surface leaving areas of deep rich soil interspersed with rocky canyons and deep valleys. In addition to the geological transformation of the land, wildland fuels vary within a localized area based on slope, aspect, elevation, management practices, and past disturbances. Geological events and other factors have created distinct landscapes that exhibit different fuel characteristics and wildfire concerns.

In order to facilitate a mutual understanding of wildfire risks specific to commonly known areas in the county, the landscape-level wildfire risk assessments in the following sections are based on four predominant landscape types that exhibit distinct terrain and wildland fuels. The three landscapes identified for the assessments are: agricultural lands, shrub steppe lands, and riparian areas. These landscapes, although intermixed in some areas, exhibit specific fire behavior, fuel types, suppression challenges, and mitigation recommendations that make them unique from a planning perspective.

Overall Fuels Assessment

The gentle terrain that dominates Franklin County facilitates extensive farming and ranching operations. Agricultural fields occasionally serve to fuel a fire after curing; burning in much the same manner as short to tall grassy fuels. Fires in grass and rangeland fuel types tend to burn at relatively moderate intensity with moderate flame lengths, rapid rates of spread, and short-range spotting. Common suppression techniques and resources are generally quite effective in this fuel type. Homes and other improvements can be easily protected from direct flame contact and radiant heat through adoption of precautionary measures around structures.

Rangelands with a significant shrub component will have much higher fuel loads with greater spotting potential than grass and agricultural fuels. Although fires in agricultural and rangeland fuels may not present the same control problems as those associated with large, high intensity fires in timber, they can cause significant damage if precautionary measures have not been taken prior to a fire event. Wind driven fires in these fuel types spread rapidly and can be difficult to control. During extreme drought and when pushed by high winds, fires in agricultural and rangeland fuels can exhibit extreme rates of spread, which complicates suppression efforts.

Riparian areas in arid environments often have a higher amount of fuel loading due to the relatively abundant water supply. Vegetation tends to be more abundant and robust in these areas. Fuel loading often compounds year after year as new growth replaces old growth.

Deciduous trees and shrubs are common along waterways and contribute to on the ground fuel loads as they lose their leaves every year. Riparian areas experience a higher amount of recreation use due to various outdoor opportunities (fishing, camping, swimming, etc.). The increased activity may lead to unusually high amounts of ignitions.

Overall Mitigation Activities

There are many specific actions that will help improve safety in a particular area; however, there are also many potential mitigation activities that apply to all residents and all fuel types. General mitigation activities that apply to all of Franklin County are discussed below while area-specific mitigation activities are discussed within the individual landscape assessments.

The safest, easiest, and most economical way to mitigate unwanted fires is to stop them before they start. Generally, prevention actions attempt to prevent human-caused fires. Campaigns designed to reduce the number and sources of ignitions can take many forms. Traditional "Smokey Bear" type campaigns that spread the message passively through signage can be quite effective. Signs that remind people of the dangers of careless use of fireworks, burning when windy, and leaving unattended campfires have been effective. Fire danger warning signs posted along access routes remind residents and visitors of the current conditions. It's impossible to say just how effective such efforts actually are; however, the low costs associated with posting of a few signs is inconsequential compared to the potential cost of fighting a fire.

Burn Permits: Washington State Department of Natural Resources is the primary agency issuing burn permits in forested areas of the state. Washington Department of Ecology (DOE) is the primary agency issuing burn permits for improved property and agricultural lands. All DOE burn permits are subject to fire restrictions in place with WA DNR & local fire protection districts. Washington DNR has a general burning period referred to as "Rule Burn" wherein a written burn permit is not required in low to some moderate fire dangers.

The timeframes for the Rule Burn are from October 16^{th} to June 30^{th}. Washington DNR allows for Rule Burns to be ten foot (10') piles of forest, yard, and garden debris. From July 1^{st} to October 15^{th} if Rule Burns are allowed, they are limited to four foot (4') piles.

Defensible Space: Effective mitigation strategies begin with public awareness campaigns designed to educate homeowners of the risks associated with living in a flammable environment. Residents of Franklin County must be made aware that home defensibility starts with the homeowner. Once a fire has started and is moving toward a structure or other valued resources, the probability of that structure surviving is largely dependent on the structural and landscaping characteristics of the home. "Living with Fire, A Guide for the Homeowner" is an excellent tool for educating homeowners as to the steps to take in order to create an effective defensible space. Residents of Franklin County should be encouraged to work with local fire departments and fire management agencies within the county to complete individual home site evaluations. Home defensibility steps should be enacted based on the results of these evaluations. Beyond the homes, forest management efforts must be considered to slow the approach of a fire that threatens a community.

Evacuation Plans: Development of community evacuation plans are necessary to assure an orderly evacuation in the event of a threatening wildland fire. Designation and posting of escape routes would reduce chaos and escape times for fleeing residents. Community safety zones should also be established in the event of compromised evacuations. Efforts should be made to educate homeowners through existing homeowners associations or creation of such organizations to act as conduits for this information.

Accessibility: Also of vital importance is the accessibility of the homes to emergency apparatus. If a home cannot be protected safely, firefighting resources will not jeopardize lives to protect a structure. Thus, the fate of the home will largely be determined by homeowner actions prior to the event. In many cases, homes' survivability can be greatly enhanced by following a few simple guidelines to increase accessibility such as widening or pruning driveways and creating a turnaround area for large vehicles.

Fuels Reduction: Recreational facilities such as campgrounds and boat launches along Columbia and Snake Rivers should be kept clean and maintained. In order to mitigate the risk of an escaped campfire, escape-proof fire rings and barbeque pits should be installed and maintained. Surface fuel accumulations in shrublands can be kept to a minimum by periodically conducting thinning or clearing, and possibly controlled burns. Other actions that would reduce the fire hazard would be creating a fire resistant buffer along roads and power line corridors and strictly enforcing fire-use regulations.

Emergency Response: Once a fire has started, how much and how large it burns is often dependent on the availability of suppression resources. In most cases, rural fire departments are the first to respond and have the best opportunity to halt the spread of a wildland fire. For many districts, the ability to reach these suppression objectives is largely dependent on the availability of functional resources and trained individuals. Increasing the capacity of departments through funding and equipment acquisition can improve response times and subsequently reduce the potential for resource loss.

Other Activities: Other specific mitigation activities are likely to include improvement of emergency water supplies, access routes, and management of vegetation along roads and power line right-of-ways. Furthermore, building codes should be revised to provide for more fire-conscious construction techniques such as using fire resistant siding, roofing, and decking in high risk areas.

Agricultural Landscape Risk Assessment

The agricultural landscape is widespread across Franklin County. Franklin County is the fifth highest wheat and apple producing county in the state. Other crops include cherries, barley, and hay as well as extensive areas of fallow land set aside in the CRP (Conservation Reserve

Program). Most of these crops are vulnerable to wildland fire at certain times of the year. The agriculture landscape is the predominant cover vegetation and fuel type throughout the county, particularly in the central portion. Interspersed throughout this landscape are stream channels and rocky scabland areas. Landownership in the agricultural landscape is predominantly private with many sections owned by the State of Washington and scattered federal holdings. The major populated centers within this landscape type include Eltopia, Mesa, and Connell. Other rural development found throughout the agricultural landscape includes individual farms, small subdivisions, railroad sidings and grain elevators. Development is widely distributed. New development occurs primarily near communities and along major roads. Occasionally farmland is subdivided between family members for new home sites or for development of new farming facilities. Most of the pressure for multi-housing subdivisions occurs in close proximity to existing towns. In nearly all developed areas, structures are in close proximity to vegetation that becomes a significant fire risk at certain times of the year.

Wildfire Potential

Wildfire potential in the agricultural landscape is moderate in the rural farmland and moderate to high in the shrubby draws and waterways, pastures, and scattered patches of scabland. Virtually all of the populated areas within the agricultural landscape face similar challenges related to wildfire control and opportunities for fuels mitigation efforts. Farming and ranching activities have the potential to increase the risk of a human-caused ignition. Large expanses of crops, CRP, rangeland or pasture provide areas of continuous fuels that may threaten homes and farmsteads. Under extreme weather conditions, escaped fires in these fuels could threaten individual homes or a town site; however, this type of fire is usually quickly controlled. Clearings and fuel breaks disrupt a slow moving wildfire enabling suppression before a fire can ignite heavier fuels. High winds increase the rate of fire spread and intensity of crop and rangeland fires. It is imperative that homeowners implement fire mitigation measures to protect their structures and families prior to a wildfire event in these areas.

Wildfire risk in the agricultural landscape is at its highest during late summer and fall when crops are cured and daily temperatures are at their highest. A wind-driven fire in agricultural fuels or dry native fuel complexes would produce a rapidly advancing, but variable intensity fire. Fires burning in some types of unharvested fields would be expected to burn more intensely with larger flame lengths due to the greater availability of fuels resulting from the higher productivity of the vegetation. Fields enrolled in the CRP or set aside for wildlife habitat can burn very intensely due to an increased amount of fuel build-up from previous years' growth. Fires in these types of fuels are harder to extinguish completely due to the dense duff layer, often leading to hold over fires that may reemerge at a later date causing additional fire starts.

The eastern half of Franklin County is a mosaic of dryland agriculture, CRP/SAFE (State Acres for Wildlife Enhancements) acres and shrub steppe. A majority of the farmers use a production practice called summer fallow to allow soil moisture to increase by leaving fields fallow for a full crop year. This allows the wheat producers to rotate half their cropland each year: one year it's planted to wheat and then next year it lies fallow. The relative threat level in this agricultural area increases in July and August because of significant wildfire hazard. Relative humidity is usually lower during this time, afternoon winds tend to increase, and the standing grain is cured to the point where it readily ignites. The ripened wheat, hot daytime temperatures, and erratic winds can produce extreme fire behavior and long flame lengths which can easily spread to adjacent rangelands or CRP/SAFE fields. These fires tend to burn very quickly and intensely. Summer fallow fields act as a natural barrier during these wildfires so when the fire reaches these areas, it will burn itself out or the fire slows enough that it is easily controlled. Irrigated ag lands are located primarily in the western half of the County near the Columbia River and have been given a much lower threat level than the dryland agriculture.

Ingress-Egress

Interstate 182 and State Route 260 are the primary emergency access routes traveling east to west through the county. U.S. Highway 395, State Route 17, and Highway 12 are the primary access routes running north and south. County roads as well as rural ranch access roads are well distributed throughout most of the county often following section lines or circumnavigating the multitude of draws and canyons. In remote rural areas, county roads often change from a paved or maintained gravel surface to unimproved primitive roads making access possible only during certain times of the year. Limited access within remote areas and a lack of maintenance on existing travel routes, increases fire suppression response time and has a direct effect on fire spread leading to increased fire size and destructive potential.

There are a few bridges in the agricultural landscape of Franklin County. Bridge load rating signs are mostly in place for the existing bridges and do not impose a limitation to access for firefighting equipment.

Infrastructure

Urban residents throughout most of agricultural landscape area have municipal water systems, which includes a network of public fire hydrants. New development is required by the International Fire Code to have hydrant placement in their development plan. Subdivisions and development outside municipal boundaries typically rely on community water systems or multiple-home well systems.

Above ground, high voltage transmission lines cross the planning area in many directions in corridors cleared of most vegetation, which provides for a defensible space around the power line infrastructure and may provide a control point for fire suppression, if well maintained. Local public electrical utility lines are both above and below ground traveling through back yards and along roads and highways. Many of these lines are exposed to damage from falling trees and branches. Power and communications may be cut to some of these during a wildfire event.

Public utility lines travel both above and below ground along roads and cross-country to remote facilities. Many irrigation systems and wells rely on above ground power lines for electricity. These power poles pass through areas of dense wildland fuels that could be destroyed or compromised in the event of a wildfire. Cell phone service is well established in most parts of the county with only limited dead zones.

Fire Protection

The agricultural landscape type is present in all of the fire districts in Franklin County. The fire districts provide initial wildland fire protection. Mutual aid agreements between fire districts supplement wildland fire protection when needed. Only the Pasco Fire Department, Connell Fire Department, and Franklin County District #3 and District #5 have structure fire capabilities within the County. The DNR does not provide structural fire suppression, but does provide wildfire protection on non-forested land that threatens DNR-protected lands. The BLM provides wildfire protection on their ownership within Franklin County. BLM also does not provide structural fire suppression.

Potential Mitigation Activities

Mitigation measures needed in the agricultural landscape include maintaining a defensible space around structures and access routes that lie adjacent to annual crops and other wildland fuels. Around structures, this includes maintaining a green or plowed space, mowing weeds and other fuels away from outbuildings, pruning and/or thinning larger trees, using fire resistant construction materials, and locating propane tanks, fuel tanks, and firewood away from structures. Roads and driveways accessing rural residents may or may not have adequate road widths and turnouts for firefighting equipment depending on when the residences were constructed. Performing road inventories in high risk areas to document and map their access limitations will improve firefighting response time and identify areas in need of enhancement. Primitive or abandoned roads that provide key access to remote areas should also be maintained in such a way that enables access for emergency equipment so that response times can be minimized. Roads can be made more fire resistant by frequently mowing along the edges or spraying weeds to reduce the fuels. Aggressive initial attack on fires occurring along travel routes will help ensure that these ignitions do not spread to nearby home sites. Designing a plan to help firefighters control fires in CRP lands that lie adjacent to agricultural crops would significantly lessen a fire's potential of escaping to the higher value resource. Mitigation associated with this situation might include installing fuel breaks or plowing a fire resistant buffer zone around fields and along predesigned areas to tie into existing natural or manmade barriers or implementing a prescribed burning program during less risky times of the year.

Maintaining developed drafting sites, increasing access to water from irrigation facilities, and developing other water resources throughout the agricultural landscape will increase the effectiveness and efficiency of emergency response during a wildfire.

Shrub/Steppe Landscape Risk Assessment

The shrub/steppe is a dominant landscape in Franklin County, although much of it has been covered by irrigated farm fields. This unique geological feature was created by ice age floods that swept across eastern Washington and down the Columbia River Plateau periodically during the Pleistocene era. Typical vegetation found throughout this landscape is grass, mixed shrub and sagebrush with areas of wetlands, cultivated crops, and CRP fields. The shrub/steppe landscape prevails in the eastern portion of the county and along the major waterways of the Palouse and Snake Rivers. Landownership is predominantly private with large acreages owned by the U.S. Fish & Wildlife Service and the Bureau of Land Management. State ownership includes school sections 16 and 36, and the Sunnyside and Snake River Wildlife Area managed by the Washington Department of Fish and Wildlife. BLM ownership includes large continuous holdings of rangeland with an off-road vehicle park and wilderness area. Private landownership includes cattle ranches and in holdings of cultivated farmland and CRP fields. Major population centers within the shrub/steppe landscape include Connell, Kahlotus, and Mesa. New development occurs primarily near communities and along major roads. Most of the pressure for multi-housing subdivisions occurs in close proximity to the towns. Rural development is widely dispersed consisting primarily of isolated ranching headquarters, home sites, irrigation systems, and developed springs or wells. In nearly all developed areas, structures are in close proximity to vegetation that becomes a significant fire risk at certain times of the year.

Wildfire Potential

The shrub/steppe landscape has a moderate to high wildfire potential due to a characteristically high occurrence of shrubby fuels mixed with grass, sloping terrain and somewhat limited access. Large expanses of open rangeland or pasture provide a continuous fuel bed that could, if ignited, threaten structures and infrastructure under extreme weather conditions. Cattle grazing will often reduce fine, flashy fuels reducing a fire's rate of spread; however, high winds increase the rate of fire spread and intensity of rangeland fires. A wind-driven fire in dry, native fuel complexes on variable terrain produces a rapidly advancing, very intense fire with large flame lengths, which enables spotting ahead of the fire front.

Wildfire risk in the shrub/steppe landscape is at its highest during summer and fall when daily temperatures are high and relative humidity is low. Fires burning in some types of unharvested fields would be expected to burn more intensely with larger flame lengths due to the greater availability of fuels. Fields enrolled in conservation programs or managed for wildlife habitat can burn very intensely due to an increased amount of fuel build-up from previous years' growth. Fires in this fuel type are harder to extinguish completely due to the dense duff layer, which often leads to hold-over fires that may reemerge at a later date causing additional fire starts.

Ingress-Egress

Interstate 182 and State Route 260 are the primary emergency access routes traveling east to west through the county. U.S. Highway 395, State Route 17, and Highway 12 are the primary access routes running north and south. County roads as well as rural ranch access roads are well distributed throughout most of the county often following section lines or circumnavigating the multitude of draws and canyons. In remote rural areas, county roads often change from a paved or maintained gravel surface to unimproved primitive roads making access possible only during certain times of the year. Limited access within remote areas and a lack of maintenance on existing travel routes, increases fire suppression response time and has a direct effect on fire spread leading to increased fire size and destructive potential.

There are a few bridges in the shrub/steppe landscape of Franklin County. Bridge load rating signs are mostly in place for the existing bridges and do not impose a limitation to access for firefighting equipment.

Infrastructure

Residents living in the populated centers and most subdivisions surrounding the towns have access to municipal water supply systems with public fire hydrants. Outside these areas, development relies on individual, co-op, or multiple-home well systems. Creeks, ponds, and developed drafting areas provide water sources for emergency fire suppression in the rural areas to a limited extent. Irrigation systems are capable of providing additional water supply for suppression equipment on a limited basis. Additional water resources distributed and documented throughout the agricultural landscape are needed to provide water for fire suppression.

Public utility lines travel both above and below ground along roads and cross-country to remote facilities. Many irrigation systems and wells rely on above ground power lines for electricity. These power poles pass through areas of dense wildland fuels that could be destroyed or compromised in the event of a wildfire. Cell phone service is well established in most parts of the county with only limited dead zones.

Fire Protection

The shrub/steppe landscape type is present within Franklin County Fire Districts #1and #2. The fire districts provide initial wildland fire protection. Mutual aid agreements between fire districts supplement wildland fire protection when needed. Only the Pasco Fire Department, Connell Fire Department, and Franklin County District #3 and District #5 have structure fire capabilities within the County. The DNR does not provide structural fire suppression, but does provide wildfire protection on non-forested land that threatens DNR-protected lands. The BLM provides wildfire protection on their ownership within Franklin County. BLM also does not provide structural fire suppression.

Potential Mitigation Activities

Mitigation measures needed in the shrub/steppe landscape include maintaining a defensible space around structures and access routes that lie adjacent to wildland fuels. Around structures this includes maintaining a green or plowed space, mowing weeds and other fuels away from outbuildings, pruning and/or thinning larger trees, using fire resistant construction materials, and locating propane tanks and firewood away from structures. Roads and driveways accessing rural development need to be kept clear of encroaching fuels to allow escape and access by emergency equipment. Performing road inventories in high risk areas and documenting and mapping their access limitations will improve firefighting response time and identify areas in need of improvement. Primitive or abandoned roads that provide key access to remote areas should be maintained to allow access for emergency equipment so that emergency response times are minimized. Designing a plan to help firefighters control fires in conservation lands and wildlife habitat areas will significantly lessen a fire's potential of escaping to other areas. Mitigation associated with this situation might include managed grazing in designated fuel reduction areas, creating fuel breaks, and implementing a prescribed burning program during less risky times of the year.

Additional mitigation activities include installing more water storage sites, improving water access from irrigation facilities, and developing other water resources throughout the landscape. This will increase the effectiveness and efficiency of emergency response during a wildfire.

Riparian Areas Risk Assessment

The riparian landscape occurs in small to large drainages throughout the County. These areas produce high densities of shrubs and grass with scattered deciduous trees due to the relative abundance of water. Upslope from the waterway, vegetation generally resorts back to the typical shrub-steppe fuel type that dominates much of the County. Landownership in this area is mostly privately held parcels with several sections owned by the U.S. Fish & Wildlife Service and the State of Washington. These areas are generally low in population, except for the city of Pasco.

Wildfire Potential

The riparian area landscape has a moderate to high wildfire potential due to a characteristically high fuel load occurrence, terrain that can exhibit a chimney effect, high recreation use, and somewhat limited access. The steep walls contribute to rapid rates of spread by funneling fire up canyon. The high amount of fuel loading, coupled with the chimney effect, could create very intense fires.

Wildfire risk in the riparian area landscape is at its highest during summer and fall when daily temperatures are high and relative humidity is low. Fires burning in some types of riparian vegetation would be expected to burn more intensely with larger flame lengths due to the greater availability of fuels. Some riparian areas occur within narrow walls that would increase the intensity of a wildfire. These areas are not easily accessible which would compound the difficulties during fire suppression efforts. Most firefighters learn early that these areas are dangerous due to the unpredictability of fire behavior.

Ingress-Egress

Interstate 182 and State Route 260 are the primary emergency access routes traveling east to west through the county. U.S. Highway 395, State Route 17, and Highway 12 are the primary access routes running north and south. County roads as well as rural ranch access roads are well distributed throughout most of the county often following section lines or circumnavigating the multitude of draws and canyons. In remote rural areas, county roads often change from a paved or maintained gravel surface to unimproved primitive roads making access possible only during certain times of the year. Limited access within remote areas and a lack of maintenance on existing travel routes, increases fire suppression response time and has a direct effect on fire spread leading to increased fire size and destructive potential.

There are a few bridges in the riparian landscape of Franklin County. Bridge load rating signs are mostly in place for the existing bridges and do not impose a limitation to access for firefighting equipment.

Infrastructure

Unimproved campsites as well as interpretive signs are common in these areas providing recreational users with information and areas to camp. The interpretive signs can assist land managers with educating the public about the risk of wildfire and how to minimize the risk. Providing campers with fire rings keeps fires contained to specific sites and reduces the risk of an escape.

Creeks, ponds, and developed drafting areas provide water sources for emergency fire suppression in the rural areas to a limited extent. Irrigation systems are capable of providing additional water supply for suppression equipment on a limited basis. Additional water resources distributed and documented throughout the agricultural landscape are needed to provide water for fire suppression.

Public utility lines travel both above and below ground along roads and cross-country to remote facilities. Many irrigation systems and wells rely on above ground power lines for electricity. These power poles pass through areas of dense wildland fuels that could be destroyed or compromised in the event of a wildfire. Cell phone service is well established in most parts of the county with only limited dead zones.

Fire Protection

The riparian area landscape type is present in all of the Franklin County fire districts. The fire districts provide initial wildland fire protection. Mutual aid agreements between fire districts supplement wildland fire protection when needed. Only the Pasco Fire Department, Connell Fire Department and Franklin County District #3 and District #5 have structure fire capabilities within the County. The DNR does not provide structural fire suppression, but does provide wildfire protection on non-forested land that threatens DNR-protected lands. The BLM provides wildfire protection on their ownership within Franklin County. BLM also does not provide structural fire suppression.

Potential Mitigation Activities

The high fuel loading and the narrow canyons are very conducive to rapidly spreading surface fires. During a wildfire event, recreationists would have very little time to evacuate. Therefore, it is very important to educate the public on the dangers of wildfires. The use of campfires, fireworks, and other potential ignition sources should be highly regulated during the fire season, especially in areas adjacent to structures and development. Using escape-proof fire rings and BBQ pits at recreational areas, limiting off-road vehicle use to designated trails, and restricting fireworks will help reduce the potential for an ignition.

Chapter 6

Mitigation Recommendations

Critical to implementation of this Community Wildfire Protection Plan are the identification and implementation of an integrated schedule of action items targeted at achieving a reduction in the number of human caused fires and the impact of wildland fires in Franklin County. This section of the plan identifies and prioritizes potential mitigation actions, including treatments that can be implemented in the county to pursue that goal. As there are many land management agencies and thousands of private landowners in Franklin County, it is reasonable to expect that differing schedules of adoption will be made and varying degrees of compliance will be observed across various ownerships.

The primary land management agencies in Franklin County, specifically the USDI Bureau of Land Management and US Fish and Wildlife Service, Bureau of Reclamation, and Washington Department of Natural Resources are participants in this planning process and have contributed to its development. Where available, their schedule of land treatments have been considered in this planning process to better facilitate a correlation between their identified planning efforts and the efforts of Franklin County.

Franklin County encourages the building of disaster resistance in normal day-to-day operations. By implementing plan activities through existing programs and resources; the cost of mitigation is often a small portion of the overall cost of a project's implementation.

All risk assessments were made based on the conditions existing during 2013. Therefore, the recommendations in this section have been made in light of those conditions. However, the components of risk and the preparedness of the county's resources are not static. It will be necessary to fine-tune this plan's recommendations regularly to adjust for changes in the components of risk, population density changes, infrastructure modifications, and other factors.

Maintenance and Monitoring

As part of the policy of Franklin County, the Community Wildfire Protection Plan will be reviewed at least annually at special meetings of the CWPP steering committee, open to the public and involving all municipalities/jurisdictions, where action items, priorities, budgets, and modifications can be made or confirmed. Amendments to the plan should be documented and attached to the formal plan. Re-evaluation of this plan should be made on the 5th anniversary of its acceptance, and every 5-year period following.

Prioritization of Mitigation Activities

The action items recommended in this chapter were prioritized through a group discussion and voting process. The action items in Tables 6.1 – 6.5 are ranked as "High", "Moderate", or "Low" priorities for Franklin County as a whole. The CWPP committee does not want to restrict funding to only those projects that are high priority because what may be a high priority for a specific community may not be a high priority at the county level. Regardless, the project may be just what the community needs to mitigate disaster. The flexibility to fund a variety of diverse projects based on varying criteria is a necessity for a functional mitigation program at the county and community level.

Policy and Planning Efforts

Wildfire mitigation efforts must be supported by a set of policies and regulations at the county level that maintain a solid foundation for safety and consistency. The recommendations enumerated here serve that purpose. Because these items are regulatory in nature, they will not necessarily be accompanied by cost estimates. These recommendations are policy related and therefore are recommendations to the appropriate elected officials; debate and formulation of alternatives will serve to make these recommendations suitable and appropriate.

Table 6.1. Action Items in Safety and Policy.

Action Item	Goals Addressed (see page 4)	Responsible Organization	Timeline
6.1.a: Distribute Firewise-type educational brochures with occupancy permit.	**CWPP Goal #1, 2, 4, 6, 7, & 9** High	**Lead:** Planning Department **Support:** Franklin Conservation District	Ongoing
6.1.b: Standardize enforceable outdoor burning ordinance with Benton County.	**CWPP Goal #1, 5, & 9** Moderate	**Lead:** Franklin Co. Fire Marshal **Support:** Franklin County Fire Depts. & Districts	1 year
6.1.c: Fund the development of Fire Danger Rating System signs to be placed throughout the County that are consistent with Benton County.	**CWPP Goal #1, 5, & 9** Moderate	**Lead:** Franklin Co. Fire Marshal **Support:** Franklin County Fire Depts. & Districts	1 year
6.1.d: Plan with pre-triage in mind to speed up handing an incident to a new team.	**CWPP Goal #1, 2, 6, & 9** Moderate	**Lead:** Franklin Co. Emergency Management **Support:** Franklin County Fire Depts. & Districts	2 years
6.1.e: Adopt a County ordinance requiring all existing and new construction to create and maintain "defensible space" around homes.	**CWPP Goal #1, 2, 3, 5, 6, & 9** Moderate	**Lead:** Franklin Co. Commissioners **Support:** Franklin County Fire Depts. & Districts	3 years

Fire Prevention and Education Projects

The protection of people and structures will be tied together closely because the loss of life in the event of a wildland fire is generally linked to a person who could not, or did not, flee a structure threatened by a wildfire or to a firefighter combating that fire. Many of the recommendations in this section involve education and increasing wildfire awareness among Franklin County residents.

Residents and policy makers of Franklin County should recognize certain factors that exist today, the absence of which would lead to increased risk of wildland fires in Franklin County. The items listed below should be acknowledged and recognized for their contributions to the reduction of wildland fire risks:

Shrub/Steppe Management has a significant impact on the fuel composition and structure in Franklin County. The shrub/steppe management programs of the Bureau of Land Management, Bureau of Reclamation, and numerous private landowners in the region have led to a reduction of wildland fuels. Furthermore, shrub/steppe systems are dynamic and will never be completely free from risk. Treated areas will need repeated treatments to reduce the risk to acceptable levels in the long term. Recommended treatments include mechanical thinning of shrubs and/or light prescribed burning to reduce fuel loads. Monitoring invasive species in these areas will also be required.

Table 6.2. Action Items for Fire Prevention, Education, and Mitigation.

Action Item	Goals Addressed (see page 4)	Responsible Organization	Timeline
6.2.a: Implementation of youth and adult wildfire educational programs.	**CWPP Goal #1, 4, 6, & 9** High	**Lead:** Franklin Conservation District and WSU Extension **Support:** Franklin County Fire Districts and local schools	1year
6.2.b: Distribute educational information regarding construction in high risk wildfire areas.	**CWPP Goal #1, 4, 6, & 9** High	**Lead:** Franklin Conservation District and WSU Extension **Support:** Franklin County Fire Districts and local schools	1year
6.2.c: Prepare for wildfire events in high risk areas by conducting home site risk assessments and developing area-specific “Response Plans” to include participation by all affected jurisdictions and landowners.	**CWPP Goal #1, 2, 4, 6, & 9** High	**Lead:** Franklin Conservation District and WSU Extension **Support:** Franklin County Fire Districts	2 years

Table 6.2. Action Items for Fire Prevention, Education, and Mitigation.

Action Item	Goals Addressed (see page 4)	Responsible Organization	Timeline
6.2.d: Work with area homeowner's associations to foster cooperative approach to fire protection and awareness and identify mitigation needs.	**CWPP Goal #1, 2, 4, 6, & 9** High	**Lead:** Franklin Conservation District and WSU Extension **Support:** Franklin County Fire Districts	2 years
6.2.e: Work with WSU Extension, Master Gardeners, and other existing programs to offer firewise landscaping clinics to assist property owners in maintaining fire-resistant defensible space around structures.	**CWPP Goal #1, 4, 6, & 9** Moderate	**Lead:** Franklin Conservation District **Support:** Spokane Master Gardeners and WSU Extension	Ongoing
6.2.f: Develop a range of public education programs to encourage healthy management of natural resources on private property.	**CWPP Goal #1, 4, 6, & 9** High	**Lead:** Franklin Conservation District **Support:** Franklin County Fire Districts, WSU Extension, and BLM	1 year
6.2.g: Review building codes and revise to meet Firewise standards as needed**.**	**CWPP Goal #1, 3, 5, 6, 8, & 9** Low	**Lead:** CWPP Steering Committee **Support:** County Emergency Management and Building & Planning Department	5 years
6.2.h: Develop a Countywide chip day where property owners can have their slash disposed of.	**CWPP Goal #1, 2, 4, 6, & 9** Moderate	**Lead:** Franklin Conservation District **Support:** Franklin Co. Fire Districts	2 years
6.2.i: Locate funding for fuel reduction projects throughout the County, but particularly around Pasco.	**CWPP Goal #1, 2, 4, 6, 7, & 9** Moderate	**Lead:** Franklin Conservation District **Support:** Franklin Co. Fire Districts	3 years
6.2.j: Develop a residential/agriculture burning procedures pamphlet that addresses each Fire District, Pasco, and Connell.	**CWPP Goal #1, 4, 5, 6, & 9** Moderate	**Lead:** Franklin Conservation District **Support:** Franklin Co. Fire Districts	1 year
6.2.k: Fund the existing Fire Prevention/ Public Education team to continue the public information campaign addressing wildland fire, fire safety, Firewise, etc.	**CWPP Goal #1, 4, 5, 6, & 9** Moderate	**Lead:** Franklin Co. Fire Districts **Support:** Franklin Conservation District	1 year then On-going
6.2.l: Provide residents of Connell with a one-time offer to remove debris from select properties (identified by Chief) at no charge to the property owner.	**CWPP Goal #1, 6, & 9** Moderate	**Lead:** Franklin Co. Fire Districts **Support:** Franklin Conservation District	1 year

Infrastructure Enhancements

Critical infrastructure refers to the communications, transportation, power lines, and water supply that service a region. All of these components are important to central Washington and to Franklin County specifically. These networks are, by definition, a part of the wildland urban interface in the protection of people, structures, infrastructure, and unique ecosystems. Without supporting infrastructure, a community's structures may be protected, but the economy and way of life lost. As such, a variety of components will be considered here in terms of management philosophy, potential policy recommendations, and mitigation recommendations.

Table 6.3 Action Items for Infrastructure Enhancement.

Action Item	Goals Addressed (see page 4)	Responsible Organization	Timeline
6.3.b: Map, develop GIS database, and provide signage for onsite water sources such as hydrants, underground storage tanks, and drafting or dipping sites on all ownerships across the county.	**CWPP Goal #1, 2, 6, 8, & 9** High	**Lead:** Franklin County Fire Districts **Support:** Franklin County GIS Dept.	1 year
6.3.d: Develop a program to encourage landowners to put up reflective address signage on their drive to allow firefighters to better locate residences.	**CWPP Goal #1, 2, 6, 8, & 9** High	**Lead:** Planning Department **Support:** Franklin County Fire Districts, BLM	1 year
6.3.e: Develop a program to replace worn out road signage with new reflective road signs to allow firefighters to easily navigate to a wildfire.	**CWPP Goal #1, 2, 6, 8, & 9** High	**Lead:** Franklin County Fire Districts **Support:** CAD GIS Dept.	1 year
6.3.f: Provide funding to create County map books to be placed in all emergency vehicles which will allow emergency responders to navigate across jurisdictions.	**CWPP Goal #1, 6, 8, & 9** Moderate	**Lead:** Franklin County Emergency Department **Support:** Franklin County GIS Dept., Fire Districts	1 year

Resource and Capability Enhancements

There are a number of resource and capability enhancements identified by the rural and wildland firefighting districts in Franklin County. All of the needs identified by the districts are in line with increasing the ability to respond to emergencies and are fully supported by the CWPP steering committee.

The implementation of each action item will rely on either the isolated efforts of the rural fire districts or a concerted effort by the county to achieve equitable enhancements across all of the districts. Given historic trends, individual departments competing against neighboring departments for grant monies and equipment will not necessarily achieve countywide equity.

Table 6.4 Action Items for Resource and Capability Enhancements.

Action Item	Goals Addressed (see page 4)	Responsible Organization	Timeline
6.4.a: Improve departmental capability by establishing a program to increase the retention and recruitment of volunteer firefighters.	**CWPP Goal #1, 4, 6, 7, & 9** High	**Lead:** Franklin County Fire Districts **Support:** Washington DNR, and BLM	Ongoing
6.4.b: Update personal protective equipment for all fire districts in Franklin County and provide training on the importance of proper PPE.	**CWPP Goal #1, 4, 6, 7, & 9** High	**Lead:** Franklin County Fire Districts **Support:** Washington DNR, BLM	Ongoing
6.4.c: Enhance radio availability in each district, link to existing dispatch, improve range within the region, and convert to a consistent standard of radio types.	**CWPP Goal #1, 6, 8, & 9** High	**Lead:** Franklin Dispatch/Information Services **Support:** Franklin County Fire Districts	3 years
6.4.d: Obtain funding to support the Type 3 Communication Trailer including annual maintenance.	**CWPP Goal #1, 6, 8, & 9** High	**Lead:** Franklin County Emergency Management **Support:** Franklin County Fire Districts	1 year / Ongoing
6.4.e: Obtain monitors for hazardous materials, air quality, and hazmat kits to protect citizens should a wildland fire burn into areas were such things are stored.	**CWPP Goal #1, 6, & 9** High	**Lead:** Franklin County Emergency Management **Support:** Franklin County Fire Districts	2 years
6.4.f: Training for Fire Districts including FFT1, Engine Boss, ICS, etc.	**CWPP Goal #1 & 9** High	**Lead:** Region 8 Fire Training Group **Support:** Franklin County Fire Districts, DNR	Ongoing

Table 6.4 Action Items for Resource and Capability Enhancements.

Action Item	Goals Addressed (see page 4)	Responsible Organization	Timeline
6.4.g: Fire District #2 & #5 need fire hose and wildland fire engine upgrades.	**CWPP Goal #1 & 9** High	**Lead:** Franklin County Fire Districts #2 & #5 **Support:** Franklin County Emergency Management	2 years
6.4.h: Upgrade Connell Fire department's firefighting apparatus.	**CWPP Goal #1 & 9** High	**Lead:** Connell Fire Department **Support:** Franklin County Fire Districts	3 years
6.4.i: Fire and EMS training designed for law enforcement needs for County dispatch.	**CWPP Goal #1, 8, & 9** High	**Lead:** Franklin County Emergency Management **Support:** Franklin County Fire Districts	2 years
6.4.j: Upgrade and interlink the County's CAD system to accurately fulfill resource requests.	**CWPP Goal #1, 8, & 9** High	**Lead:** Franklin County Emergency Management **Support:** Franklin County Fire Districts	2 years
6.4.k: Purchase water tenders and Type 3 engines to be used in both rural and suburban settings.	**CWPP Goal #1 & 9** High	**Lead:** Franklin County Fire Districts **Support:** Franklin County Emergency Management	3 years
6.4.l: Support the County Emergency Management activation of the Emergency Operations Center during a large wildland fire and other disasters.	**CWPP Goal #1, 8, & 9** High	**Lead:** Franklin County Fire Districts **Support:** Franklin County Sheriff's Department	Ongoing
6.4.m: Train local firefighters to perform home assessments which will provide home owners with quality advice on how to make their homes defensible.	**CWPP Goal #1, 4, 6, & 9** High	**Lead:** Region 8 Fire Training Group **Support:** Franklin County Fire Districts, DNR	Ongoing

Proposed Project Areas

The following project areas were identified by the CWPP steering committee and from citizens' recommendations during the public meetings. Most of the sites were visited during the field assessment phase. The areas where these projects are located were noted as having multiple factors contributing to the potential wildfire risk to residents, homes, infrastructure, and the ecosystem. Treatments within the project areas will be site specific, but will likely include homeowner education, creation of a wildfire defensible space around structures, fuels reduction, and access corridor improvements. All work on private property will be performed with consent of, and in cooperation with the property owners. Specific site conditions may call for other types of fuels reduction and fire mitigation techniques as well. Defensible space projects may include, but are not limited to thinning, pruning, brush removal, chipping, noncombustible building materials, noncombustible perimeter around structures, and general range health improvements.

Table 6.5. Proposed 5- Year Fuels Reduction Project Areas.

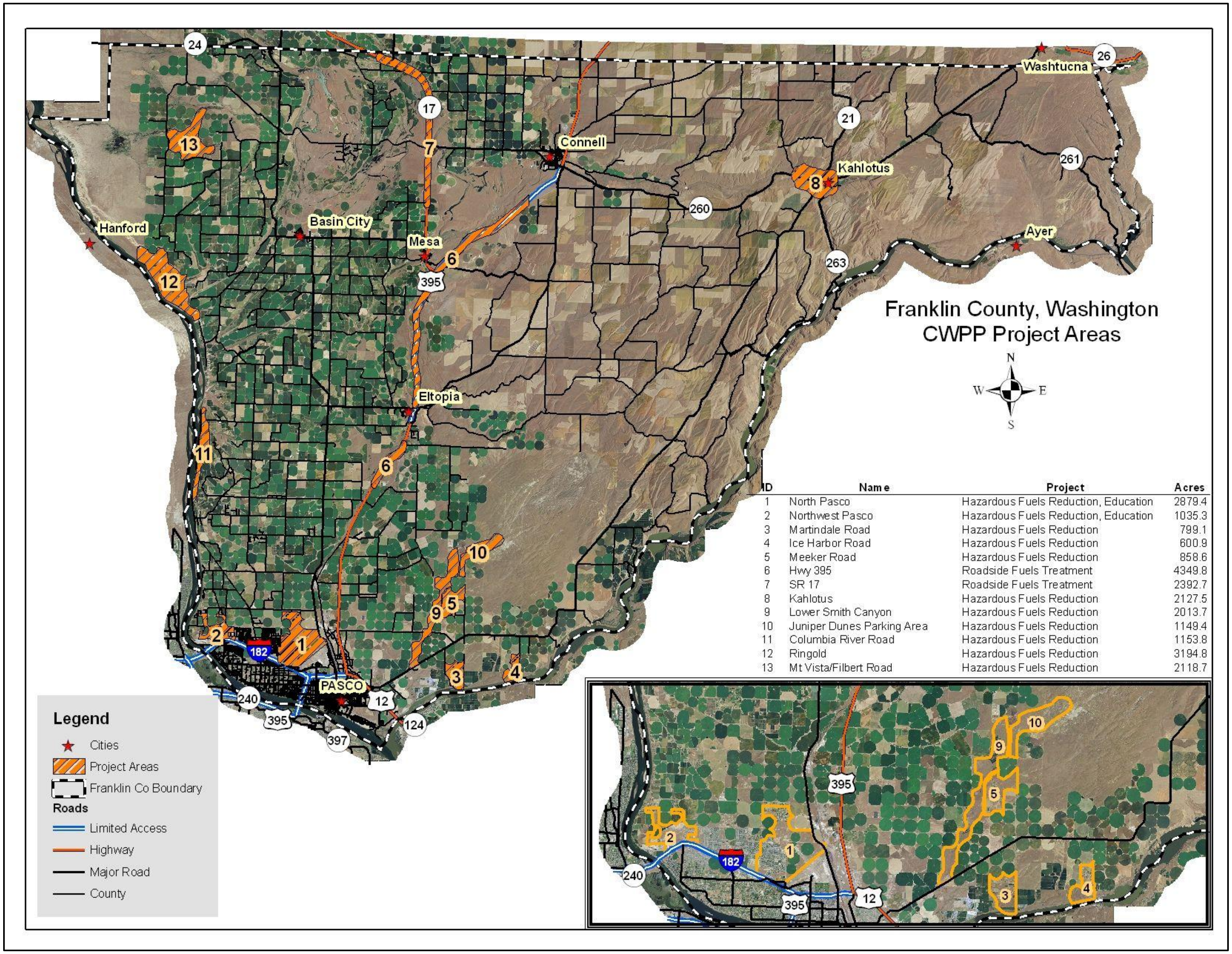
Map Id#	Project Name	# of Acres	# of Structures	Priority
1	North Pasco	2,879	2311	Moderate
2	Northwest Pasco	1,035	494	Low
3	Martindale Road	799	53	High
4	Ice Harbor Road	601	26	Moderate
5	Meeker Road	859	41	Moderate
6	Highway 395	4,350	2	Moderate
7	State Route 17	2,393	3	Moderate
8	Kahlotus	2,128	62	High
9	Lower Smith Canyon	2,014	0	Moderate
10	Juniper Dunes Parking Area	1,149	0	Moderate
11	Columbia River Road	1,154	4	Moderate
12	Ringold	3,195	0	Moderate
13	Mt. Vista/Filbert Road	2,119	0	Moderate
14	Basin City			Moderate

The steering committee does not want to restrict funding to only those projects that are high priority because what may be a high priority for a specific community may not be a high priority at the county or agency level. Regardless, the project may be just what the community needs to mitigate disaster. The flexibility to fund a variety of diverse projects based on varying criteria, landowner participation, and available dollars is a necessity for a functional mitigation program at the county and community level.

During the next 5 years, Franklin County will continue to search for opportunities to complete projects. These projects may include point protection program, chipping programs, educational pamphlets, public relations/education, and Fire Danger Rating System signs for Kahlotus, Fire District #2, and #4.

The Washington Department of Natural Resources, Bureau of Land Management, Conservation District, and/or individual Fire Protection Districts may take the lead on implementation of many of these projects; however, project boundaries were purposely drawn without regard to land ownership in order to capture the full breadth of the potential wildland fire risk. Coordination and participation by numerous landowners will be required for the successful implementation of the identified projects. A map of the Proposed Project Areas is included on the following page.

Figure 6.1. Map of Proposed Projects.



ID	Name	Project	Acres
1	North Pasco	Hazardous Fuels Reduction, Education	2879.4
2	Northwest Pasco	Hazardous Fuels Reduction, Education	1035.3
3	Martindale Road	Hazardous Fuels Reduction	799.1
4	Ice Harbor Road	Hazardous Fuels Reduction	600.9
5	Meeker Road	Hazardous Fuels Reduction	858.6
6	Hwy 395	Roadside Fuels Treatment	4349.8
7	SR 17	Roadside Fuels Treatment	2392.7
8	Kahlotus	Hazardous Fuels Reduction	2127.5
9	Lower Smith Canyon	Hazardous Fuels Reduction	2013.7
10	Juniper Dunes Parking Area	Hazardous Fuels Reduction	1149.4
11	Columbia River Road	Hazardous Fuels Reduction	1153.8
12	Ringold	Hazardous Fuels Reduction	3194.8
13	Mt Vista/Filbert Road	Hazardous Fuels Reduction	2118.7

Representative Fuels Treatment Project Prescriptions

The following project areas were identified during the field assessments and interviews as potentially having several factors contributing to high wildfire risk as well as being representative of the types of projects likely to be pursued for grant funding. The intent is that these project prescriptions be as site specific as possible, but serve as templates for writing prescriptions for similar projects throughout the County. These projects/templates will aid land stewards in applying for grants specific to their property. The chosen project areas do not reflect the highest priority projects identified by the steering committee, but were written for communities with a high level of existing interest in implementation.

- The Columbia River Road project area consists of numerous homes that have been built on a plateau above the Columbia River. Moderate slope exists between the homes and the river with scattered shrubs and grasses. Many homes have irrigated landscaping and noncombustible roofing.
- Highway 395 is a main corridor connecting Interstates 90 and 82 and serves to connect Spokane to the Tri-Cities. This project area crosses numerous ownerships, both private and public. Vegetation along this stretch of road is primarily grass with scattered shrubs. Irrigated agriculture is prevalent on the west side of the highway, while vast acreage of dryland agriculture and CRP extends eastward.
- Martindale is a small cluster of homes nestled within vast acreages of agriculture along the Snake River. Much of the surrounding area is irrigated agriculture but there are significant native grasses and shrubs that extend from the river, through the community, and continues to the northeast.

The project areas were identified without regard for landownership boundaries; thus, site-specific prescriptions will require coordination and approval by the various landowners. The following descriptions provide as much detail as possible regarding the objectives, prescription, and unique nature of each project; however, exact acreages and site plans will be determined after consultation with the affected landowners. The prescriptions described in the following projects may be modified to suit other similar projects, for example the Martindale project may apply to the Pasco project area.

Columbia River Road

This project area encompasses a stretch of the breaks that occur along the Columbia River. Slopes encountered in this project area are moderately steep and extremely unstable as evidenced by the numerous landslides that have occurred over the years. Several homes have been constructed on a bench adjacent to the Columbia River. Dryland and irrigated agriculture exists to the east of this project area. Many of the homes are situated on the break of a moderately steep slope which can increase fire activity and expose the homeowners to higher intensity wildland fires. Embers would be another concern for most of the homeowners in this project area, as they can collect in gutters and under decks, and may ignite homes regardless of having an irrigated lawn.

The surrounding vegetation consists of various bunchgrass species as well as scattered shrubs. Invasive weeds such as cheatgrass do occur and have been known to increase the length of the fire season because this species cures much earlier than native grasses. Only four homes exist in the current project area; however, the perimeter could easily be expanded to include numerous others.

Columbia River Road is the primary access to this area, but it does not pass through because of frequent landslide activity. Numerous ATV trails occur at the southern end of this project area which can increase the ignition potential during dry conditions.

Project Prescription

Homeowners will manage their property with Firewise principles in mind. This means that structures will have a non-combustible material around the perimeter and extending out three to five feet from the structure. Shrubs within thirty feet from any structure will be heavily thinned (2.5 times a shrub's height between shrubs). They will also be mindful of anywhere that embers could accumulate and ignite such as patio furniture cushions, decks, roof vents, etc.

Education is often the most critical part in protecting a community such as that in theColumbia River project area. Often, having a trained individual perform a home assessment for a homeowner is sufficient. The home assessment determines a score which tells the homeowner the level of risk their property would face in the event of a wildland fire. The trained individual will then provide advice on how to minimize the risks identified in the home assessment.

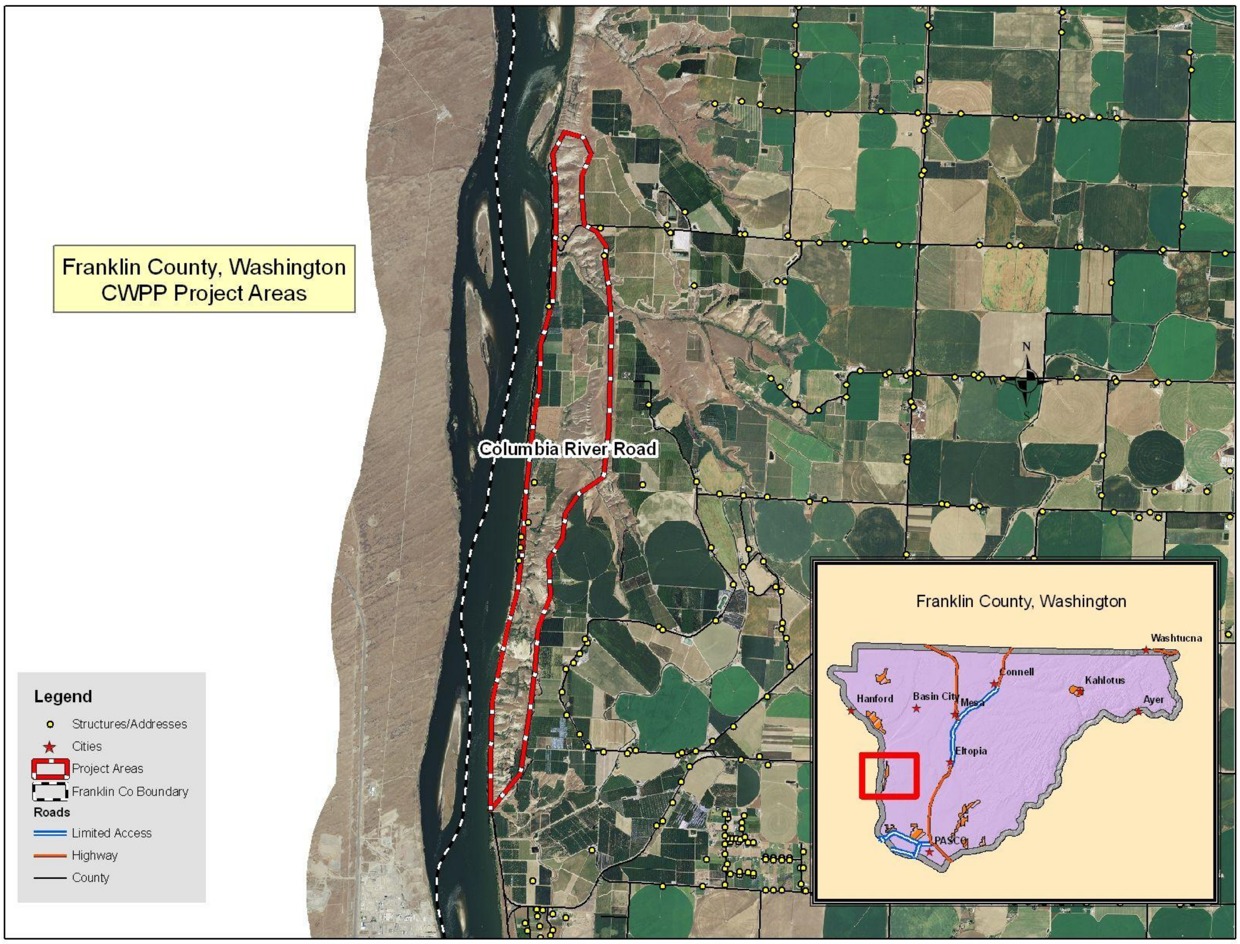
A community workshop is another form of education that will benefit the community. The workshop will be scheduled for a weekend that allows as many people to attend as possible. Free lunch and fire safe plant giveaways are a great way to get people to attend. Experts from Bureau of Land Management, Washington Department of Natural Resources, conservation districts, weed boards, consultants, and any others will be invited to attend to provide the homeowners with advice.

Select a property to be a 'demo' for other properties to use as guidance can also be a useful tool in educating a community. The demo property will be in a highly visible location and the property owner should be extremely motivated to maintain the property and provide encouragement to neighbors. Homeowners are often reluctant to cut down any trees because they want it to look natural and not like a clearcut. Providing these homeowners with a property that allows them to visualize what their property will look like often gets them over that hurdle.

A fuel break will be developed on the slope just north of the landslide area. The fuel break would run up the slope at a width of at least fifty feet. Fuels in this fifty foot strip would be reduced to approximately 2.5 times a shrub's height between shrubs. Invasive weeds will be treated with appropriate herbicide annually if necessary. Slash may be piled and burned during the wet season, or chipped and spread back onto the landscape to reduce erosion.

Persons initiating work in any proposed project areas should refer to the County's Critical Areas Ordinance http://www.co.franklin.wa.us/planning/documents/AdoptedCriticalAreasOrdinance3-2009-asamended2012.pdf to determine if the project is within, adjacent to, or is likely to impact a critical area. The Critical Areas Planning Director may be consulted to determine if a project will impact a critical area and a waiver may be given.

Figure 6.2. Columbia River Project Area Map.



[This page intentionally left blank.]

Highway 395

The purpose of this project area is to provide a buffer between the heavily traveled highway and the wildland fuels to the east. The large amount of traffic through this project area creates a very high, human-caused ignition potential. The summer of 2013 witnessed several roadside fires ignited along Highway 395 near Connell that were believed to be caused by a defective wheel bearing on a tractor trailer. This particular event was extinguished relatively quickly primarily because of its close proximity to Connell and easy access. For a wildland fire exhibiting rapid rates of spread through the unbroken fuels east of the highway, potentially impacting Kahlotus, Washtucna, and beyond, is not unimaginable.

A majority of the landscape west of the highway is irrigated agriculture that may burn on occasion. East of the highway is mostly dryland agriculture, CRP fields, or natural fuels. The natural vegetation is comprised of native bunchgrasses, scattered shrubs, and invasive species (cheatgrass).

Highway 395 is a main travel route between Interstate 90 and 82 that connects Spokane with the Tri-cities. Highway 17 intersects with Highway 395 in Mesa. Highway 17 travels north from Mesa passing through Othello, Moses Lake, and Soap Lake before terminating in Brewster.

Project Prescription

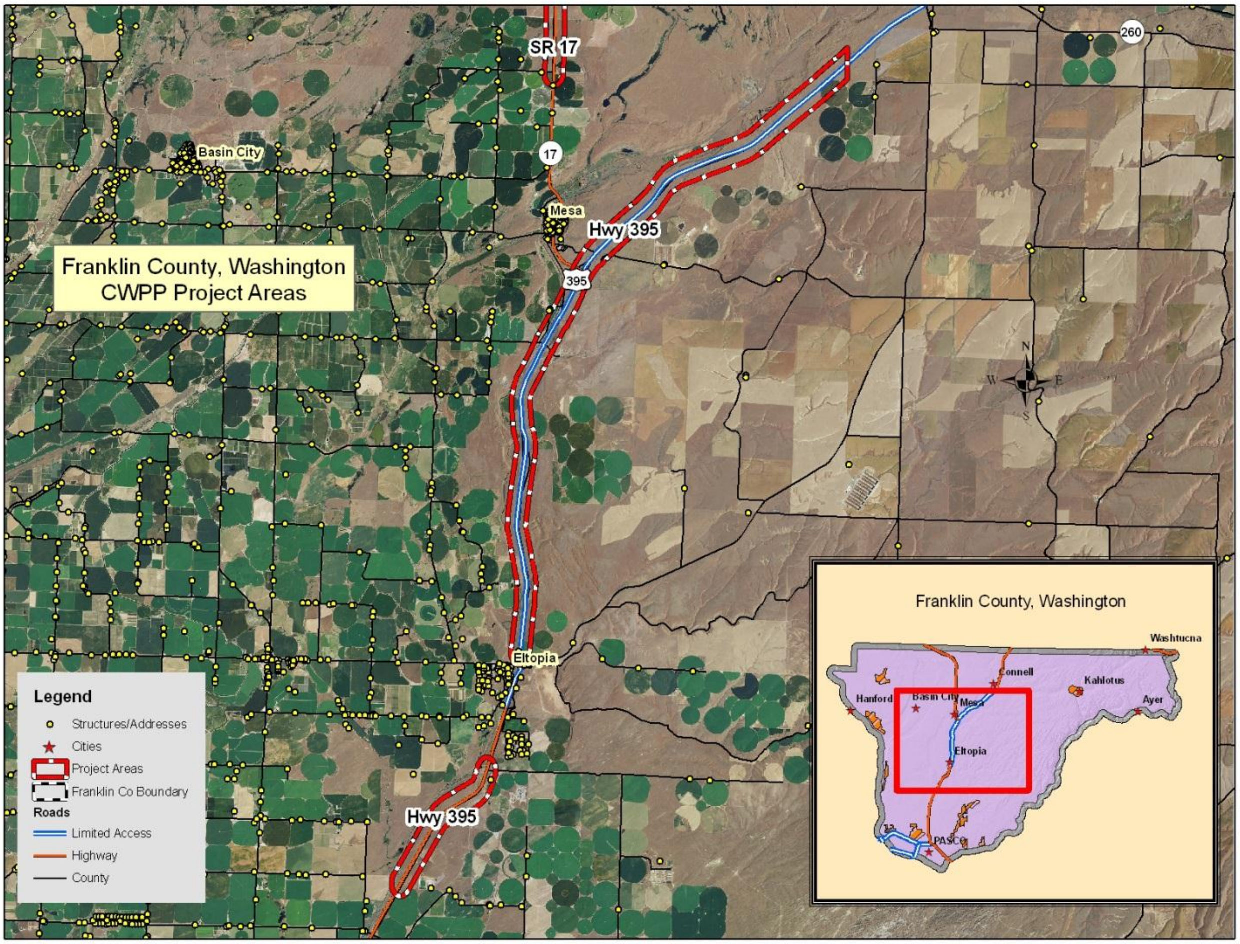
The Highway 395 project encompasses numerous landowners both private and public. Due to the size of this project, it may be necessary to split the project into several sections and complete one or two sections per year.

Prescribed burning does not appear to be an option for this project due to liability issues and unlikely landowner agreement. Therefore it is recommended that a fuel break be created parallel to the highway. This fuel break will be constructed by disking a ten to fifteen foot wide strip along the east and west sides of the highway. This could also be achieved through mowing however it would not be as effective. The fuel break will lie completely within the road right-of-way and will not require adjacent landowner permission.

The fuel break will be initiated prior to the growing season (i.e. April) and maintained through the wildfire season (i.e. October).

Controlling the spread of invasive plant species in disturbed areas is a major concern in Franklin County. The Franklin County Noxious Weed Board will be asked to provide guidance and/or assistance with monitoring invasive weeds within the treated areas. If treatments are required, the Franklin County Noxious Weed Board should be consulted to determine the proper herbicide to use, time of year to apply, and how often to apply.

Figure 6.3. Highway 395 Project Area Map.



Martindale

The Martindale project is a small cluster of approximately fifty structures just north of the Snake River near the confluence of the Snake and Columbia Rivers. There is irrigated agriculture bounding this community on the west, north, and lower half of the east flanks. Throughout the community there are many areas of natural vegetation that continues towards the northeast and through another small cluster of homes. The terrain is gently rolling with some minor drainages that lead to the river.

The Martindale Road provides river access for recreating, fishing, and boating. These activities increase the ignition potential for this area. Fire Danger Rating signs should be erected to educate users of the wildand fire risk in the area.

Project Prescription

Homeowners should manage their property with Firewise principles in mind. This means that structures should have a three to five foot wide strip of non-combustible material around the perimeter of the structure. Shrubs that occur within thirty feet of the structure should be heavily thinned (2.5 times a shrub's height between shrubs or clusters of shrubs).

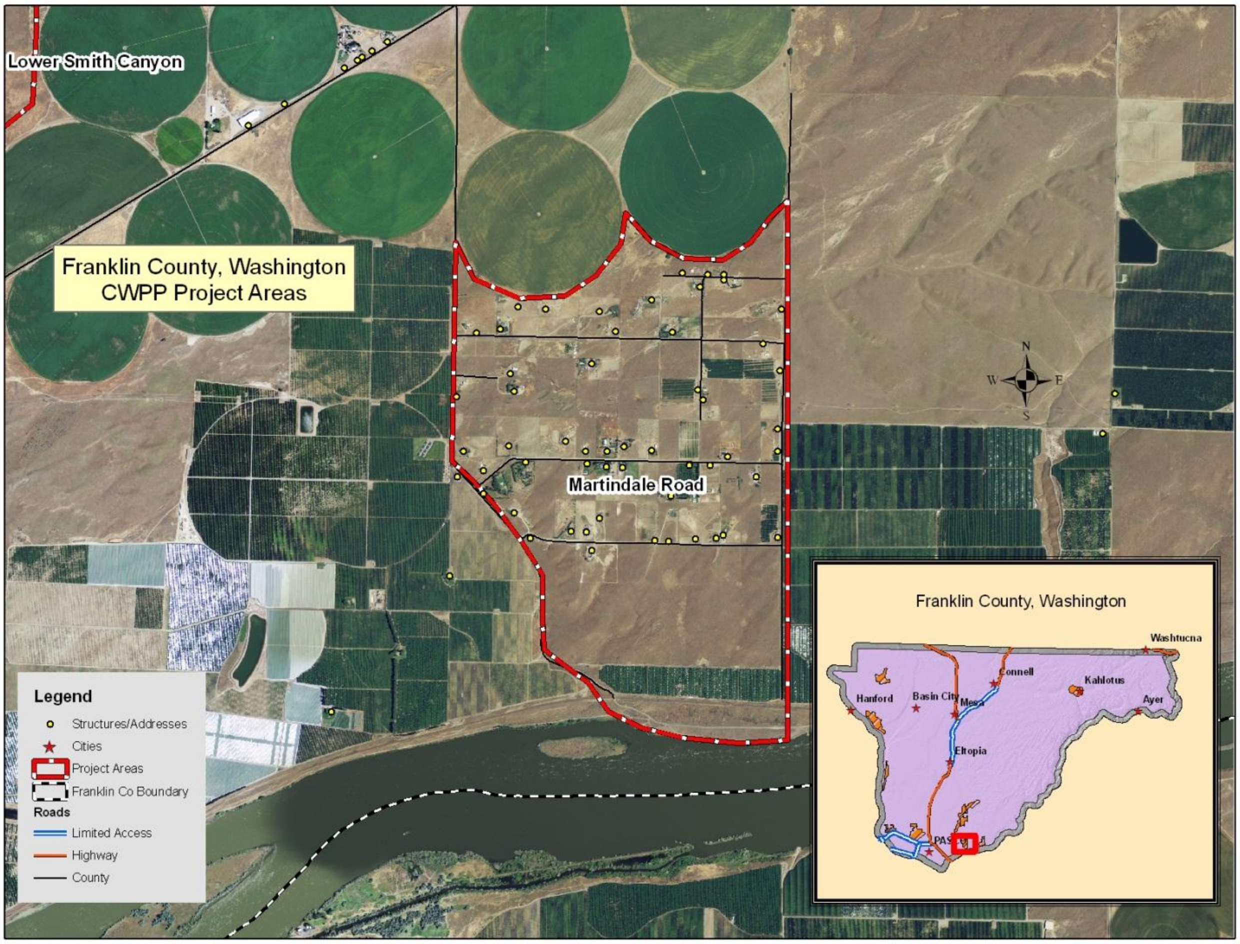
Roadside fuels will be treated to create fuel breaks throughout the community. This will also enable fire apparatus to gain access to structures if needed. This will be achieved through a thirty foot 'buffer' in addition to the road width. The buffer can be done on one side of the road or thirty feet on each side of the road. Roadside treatments should include thinning shrubs to the same standards as mentioned above. Monitor and spray herbicides to reduce invasive weeds along roads and around homes.

Education is often the most critical part in protecting a community such as Martindale. Often, having a trained individual perform a home assessment for a homeowner is sufficient. The home assessment determines a score telling the homeowner the level of risk their property would face in the event of a wildland fire. The trained individual would then provide advice on how to minimize the risks identified in the home assessment.

A community workshop is another form of education that will benefit the community. The workshop will be scheduled for a weekend that allows as many people to attend as possible. Free lunch and fire safe plant giveaways are a great way to get people to attend. Experts from Bureau of Land Management, Washington Department of Natural Resources, conservation districts, weed boards, consultants, and any others will be invited to attend to provide the homeowners with advice.

Select a property to be a 'demo' for other properties to use as guidance can also be a useful tool in educating a community. The demo property will be in a highly visible location and the property owner should be extremely motivated to maintain the property and provide encouragement to neighbors. Homeowners are often reluctant to cut down any trees because they want it to look natural and not like a clearcut. Providing these homeowners with a property that allows them to visualize what their property will look like often gets them over that hurdle.

Figure 6.4. Martindale Project Area Map.



Regional Land Management Recommendations

Wildfires will continue to ignite and burn depending on the weather conditions and other factors enumerated earlier. However, active land management that modifies fuels, promotes healthy shrubland and grassland conditions, and promotes the use of natural resources (consumptive and non-consumptive) will ensure that these lands have value to society and the local region. The Washington DNR, Washington Department of Fish and Wildlife Service, BLM, Bureau of Reclamation, private landowners, and all agricultural landowners in the region should be encouraged to actively manage their wildland-urban interface lands in a manner consistent with reducing fuels and wildfire risks.

Targeted Livestock Grazing

Livestock grazing, particularly cattle, has been a long standing tradition in the rangelands of central Washington. Historically, ranchers were able to make agreements with state and federal land managers to expand their grazing operations on public ground for mutual benefit. In the last 30 years, this practice has been limited due to liability issues, environmental concerns, and litigation. Additionally, where federal grazing allotments are still available, the restrictions on timing are often inappropriate and/or too inflexible for the objectives of reducing fuel loads (i.e. wildfire risk), eradicating noxious and invasive species, and restoring native grass and sagebrush communities.

Most rangeland ecologists agree that in site-specific situations, livestock can be used as a tool to lower fire risk by reducing the amount, height, and distribution of fuel. Livestock can also be used to manage invasive weeds in some cases and even to improve wildlife habitat.

Targeted grazing can indeed reduce the amount, height, and distribution of fuel on a specific rangeland area, potentially decreasing the spread and size of wildfires under normal burning conditions. By definition, "targeted" or "prescribed" grazing is the use of an appropriate kind of livestock at a specified time, duration, and intensity to accomplish a specific vegetation management goal.

There are many factors to consider regarding the use of livestock for reducing the amount, height, and continuity of herbaceous cover (especially cheatgrass) in site-specific situations:

- During the spring, cheatgrass is palatable and high in nutritional value before the seed hardens. Repeated intensive grazing (two or three times) at select locations during early growth can reduce the seed crop that year, as well as the standing biomass. In areas where desirable perennial species are also present, the intensive grazing of cheatgrass must be balanced with the growth needs of desired plants that managers and producers want to increase.
- Late fall or winter grazing of cheatgrass-dominated areas, complemented with protein supplement for livestock, should also be considered. After the unpalatable seeds have all dropped, cheatgrass is a suitable source of energy, but low in protein. Strategic intensive grazing of key areas can reduce carry-over biomass that would provide fuel during the next fire season. Late fall grazing can also target any fall-germinating cheatgrass before winter dormancy, thus reducing the vigor of these plants the following spring. Fall/winter grazing when desirable perennial grasses are dormant and their seeds have already dropped, results in minimal impact to these species and therefore can be conducted with minimal adverse impact to rangeland health in many areas.
- The Bureau of Land Management (BLM) in some locations has an active "green-strip" program designed to reduce fire size and spread in key areas. Obviously, livestock can be used to maintain such green-strips to reduce the fine fuels (grasses) and control the spread of fire.
- The concept of "brown-strips" refers to areas where one or more treatments (prescribed fire, mechanical thinning, herbicide, and/or grazing) are used to reduce shrub cover, releasing the native perennial grasses. These grassy areas are preferred by cattle, which

can then be grazed to reduce herbaceous fuels. This method leaves "brown-strips" when the stubble dries out in mid-summer, serving as fuel breaks to control the spread of wildfire. Where appropriate, protein-supplemented cows or sheep could be used to intensively graze and create brown-strips (e.g. along fences) to reduce the spread of fires during or after years of excess fuel build-up.

- Targeted grazing for the management of herbaceous fuels often requires a high level of livestock management, especially appropriate timing, as well as grazing intensity and frequency. In order to meet prescription specifications, operators often use herders, portable fencing, and/or dogs to ensure pastures are grazed to specification before the livestock are moved. Other expenses may include feed supplements, guardian dogs and/or night enclosures for protection from predators, water supply portability, mobile living quarters, and grazing animal transport. Targeted grazing is a business whose providers must earn a profit. Therefore, land management agencies need the option of contracting such jobs to willing producers and paying them for the ecosystem service rendered. This payment approach is already being implemented in some private and agency-managed areas to a limited extent, primarily for control of invasive perennial weeds. The use of and payment for prescription livestock grazing as a tool has substantial potential in the immediate and foreseeable future for managing vegetation in site-specific situations.
- In general, and less intensively, livestock can be used strategically by controlling the timing and duration of grazing in prioritized pastures where reduction of desirable perennial grass cover is needed for fire reduction purposes. Strategic locations could be grazed annually to reduce fuel loads and continuity at specific locations. Rotation of locations across years prevents overgrazing of any one area but confers the benefits of fuel load reductions to much larger landscapes. Even moderate grazing and trampling can reduce fuels and slow fire spread.[38]

Dormant season grazing of perennial grasses has also been reported to aid in seedling recruitment. Some seeds require scarification before they will germinate. That can be accomplished by passage through the digestive tract or by hoof action on the seed. Hoof action can also press the seed into the ground and compress the soil around it, i.e. preparing a beneficial seed bed. These processes can also reasonably be expected to provide some benefit to the exotic annual grasses. These grasses; however, appear to succeed very well without that assistance. One can speculate that the perennial grasses would demonstrate a greater response to these effects and thus would gain some edge in the struggle for dominance with the exotic annuals. If those annuals were also grazed in the early spring before the perennials started or during fall germination events, or both, it is likely the annuals would have less vigor and produce less seed

[38] McAdoo, Kent, et al. "Northeastern Nevada Wildfires 2006: Part 2 – Can Livestock Grazing be Used to Reduce Wildfires?" University of Nevada Cooperative Extension. Fact Sheet-07-21. Available online at http://www.unce.unr.edu/publications/files/nr/2007/fs0721.pdf. Accessed June 2011.

which would detract from their ability to out compete the perennials.[39] While the exact details of how the perennials benefit from dormant season grazing are not fully understood, Agricultural Research Service research in Nevada has reported success in decreasing annual grass dominance.

Targeted grazing can reduce wildfire risk in specific areas. The targeted grazing strategies discussed above all require a very flexible adaptive management approach by both land management agencies and targeted grazing providers. Managers must determine objectives, then select and implement the appropriate livestock grazing prescription, monitor accomplishments, and make adjustments as needed.[40]

Many local residents feel that livestock grazing is a more desirable tool for managing wildland fire risk on both private and public lands because it poses less risk than prescribed burning, is less expensive than chemical applications, can be managed effectively for the long-term, and it benefits a large sector of the local economy.

[39] Schmelzer, L., Perryman, B. L., Conley, K., Wuliji, T., Bruce, L. B., Piper, K. 2008. *"Fall grazing to reduce cheatgrass fuel loads"*. Society for Range Management 2008.

[40] McAdoo, Kent, et al. "Northeastern Nevada Wildfires 2006: Part 2 – Can Livestock Grazing be Used to Reduce Wildfires?" University of Nevada Cooperative Extension. Fact Sheet-07-21. Available online at http://www.unce.unr.edu/publications/files/nr/2007/fs0721.pdf. Accessed June 2011.

[This page intentionally left blank.]

Chapter 7

Supporting Information

List of Tables

List of Figures

Signature Pages

This Franklin County Community Wildfire Protection Plan has been developed in cooperation and collaboration with representatives of the following organizations and agencies.

Franklin County Commissioners

Brad Peck - Absent | n/a

Brad Peck | Date

Franklin County Commissioner District #1

May 21, 2014

Robert Koch | Date

Franklin County Commissioner District #2

May 21, 2014

Rick Miller | Date

Franklin County Commissioner District #3

FRANKLIN COUNTY RESOLUTION NO. 2014 220

BEFORE THE BOARD OF COUNTY COMMISSIONERS, FRANKLIN COUNTY, WASHINGTON

RE: FRANKLIN COUNTY, WASHINGTON COMMUNITY WILDFIRE PROTECTION PLAN, MAY 2014

WHEREAS, the Board of County Commissioners of Franklin County understand the necessity to mitigate, prepare for, respond to and recover from disasters and other extraordinary emergencies, both natural and human caused; and

WHEREAS, a planning committee representing Franklin County has coordinated an extensive plan to help our county and responders refine their priorities and management for the protection of life, property and critical infrastructure in the wildland-urban interface on both public and private land; and

WHEREAS, the Board of Franklin County Commissioners constitutes the legislative authority of Franklin County and desires approve the Franklin County, Washington Community Wildfire Protection Plan, May 2014:

NOW, THEREFORE, BE IT RESOLVED that the Franklin County Board of Commissioners hereby approves the attached Franklin County, Washington Community Wildfire Protection Plan, May 2014.

APPROVED this 21st day of May, 2014.

BOARD OF COUNTY COMMISSIONERS
FRANKLIN COUNTY, WASHINGTON

Robert E. Koch, Chairman

Brad Peck - Absent

Brad Peck, Chair Pro Tem

Rick Miller, Member

Attest:

Margo Hines

~~Mary Withers~~, Clerk to the Board

Signatures of Participation by Franklin County Fire Districts and Departments

This Community Wildfire Protection Plan and all of its components identified herein were developed in close cooperation with the participating entities listed. These members of the CWPP steering committee formally recommended that this document be adopted by the Franklin County Commissioners.

	5-21-14
Eric Mauseth, Chief Franklin County Fire District #1	Date
	5-28-14
Luke Vanhollenbeke, Chief Franklin County Fire District #2	Date
	5-21-2014
Mike Harris, Chief Franklin County Fire District #3	Date
	5-21-14
Steve Cooper, Chief Franklin County Fire District #4	Date
	5/28/14
Bryan Thornhill, Chief Franklin County Fire District #5	Date

5-24-14

Bob Gear, Chief

Pasco Fire Department

Date

May 19, 2014

Bruce Blackwell, City of Connell Mayor

Date

Signatures of Participation by other Franklin County CWPP Steering Committee Entities

This Community Wildfire Protection Plan and all of its components identified herein were developed in close cooperation with the participating entities listed. These members of the CWPP steering committee formally recommended that this document be adopted by the Franklin County Commissioners.

05-21-14

Sean Davis, Director
Franklin County Emergency Management

Date

06/02/2014

Joe Weeks, Landowner Assistance Coordinator
Southeast Region Washington State Department of Natural Resources

5/14/14

Aaron Everett, Deputy Supervisor,
Forest Practices and Federal Relations, State Forester, Washington State Department of Natural Resources

Date

6/5/14

Linda Clark, Border Resource Manager
Spokane District Bureau of Land Management

Date

June 4,2014

Brad Tucker, Project Co-Manager
Northwest Management, Inc.

Date

This plan was developed by Northwest Management, Inc. under contract with the Bureau of Land Management and Franklin County Emergency Management.

Citation of this work:

Tucker, Brad and V. Bloch. *Lead Authors.* 2014 Franklin County, Washington Community Wildfire Protection Plan. Northwest Management, Inc., Moscow, Idaho. Pp 103.

Tucker, Brad and V. Bloch. *Lead Authors.* 2014 Franklin County, Washington Community Wildfire Protection Plan Appendices. Northwest Management, Inc., Moscow, Idaho. Pp 61.

Northwest Management, Inc.
233 East Palouse River Drive
PO Box 9748
Moscow ID 83843

208-883-4488 Telephone
208-883-1098 Fax
NWManage@consulting-foresters.com
http://www.Consulting-Foresters.com/

Soils Pasco Proposed Urban Growth Area (UGA) Expansion June 2020

Soils NW Part of Pasco UGA Expansion

Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**	**Farmland Classification**
10	Chedehap fine sandy loam, 0 to 2 percent slopes	297.1	10.4%	Prime farmland if irrigated
11	Chedehap fine sandy loam, 2 to 5 percent slopes	45.5	1.6%	Prime farmland if irrigated
89	Quincy loamy fine sand, 0 to 15 percent slopes	1,509.6	52.8%	Farmland of statewide importance
90	Quincy loamy fine sand, 15 to 30 percent slopes	126.1	4.4%	
96	Quincy-Dune land complex, 5 to 40 percent slopes	23.7	0.8%	
102	Quincy-Timmerman complex, 0 to 15 percent slopes	318.0	11.1%	Farmland of statewide importance
128	Royal fine sandy loam, 0 to 2 percent slopes	49.6	1.7%	Prime farmland if irrigated
129	Royal fine sandy loam, 2 to 5 percent slopes	145.4	5.1%	Prime farmland if irrigated
184	Timmerman fine sandy loam, 2 to 5 percent slopes	40.0	1.4%	Prime farmland if irrigated
217	Winchester loamy coarse sand, 2 to 5 percent slopes	305.2	10.7%	
Totals for Area of Interest		2,860.3	100.0%	
Prime Farmland Total		577.6	20.2%	
Farmland of Statewide Importance Total		1,827.6	63.9%	

Soils NE Part of Pasco UGA Expansion

Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**	**Farmland Classification**
4	Burbank loamy fine sand, 0 to 5 percent slopes	24.6	4.0%	
5	Burbank loamy fine sand, 5 to 10 percent slopes	2.9	0.5%	
29	Hezel loamy fine sand, 0 to 15 percent slopes	6.0	1.0%	Farmland of statewide importance
44	Kennewick silt loam, 2 to 5 percent slopes	3.4	0.6%	Prime farmland if irrigated
76	Pits	91.5	14.9%	
89	Quincy loamy fine sand, 0 to 15 percent slopes	356.4	58.2%	Farmland of statewide importance
92	Quincy loamy fine sand, loamy substratum, 0 to 10 percent slopes	13.5	2.2%	Farmland of statewide importance
126	Royal loamy fine sand, 0 to 10 percent slopes	0.4	0.1%	Farmland of statewide importance
128	Royal fine sandy loam, 0 to 2 percent slopes	60.6	9.9%	Prime farmland if irrigated
129	Royal fine sandy loam, 2 to 5 percent slopes	36.3	5.9%	Prime farmland if irrigated
144	Sagemoor very fine sandy loam, 0 to 2 percent slopes	0.3	0.0%	Prime farmland if irrigated
183	Timmerman fine sandy loam, 0 to 2 percent slopes	6.5	1.1%	Prime farmland if irrigated
184	Timmerman fine sandy loam, 2 to 5 percent slopes	10.0	1.6%	Prime farmland if irrigated
Totals for Area of Interest		612.2	100.0%	
Prime Farmland Total		117.1	19.1%	
Farmland of Statewide Importance Total		376.3	61.5%	

Total for Both UGA Expansions Areas

Prime Farmland	694.7	20.0%
Farmland of Statewide Importance	2,203.9	63.5%
Total	2,898.6	83.5%

AOI means Area of Interest, the UGA expansion areas

Source: United States Department of Agriculture Natural Resources Conservation Service Web Soil Survey
Accessed on June 4, 2020 at:
https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

SOUTHERN RESIDENT KILLER WHALE PRIORITY CHINOOK STOCKS

Outline of Prey Prioritization Conceptual Model

NOAA and WDFW have developed a framework to identify Chinook salmon stocks that are important to Southern Resident killer whales to assist in prioritizing actions to increase critical prey for the whales. The framework currently includes three factors that contribute to the identification of priority Chinook salmon populations. Note, here "population" could mean management unit, stock, ESU, run, etc. Each of the three factors has a range of scores which affects its weight. For each Chinook population ranging from Southeastern Alaska to California, a total score is calculated by adding up the three individual factor scores. The Chinook salmon populations with the highest total scores are considered the highest priority to increase abundance to benefit the whales. Several sensitivity analyses provided initial help in understanding how the weighting/scoring affects the priority list. The conceptual model, factors, and scoring were reviewed at a workshop sponsored by the National Fish and Wildlife Foundation and modifications were made to incorporate feedback from participants. The factors, scoring and priority list can be adapted as new scientific information becomes available.

The three evaluation factors include:

FACTOR 1- Observed Part of SRKW Diet

Description and data sources: Prey tissues/scales and fecal samples have been collected from 2004 – present (Hanson et al. 2010, Ford et al. 2016, Hanson et al. in prep). From the prey tissues/scales collected, Genetic Stock Identification (GSI) were run to identify the Chinook stocks in the diet. The majority of samples have been collected in the summer months in inland waters of WA and B.C.

Assumption

- Chinook populations that have been observed in the diet will have higher priority than those that have not.

Caveat: There is currently no spatial correction factor for sample collection (stocks originating from near the sample locations are more likely to be collected), no correction factor for abundance (more abundant stocks are more likely to be identified in the diet), and no correction factor for potential whale selectivity (older, larger fish more likely to be recovered in scale samples).

FACTOR 2- Consumed During Reduced Body Condition or Diversified SRKW Diet

Description and data sources: For the second factor, "Consumed During Reduced Body Condition or Diverse Diet", stocks consumed during times of potential reduced body condition and increased diet diversity receive additional weight.

Since 2008, NOAA's SWFSC has used aerial photogrammetry to assess the body condition and health of SRKWs, initially in collaboration with the Center for Whale Research and, more recently, with the Vancouver Aquarium and SR[3]. Photogrammetry data has been collected during seven field efforts in five years, including September 2008, 2013, and 2015, and May and September 2016 and 2017 (Durban et al. 2017; Fearnbach et al. 2018). The proportion of Chinook salmon consumed in whales' diet was estimated by season and region (inland vs coastal waters) using the data from prey tissues/scales and fecal samples (Hanson et al. 2010, Ford et al. 2016, Hanson et al. in prep).

Assumptions

- Reduced body condition and diverse diet occurs from Oct through May.
- Whales switch from preferred prey, Chinook salmon, to other salmonids or prey when Chinook are less available.

FACTOR 3- Degree of Spatial and Temporal Overlap

Description and data sources: Recent prey mapping from Shelton et al. in press (CWT data) was used to assess the overlap in time and space distribution of individual fall Chinook salmon stocks and SRKWs. The distribution/timing of all Chinook salmon stocks across the whales' range from California to Southwest Vancouver Island (and the inland waters of the Salish Sea) was divided into weighted spatial/temporal areas. Currently, Shelton et al. in press includes detailed information on fall runs. Available data for spring Chinook was included, but detailed analyses of data from spring runs are in progress and will be completed in the next two years, incorporating both recoveries in directed Chinook troll fisheries, and Chinook recovered as bycatch in fisheries not targeting Chinook.

For spring run Chinook we relied on reports from the Chinook Technical Committee of the Pacific Salmon Commission (PSC 2018a, 2018b) and published literature (e.g. Satterthwaite et al. 2013, Wahle et al. 1981, Weitkamp 2010) to assign approximate ocean distributions. For stocks with less information, we assumed that the risk to predation was low in seasons and regions that did not correspond to the return timing and origin of each stock (for example, Columbia spring Chinook are assumed to be most available to whales in winter and spring months near the mouth of the Columbia River, but because of their approximate ocean distribution, they are not available in other regions or seasons – particularly mid-summer to fall). Because of limited recoveries, we also assumed that for stocks returning to the Salish Sea (Strait of Georgia, Puget Sound), the distribution was similar in the Salish Sea to Southwest Vancouver Island distributions.

The spatial/temporal Areas currently include: 1) Southwest Vancouver Island (WCVI); 2) Salish Sea; 3) Cape Falcon, Oregon north to British Columbia border; 4) Cape Falcon, OR south to Cape Mendocino (northern California); 5) Cape Mendocino, CA to Point Sur, CA. Seasons are defined as: Spring: April-May; Summer: June-July; Fall: Aug-Oct: Winter: November-March. These areas reflect the division of Chinook run timing (approximately), correspond to periods of coded wire tag recoveries in fisheries, and correspond to predictable patterns of SRKW movement. SRKW distribution data was assessed from multiple sources (e.g. Center for Whale Research, The Whale Museum, NWFSC satellite tagging, NWFSC coastal hydrophones, coastal spring/winter NWFSC cruises, other opportunistic observations).

Assumptions

- Chinook salmon stocks that overlap in space and time are potential prey.
- Chinook salmon stocks that have a higher degree of overlap in space and time have a higher priority than stocks that have a relatively lower degree of overlap.
- Weighted spatial/temporal areas accommodate variation in the distribution of SRKW and Chinook salmon

Caveat- CWT model interpolates movement of stocks seasonally to account for gaps in fishing effort. Also, the hatchery releases going into the CWT model are not comprehensive, but rather model the distribution of major stock groupings. Within regions and run type (e.g. fall Puget Sound), the ocean distribution is assumed to be the same for all watersheds. Smaller release groups, such as those from the San Juan Islands (SJUA in RMIS) were not included in Shelton et al. because of the low recovery rates – though the ocean distribution of these fish is assumed to be similar to those populations originating from Puget Sound. In particular, ocean distributions of spring run stocks tend to be less well understood than fall stocks. We use the best information available but acknowledge that advances in estimates of ocean distribution of many stocks will improve with the completion of on-going research over the course of the next 1-3 years.

Weight and Scoring

FACTOR 1

If the Chinook stock was observed >=5% of the whales diet in summer or fall/wi/spr, the stock receives 1 point. If it was not observed in the diet, the stock receives 0 points. This prioritizes stocks observed in the diet compared to those that have not been observed.

FACTOR 2

Current data indicate that both reduced body condition and a diversified diet occur in non-summer months. If a stock is consumed during October through May, it receives 1 point. If it is consumed during June through September, the stock receives 0 points. This prioritizes stocks that are consumed during periods with a higher likelihood of food limitation or stress in the whales' health.

FACTOR 3

For each space/time area described above, if more than 25% of the Chinook stock is distributed in that area, the area receives a sub-score of 2. For areas that contain between 5% and 25% of the Chinook stock, the area receives a sub-score of 1. If an area contains less than 5% of the Chinook stock, it receives a sub-score of 0. The sub-scores for each area are multiplied by an importance weight for each area. The final score for the Chinook stock/population is the sum of the products of the scores and weight for each area normalized such that the highest possible score of a given stock is equal to 3.

Here are the seven space/time combinations included in Factor 3 and their associated weights.

1. WA coast in Winter/Spring; weight = 0.5
2. WA coast in Summer/Fall; weight = 0.5
3. Salish Sea in Winter/Spring; weight = 0.5
4. Salish Sea in Summer/Fall; weight = 0.5
5. OR / N.CA coast in Winter/Spring; weight = 0.25
6. CA coast in Winter/Spring ; weight = 0.25
7. West Coast of Vancouver Island in Winter/Spring; weight = 0.5

The Salish Sea and coastal waters off WA have a 0.5 weight. The areas off BC, OR/North CA and CA have a 0.25 weight. This structure means that the areas of highest SRKW use – the Salish Sea and coastal WA – are treated as twice as important as the other areas.

References

Durban, J. W., H. Fearnbach, L. Barrett-Lennard, M. Groskreutz, W. Perryman, K. Balcomb, D. Ellifrit, M. Malleson, J. Cogan, J. Ford, and J. Towers. 2017. Photogrammetry and Body Condition. Availability of Prey for Southern Resident Killer Whales. Technical Workshop Proceedings. November 15-17, 2017.

Fearnbach, H., J. W. Durban, D. K. Ellifrit and K. C. Balcomb III. 2018. Using aerial photogrammetry to detect changes in body condition in endangered Southern Resident killer whales. Endangered Species Research. https://doi.org/10.3354/esr00883.

Ford, M. J., J. Hempelmann, M. B. Hanson, K. L. Ayres, R. W. Baird, C. K. Emmons, J. I. Lundin, G. S. Schorr, S. K. Wasser, and L. K. Park. 2016. Estimation of a killer whale (*Orcinus orca*) population's diet using sequencing analysis of DNA from feces. PLoS ONE. 11(1):e0144956. Doi:10.1371/journal.pone.0144956.

Hanson, M. B., R. W. Baird, J. K. B. Ford, J. Hempelmann-Halos, D. M. Van Doornik, J. R. Candy, C. K. Emmons, G. S. Schorr, B. Gisborne, K. L. Ayres, S. K. Wasser, K. C. Balcomb, K. Balcomb-Bartok, J. G. Sneva, and M. J. Ford. 2010. Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. Endang.Spec. Res. 11: 69-82.

Pacific Salmon Commission (PSC) Joint Chinook Technical Committee Report. 2018a. 2017 Exploitation Rate Analysis And Model Calibration Volume One. Available at: http://www.psc.org/publications/technical-reports/technical-committee-reports/chinook/

Pacific Salmon Commission (PSC) Joint Chinook Technical Committee Report. 2018b. 2017 Exploitation Rate Analysis And Model Calibration Volume Two: Appendix Supplement. Available at: http://www.psc.org/publications/technical-reports/technical-committee-reports/chinook/

Satterthwaite, W. H., M. S. Mohr, M. R. O'Farrell, and B. K. Wells. 2013. A comparison of temporal patterns in the ocean spatial distribution of California's Central Valley Chinook salmon runs. Canadian Journal of Fisheries and Aquatic Sciences 70:574–584.

Shelton, A.O., W.H. Satterthwaite, E.J. Ward, B.E. Feist, and B. Burke. In press. Using hierarchical models to estimate stock-specific and seasonal variation in ocean distribution, survivorship, and aggregate abundance of fall run Chinook salmon. Can. J. Fish. Aquat. Sci. DOI: 10.1139/cjfas-2017-0526.

Wahle, R.J., E. Chaney, and R.E. Pearson. 1981 Areal distribution of marked columbia river basin spring Chinook salmon recovered in fisheries and at parent hatcheries. Marine Fisheries Review 43:1-9.

Weitkamp, L. A. 2010. Marine distributions of Chinook salmon from the West Coast of North America determined by coded wire tag recoveries. Transactions of the American Fisheries Society 139:147–170

Priority Chinook Stocks Using Conceptual Model

ESU / Stock Group	Run Type	Rivers or Stocks in Group	Diet Contribution Score (0,1)	Killer Whale Reduced Body Condition or Diverse Diet Score (0,1)	Spatio-Temporal Overlap Score (0 - 3)	
			Avg. Factor 1 (see note)	Avg. Factor 2 (see note)	Avg. Factor 3	Total Score (sum of factors)
Northern Puget Sound	Fall	Nooksack, Elwha, Dungeness, Skagit, Stillaguamish, Snohomish	1	1	3.00	5.00
Southern Puget Sound	Fall	Nisqually, Puyallup, Green, Duwamish, Deschutes, Hood Canal systems	1	1	3.00	5.00
Lower Columbia	Fall	Fall Tules and Fall Brights (Cowlitz, Kalama, Clackamas, Lewis, others)	1	1	2.63	4.63
Strait of Georgia	Fall	Lower Strait (Cowichan, Nanaimo), Upper Strait (Klinaklini, Wakeman, others), Fraser (Harrison)	1	1	2.63	4.63
Upper Columbia & Snake Fall	Fall	Upriver Brights	1	1	2.25	4.25
Fraser	Spring	Spring 1.3 (upper Pitt, Birkenhead; Mid & Upper Fraser; North and South Thompson) and Spring 1.2 (Lower Thompson, Louis Creek, Bessette Creek)	1	1	2.25	4.25
Lower Columbia	Spring	Lewis, Cowlitz, Kalama, Big White Salmon	1	1	2.25	4.25
Middle Columbia	Fall	Fall Brights	1	1	2.06	4.06
Snake River	Spring-Summer	Snake, Salmon, Clearwater	1	1	1.88	3.88
Northern Puget Sound	Spring	Nooksack, Elwha, Dungeness, Skagit (Stillaguamish, Snohomish)	1	1	1.88	3.88
Washington Coast	Spring	Hoh, Queets, Quillayute, Grays Harbor	1	1	1.69	3.69
Washington Coast	Fall	Hoh, Queets, Quillayute, Grays Harbor	1	1	1.69	3.69
Central Valley	Spring	Sacramento and tributaries	1	1	1.50	3.50
Middle & Upper Columbia Spring	Spring	Columbia, Yakima, Wenatchee, Methow, Okanagan	1	1	1.31	3.31
Middle & Upper Columbia Summers	Summer		1	1	1.31	3.31

Fraser	Summer	Summer 0.3 (South Thompson & lower Fraser; Shuswap, Adams, Little River, S. Thompson mainstem, Maria Slough in Lower Fraser) and Summer 1.3 (Nechako, Chilko, Quesnel; Clearwater River in North Thompson)	1	0	1.88	2.88
Central Valley	Fall and Late Fall	Sacramento, San Joaquin	1	1	0.75	2.75
Klamath River	Fall	Upper Klamath and Trinity	1	1	0.75	2.75
Klamath River	Spring	Upper Klamath and Trinity	1	1	0.75	2.75
Upper Willamette	Spring	Willamette	0	0	2.25	2.25
Southern Puget Sound	Spring	Nisqually, Puyallup, Green, Duwamish, Deschutes, Hood Canal systems	0	0	1.88	1.88
Central Valley	Winter	Sacramento and tributaries	0	0	1.50	1.50
North & Central Oregon Coast	Fall	Northern (Siuslaw, Nehalem, Siletz) and Central (Coos, Elk, Coquille, Umpqua)	0	0	1.41	1.41
West Coast Vancouver Island	Fall	Robsertson Creek, WCVI Wild	1	0	0.38	1.38
Southern Oregon & Northern California Coastal	Fall	Rogue, Chetco, Smith, lower Klamath	0	0	0.75	0.75
Southern Oregon & Northern California Coastal	Spring	Rogue	0	0	0.75	0.75
California Coastal	Fall	Mad, Eel, Russian	0	0	0.75	0.75
California Coastal	Spring	Mad, Eel, Russian	0	0	0.75	0.75
Southeastern Alaska	Spring	Taku, Situk, Chilkat, Chickamin, Unuk, Alsek, Stikine	0	0	0.00	0.00
Northern BC	Spring	Yakoun, Skeena, Nass	0	0	0.00	0.00
Central BC	mostly Summer	Atnarko, Dean River, Rivers Inlet	0	0	0.00	0.00

Note: Factor 1 and 2 are not literal averages. If a major component of the rivers in the ESU / Stock group had 1 then this was scored a 1. If no major component was scored a 1, this was scored a 0

United States Census Bureau

The 2020 Census is Happening Now. Respond Today.

QuickFacts

Pasco city, Washington

QuickFacts provides statistics for all states and counties, and for cities and towns with a ***population of 5,000 or more***.

Table

All Topics	Pasco city, Washington
Population estimates, July 1, 2019, (V2019)	**75,432**
PEOPLE	
Population	
Population estimates, July 1, 2019, (V2019)	**75,432**
Population estimates base, April 1, 2010, (V2019)	62,163
Population, percent change - April 1, 2010 (estimates base) to July 1, 2019, (V2019)	21.3%
Population, Census, April 1, 2010	59,781
Age and Sex	
Persons under 5 years, percent	9.7%
Persons under 18 years, percent	33.6%
Persons 65 years and over, percent	8.1%
Female persons, percent	48.8%
Race and Hispanic Origin	
White alone, percent	69.1%
Black or African American alone, percent (a)	2.4%
American Indian and Alaska Native alone, percent (a)	1.1%
Asian alone, percent (a)	2.5%
Native Hawaiian and Other Pacific Islander alone, percent (a)	0.2%
Two or More Races, percent	4.6%
Hispanic or Latino, percent (b)	55.1%
White alone, not Hispanic or Latino, percent	38.6%
Population Characteristics	
Veterans, 2014-2018	2,712
Foreign born persons, percent, 2014-2018	23.1%
Housing	
Housing units, July 1, 2019, (V2019)	X
Owner-occupied housing unit rate, 2014-2018	69.8%
Median value of owner-occupied housing units, 2014-2018	$186,900
Median selected monthly owner costs -with a mortgage, 2014-2018	$1,351
Median selected monthly owner costs -without a mortgage, 2014-2018	$447
Median gross rent, 2014-2018	$895
Building permits, 2019	X
Families & Living Arrangements	
Households, 2014-2018	21,283
Persons per household, 2014-2018	3.35
Living in same house 1 year ago, percent of persons age 1 year+, 2014-2018	81.5%
Language other than English spoken at home, percent of persons age 5 years+, 2014-2018	50.4%
Computer and Internet Use	
Households with a computer, percent, 2014-2018	88.3%
Households with a broadband Internet subscription, percent, 2014-2018	80.2%
Education	
High school graduate or higher, percent of persons age 25 years+, 2014-2018	74.4%
Bachelor's degree or higher, percent of persons age 25 years+, 2014-2018	18.3%
Health	
With a disability, under age 65 years, percent, 2014-2018	8.6%
Persons without health insurance, under age 65 years, percent	15.3%
Economy	
In civilian labor force, total, percent of population age 16 years+, 2014-2018	68.5%

In civilian labor force, female, percent of population age 16 years+, 2014-2018	61.0%
Total accommodation and food services sales, 2012 ($1,000) (c)	71,103
Total health care and social assistance receipts/revenue, 2012 ($1,000) (c)	193,462
Total manufacturers shipments, 2012 ($1,000) (c)	D
Total merchant wholesaler sales, 2012 ($1,000) (c)	595,492
Total retail sales, 2012 ($1,000) (c)	722,824
Total retail sales per capita, 2012 (c)	$11,053

Transportation

Mean travel time to work (minutes), workers age 16 years+, 2014-2018	21.8

Income & Poverty

Median household income (in 2018 dollars), 2014-2018	$61,662
Per capita income in past 12 months (in 2018 dollars), 2014-2018	$23,159
Persons in poverty, percent	16.5%

BUSINESSES

Businesses

Total employer establishments, 2017	X
Total employment, 2017	X
Total annual payroll, 2017 ($1,000)	X
Total employment, percent change, 2016-2017	X
Total nonemployer establishments, 2018	X
All firms, 2012	3,312
Men-owned firms, 2012	1,433
Women-owned firms, 2012	1,141
Minority-owned firms, 2012	1,052
Nonminority-owned firms, 2012	1,990
Veteran-owned firms, 2012	317
Nonveteran-owned firms, 2012	2,713

GEOGRAPHY

Geography

Population per square mile, 2010	1,960.4
Land area in square miles, 2010	30.50
FIPS Code	5353545

About datasets used in this table

Value Notes

Estimates are not comparable to other geographic levels due to methodology differences that may exist between different data sources.

Some estimates presented here come from sample data, and thus have sampling errors that may render some apparent differences between geographies statistically indistinguishable. Click the Quick Info icon to the row in TABLE view to learn about sampling error.

The vintage year (e.g., V2019) refers to the final year of the series (2010 thru 2019). *Different vintage years of estimates are not comparable.*

Fact Notes

- **(a)** Includes persons reporting only one race
- **(b)** Hispanics may be of any race, so also are included in applicable race categories
- **(c)** Economic Census - Puerto Rico data are not comparable to U.S. Economic Census data

Value Flags

- **-** Either no or too few sample observations were available to compute an estimate, or a ratio of medians cannot be calculated because one or both of the median estimates falls in the lowest or upper in open ended distribution.
- **D** Suppressed to avoid disclosure of confidential information
- **F** Fewer than 25 firms
- **FN** Footnote on this item in place of data
- **N** Data for this geographic area cannot be displayed because the number of sample cases is too small.
- **NA** Not available
- **S** Suppressed; does not meet publication standards
- **X** Not applicable
- **Z** Value greater than zero but less than half unit of measure shown

QuickFacts data are derived from: Population Estimates, American Community Survey, Census of Population and Housing, Current Population Survey, Small Area Health Insurance Estimates, Small Area Income and F Estimates, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits.

- Environment
- Local News
- Northwest

Washington’s greenhouse-gas emissions continue to trend higher in latest inventory

Nov. 19, 2019 at 11:55 am Updated Nov. 19, 2019 at 6:20 pm

The Colstrip power plant, which provides power to Washington state residents, is located in southeast Montana and is partially owned by Puget Sound... (Mike Siegel / The Seattle Times)

By
Evan Bush
Seattle Times staff reporter

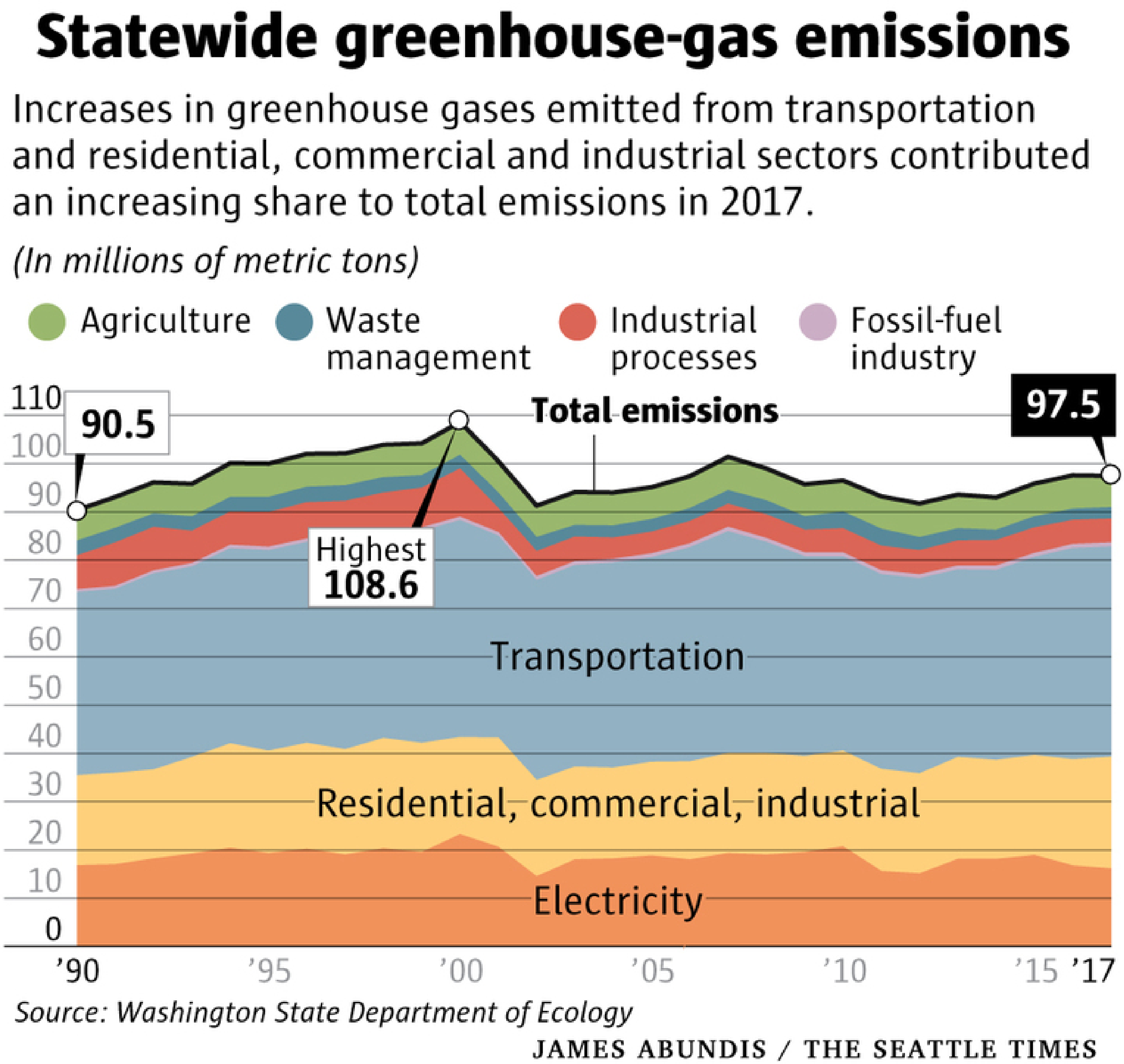
As scientists issue increasingly dire warnings over climate change, Washington state's greenhouse-gas emissions continue to trend higher, according to the latest state inventory.

Emissions in 2017, the most recent year for which information is available, were similar to those in 2016 but up about 1.6% when compared with 2015, according to data released Tuesday by the state Department of Ecology.

Rising emissions from transportation and building heating cut away at gains in other sectors of the economy, according to the report. The data shows just how challenging it will be to steer the state toward a greener future as it continues its rapid growth.

The trend in overall emissions points upward even as emissions per resident have declined, said Andy Wineke, a spokesman for the Ecology Department.

"Washington state has a booming economy, a growing population," Wineke said. "But if we're going to reduce greenhouse-gas emissions, we're going to have to reduce them across the board. I am definitely seeing reasons for cautious optimism, but the size of the challenge has not shrunk."



State legislators in 2008 wrote into law a plan to reduce greenhouse-gas emissions to 1990 levels by 2020.

“At this point, we’re not on track to hit the 2020 target,” Wineke said. “The bigger concern is, of course, whether the targets we adopted in 2008 are sufficient to reduce the impacts.”

After 2020, the next marker is 2035, when the state is supposed to have dropped emissions to 25% percent below 1990 levels. Then, by 2050, the state is supposed to have cut emissions in half compared with 1990. Every two years, the Ecology Department is required by law to produce what amounts to a progress report.

In 2017, the state produced nearly 97.5 million metric tons of carbon-dioxide equivalent. In 2015, that figure was 95.9 million, according to the Ecology data, which calculated information from the U.S. Environmental Protection Agency and the Washington State Department of Commerce. The numbers lag years behind because the data takes time to gather and is difficult to compute.

Climate experts last year delivered dire warnings about the effects of warming on the world, and called for society-altering shifts in human behavior and the world's economy. A United Nations Intergovernmental Panel on Climate Change called for "rapid and far-reaching" changes in energy systems, land use, city and industrial design, transportation and building use.

A report produced by the U.S. Global Change Research Program detailed expected climate effects across the country. The Pacific Northwest can expect both more drought and more extreme rain events. If emissions are left unchecked, higher temperatures will likely cause salmon to lose habitat, disrupt Northwest crops such as cherries, and contribute to more wildfires.

Lawmakers took several steps during the most recent legislative session to reduce Washington's greenhouse-gas emissions in years to come.

Gov. Jay Inslee this year signed a package of bills that would rid Washington's electric grid of fossil-fuel-generated power by 2045. Electricity generation accounted for nearly 17% of Washington's emissions in 2017, according to the Ecology data.

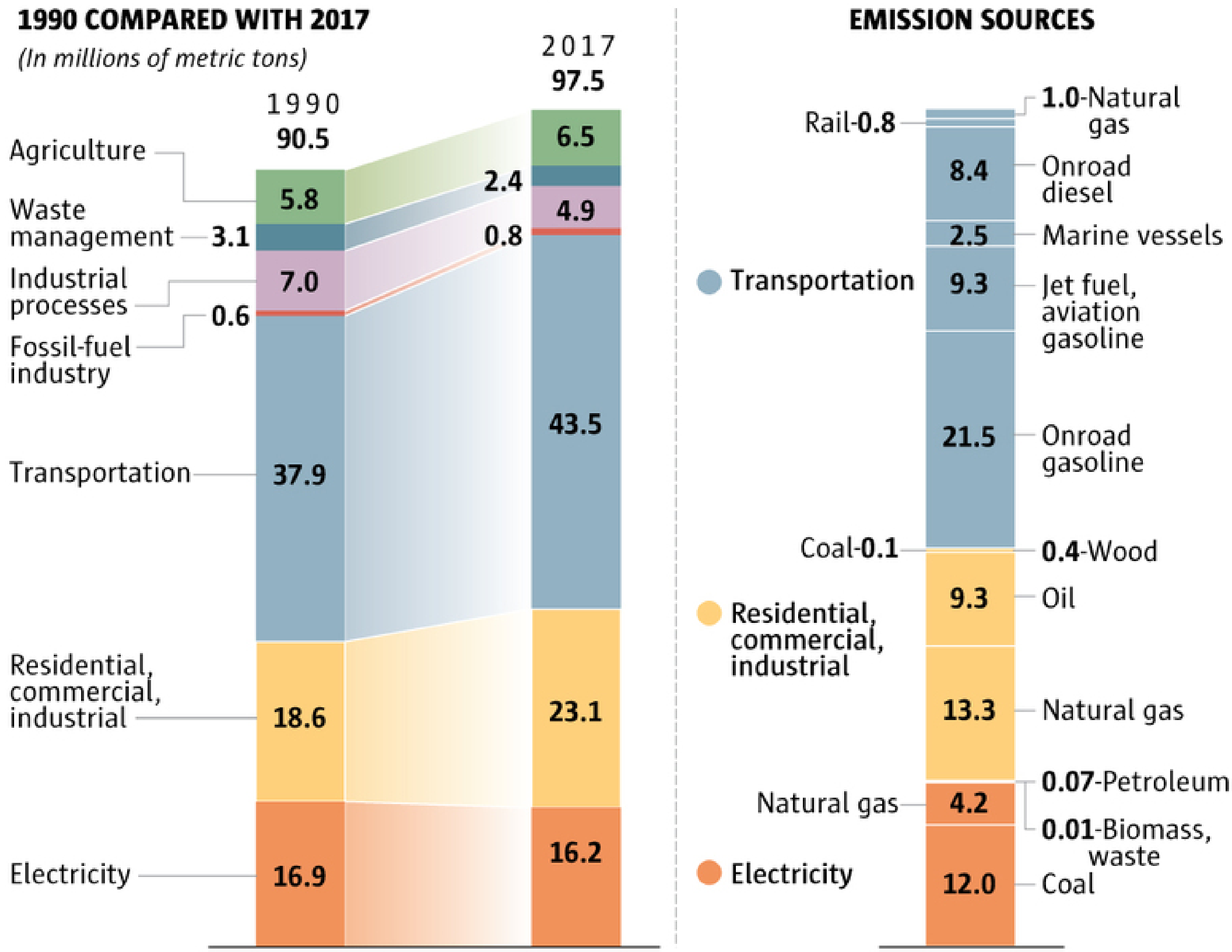
Several coal-fueled power plants that serve Washington residents are going offline soon. Two of the four units at the Colstrip coal-fired power plant in Montana are slated to shut down in the coming months. A burner at TransAlta's Centralia power plant will stop firing coal next year.

Lawmakers also created new conservation standards for energy use in large buildings and phased out hydrofluorocarbons used in refrigeration, moves Wineke said would eventually slice about a million metric tons of carbon-dioxide equivalent from the statewide emissions total.

"We took a giant leap forward as a state and passed the strongest 100% clean energy bill in the nation and the strongest package of decarbonization bills in a single year," said State Sen. Reuven Carlyle, D-Seattle. "We can do that same level of work in transportation and other sectors."

Washington statewide greenhouse-gas emissions

The amount of total greenhouse-gas emissions was calculated using a measurement called the carbon-dioxide equivalent, which takes into count the heat-trapping ability and impacts of various greenhouse gases. The Environmental Protection Agency this year changed how it calculates methane from landfills. These figures reflect the new methodology.



Sen. Doug Ericksen, R-Ferndale, noted that the state is producing less carbon now than in 2000, when emissions peaked at 108.6 million metric tons. Ericksen said Washington had a "minuscule" impact on greenhouse gases compared to the rest of the world. He worries that a swift transition to clean energy could cause reliability issues in the electricity grid.

"In the bigger picture of things, what's more important to the people of Washington state: Some kind of virtue signaling that makes no difference, or the power to their homes to operate their computers?" Ericksen said.

Low-carbon advocates described last session's legislative action as merely a beginning.

"It's really only going to affect 10-15% of our emissions," said Doug Ray, chair of the Carbon Washington board of directors, which put a carbon-tax initiative on the ballot in 2016 that voters rejected. "The area they missed was the transportation sector. We got nothing done. We're well set up for this: Our electricity is already low carbon."

Carlyle said Democrats, who control both chambers of the state Legislature, are considering policies on clean fuel standards, more stringent carbon goals, and revamping how transportation is funded to boost transit.

"We have to move forward at an accelerated rate," Carlyle said, on reducing greenhouse gases. "That's the moral and policy imperative of our time."

Accessed on Nov. 27, 2019 at: https://www.seattletimes.com/seattle-news/environment/washingtons-greenhouse-gas-emissions-continue-to-trend-higher-in-latest-inventory/

10: Public Health Impacts

Public Health Impacts of Climate Change in Washington State: Projected Mortality Risks Due to Heat Events and Air Pollution

J. Elizabeth Jackson, MA[1,2]; Michael G. Yost, PhD[3]; Catherine Karr, MD, PhD, MS[4,3]; Cole Fitzpatrick, MA[3]; Brian K. Lamb, PhD[5]; Serena H. Chung, PhD[5]; Jack Chen, PhD[6]; Jeremy Avise, PhD[7]; Roger A. Rosenblatt, MD[1]; Richard A. Fenske, PhD[3]

Abstract

Climate change is likely to have serious and long-term consequences for public health. Among these are illness and mortality related to heat and worsening air quality In this study we examined the historical relationship between age- and cause-specific mortality rates and heat events at the 99th percentile of humidex values in the greater Seattle area (King, Pierce and Snohomish counties), Spokane County, the Tri-Cities (Benton and Franklin counties) and Yakima County from 1980 through 2006; the relative risk of mortality during heat events compared with more temperate periods were then applied to population and climate projections for Washington State to calculate number of deaths above the baseline (1980-2006) expected to occur during projected heat events in 2025, 2045 and 2085. We also estimated excess deaths due to ground-level ozone concentrations for mid century (2045-2054) in King and Spokane counties. Estimates were based on current (1997-2006) ozone measurements and mid-21st century ozone projections, using estimates from the scientific literature to determine the effect of ozone on overall and cardiopulmonary mortality. For the historical heat analysis, relative risks derived for the greater Seattle area showed a significant dose-response relationship between duration of the heat event and the daily mortality rate for non-traumatic deaths for persons aged 45 and above, typically peaking at four days of exposure to humidex values above the 99th percentile. Three different warming scenarios were considered, including high, low and moderate estimates. In the greater Seattle area, the largest number of excess deaths in all years and scenarios was predicted for persons aged 65 and above. Under the middle scenario, this age group is expected to have 96 excess deaths in 2025, 148 excess deaths in 2045 and 266 excess deaths in 2085 from all non-traumatic causes. Daily maximum 8 hour ozone concentrations are forecasted to be 16-28% higher in the mid 21st century

[1]Department of Family Medicine, University of Washington, Seattle, Washington
[2]Department of Sociology, University of Washington, Seattle, Washington
[3]Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, Washington
[4]Department of Pediatrics, University of Washington, Seattle, Washington
[5]Laboratory for Atmospheric Research, Department of Civil and Environmental Engineering, Washington State University, Pullman, Washington
[6]Institute for Chemical Process and Environmental Technology, National Research Council Canada, Ottawa, ON, Canada
[7]Atmospheric Modeling and Support Section, California Air Resources Board, Sacramento, California

compared to the recent decade of 1997-2006. We estimated that the total non-traumatic ozone mortality rate by mid-century for King County would increase from baseline (0.026 per 100,000; 95% confidence interval 0.013-0.038) to 0.033 (0.017-0.049). For the same health outcome in Spokane County, the baseline period rate was 0.058 (0.030- 0.085) and increased to 0.068 (0.035 -0.100) by mid-century. The cardiopulmonary death rate per 100,000 due to ozone was estimated to increase from 0.011 (0.005-0.017) to 0.015 (0.007-0.022) in King County, and from 0.027 (0.013-0.042) to 0.032 (0.015-0.049) in Spokane County. Public health interventions aimed at protecting Washington's population from excessive heat and increased ozone concentrations will become increasingly important for preventing deaths, especially among older adults. Furthermore, heat and air quality related illnesses that do not result in death, but are serious nevertheless, may be reduced by the same measures.

1. Introduction

Climate change is likely to have serious and long-term consequences for public health. Researchers have identified a number of broad health issues associated with climate change, such as severe weather events, worsening air pollution, infectious diseases related to changes in vector biology, food and water contamination and shortages, as well as more indirect impacts such as food security, large-scale migration and civil conflict (Frumkin et al. 2008). These authors emphasize that the health effects of climate change will vary by region, population group, and capacity for public health responses. Recent reviews of the impacts of climate change have documented variability in mortality and morbidity for the United States (Patz et al. 2001), and globally (Patz et al. 2005).

This report was not able to address many of these very important issues, although we hope to do so in subsequent work. Instead, our worked has focused on two key public health concerns related to climate change: heat-related illness and worsening air quality (Luber et al. 2008; Kinney 2008). Annual average temperatures in the United States and globally are rising, although the effects vary from region to region. It is estimated that 400-700 people die from documented thermal stress, or hyperthermia, each year in the United States (Bernard and McGeehin 2004). Because the immediate cause of death is usually some form of cardiovascular failure, and hyperthermia is often not noted on the death certificate as an underlying factor, the number of heat-related deaths is underestimated (Wolfe et al. 2001; CDC 2006).

Relatively short but intense heat waves over the last 30 years have been responsible for hundreds of deaths in the United States and Canada, and thousands of deaths in Europe (Jones et al. 1982; Semenza et al. 1996; Whitman et al. 1997; Naughton et al. 2002; Kaiser et al. 2007). Climate projections suggest that these events will become more frequent, more intense and longer lasting in the remainder of the 21st century (Meehl and Tebaldi 2004). The greatest impacts will be in cities with milder summers, less air conditioning and higher population density (McGeehin and Mirabelli 2001). An aging population also will put more people at risk (Smoyer et al. 2000).

Retrospective epidemiological research has identified groups most likely to be harmed by heat waves and suggests strategies to mitigate these harms through public interventions. The groups at greatest risk include the following: children, due to slower adaptation during exercise (AAP 2000); the elderly, due to changes in the physiological ability to maintain normal body temperature (Borrell et al. 2006; Basu et al. 2005; CDC 2005); poor and socially isolated populations, due to less access to mitigation measures (Greenberg et al. 1983; McGeehin et al. 2001; Browning et al. 2006); some urban dwellers, due to heat island effects and lack of vegetation (Grimmond and Oke 1999; DeGaetano and Allen 2002); outdoor laborers, due to extended exposures and lack of access to drinking water and shade (Greenberg et al. 1983; WA Dept Labor and Industries 2008); people with chronic illnesses (e.g., diabetes, heart disease), due to increased vulnerability to sustained heat (Medina-Ramon et al. 2006); and the mentally ill, due to behavioral factors and the effects of psychoactive medications (Kaiser et al. 2001).

Methods used for estimating mortality due to heat generally rely on an analysis of regional weather data in combination with daily mortality data. This typically requires large, dense urban areas for daily values to be sufficiently stable to support analyses. Most such studies consider the effects of both temperature and humidity. Studies of heat-related mortality in Philadelphia and Toronto have used synoptic climate modeling to identify regional conditions associated with elevated mortality (Kalkstein et al. 1996; Pengelly et al. 2005; Cheng et al. 2005). Regional and temporal differences in the effect of heat on mortality have been identified (Kalkstein and Davis 1989; Davis et al. 2003).

In addition to heat, adverse effects of climate change on air quality have recently come under investigation. The primary ambient air pollutants of concern for public health risk in Washington State include both fine particulate matter and ozone. An expanding evidence base regarding the relationship of these pollutants to adverse health outcomes has resulted in lowering of the concentrations of these pollutants in federal standards (U.S. EPA 2006, U.S. EPA 2008), Despite overall improvement in regional air quality over the decade, adoption of these more protective federal standards make it likely that future climate change related increases in ozone or PM2.5 could lead to more days of exposure above health-based guidelines for Washington residents (PSCAA, 2007).

The influence of meteorology on ozone and particulate matter concentrations is well documented (EPRI 2005, Bernard 2001). There is considerable evidence that ozone concentrations would increase in the United States as a result of climate change, if precursor emissions were held constant; data regarding influences of climate change on particulate matter are far fewer, precluding clear conclusions (CCSP 2008). For both of these pollutants regional-specific assessments of potential health impacts are few (Knowlton et al. 2004).

While ozone and fine particulate matter are associated with multiple health outcomes, including increases in prevalence, clinical utilization, and severity of cardiac and respiratory disease, most studies have focused on premature mortality as an endpoint. This reflects recognition of this endpoint as the most serious outcome, as well as its status as the most accessible and reliable health outcome for which data are available for evaluation in large population based studies. Numerous epidemiologic studies in the United States and abroad have identified increased premature mortality in association with increased ozone exposure (Bell 2004b). The robustness of this evidence base, including several recent multi-city and meta-analyses, has been noted in a recent National Academy of Sciences report (NRC 2008). While the effect estimates vary somewhat by study design and region, the studies viewed as a whole provide a pattern of consistency with generally comparable magnitude of effect estimates.

Increasingly, region-level modeling of ozone and other air pollutants under climate change scenarios is being conducted (Weaver et al, 2009). In the Pacific Northwest regional projections of future air quality at the resolution of approximately county level scales (36 km horizontal grids) have been developed. We sought to integrate knowledge of the concentration-mortality response with Washington State ozone pollution projections to provide an initial quantitative assessment of potential mortality impacts in the mid 21st century. Specifically, we estimated the excess mortality due to climate-related ambient ozone concentrations in Spokane County and King County, Washington for the recent decade (1997-2006) and mid century decade (2045-2055).

Increased levels of $PM_{2.5}$ are an important factor in poor air quality conditions in the State of Washington. Climate change, however, has not been shown conclusively to be a significant factor in projecting future $PM_{2.5}$ levels. In an attribution study of various contributions to future air quality projections, Avise et al (2008) showed that projected changes in weather patterns for the 2050s produced an insignificant (0.2 µg/m3) reduction in $PM_{2.5}$ for EPA Region 10 (Alaska, Idaho, Oregon, Washington). Nevertheless, future changes in local and Asian emissions are projected to increase $PM_{2.5}$ levels by 2 µg/m3 (from a current value of 4 µg/m3) over the same period in this region, and interaction between this increase and climate change may have an amplified impact on human health in the future. Such interactions are beyond the scope of the current project but merit future research given the increasing evidence for adverse public health consequences of $PM_{2.5}$ exposure.

This study had three goals. First, we determined the historical relationship between extreme heat events and mortality in different regions of Washington State, for selected age groups and causes of death. Second, we used these findings to predict the number of excess deaths by age group and cause during projected heat events in years 2025, 2045 and 2085. Finally, we used estimates of the relationship between ozone concentration and mortality available from the scientific literature to predict the number of excess deaths in mid-century (2045-2054) due to ozone under a changing climate, assuming a growing population.

2. Methods

2.1. Estimates of Relative Risk of Mortality Due to HeatEvents, 1980-2006

Four study areas were selected for the heat event analysis (Figure 1): greater Seattle area (King, Pierce and Snohomish counties); Tri-Cities

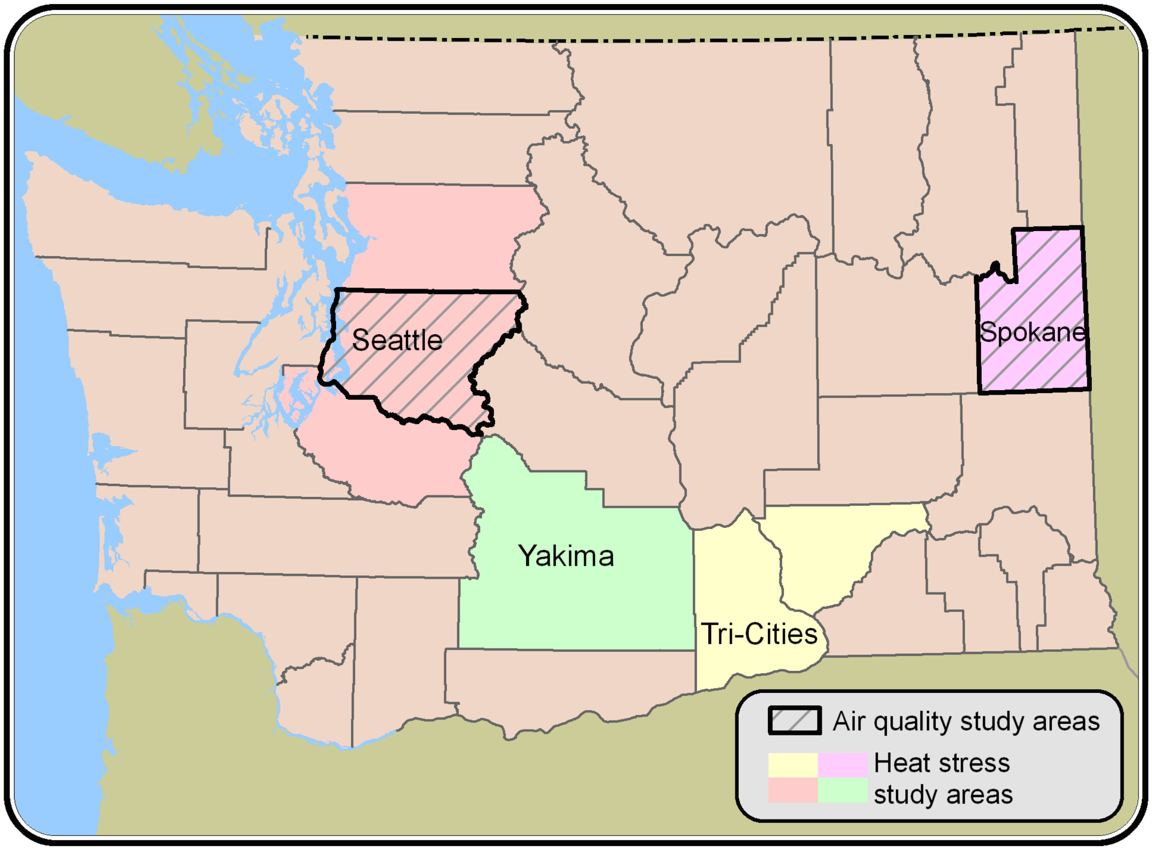


Figure 1. Map of study areas.

(Benton and Franklin counties); Spokane County; Yakima County. Daily historic weather data were drawn from the 16th degree downscaled models (Elsner et al. 2009, this report; Mote and Salathé 2009, this report). Grid points falling within study area counties (grid size ~7.2 km by 4.8km) were identified by spatially joining the grid points and county boundaries using ESRI ArcMap software. The humidex, a measure of the combined effect of heat and humidity on human physiology (Masterton and Richardson 1979, Environment Canada 2008), and has been used in other mortality studies and as a basis for declaring heat warnings (Smoyer-Tomic and Rainham, 2001). The humidex value was calculated for each grid point from daily maximum temperature and relative humidity data using the following formula:

$$\text{Humidex} = T + 5/9 * (v - 10)$$

where: $v = \text{vapor pressure} = (6.112 \times 10^{(7.5*T/(237.7+T))}) * H/100)$

T= air temperature (degrees Celsius), H= humidity (%)

Grid point humidex values were averaged across all grids in each county to yield a county-level humidex value for each day from January 1, 1970 to December 31, 2006. Thresholds at the humidex 99th percentile were identified for this entire historical period in each study area. After finding the 99%tile value, we then determined which months in the historical record had heat events and used observation frame for the analysis. This approach allowed us to unambiguously define both the humidex threshold and the months for observing heat events. The duration of events was determined the weather event. Heat events were defined as one or more consecutive days of the humidex above these thresholds; the number and duration of heat events were counted in each study area over the period. Since only daily observations of mortality were available, it was not possible or necessary to resolve the heat event time periods to less than 1 day intervals.

Annual county population estimates by age group from 1980 through 2006 were obtained from Washington State's Office of Financial Management (OFM 2008a). Complete mortality data from 1980 through 2006 were obtained from the Washington State Department of Health. Computerized mortality data was not available for earlier periods prior to 1980. Daily numbers of deaths for each year were aggregated by cause, age group, and county of residence.

Heat has been cited frequently as a contributing factor in deaths due to failure of the circulatory and respiratory systems, Therefore, the following cause-of-death categories were examined: all non-traumatic causes (ICD-9: 001-799; ICD-10: A00-R99), circulatory (ICD-9: 390-459; ICD-10: I00-I99, G45, G46), respiratory (ICD-9: 460-519; ICD-10: J00-J99), cardiovascular (ICD-9: 393-429; ICD-10: I05-I52), and ischemic (ICD-9: 410-414; ICD-10: I20-I25); cardiovascular and ischemic are subsets of circulatory. The ICD grouping used are from a study of heat- and air quality-related mortality in Toronto (Cheng et al. 2005). Heat events have been shown to present increased risks for older persons, so data were examined according to the following age categories: 45 years and older, 64 years and older and 85 years and older.

Observed and expected crude daily mortality rates for age and cause-of-death specific groupings were calculated for heat event days (days 1 to day 5+) and non-heat event days (day 0) during the years from 1980-2006. Only data in the months of May – September between 1980 and 2006 were used in the analysis. Daily mortality observed during heat events in the months of May- September were accumulated in 5 time periods of roughly 5-year duration: 1980-1984; 1985-1989; 1990-1994; 1995-1999; and 2000-2006. Mortality was computed in six age-specific categories of 0-4, 5-14, 15-44, 45-64, 65-84, and 85+ years. The deaths occurring in each consecutive day of a heat event were counted for each study area, and classified according to the duration of heat exposure prior to the day of death for heat event days 1 through day 5+ of heat events. The average daily mortality rates on days between May and September with no defined heat event (designated as day 0) were treated as the baseline mortality rates for each time period. Expected values for the number of deaths in each day of a heat event in an annual period were calculated by applying the average daily mortality rate for non-heat event days to the number of days observed in each heat event during a specific time period. The total observed and expected deaths were then summed for each exposure duration category for all heat events. The mortality relative risks by heat event duration, specific age and disease categories were computed from the ratios of observed over expected duration-specific mortality. Calculating separate relative risks for each elapsed day of a heat event (starting with day 1 of the heat event) allows evaluation of the influence of a single day versus more prolonged heat events on mortality.

Confidence intervals were computed assuming Poisson intervals for the observed number of cases as recommended by the Washington State Department of Health (DOH 2002). Exact 95% confidence intervals were computed using Poisson distribution percentiles when the number of observed deaths was <500; for >500 observed deaths, intervals were computed using a normal approximation method (Breslow and Day 1987). This procedure was repeated separately for each heat study area in order to control for regional differences in the effect of heat events on mortality. Given the smaller population in Eastern Washington, a combined analysis of Benton, Franklin, Spokane and Yakima county study areas also was performed.

2.2. Population Projections for Washington State in the 21st Century

Projected county population estimates by age group were obtained from the Washington Office of Financial Management for the years 2005-2030 (OFM 2008b). In predicting future excess deaths during extreme heat events, population was held constant at 2025 projected estimates, allowing differences in excess deaths between years to be interpreted as the component due to climate change. For the analysis of excess deaths related to ozone concentrations, calculated total and age-group populations were calculated by extending the Office of Financial Management linear projections to 2045 through 2054. Washington State population forecasts are developed from a cohort component demographic forecast model that accounts for births, deaths and net migration. Projected births are derived from a natural change model component of the childbearing population, applying historical trends in fertility rates by county. Annual deaths, in terms of life expectancy generally follow national trends, and survival expectations are adjusted to follow Social Security Administration projections in 2007. Migration is the most important variable component of the population forecasts. The state's future net migration is based on an econometric model where Washington's relative attractiveness to job seekers is weighed against the attractiveness of California and other state destinations. A historical comparison of the actual and fitted net migration for 1978-2008 using OFM's migration model found an R^2 of 0.91, indicating reasonably good agreement.

2.3. Projected Excess Mortality Due to Heat Events

Projected heat events were determined for three years: 2025, 2045 and 2085. Three climate change scenarios were selected for high, moderate and low summer (May-Sept.) warming, for a total of nine modeled future heat regimes. The low scenario chosen was the PCM1-B1 model, the high scenario chosen was the HADCM-A1B model, and the middle scenario was the mean of the two composite models using either the A1B or B1 emissions scenario (Salathé et al., 2009, this report). Expected monthly temperature deviations in Celsius for each scenario and time period were added to the observed daily temperature and relative humidity distributions in each study area from 1970 to 1999; the daily humidex was then calculated for each of the new temperature distributions. Historical humidex thresholds at the 99th percentile were applied to the estimated future distributions, and the number and duration of expected heat events in 2025, 2045 and 2085 were calculated for each scenario.

Projections of heat-related mortality applied the baseline mortality rate and duration-specific relative risks derived from the historical analysis to the expected future population structure and expected number and duration of heat events in each of three heat scenarios for 2025, 2045 and 2085. Excess deaths, which are the number of expected deaths above the baseline number of deaths, were calculated for each heat scenario for each year. The use of a 30-year baseline allowed us to calculate mean annual excess deaths in a sample of 30 simulated years for each region and year.

2.4. Projected Excess Mortality Due to Air Pollution

We adapted a health risk assessment modeling approach described by Knowlton et al. (2004) in their effort to assess ozone mortality impacts in the northeastern United States. We selected two populous but distinct climatological areas of the State for this initial assessment. Using the following formula, we estimated ozone related mortality for King County and Spokane County in the recent decade (1997-2006) and at mid-century (2045-2054):

$$M = (P/100{,}000) * B * CR * E$$

where M is the excess mortality due to ozone, P is the estimated population in the county for the period of interest, B is the baseline county-level mortality rate, CR is the concentration-response function that describes the expected change in daily mortality per incremental increase in ozone, and E is the concentration of ozone during the period of interest. We calculated overall non-traumatic mortality as well as mortality specific to cardiopulmonary causes.

The population (P) data were derived from annual population size estimates available from the U.S. Census for King and Spokane County for 1997-2006 and projections of the annual population for these counties in 2045-2054, as described above. The mean of each decade's annual averages was calculated. These data demonstrated that from the period of 1997-2006 to mid-century (2045-2054), the annual average population size for King County is expected to increase from 1,758,260 to 2,629,160 (50% increase). In Spokane County, the population is expected to grow from 424,636 to 712,167 (68% increase).

The county-level non-traumatic (categorized as above) and cardiopulmonary (ICD-9: 393-429, 460-519; ICD-10: I05-I52, J00-J99) mortality rates were calculated by dividing the daily average number of total non-traumatic deaths and cardiopulmonary deaths in the baseline decade of each county by its annual population average. For 1997-2006, the mean daily total non-traumatic and cardiopulmonary death rates per 100,000 for King County were 1.55 and 0.57, respectively. For Spokane County, these rates were 2.03 and 0.78, respectively.

We examined concentration-response (CR) functions for ozone based on three meta-analyses, two multi-city time series, and one case-crossover study of populations in the United States, all of which were reviewed in a recent National Academy of Science report which summarized estimates of the percentage increase in mortality from short-term increases in ozone (NAS 2008). We decided to apply the analysis by Bell et al. (2004b) to our data. This analysis included data and methods developed for the National

Mortality and Morbidity Air Pollution Study (NMMAPS). This landmark study estimated a national average relative rate of mortality (non-injury mortality and cardiopulmonary mortality) associated with short-term average ambient ozone concentrations in 1987-2000 based on 95 large U.S. urban communities made up of almost 40% of the U.S. population (including Spokane and Seattle). Of note, the city-specific estimates for King and Spokane County within the NMMAPS analyses were nearly identical to the combined multi-city concentration-response function employed in this assessment, further supporting its appropriateness. Estimates available per 24-hour average ozone concentration were converted to 8-hour maximum concentrations based on the recommended ratio of 8-hour ozone to a 24-hour average of 1.53 (NAS 2008). The concentration-response for ozone-related non injury mortality and cardiopulmonary mortality derived from this analysis was 0.80% (95% confidence interval 0.41%-1.18%), and 0.98% (0.47%- 1.50%), respectively per 10 parts per billion (ppb) increase in 8-hour maximum daily ozone concentration over the previous week.

Exposure to ozone ($E_{1997\text{-}2006}$) in the recent decade of each county was assessed based on 8-hour maximum daily ozone (ppb) concentration data drawn from the Washington State Department of Ecology state monitoring network for each county for the months May-September (warm season) from 1997-2006. A warm season "baseline" decadal daily average was calculated.

We then estimated future comparable measurements of ozone in the mid-century decade ($E_{2045\text{-}2054}$). To accomplish this, we derived the change (delta) in ozone concentration predicted from a modeling framework which calculated both daily 8 hour maximum concentrations for the baseline decade of this century (1990-1999) as well as for 2045-2054. Specifically, daily 8 hour maximum daily average ozone concentration for May-September of the mid-century decade (2045-2054) were derived by coupling a global climate model projection with regional meteorology and chemistry models for the 36 km grids that coincide with King and Spokane Counties.

The modeling framework is described in detail in Chen et al 2008 (online discussion paper under review). Briefly, the regional Mesoscale Meteorological model version 5 (MM5) was used to downscale the Parallel Climate Model (PCM) to produce regional meteorological fields which were used to drive the Community Multi-scale Air Quality (CMAQ) model, which downscaled the Model for Ozone and Related Chemical Tracers, version 2.4 (MOZART2 outputs) and accounted for regional pollutant emissions to predict photochemical ozone and PM levels. The MM5/CMAQ modeling treats increased ozone formation under climate change as a direct effect of increasing temperature as well as broad indirect effects. The 2050's projections were based on the IPCC A2 scenario, changes in U.S. emissions due to population growth and economic expansion, and alterations in land use/land cover that can affect both meteorological conditions and biogenic emissions important for ozone formation. Future chemical boundary conditions were obtained through downscaling of MOZART-2 based on the IPCC A2 emissions scenario. Projected changes in U.S. anthropogenic emissions are estimated using the EPA Economic Growth Analysis System (EGAS), and changes in land-use are projected using data from the Community Land Model (CLM) and the Spatially Explicit Regional Growth Model (SERGOM).

It is important to recognize that the county monitoring data are influenced by fresh nitrogen oxide emissions largely derived from traffic sources which cause titration (loss) of ozone in the urban areas, while the model results, based upon 36 km grids, tend to minimize this effect since the NOx emissions are diluted significantly due to the size of the grid. This is clear from evaluation of the modeling system which consistently shows that the model overestimates low ozone levels. Consequently, urban monitors will record relatively low ozone concentrations while nearby more rural monitors will record higher ozone concentrations. The model results will not correctly reflect these differences. This is clear from evaluation of the modeling system which consistently shows that the model overestimates low ozone levels (Chen et al., 2008).

Because of this bias in the model, we employed the model results in a relative sense where the change in predicted ozone levels between the baseline period and the future decade were added to the baseline measured values at each site to yield an estimate of future levels. This is essentially the same approach that EPA uses for analysis of ozone control strategies where it is recognized that the models perform better in predicting the change in ozone due to a control compared to predictions of absolute levels.

3. Results

3.1. Estimates of Excess Mortality Due to Heat Events, 1980-2006

The heat study areas accounted for approximately two-thirds of Washington State's population in 2006; King, Pierce and Snohomish counties combined made up just over half of the state's 2006 population of 6.3 million (Table 1). Persons aged 85 and over made up approximately one percent of the total population in most study areas, and one half of one percent in the Tri-Cities region in 1980; by 2006 this age group had roughly doubled in all areas as a proportion of total population. Among study areas, the mean daily maximum humidex from May to September, 1970-2006, was lowest in the greater Seattle area (23.2°C, 73.8°F) and highest in the Tri-Cities (28.1°C, 82.6°F). The 99^{th} percentile for the annual daily maximum humidex ranged from 10°C to 12°C (18-20°F) higher than the May-September mean daily maximum. Number of heat events above the 99^{th} percentile averaged 1.6 to 1.8 per year, with a mean duration of 2.0 to 2.3 days, and maximum duration from 6 days (greater Seattle area) to 10 days (Yakima).

Residents of the greater Seattle area experienced 14,250 deaths from all non-traumatic causes in all months of 1980, and 19,341 in 2006; in the Spokane, Tri-Cities and Yakima areas combined, there were 4,676 deaths from non-traumatic causes in 1980, and 6,264 in 2006 (not shown in tables). Annual mortality rates by non-traumatic causes in all study areas ranged from 36 to 130 per 100,000 for persons aged zero to 14 and from 36 to 58 per 100,000 for those aged 15 to 44. Deaths for specific causes (e.g. ischemic disease) in these age groups were on the order of 20 per 100,000 or fewer annually in all study areas.

Mortality rates for all non-traumatic causes, circulatory causes and respiratory causes increased with age, and were highest for persons 85 years of age or older. In the greater Seattle area, the non-traumatic annual

Table 1. Baseline climate and population parameters 1980-2006.

	Greater Seattle Area	Spokane	Tri-Cities	Yakima
Counties included	King, Pierce, Snohomish	Spokane	Benton, Franklin	Yakima
1980 Population				
Total	2,236,898	367,867	157,983	187,226
45 to 64	395,521	62,823	25,928	32,670
65 to 84	184,078	35,232	9,141	19,009
85 and above	20,398	4,221	739	1,912
2006 Population				
Total	3,488,123	471,872	242,781	251,381
45 to 64	847,217	113,889	55,611	52,829
65 to 84	288,330	46,746	19,633	22,134
85 and above	51,580	9,502	2,774	4,493
Humidex, °C (°F)				
Mean daily high, May-Sep	23.2(73.8)	26.2(79.2)	28.1(82.6)	24.9(76.8)
99th pctl of daily high, annually	33.6(92.5)	38.1(100.6)	38.3(100.9)	35.5(95.9)
Heat events above 99th pctl				
Mean annual number	1.7	1.8	1.6	1.6
Mean(max) duration in days	2.2(6)	2.0(9)	2.2(9)	2.3(10)

mortality rate among those aged 85 and above was 14,937 per 100,000 in 1980 and 12,460 per 100,000 in 2006; in the other study areas combined there were similar rates in this age group: 14,871 per 100,000 and 12,517 per 100,000 in 1980 and 2006, respectively. Annual mortality rates for all causes but respiratory were higher for all age groups in 1980 than in 2006. About half of all non-traumatic deaths in 1980, and about one third in 2006, were from circulatory causes, the bulk of these from cardiovascular causes. Only about one-tenth of non-traumatic deaths occurred due to respiratory causes annually (not shown in tables).

In the greater Seattle area, risk of death due to all non-traumatic causes and circulatory causes rose for the overall population aged 45 years and above beginning on day 1 of heat events, peaked on day 4, and declined slightly for days 5 and beyond (Table 2a; Figure 2). The highest relative risk (RR) estimated for non-traumatic deaths was 1.3 (95% confidence interval (CI): 1.2-1.5) for persons aged 65 and above, and 1.5 for those aged 85 and above (95% CI: 1.2-1.8). Relative risk of death due to circulatory causes followed a similar pattern for persons aged 65 and above, and 85 and above, with the highest effect observed in association with 4 days of exposure (RR=1.4, 95% CI: 1.1-1.7, and 1.5, 1.1-2.0, respectively) (Figure 3). Risk of death from non-traumatic and circulatory causes was significantly elevated for all ages on most days of heat events. Duration-specific relative risks due to respiratory causes were less likely to reach statistical significance and were based on smaller sample sizes (Figure 4); the risk was greatest on day 3 for persons aged 45 and over (RR = 1.4; 95% CI: 1.1-1.7) and 65 and over (RR = 1.4; 95% CI: 1.1-1.8). However, the highest estimates were observed on day 5 for all age ranges, and confidence intervals suggest the possibility of substantially elevated risks on day 5 and beyond for anyone aged 45 and above (RR = 1.5; 95% CI: 0.9-2.3), and particularly

Table 2a. Mortality relative risks for selected causes and age groups by heat event duration, greater Seattle area vs. Spokane, Tri-Cities & Yakima combined, 1980-2006† number designations.

	Greater Seattle Area					Spokane, Tri-Cities, Yakima				
Day of heat event	1	2	3	4	5+	1	2	3	4	5+
All non-traumatic causes										
aged 45+	**1.0**	**1.2**	**1.1**	**1.3**	**1.2**	1.0	1.1	1.1	1.0	1.0
	(1,1.1)	(1.1,1.3)	(1,1.2)	(1.1,1.5)	(1,1.4)	(0.9,1.1)	(1,1.2)	(1,1.3)	(0.8,1.3)	(0.9,1.3)
aged 65+	**1.1**	**1.2**	**1.1**	**1.3**	**1.2**	1.0	1.1	1.1	1.1	1.0
	(1,1.1)	(1.1,1.3)	(1,1.2)	(1.2,1.5)	(1,1.4)	(0.9,1.1)	(0.9,1.2)	(0.9,1.3)	(0.8,1.3)	(0.8,1.2)
aged 85+	**1.1**	**1.3**	**1.3**	**1.5**	1.1	1.0	1.1	1.1	1.1	1.0
	(1,1.1)	(1.2,1.5)	(1.1,1.5)	(1.2,1.8)	(0.8,1.5)	(0.8,1.1)	(0.9,1.3)	(0.8,1.5)	(0.7,1.6)	(0.6,1.4)
Circulatory										
aged 45+	1.0	**1.2**	**1.2**	**1.3**	1.1	1.0	1.1	1.1	1.0	1.1
	(1,1.1)	(1.1,1.3)	(1,1.3)	(1.1,1.6)	(0.8,1.3)	(0.9,1.1)	(0.9,1.2)	(0.9,1.4)	(0.7,1.4)	(0.8,1.4)
aged 65+	**1.1**	**1.2**	**1.2**	**1.4**	1.1	1.0	1.1	1.2	1.1	1.0
	(1,1.2)	(1.1,1.3)	(1,1.3)	(1.1,1.7)	(0.9,1.4)	(0.9,1.2)	(0.9,1.3)	(0.9,1.5)	(0.8,1.5)	(0.7,1.4)
aged 85+	1.1	**1.4**	**1.3**	**1.5**	1.2	1.1	1.1	1.2	1.1	1.1
	(1,1.2)	(1.2,1.6)	(1.1,1.6)	(1.1,2)	(0.8,1.7)	(0.9,1.3)	(0.8,1.4)	(0.8,1.8)	(0.6,1.8)	(0.6,1.7)
Respiratory										
aged 45+	1.0	**1.3**	**1.4**	1.1	1.5	0.9	1.0	0.9	0.6	0.8
	(0.8,1.1)	(1.1,1.5)	(1.1,1.7)	(0.7,1.7)	(0.9,2.3)	(0.7,1.1)	(0.7,1.4)	(0.5,1.5)	(0.2,1.3)	(0.3,1.5)
aged 65+	1.0	**1.3**	**1.4**	1.2	1.6	0.8	1.0	1.0	0.5	0.8
	(0.8,1.1)	(1,1.5)	(1.1,1.8)	(0.7,1.8)	(0.9,2.5)	(0.6,1.1)	(0.7,1.4)	(0.6,1.7)	(0.1,1.4)	(0.3,1.6)
aged 85+	0.8	1.3	1.3	1.4	1.5	0.6	1.3	0.7	0.8	0.6
	(0.6,1)	(0.9,1.7)	(0.9,2)	(0.6,2.7)	(0.5,3.2)	(0.3,1)	(0.7,2.2)	(0.1,2)	(0.1,2.9)	(0.1,2.3)

† Bolded relative risk values are significantly greater than 1 ($p < .05$)

for persons aged 65 and above (RR = 1.6; 95% CI: 0.9-2.5). The overall relative risk of death for non-traumatic causes was 1.1 for persons aged 65 and above and 1.2 for persons aged 85 and above (which can also be expressed as elevated risks of death during heat events of 10% and 20%, respectively), compared with more temperate periods; overall RRs were similar for circulatory causes (not shown in tables).

Relative risks were derived for Eastern Washington study areas combined as a group (Table 2a). For residents of these areas, the risk of death by any cause on any given day of a heat event was not significantly elevated for any age group. However, risk estimates for death due to all non-traumatic causes, and for circulatory causes specifically, initially increased as the duration of heat event increased, rising from approximately 1.0 on day 1 to 1.1-1.2 on days 2-3, and falling back to about 1.0 on day 5 and beyond, for all age ranges. Non-traumatic death risk estimates on days 2 and 3 for persons aged 45 and above approached statistical significance (RR = 1.07 95% CI: 0.96-1.19 and 1.12 95% CI: 0.96-1.31, respectively). Relative risks were more variable for death due to respiratory causes, and followed no clear pattern. The overall relative risk of death for non-traumatic causes was 1.03 for persons aged 65 and above and 1.02 for persons aged 85 and above, for elevated risks of death during heat events of 2% and 3%, respectively, compared with more temperate periods. For circulatory causes, overall relative risks were 1.06 for persons aged 65 and over and 1.10 for those aged 85 and over, indicating elevated risks during heat wave of 6% and 10%, respectively (not shown in tables).

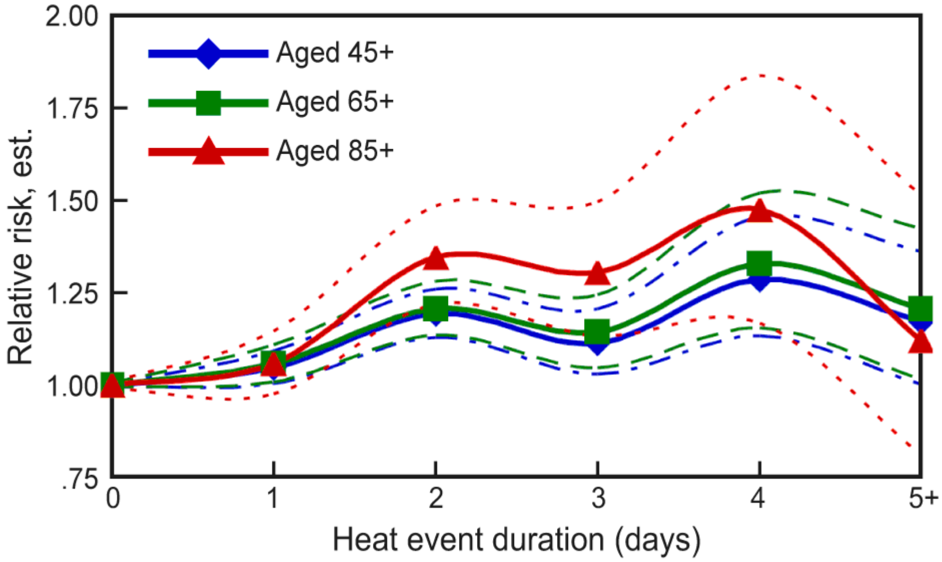


Figure 2. Mortality relative risk estimates (solid lines) for all non-traumatic causes (ICD-9: 001-799; ICD-10: A00-R99) by heat event duration (99th percentile), Greater Seattle Area (King, Pierce and Snohomish counties), 1980-2006. Dotted lines show estimated 95% confidence limits.

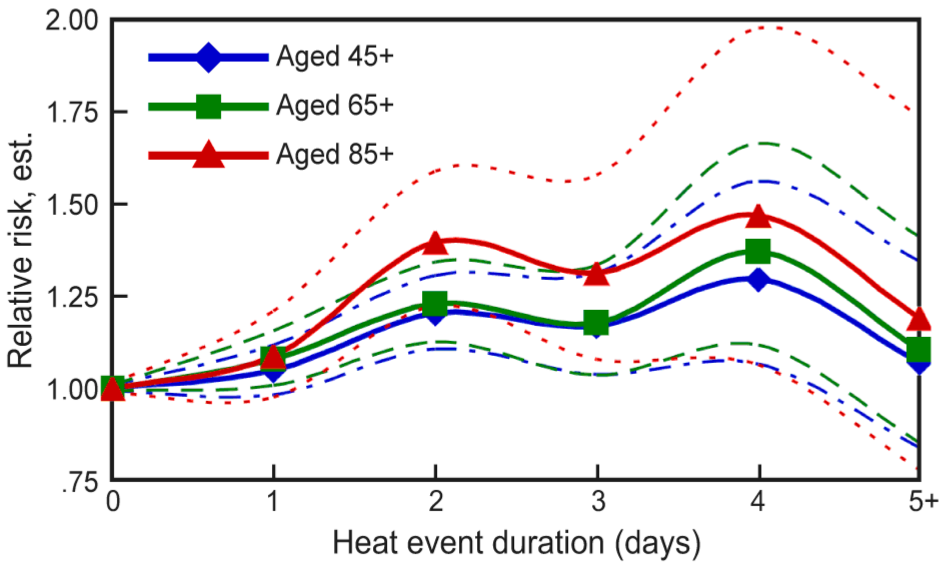


Figure 3. Mortality relative risk estimates (solid lines) for circulatory causes (ICD-9: 390-459; ICD-10: I00-I99, G45, G46) by heat event duration (99th percentile), Greater Seattle Area (King, Pierce and Snohomish counties), 1980-2006. Dotted lines show estimated 95% confidence limits.

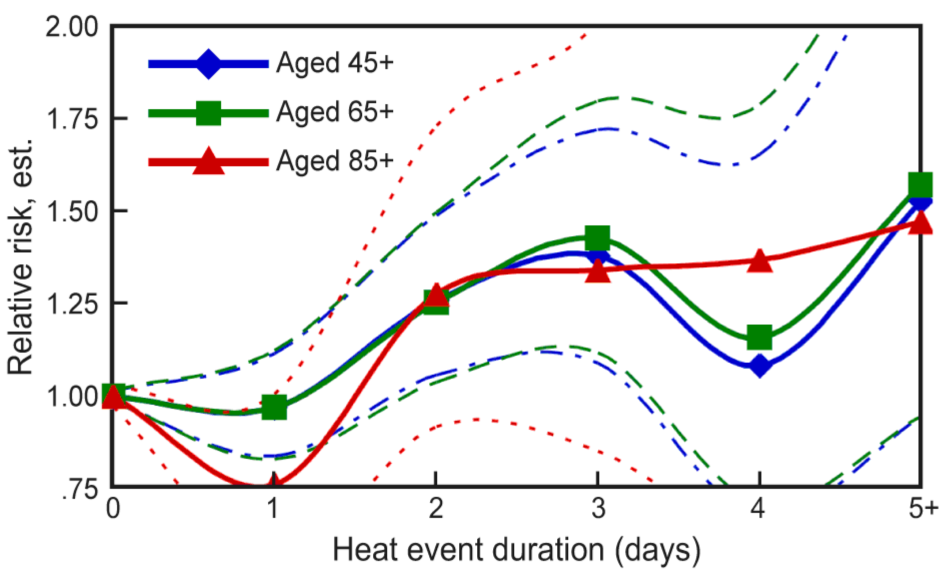


Figure 4. Mortality relative risk estimates (solid lines) for respiratory causes (ICD-9: 460-519; ICD-10: J00-J99) by heat event duration (99th percentile), Greater Seattle Area (King, Pierce and Snohomish counties), 1980-2006. Dotted lines show estimated 95% confidence limits.

Table 2b. Mortality relative risks for selected causes and age groups by heat event duration, Spokane, Tri-Cities & Yakima, 1980-2006.

	Spokane					Tri-Cities					Yakima				
Day of heat event	1	2	3	4	5+	1	2	3	4	5+	1	2	3	4	5+
All non-traumatic causes															
aged 45+	1.0	1.1	1.1	0.9	0.9	1.1	1.1	1.0	1.0	1.3	1.0	1.0	1.1	1.2	1.3
	(0.9,1.1)	(0.9,1.3)	(0.9,1.4)	(0.6,1.3)	(0.6,1.1)	(0.9,1.3)	(0.8,1.4)	(0.7,1.5)	(0.6,1.6)	(0.8,2.1)	(0.8,1.1)	(0.8,1.3)	(0.8,1.5)	(0.8,1.7)	(0.9,1.8)
aged 65+	1.0	1.1	1.1	0.9	0.9	1.0	1.1	1.2	1.1	1.1	0.9	1.0	1.1	1.2	1.2
	(0.9,1.1)	(0.9,1.3)	(0.9,1.4)	(0.6,1.3)	(0.6,1.2)	(0.8,1.2)	(0.8,1.5)	(0.7,1.8)	(0.6,1.9)	(0.6,2)	(0.8,1.1)	(0.8,1.2)	(0.8,1.5)	(0.8,1.8)	(0.8,1.7)
aged 85+	1.0	1.1	1.1	1.0	0.9	1.0	1.0	1.5	0.7	1.5	0.9	0.9	1.0	1.4	1.0
	(0.8,1.2)	(0.8,1.4)	(0.7,1.6)	(0.5,1.7)	(0.5,1.5)	(0.7,1.4)	(0.6,1.7)	(0.7,2.9)	(0.2,2.2)	(0.4,3.7)	(0.7,1.3)	(0.6,1.4)	(0.5,1.7)	(0.7,2.5)	(0.4,2.1)
Circulatory															
aged 45+	1.0	1.1	1.1	0.9	0.8	1.1	1.1	1.1	1.3	1.4	1.0	0.9	1.2	1.0	1.4
	(0.9,1.2)	(0.9,1.4)	(0.8,1.5)	(0.5,1.5)	(0.5,1.2)	(0.9,1.4)	(0.7,1.6)	(0.6,2)	(0.6,2.4)	(0.5,2.6)	(0.8,1.2)	(0.6,1.2)	(0.8,1.8)	(0.5,1.8)	(0.8,2.1)
aged 65+	1.1	1.1	1.1	1.0	0.8	1.0	1.2	1.3	1.3	1.0	1.0	0.9	1.2	1.1	1.3
	(0.9,1.2)	(0.9,1.4)	(0.8,1.6)	(0.6,1.7)	(0.5,1.3)	(0.7,1.3)	(0.8,1.7)	(0.7,2.3)	(0.6,2.6)	(0.3,2.4)	(0.7,1.2)	(0.6,1.3)	(0.7,1.8)	(0.5,1.9)	(0.7,2.1)
aged 85+	1.1	1.1	1.2	1.0	0.8	1.2	0.8	1.7	0.9	1.8	1.0	1.0	1.0	1.2	1.4
	(0.8,1.4)	(0.8,1.6)	(0.7,2)	(0.4,2.1)	(0.3,1.6)	(0.8,1.8)	(0.3,1.7)	(0.6,3.8)	(0.1,3.1)	(0.4,5.2)	(0.7,1.5)	(0.6,1.7)	(0.4,2)	(0.4,2.8)	(0.5,3.1)
Respiratory															
aged 45+	0.9	1.0	0.9	0.2	0.9	0.8	1.7	1.4	1.3	0.0	0.7	0.5	0.7	0.8	0.8
	(0.7,1.3)	(0.6,1.6)	(0.4,1.8)	(0,1.2)	(0.3,1.9)	(0.4,1.5)	(0.8,3.2)	(0.3,4)	(0.2,4.9)	(0,3.4)	(0.3,1.2)	(0.1,1.3)	(0.1,2.1)	(0.1,2.9)	(0,2.5)
aged 65+	0.9	1.1	1.0	0.0	0.8	0.8	1.7	1.6	1.6	0.0	0.6	0.3	0.8	0.9	0.9
	(0.6,1.3)	(0.7,1.6)	(0.4,2)	(0,0.9)	(0.3,1.9)	(0.3,1.5)	(0.8,3.4)	(0.3,4.6)	(0.2,5.7)	(0,4)	(0.3,1.2)	(0,0.9)	(0.2,2.3)	(0,3.3)	(0.1,3.3)
aged 85+	0.6	1.3	0.8	0.0	0.5	0.4	2.5	0.0	0.0	0.0	0.7	0.8	0.8	2.6	1.3
	(0.2,1.1)	(0.5,2.5)	(0.1,2.7)	(0,2.6)	(0,2.6)	(0,2.1)	(0.5,7.2)	(0,7.6)	(0,11.3)	(0,17.4)	(0.1,1.9)	(0.1,2.8)	(0,4.2)	(0.3,9.4)	(0,7.1)

Relative risks of death during heat events were examined for all three eastern study areas individually as well (Table 2b). No statistically significant excess risk for the cause- and age-groups considered was observed and confidence intervals were much wider due to smaller population size, although a few patterns emerged. In Spokane, relative risks for non-traumatic cause-of-death remained close to 1.0, but for all age ranges, wherein point estimates for the relative risks were was approximately 1.0 on day 1, they increased to 1.1 on days 2 and 3 (95% CI: 0.9-1.4 for ages 45+ and 65+) and then decreased to 0.9 on day 5 and beyond. Relative risks for circulatory cause-of-death followed a similar pattern. In the Tri-Cities, elevated relative risk of death by all non-traumatic or circulatory causes for persons 45 years of age and older approached statistical significance on day 1 (RR = 1.1; 95% CI: 0.9-1.3 and RR = 1.1; CI: 0.9-1.4, respectively). In Yakima, relative risk of death for all non-traumatic causes or by circulatory causes peaked on day 5 for persons aged 45 and above (RR = 1.3 and 1.4; 95% CI: 0.9-1.8 and 0.8-2.1, respectively). In general, although not statistically significant, the estimates suggested an increased risk of death for all non-traumatic causes and circulatory causes among persons aged 45 and above.

Table 3. Projected climate and population parameters

	Greater Seattle Area			Spokane			Tri-Cities			Yakima		
	2025	2045	2085	2025	2045	2085	2025	2045	2085	2025	2045	2085
Population (in thousands)												
Total	4,091	4,910	6,542	561	684	933	293	355	480	287	346	463
45 to 64	980	1,082	1,242	131	147	176	62	78	110	59	69	87
65 to 84	638	1,005	1,765	86	130	223	36	51	82	33	46	73
85 and above	73	105	161	11	13	18	4	8	15	5	6	7
Low summer warming												
Mean high humidex, °C (°F),	24.0	24.4	25.1	26.9	27.2	27.8	28.7	29.0	29.6	25.6	25.9	26.5
May-September	(75.2)	(75.9)	(77.2)	(77.2)	(81.0)	(82.0)	(83.7)	(84.2)	(85.3)	(78.1)	(78.6)	(79.7)
Mean annual heat events	2.6	3.1	3.8	2.5	2.9	3.2	2.5	2.9	3.3	2.5	3.0	3.4
Mean(max) event duration in days	2.2(6)	2.3(7)	2.3(8)	2.3(9)	2.6(9)	2.7(9)	2.4(9)	2.5(12)	2.6(13)	2.4(11)	2.5(13)	2.6(13)
Moderate summer warming												
Mean high humidex, °C (°F),	24.8	25.8	27.5	27.6	28.5	30.1	29.4	30.2	31.7	26.2	27.1	28.6
May-September	(76.6)	(78.4)	(81.5)	(81.7)	(83.3)	(86.2)	(84.9)	(86.4)	(89.1)	(79.2)	(80.8)	(83.5)
Mean annual heat events	3.6	4.7	7.2	3.2	4.1	6.0	3.2	4.2	5.9	3.2	4.3	5.9
Mean(max) event duration in days	2.3(7)	2.6(14)	2.9(18)	2.6(9)	3.0(14)	3.4(17)	2.7(13)	3.0(14)	3.6(17)	2.8(13)	2.9(14)	3.5(17)
High summer warming												
Mean high humidex, °C (°F),	26.3	28.1	31.3	29.0	30.6	33.5	30.6	32.2	34.8	27.5	29.1	31.8
May-September	(79.3)	(82.6)	(88.3)	(84.2)	(87.1)	(92.3)	(87.1)	(90.0)	(94.6)	(81.5)	(84.4)	(89.2)
Mean annual heat events	5.8	8.8	10.1	4.8	6.6	8.4	4.9	6.9	8.9	5.2	6.8	9.4
Mean(max) event duration in days	2.7(18)	3.2(18)	6.1(57)	3.4(16)	3.8(17)	5.6(50)	3.5(16)	3.9(24)	5.6(50)	3.4(17)	3.9(24)	5.4(42)

3.2. Projected Mortality Due to Heat Events: 2025-2085

Projected population and climate factors are shown in Table 3. Population projections for Washington State indicate an expected increase in total population between 2006 and 2025 of 14% to 21%. The group expected to grow fastest in all areas are persons aged 65 to 84; this age group is expected to grow by 121% in the greater Seattle area, by 84% in Spokane and the Tri-Cities, and by 49% in Yakima. The expected number and duration of heat events above the humidex historical 99th percentile thresholds will also increase. Under the moderate warming scenario, the greater Seattle area can expect 3.6 heat events with a mean duration of 2.3 days, and in 2085 this will increase to 7.2 heat events of 2.9 days mean duration. Spokane can expect approximately 3.2 heat events of 2.6 days mean duration in 2025, and 6.0 heat events of 3.4 days mean duration in 2085.

The mean numbers of excess deaths that can be expected annually from heat events above the 99th percentile are presented in Table 4 for the greater Seattle area and for Spokane, the Tri-Cities and Yakima combined, holding population constant at 2025 projected levels. Holding the population level constant allows for the comparison of excess deaths

Table 4. Projected Annual Excess Deaths by Cause and Age Group for Low, Middle and High Warming Scenarios

	Low			Middle			High		
	2025 mean (se)	2045 mean (se)	2085 mean (se)	2025 mean (se)	2045 mean (se)	2085 mean (se)	2025 mean (se)	2045 mean (se)	2085 mean (se)
Greater Seattle Area									
Non-traumatic deaths									
aged 45+	68(10)	89(12)	107(13)	101(12)	156(17)	280(22)	211(20)	401(26)	988(32)
aged 65+	64(9)	84(11)	102(12)	96(12)	148(17)	266(21)	200(19)	382(25)	956(32)
aged 85+	32(4)	40(5)	48(6)	46(5)	68(7)	117(8)	89(8)	160(9)	304(8)
Circulatory deaths									
aged 45+	34(5)	43(6)	52(6)	49(6)	72(7)	124(8)	95(8)	170(9)	326(8)
aged 65+	35(5)	45(6)	54(6)	51(6)	75(8)	130(9)	99(9)	178(10)	351(9)
aged 85+	20(3)	26(3)	31(3)	30(3)	44(5)	76(5)	58(5)	105(6)	215(5)
Respiratory deaths									
aged 45+	9(1)	11(2)	14(2)	13(2)	22(3)	44(5)	31(4)	66(6)	218(11)
aged 65+	8(1)	11(2)	13(2)	13(2)	22(3)	42(5)	30(4)	64(6)	213(11)
aged 85+	1(0)	2(0)	2(1)	2(1)	4(1)	8(1)	6(1)	14(2)	53(3)
Spokane, Tri-Cities, Yakima									
Non-traumatic deaths									
aged 45+	12(2)	15(2)	17(2)	17(2)	24(2)	37(2)	31(2)	45(2)	76(2)
aged 65+	9(1)	11(1)	13(1)	13(1)	18(2)	27(2)	23(2)	32(1)	45(2)
aged 85+	1(0)	1(0)	1(0)	1(0)	2(0)	3(0)	3(0)	4(0)	4(1)

† Population held constant at 2025 projections

due to heat events alone, without introducing uncertainty in the population projections beyond 2025, which are increasingly speculative. Under a climate scenario that yields relatively low summer (May-Sept.) warming, during heat events the greater Seattle area can expect 68 excess deaths in 2025, and 89 excess deaths in 2045 and 107 excess deaths in 2085 from all non-traumatic causes among persons 45 years of age and older, than during more temperate periods. Under the moderate warming scenario, which is also the most reliable estimate, Seattle can expect 101 excess deaths in 2025, 156 excess deaths in 2045 and 280 excess deaths in 2085 from all non-traumatic causes among adults 45 and above. Under the highest warming scenario, 211 excess deaths in 2025, 401 excess deaths in 2045 and 988 excess deaths in 2085 are expected during extreme heat in the same cause- and age-group. The bulk of all non-traumatic deaths will happen in persons 65 years old or older, with approximately one third to one half of these occurring among those aged 85 and above. Under the moderate scenario, just under half of all excess deaths in the greater Seattle area will occur by circulatory failure, and about 1 in 7 will be due to respiratory failure.

In the combined eastern study areas, 12 to 31 excess deaths by non-traumatic causes in persons aged 45 and older are expected in 2025, depending on the scenario. By 2085, this same age-cause group is expected to yield between 17 and 76 excess deaths. As in Seattle, most non-traumatic deaths among the population aged 45 and above will occur among persons aged

Table 5. Baseline decade (1997-2006) and mid-century decade (2045-2054) estimates of population size, daily ozone concentration, mortality rate due to ozone, and excess deaths due to ozone (May-September).

Estimates	**King County**		**Spokane County**	
May -September	1997-2006	2045-2054	1997-2006	2045-2054
O_3 (ppb)[1]	20.7	26.5	35.5	41.6
Population	1,758,260	2,629,160	424,636	712,617
O_3 Non Traumatic Mortality rate (95% CI)[2]	0.026 (0.013- 0.038)	0.033 (0.017 -0.049)	0.058 (0.030-0.085)	0.068 (0.035-0.100)
O_3 Cardiopulmonary mortality rate (95% CI)[2]	0.011 (0.005-0.017)	0.015 (0.007-0.022)	0.027 (0.013-0.042)	0.032 (0.015-0.049)
O_3 Non traumatic deaths (95% CI)3	69 (35-102)	132 (68-196)	37 (19-55).	74 (38-109).
O_3 Cardiopulmonary deaths (95% CI)[3]	31 (15-47)	59 (28-90)	18 (9-27)	35 (17-54)

[1]Average daily maximum 8 hour ozone concentration
[4]Rate expressed per 100,000 for May-September with 95% confidence interval
[5]Number of deaths May-September

65 and above; however, comparatively few deaths are expected to occur in persons 85 years of age or older, even though the proportion of the population aged 85 and older is similar between regions.

3.3. Projected Excess Mortality Due to Air Pollution

Using the modeling framework, the delta or forecasted change in ozone for the mid century was calculated and determined to be +5.8 ppb in King County and +6.1 ppb in Spokane County. This was then applied to the baseline decade measurements made at monitoring stations. Baseline decade summertime (May-Sept.) average 8 hour average maximum daily ozone concentrations for King County based on regulatory monitoring measurements were 20.7 ppb for 1997-2006. So, applying the model delta, the future ozone concentrations in the mid century are forecasted to be approximately 26.5 ppb, a 28% increase. In Spokane County, the measured ozone concentrations were higher than in King County, with a 35.5 ppb average 8 hour maximum ozone concentration based on regulatory monitor data for 1997-2006. Applying the model delta predicts future ozone concentration at approximately 41.6 ppb in Spokane County, a 17% increase.

Using the health risk assessment framework, estimates of the total ozone related non-traumatic mortality and cardiopulmonary mortality as rates (per 100,000) and numbers of death for each county for each decade were summarized (Table 5). We estimated that the total non traumatic ozone mortality rate in the recent and mid-century period for King County will increase from 0.026 (95% confidence interval 0.013-0.038) to 0.033 (95% confidence interval 0.017-0.049) (Table 1). For the same health outcome in Spokane County, the rate is 0.058 (0.030-0.085) in the recent decade and increases to 0.068 (0.035-0.100) in the mid century. The estimated annual number of May-September excess deaths in King County due to ozone in 1997-2006 is 69 (95% CI 35-102). Using projections of the future population size and ozone concentration increase this to 132 (95% CI 68-

195). For Spokane County the warm season excess deaths due to ozone in the recent decade are estimated to be 37 (95% CI 19-55). In mid-century this is predicted to be 74 (95% CI 38-109).

The cardiopulmonary death rate per 100,000 due to ozone was estimated to increase from 0.011 (95% CI 0.005-0.017) to 0.015 (0.007-0.022) in King County comparing the recent decade to mid-century. In Spokane, the daily cardiopulmonary death rate attributed to ozone increases from 0.027 (95% CI 0.013-0.042) to 0.032 (95% CI 0.015-0.049) across the decades. This translates to an estimated annual number of May - September excess deaths in King County due to ozone in 1997-2006 of 31 (95% CI 14.7-47) and an increase in mid century to 59 (95% CI 28-90). For Spokane, the estimated baseline deaths due to ozone is 18 (95% CI 9-27) and in the mid century is estimated to increase to 35 (95% CI 17-54).

4. Discussion

4.1. Mortality and Heat Events

In the greater Seattle area there is a clear relationship between heat events and elevated risk of mortality for persons aged 45 and above. The elevated risk is apparent for non-traumatic causes in general, and for circulatory and respiratory causes specifically. The majority of circulatory deaths are due to cardiovascular causes; an analysis of cardiovascular deaths (not presented) showed that the relative risks associated with circulatory cause-of-death were driven primarily by cardiovascular deaths. Respiratory deaths were too small in number to allow for an analysis of more specific causes. The highest relative risks were for persons aged 65 and above; relative risks for persons aged 45 to 64 were smaller (not presented) and this age group contributed relatively few excess deaths in the historical period (not shown). Analyses of age groups younger than 45 were inconclusive, as there were insufficient numbers of deaths to produce stable relative risk values (not presented). We did not attempt to extend the mortality analysis beyond the duration of the heat event itself. This approach may have missed some latent deaths if they occurred after the heat event ended. However, by limiting the analysis just to the heat event, the calculated risk estimates should be conservative because they would tend to understate the deaths attributable to the event.

In the Spokane, Tri-Cities and Yakima study areas, separately or combined, only a few, isolated relative risks were statistically significant. Some patterns in relative risk, however, suggest real differences in mortality rates during heat events, but with samples perhaps too small to support statistical significance.

Projected annual numbers of excess deaths in the greater Seattle area were substantial under some conditions; even under moderate summer (May-Sept.) warming, the area can expect around 100 excess non-traumatic deaths in 2025 and more than 150 excess in 2045. The projections for the eastern study areas combined were much smaller. Even when projected population is taken into account, excess deaths per 100,000 were much lower in Spokane, Tri-Cities and Yakima than in the greater Seattle area. This could be explained in a number of ways. The urban heat island effect may be stronger in the more densely settled Seattle area. To the extent that socioeconomic inequality is greater in urban portions of the Seattle area, this may explain the higher relative risks for mortality during heat waves.

Perhaps the best possible explanation is the greater market penetration of residential air conditioning in Spokane, Tri-Cities, and Yakima in comparison to the greater Seattle area. According to a corresponding study by Elsner et al. (2009), market penetration of residential air conditioning is significantly higher in the study areas east of the Cascade Mountains. As of 1980, the Spokane (24%), Tri-Cities (54%), and Yakima (21%) study areas had significantly higher percentages of residential air conditioning than the greater Seattle area (8%). According to projections for 2020, the disparity will grow even more as the Seattle study area (10%) will still have significantly lower percentages of residential air condition than the Spokane (41%), Tri-Cities (68%), and Yakima (30%) study areas. This association between lowered risks for heat related illness and higher prevalence of residential air conditioning has also been cited by a number of authors (McGeehin et al. 2001; Chestnutt et al. 1998) as a mitigating factor on heat related illness during heat events.

The numbers of excess deaths shown in Table 4 are estimates averaged across 30 annual climate scenarios. The variability in the estimates, due to the changing frequency and duration of heat events in the annual scenarios, is reflected in the standard error term for each value. We acknowledge that in using the inter-annual variation as a measure of uncertainty, not all sources of uncertainty may have been included, and therefore the standard errors likely will be artificially small. Although variability in the climate data contributes much to uncertainty in these estimates, we did not account for additional uncertainty due to the underlying risk estimates. In some cases, age-specific mortality rates for some disease categories are very close to baseline, and may not indicate a net excess. For example, the projections for circulatory deaths in the greater Seattle area show slightly fewer excess deaths in the 45+ category than in the 65+ category, because the overall point estimates indicate a small protective effect for the 45-64 age group (data not shown). This probably reflects statistical uncertainties in the age-specific relative risk calculations, which have some confidence limits which overlapped unity. However in the remaining categories where the relative risk estimates were significantly elevated, there are consistent trends in excess deaths across projection scenarios.

A limitation of this analysis was the use of the county as the geographic level at which mortality data were linked with climate data. This decision was driven by the ready availability of both death certificate and population data at that level, and the substantial difficulty of creating smaller areas of analysis that were geographically stable (and therefore containing a consistent population base) for each year over the historical period. The necessity of averaging climate variables over a comparatively large area meant that local extremes in temperature and humidity were dampened, and the estimated effect of heat on mortality may have been attenuated. However, this suggests that our analysis yielded conservatively-biased estimates of the relationship between heat and mortality, and that the actual effects may be larger.

In addition, the reliability of the projections for excess deaths in each of the nine future heat regimes depends upon the reliability of both climate projections and population projections. The middle 2025 scenario, combining the closest time period with the average climate scenario, is the most reliable of the nine simulations. Excess death estimates using the low and high warming scenarios must be interpreted cautiously, as extremes bracketing the best estimate. Estimates of excess deaths for 2045 and 2085 were made using 2025 projected populations. To the extent that population continues to grow beyond 2025, particularly if more growth occurs in higher age ranges, excess death estimates will be conservative.

Other issues that should be mentioned concern our use of ICD-9 and ICD-10 codes to categorize deaths by cause. First, ICD-9 and ICD-10 codes are not perfectly comparable, so cause-specific rates may appear to change between years when different coding schemes were in use for no other reason than deaths are grouped somewhat differently in each system. However, we did not aim to analyze changing mortality rates over time, so the change in coding scheme is not central to the analysis. Second, since deaths are not classified as being caused by heat, some inference is necessary in choosing cause-of-death groupings that are believed to be influenced by heat. Since we cannot precisely isolate cause of deaths that are due solely or substantially to heat, inaccurate cause of death information could create potential non-differential misclassification and estimates of the effect of heat on mortality are potentially conservatively biased.

Finally, the analytic method we chose relies upon a dense population with substantial numbers of deaths each day. Members of smaller, more isolated populations may also experience elevated risk of mortality during heat events, perhaps to an even greater extent than in larger, central populations, perhaps due to increased exposure or lack of access to cooling. This analysis is not sensitive enough to determine relative risks for smaller, rural locales.

4.2. Mortality and Ozone

We assessed the potential health impacts of ozone related climate change at a locally relevant regional scale, the county, for two highly populated regions of Washington State; King and Spokane counties. Given the assumptions of our models, increases in projected ozone concentrations will increase the mortality rate due to this pollutant in both areas. The higher ozone concentrations and underlying mortality rates observed in Spokane County yield higher current and future decade mortality rates due to ozone in this eastern Washington setting. However, the relative change in ozone related mortality is predicted to be greater in King County, due to a larger relative change (increase) in predicted ozone concentrations for this Western Washington region in mid-century.

The availability of regionally downscaled climate models and meteorological and air pollution models provides an opportunity for this initial public health assessment of climate change and ozone in Washington State. However, the models and subsequent estimates are subject to influence based on assumptions for the underlying components and the scope of available data sources. We applied a single climate change scenario-ozone model to forecast future ozone concentrations that incorporates the range of influences on ozone formation through both direct and indirect meteorological changes. Previous application of climate change related ozone forecasting and subsequent health impact have relied on ozone projections focused on the direct impacts of climate change and do not incorporate land use/land cover projections, anthropogenic emission changes, and future boundary conditions (Knowlton et al. 2004; Bell et al.2007).

We used a concentration response function from the NMMAPS study. Several features support its selection. The effect estimates fall within the range of those reported among the National Academy of Sciences recent review of U.S. based studies that include multiple cities or meta analyses where the point estimates ranged between 0.46% - 1.50 % increase in mortality per 10 ppb increase in 8 hour ozone concentrations, with the lower and upper bounds of the confidence intervals ranging from 0.23%-2.10 % (Thurston 2001, Levy 2001, Stieb 2002, Bell 2004, Bell 2006, Schwartz 2006, NAS 2008). NMMAPS and the studies cited include temperature and particulate matter air pollution in the ozone concentration-response model, to remove confounding by the influence of these factors on mortality.

There is an ongoing need for better data on the portion of mortality that represents people who are at risk of death within a few days irregardless of ozone exposure - the so-called "harvesting effect". However, the current evidence suggests that mortality due to ozone is not restricted to this subgroup of individuals (NRC 2008). While individuals within the population with pre-existng disease, particularly cardiopulmonary conditions and at extremes of the age range are likely more vulnerable to the effects of increasing ozone, the distribution of ozone-mortality effects on subpopulations are not well characterized unlike the overall (population-weighted) average concentration effects such as applied in this study.

In the first study of this kind to apply regional climate model outputs to county level public health risk assessment for ozone mortality (Knowlton, 2004), the estimated 1990s baseline decade (1990s) ozone mortality for 31 northeast U.S. counties were between 5 and 123 (for June- August period). This was calculated based on modeling the baseline 1990s decade ozone concentrations using a regional climate ozone model under the IPCC A2 scenario. Our baseline 1990s ozone mortality estimates for King and Spokane County yield comparable findings (69 and 37, respectively for May-September period), although our baseline decade ozone concentrations were based on regulatory monitoring network measurements, rather than application of the regional model for the 1990s. We predict slightly larger increases between our measurements in the current decade and the mid century modeled projections, a +6.1 ppb change for Spokane County and +5.8 ppb for King County compared to more modest increases of 1-4 ppb in the northeastern county based analysis. This likely reflects that the climate change ozone model employed by Knowlton et al did not incorporate land use/land cover projections, anthropogenic emission changes, and future boundary conditions (Knowlton et al. 2004; Bell et al. 2007) which would be expected to increase future ozone concentrations above the influence of more direct effects of climate on ozone.

The application of projected population increases on mortality rates had a strong influence on future mortality projections. This demonstrates the relative public health impact that even modest increases in ozone concentrations may have as the population grows but also underscores the uncertainties inherent in risk assessment such as this. In the future, we plan to employ both alternative models of climate change-ozone concentrations with differing underlying assumptions as they become available for our region.

6. Research Gaps and Recommendations for Future Research

Social and economic factors have been shown to influence mortality during periods of excessive heat (Greenberg et al. 1983; McGeehin et al. 2001; Browning et al. 2006). A logical next stage in the study of the effect of heat events on mortality in Washington State would be to consider socioeconomic factors that shape exposure to heat and mitigation of the effects of heat, in particular, race/ethnicity, income and occupation. Moreover, we were unable to study the mitigating influence of such things as distribution of residential air conditioning or access to cooling at work or leisure; such access is unlikely to be equally distributed across the state or adequately available to persons most at risk of serious illness or death.

A refinement of the estimated relationship between heat events and mortality could be made by reducing the size of the geographic unit used to link climate variables with mortality, so that a more precise approximation of the local heat history surrounding the decedent could be made. If fatalities were geocoded to census blocks then climate variables at the grid level could be assigned to specific blocks individually, rather than averaged over a much larger area. In addition, a variety of block-level contextual factors (e.g., neighborhood characteristics) available from Census data that might be relevant to heat-related mortality risk could be linked and analyzed in concert with other factors.

Finally, this analysis considered only fatalities, the end stage of a progression of heat-induced morbidity that many individuals will not reach. A more sensitive and perhaps more revealing analysis of the effects of heat on the health and welfare of a population would consider other outcomes, such as emergency room and hospital admissions for heat-related illnesses, and even lost income and productivity due to illness.

Complexities not considered in the analysis of ozone and mortality include differences within population subgroups regarding vulnerability, housing characteristics, and activity patterns which may vary in the future. As the climate warms, people may spend more time indoors or in air conditioned settings which will decrease exposure. We applied a single baseline mortality rate based on current decade but this may change due to medical advances, access to medical care and changes in other risk factors such as smoking and diet, and aging of the population. Some acclimatization may occur but quantifying this is outside the scope of this study. We focused on short term mortality increases due to increased ozone, but other important but less severe health conditions that are known to be influenced by short term increases in ozone include hospitalization for asthma and other chronic respiratory disease, lost work and school days due to respiratory symptoms. The adverse health consequences of chronic elevated ozone exposure on health is less well-studied although an expanding literature suggests such exposure increase the prevalence of asthma and asthma symptoms (McConnell 2002, Lin 2008).

In regard to ozone and mortality, the following issues need to be addressed:

- Development of a range of climate - ozone projections reflecting different assumptions regarding population growth, emission changes, and land use changes would allow consideration of the range of potential changes in ozone concentration and the influence of potential future policy-making options on those changes.
- Consideration of other important health outcomes and medical/ public health system burdens due to increases in ozone such as asthma hospitalizations, asthma prevalence, and cardiovascular disease events should be applied to future policy-making options
- Development of robust models forecasting regional scale changes in particulate matter (e.g. PM2.5) and application in health risk studies in Washington State would further enhance climate-preparedness efforts.
- Better understanding of the effects of ozone on vulnerable subpopulations such as those with pre-existing diseases and differing age groups, particularly the very young and elderly.

Finally, a great deal more study is needed to understand the multiple effects of climate change on incidence of death or illness from causes not considered in this focused initial effort. For example, the currently observed wintertime increases in cardiopulmonary disease may be lessened with future decreases in wintertime temperatures. Characterizing this will be helpful to fully understand the global context of climate change and health in the population.

These include food- and water-borne illnesses, vector-borne disease, and exposure to risk of traumatic injury and death from extreme weather events such as flooding, storm surges and sea-level rise.

7. Conclusions

Heat stress is a significant factor in mortalities during the warmer months in Washington State, especially for persons aged 65 and above. As summer (May-Sept.) heat increases and the population grows, Washington can expect an increase in the number of heat-related deaths annually. More research should be done to explore other important factors influencing the effect of heat on mortality in Washington, including individuals' socioeconomic status and access to cooling in very hot weather.

In the last decades, overall ambient air quality has improved in Washington State through regulatory policy but health impacts continue and climate change related effects may threaten gains that have been made. A better understanding of climate change impacts on ambient air quality is critical to prepare for and alleviate potential worsened public health consequences.

References

American Academy of Pediatrics, Committee on Sports Medicine and Fitness (2000) Climatic heat stress and the exercising child and adolescent. Pediatrics 106:158-159

Avise J, Chen J, Lamb B, Wiedinmyer C, Guenther A, Salathé E, and Mass C (2008) Attribution of projected changes in US ozone and PM2.5 concentrations to global changes. Atmos Chem Phys Discuss J1 - ACPD 8:15131-15163

Basu R, Dominici F, Samet JM (2005) Temperature and mortality among the elderly in the United States: A comparison of epidemiologic methods. Epidemiology 16:58-66

Bell, ML, Samet JM, Dominici F (2004a) Time-series of particulate matter. Annu Rev Public Health 25:247-80

Bell, ML, McDermott A, Zeger SL, Samet JM, Dominici F (2004b) Ozone and short-term mortality in 95 urban communities, 1987-2000. JAMA 292:2372-78

Bell ML, Goldberg R, Hogrefe C, Kinney PL, Knowlton K, Lynn B, Rosenthal J, Rosenzweig C, Patz JA (2007) Climate change, ambient ozone, and health in 50 US cities. Climatic Change 82:61–76

Bernard SM, McGeehin MA (2004) Municipal heat wave response plans. AJPH 94:1520-1522

Bernard SM, Samet JM, Grambsch A, Ebi KL, Romieu I (2007) The potential impacts of climate variability and hange on air pollution-related health effects in the United States. Environ. Health Perspect 109:199-209 (Supplement 2)

Borrell C, Mari-Dell'Olmo M, Rodriguez-Sanz M, Garcia-Olalla P, Cayla Ja, Benach J, Muntaner C (2006) Socioeconomic position and excess mortality during the heat wave of 2003 in Barcelona. European J Epidemiology 21:633-640

Breslow NE and Day NE (1987) Statistical Methods in Cancer Research: Volume II: The Design and Analysis of Cohort Studies. Lyon, International Agency for Research on Cancer

Browning CR, Wallace D, Feinberg SL, Cagney KA (2006) Neighborhood social processes, physical conditions, and disaster-related mortality: The case of the 1995 Chicago heat wave. Am Sociol Rev 71:661-678

California Air Resources Board (2008) Methodology for Estimating Premature Deaths Associated with Long-term Exposure to Fine Airborne Particulate Matter in California. Accessed 24 October 2008 at http://www.arb.ca.gov/research/health/pm-mort/pm-mort_final.pdf

CCSP: Climate Change Science Program (2008) Analyses of the effects of global change on human health and welfare and human systems. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Gamble JL (ed.), Ebi KL, Sussman FG, Wilbanks TJ (Authors)] U.S. Environmental Protection Agency, Washington, DC, USA

CDC: Centers for Disease Control and Prevention (2005) Heat-related mortality--Arizona, 1993-2002, and United States, 1979-2002. Morbidity and Mortality Weekly 54:628-630

CDC: Centers for Disease Control and Prevention (2006) Heat-related deaths--United States, 1999-2003. Morbidity and Mortality Weekly Report 55:796-798

Changnon SA, Kunkel KE, Reinke BC (1996) Impacts and responses to the 1995 heat wave: A call to action. Bull Am Meteorol Soc 77:1497-1506

Chen J, Avise J, Lamb B, Salathé E, Mass C, Guenther A, Wiedinmyer C, Lamarque J-F, O'Neill S, McKenzie D, and Larkin N (2008) The Effects of Global Changes upon Regional Ozone Pollution in the United States. Atmos Chem Phys Discuss 8:15165-15205

Cheng CS, Campbell M, Li Q, Li G, Auld H, Day N, et al. (2005) Differential and

Combined Impacts of Winter and Summer Weather and Air Pollution due to Global Warming on Human Mortality in South-central Canada. Toronto Public Health, Toronto, Canada. Accessed July 21, 2008 at http://www.toronto.ca/health/hphe/pdf/weather_air_pollution_impacts.pdf

Chestnutt LG, Breffle WS, Smith JB, Kalkstein LS (1998) Analysis of differences in hot-weather-related mortality across 44 U.S. metropolitan areas. Environ Sci Poly 1:59-70

Davis RE, Knappenberger PC, Novicoff WM, Michaels PJ (2003) Decadal changes in summer mortality in U.S. cities. Int.J.Biometeorol. 47(3):166-175

DeGaetano AT, Allen RJ (2002) Trends in Twentieth-century temperature extremes across the United States. J of Climate 15:3188-3205

DOH: Washington Department of Health (2002) Guidelines for Using Confidence Intervals for Public Health Assessment. Washington State Department of Health, Olympia, WA. Accessed November 30, 2008 at http://www.doh.wa.gov/data/guidelines/guidelines.htm

Elsner MM, Cuo L, Voisin N, Hamlet AF, Deems JS, Lettenmaier DP, Mickelson KEB, Lee SY (2009) Implications of 21st century climate change for the hydrology of Washington State. Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. In Press

Environment Canada (2008) Humidex Brochure/Fact Sheet. Accessed November 30, 2008 at http://www.msc.ec.gc.ca/cd/brochures/humidity_e.cfm

EPRI (2005) Interactions of Climate Change and Air Quality: Research Priorities and New Directions. Electric Power Research Institute. http://www-as.harvard.edu/chemistry/trop/publications/Air_Climate_Workshop1.pdf

Frumkin H, Hess J, Luber G, Malilay J, McGeehin M. (2008) Climate change: the public health response. AJPH 98:435-445

Greenberg JH, Bromberg J, Reed CM, Gustafson TL, Beauchamp RA (1983) The epidemiology of heat-related deaths, Texas--1950, 1970-79, and 1980. AJPH 73:805-807

Grimmond CSB and Oke TR (1999) Heat storage in urban areas: Local-scale observations and evaluation of a simple model. J Appl Meteorol 38:922-940

Jones TS, Liang AP, Kilbourne EM, Griffin MR, Patriarca PA, Wassilak SG, Mullan RJ, Herrick RF, Donnell Jr, HD, Choi K, Thacker SB (1982) Morbidity and mortality associated with the July 1980 Heat Wave in St Louis and Kansas City, Mo. JAMA 247:3327-3331

Kaiser R, Rubin CH, Henderson AK, Wolfe MI, Kieszak S, Parrott CL, Adcock M (2001) Heat-related death and mental illness during the 1999 Cincinnati heat wave. Am J Forensic Med Pathol 22:303-307

Kaiser R, Le Tertre A, Schwartz J, Gotway CA, Daley WR, Rubin CH (2007) The effect of the 1995 heat wave in Chicago on all-cause and cause-specific mortality. AJPH 97:S158-62 (Supplement 1)

Kalkstein LS, Davis RE (1989) Weather and Human Mortality: An Evaluation of Demographic and Interregional Responses in the United States. Annals of the Association of American Geographers 79(1):44-64

Kalkstein LS, Jamason PF, Greene JS, Libby J, Robinson L (1996) Philadelphia Hot Weather-Health Watch/Warning System: Development and Application, Summer 1995. Bulletin of the American Meteorological Society 77(7):1519-1528

Karl T, Knight R (1997) The 1995 Chicago heat wave: How likely is a recurrence? Bull Am Meteorol Soc 78:1107-1119

Kinney PL (2008) Climate change, air quality, and human health. Am J Prevent Med 35:459-467

Knowlton K, Rosenthal JE et al. (2004) Assessing Ozone-Related Health Impacts under a

Changing Climate. Environ Health Perspect 112:1557–1563

Lin S, Liu X, Le LH , Hwang SA (2008) Chronic exposure to ambient ozone and asthma hospitalizations among children. Environ Health Perspect 116:1725–1730

Luber G, McGeehin M (2008) Climate change and extreme heat events. Am J Prevent Med 35:429-435

Masterton JM, Richardson FA (1979) A method of quantifying human discomfort due to excessive heat and humidity. Downsview, Ontario, Canada:AES, Env. Canada, CLI 1-79.

McConnell R, Berhane K, Gilliland F, London SJ, Islam T, Gauderman WJ, et al. (2002) Asthma in exercising children exposed to ozone: a cohort study. Lancet 359:386–391

McGeehin MA, Mirabelli M (2001) The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. Environ Health Perspect 109:185-189 (Supplement 2)

Medina-Ramon M, Zanobetti A, Cavanagh DP, Schwartz J (2006) Extreme temperatures and mortality: Assessing effect modification by personal characteristics and specific cause of death in a multi-city case-only analysis. Environ Health Perspect 114:1331-1336

Meehl GA, Tebaldi C (2004) More intense, more frequent, and longer lasting heat waves in the 21st century. Science 305:994-997

Mote PW, Salathé Jr. EP (2009) Future climate in the Pacific Northwest. Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. In Press

Naughton MP, Henderson A, Mirabelli MC, Kaiser R, Wilhelm JL, Kieszak SM, Rubin CH, McGeehin MA (2002) Heat-related mortality during a 1999 heat wave in Chicago. Am J Prevent Med 22:221-227

NRC: National Research Council (2008) Estimating Mortality Risk Reduction and Economic Benefits from Controlling Ozone Air Pollution. Decreasing Tropospheric Ozone Exposure. National Academies Press, Washington, DC

OFM: Washington State Office of Financial Management (2008a). Age and Historical Data. Accessed on November 30, 2008 at http://www.ofm.wa.gov/pop/historical.asp

OFM: Washington State Office of Financial Management (2008b). Estimates and Forecasts. Accessed on November 30, 2008 at http://www.ofm.wa.gov/pop/stfc/default.asp

Patz J, Campbell-Lendrum D, Holloway T, Foley JA (2005) Impact of regional climate change on human health. Nature 438:310-317

Patz JA, McGeehin MA, Bernard SM, Ebi KL, Epstein PR, Grambsch A, et al. (2001) The potential health impacts of climate variability and change for the United States. Executive summary of the report of the health sector of the U.S. national assessment. [Electronic version]. Journal of Environmental Health 64(2), 20-28

Pengelly D, Cheng C, Campbell M (2005) Influence of Weather and Air Pollution on Mortality in Toronto. Toronto Public Health, Toronto, Canada. Accessed July 21, 2008 at http://www.toronto.ca/health/hphe/pdf/weather_air_pollution_summary_june_2005.pdf.

PSCAA: Puget Sound Clean Air Agency (2007) Air Quality Data Summary. Accessed November 30, 2008 at http://www.pscleanair.org/news/library/reports/2007AQDSFinal.pdf

Salathé Jr, EP, Zhang Y, Leung LR, Qian Y (2009) Regional Climate Model Projections for the State of Washington. Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. In Press

Semenza JC, Rubin CH, Falter KH, Selanikio JD, Flanders WD, Howe HL, Wilhelm JL (1996) Heat-related deaths during the July 1995 heat wave in Chicago.

N.Engl.J.Med. 335(2):84-90

Smoyer KE, Rainham DC, Hewko JN (2000) Heat-stress-related mortality in five cities in Southern Ontario: 1980-1996. Int J Biometeorol 44:190-197

Smoyer-Tomic, KE, Rainham DCG (2001), Beating the Heat: Development and Evaluation of a Canadian Hot Weather Health-Response Plan, Environmental Health Perspectives V109(12).

USEPA: Environmental Protection Agency (2004) Air Quality Criteria for Particulate Matter. Volume II. EPA/600/P-99/002bF

USEPA: Environmental Protection Agency (2005) Air Quality Criteria for Ozone and Related Photochemical Oxidants: Volume II, January. EPA/600/R-05/004bA

USEPA: Environmental Protection Agency (2006) PM National Ambient Air Quality Standards for Particulate Matter; Final Rule October 17, 2006. Federal Register 71(200). http://www.epa.gov/ttn/naaqs/standards/pm/data/fr20061017.pdf

USEPA: Environmental Protection Agency (2008) PM National Ambient Air Quality Standards for Ozone; Final Rule March 27, 2008. Federal Register 73(60). http://www.epa.gov/EPA-AIR/2008/March/Day-27/a5645.pdf

WA Dept of Labor and Industries (2008) Outdoor Heat Exposure Rule. Washington Administrative Code 296-62-095. Accessed 30 November 2008 at http://www.lni.wa.gov/safety/topics/atoz/heatstress/

Weaver CP et al (2009) A Preliminary Synthesis of Modeled Climate Change Impacts on U.S. Regional Ozone Concentrations. Submitted to Bull. Amer. Meteorol. Soc

Whitman S, Good G, Donoghue ER, Benbow N, Shou W, Mou S (1997) Mortality in Chicago attributed to the July 1995 heat wave. AJPH 87:1515-1518

Wolfe MI (2001) Heat-related mortality in selected United States cities, summer 1999. Am J Forensic Med Pathol 22:352-357

Photo credit, page 355: Shutterstock.com

MANAGEMENT RECOMMENDATIONS FOR WASHINGTON'S PRIORITY SPECIES – VOLUME IV: BIRDS

Washington Department of FISH and WILDLIFE

Eric M. Larsen, Jeffrey M. Azerrad, and
Noelle Nordstrom, Technical Editors

May 2004

This volume should be cited as:

E. Larsen, J. M. Azerrad, N. Nordstrom, editors. 2004. Management recommendations for Washington's priority species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Individual reports within this volume should be cited using authors' names, as in the following example:

Lewis, J. C., M. Whalen, and E. A. Rodrick. 2004. Lewis' woodpecker. Pages 26-1 – 26-5 *in* E. Larsen, J. M. Azerrad, N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Front and back cover illustrations by Darrell Pruett.
Design by Jeffrey M. Azerrad.

Management Recommendations for Washington's Priority Species

Volume IV: Birds

Eric M. Larsen, Jeffrey M. Azerrad, Noelle Nordstrom, Technical Editors

May 2004

Washington Department of Fish and Wildlife
600 Capitol Way N
Olympia, WA 98501-1091

TABLE OF CONTENTS

ACKNOWLEDGMENTS

Many individuals contributed to the preparation of this volume. Special thanks goes to Steve Penland and Elizabeth Rodrick for their constant support during the volume's publication. The work could have never been completed without the generous contributions of numerous individuals that authored and/or peer-reviewed individual chapters in this volume. Special thanks goes out to Joseph Buchanan for providing a technical review of numerous chapters.

Darrell Pruett provided many of the species illustrations and Terry Johnson digitized all the associated range maps. Frank Beebe, Darrell Pruett, Siobhan Sullivan, Susan Lindstedt, Peggy Ushakoff, and staff from the Oregon Department of Fish and Wildlife created the bird species illustrations.

INTRODUCTION

Fish and wildlife are public resources. Although the Washington Department of Fish and Wildlife (WDFW) is charged with protecting and perpetuating fish and wildlife species, the agency has very limited authority over the habitat on which animals depend. Instead, protection of Washington's fish and wildlife resources is currently achieved through voluntary actions of landowners and through the State Environmental Policy Act (SEPA), Growth Management Act (GMA), Forest Practices Act (FPA), Shoreline Management Act (SMA), and similar planning processes that primarily involve city and county governments. Landowners, agencies, governments, and members of the public have a shared responsibility to protect and maintain fish and wildlife resources for present and future generations; the information contained in this document is intended to assist all entities in this endeavor.

The Washington Department of Fish and Wildlife has identified those fish and wildlife resources that are a priority for management and conservation. Priority habitats are those habitat types with unique or significant value to many fish or wildlife species. Priority species are those fish and wildlife species requiring special efforts to ensure their perpetuation because of their low numbers, sensitivity to habitat alteration, tendency to form vulnerable aggregations, or because they are of commercial, recreational, or tribal importance. Descriptions of those habitats and species designated as priority are published in the Priority Habitats and Species (PHS) List.

PHS Management Recommendations

The department has developed management recommendations for Washington's priority habitats and species to provide planners, elected officials, landowners, and citizens with comprehensive information on important fish, wildlife, and habitat resources. These management recommendations are designed to assist in making land use decisions that incorporate the needs of fish and wildlife. Considering the needs of fish and wildlife can help prevent species from becoming extinct or increasingly threatened and may contribute to the recovery of species already imperiled.

Agency biologists develop management recommendations for Washington's priority habitats and species through a comprehensive review and synthesis of the best scientific information available. Sources include professional journals and publications, symposia, reference books, and personal communications with professionals on specific habitats or species. Management recommendations are reviewed within the Department and by other resource professionals and potential users of the information. The recommendations may be revised if scientists learn more regarding a priority habitat or priority species.

Because PHS management recommendations address fish and wildlife resources statewide, they are generalized. Management recommendations are not intended as site-specific prescriptions but as guidelines for planning. Because natural systems are inherently complex and because human activities have added to that complexity, management recommendations may have to be modified for on-the-ground implementation. Modifications to management recommendations should strive to retain or restore characteristics needed by fish and wildlife. Consultation with fish and wildlife professionals is recommended when modifications are being considered.

The locations of priority habitats and species are mapped statewide. The maps represent WDFW's best knowledge of Washington State's fish and wildlife resources based on research and field surveys conducted over the past 20 years. Management recommendations should be addressed whenever priority habitats and species occur in a particular area whether or not the WDFW maps show that occurrence. These maps can be used for initial assessment of fish and wildlife resources in an area, but they should also be supplemented with a field survey or local knowledge to determine the presence of priority habitats or priority species. The PHS data show WDFW's knowledge of important fish and wildlife resources but cannot show the absence of these resources.

In summary, management recommendations for Washington's priority habitats and species...

Are:	**Are not:**
Guidelines	Regulations
Generalized	Site specific
Updated with new information	Static
Based on fish and wildlife needs	Based on other land use objectives
To be used for all occurrences	To be used only for mapped occurrences

Goals

Management recommendations for Washington's priority habitats and species are guidelines based on the best available scientific information and are designed to meet the following goals:

- Maintain or enhance the structural attributes and ecological functions of habitat needed to support healthy populations of fish and wildlife.
- Maintain or enhance populations of priority species within their present and/or historical range in order to prevent future declines.
- Restore species that have experienced significant declines.

Format

Management recommendations for each priority species are written in six primary sections:

General Range and Washington Distribution –	Summarizes information on the geographic extent of the species in Washington and throughout its range.
Rationale –	Outlines the basis for designating the species as priority.
Habitat Requirements –	Delineates the species' known habitat associations.
Limiting Factors –	Specifies factors that may limit the species' distribution and abundance in Washington.
Management Recommendations –	Provides management guidelines based on a synthesis of the best available scientific information.
Key Points –	Summarizes the most important elements of the species' biology and associated management recommendations.

Management recommendations for Washington's priority habitats and species are intended to be used in conjunction with mapped and digital data which display important fish, wildlife, and habitat occurrences statewide. Data can be obtained by calling the PHS Data Request Line at (360) 902-2543. For more information visit the PHS Website at http://wdfw.wa.gov/hab/phspage.htm. Questions and requests for additional PHS information may be directed to:

Priority Habitats and Species
WDFW Habitat Program
600 Capitol Way N
Olympia, WA 98501-1091

SPECIES STATUS DEFINITIONS

State Listed and Candidate Species

State Endangered - Any wildlife species native to the state of Washington that is seriously threatened with extinction throughout all or a significant portion of its range within the state. Endangered species are legally designated in WAC 232-12-014.

State Threatened - Any wildlife species native to the state of Washington that is likely to become endangered within the foreseeable future throughout a significant portion of its range within the state, without cooperative management or the removal of threats. Threatened species are legally designated in WAC 232-12-011.

State Sensitive - Any wildlife species native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened in a significant portion of its range within the state, without cooperative management or the removal of threats. Sensitive species are legally designated in WAC 232-12-011.

State Candidate - Wildlife species that are under review by the Department for possible listing as endangered, threatened or sensitive. A species will be considered for State Candidate designation if sufficient evidence suggests that its status may meet criteria defined for endangered, threatened or sensitive in WAC 232-12-297. Currently listed State Threatened or State Sensitive species may also be designated as State Candidate species if evidence suggests that their status may meet criteria for a higher listing of State Endangered or State Threatened. State Candidate species will be managed by the Department, as needed, to ensure the long-term survival of populations in Washington.

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE REGIONAL CONTACTS

For assistance with PHS information specific to your county, contact the following WDFW representative.

If you live in...	Contact...
Asotin, Columbia, Ferry, Garfield, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	Kevin Robinette 8702 N. Division St. Spokane, WA 99218-1199 Phone: (509) 456-4082
Adams, Chelan, Douglas, Grant, Okanogan	Tracy Lloyd 1550 Alder St. NW Ephrata, WA 98823-9699 Phone: (509) 754-4624
Benton, Franklin, Kittitas, Yakima	Ted Clausing 1701 24th Ave. Yakima, WA 98902-5720 Phone: (509) 575-2740
Island, King, San Juan, Skagit, Snohomish, Whatcom	Rich Costello 16018 Mill Creek Blvd. Mill Creek, WA 98012 Phone: (206) 775-1311
Clark, Cowlitz, Klickitat, Lewis, Skamania, Wahkiakum	Steve Manlow 2108 Grand Blvd. Vancouver WA 98661 Phone: (360) 696-6211
Clallam, Grays Harbor, Jefferson, Kitsap, Mason, Pacific, Pierce, Thurston	Steve Kalinowski 48 Devonshire Rd. Montesano, WA 98563 Phone: (360) 249-4628

Common Loon

Gavia immer

Last updated: 1999

Written by Jeffrey C. Lewis, Ruth Milner, and Morie Whalen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Common loons breed in North America from the Aleutian Islands and Bering Sea coasts, east throughout Canada and south to the northern tier of the lower 48 United States. In western North America, common loons winter along the Pacific coast from southern Alaska to Baja California.

Migrant loons arrive from the north to winter along Washington's coast, the Columbia and Snake rivers, and on lakes in northeastern Washington. Summer populations are very small (see Figure 1). Single breeding pairs have been confirmed on lakes in King, Whatcom, Chelan, Ferry, and Okanogan counties.

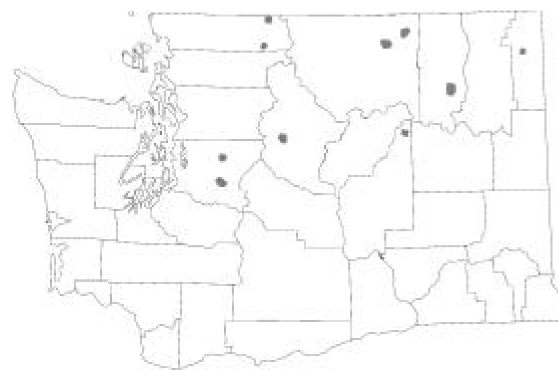


Figure 1. Known breeding distribution of the common loon, *Gavia immer*, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

RATIONALE

The common loon is a State Candidate species. This species is vulnerable to shoreline alteration and development, fluctuation of water levels during nesting (e.g., reservoir draw downs and filling), human disturbance in the vicinity of nesting areas, and encroachment by logging and road building.

HABITAT REQUIREMENTS

Nesting and Brood Rearing

Common loons breed on larger lakes (>12 ha [29.6 acres] in Alaska; Ruggles 1994) in forested areas and nest on shorelines of islands and the mainland. Nesting also may occur within 1.5 m (5 ft) of shore on masses of emergent vegetation (Vermeer 1973, Strong et al. 1987). Loons may use several types of nests, including nests constructed of vegetation; nests located on hummocks, stumps, and beaver lodges; artificial platforms; and nests scraped out of sand, gravel, or leaves (Belant and Anderson 1991). Several studies have shown that loons prefer to nest on islands (Vermeer 1973, McIntyre 1975, Ream 1976, Titus and Van Druff 1981), and breeding success may be higher on insular sites (McIntyre and Mathisen 1977, Titus and Vandruff 1981). Nest site fidelity has been reported (Strong et al. 1987). In Alaska, reproductive pairs were often found on lakes that were hydrologically connected to other lakes, had medium to high macrophyte cover, and had >50% of the shoreline suitable as nesting habitat (Ruggles 1994). Brood or nursery habitat used by adults and loon chicks is comprised of shallow, protected areas of lakes with abundant aquatic vegetation near the shore (McIntyre 1983).

Feeding

Common loons require a healthy fish population on which to feed. Studies of loon feeding habits on their breeding grounds are limited, though Vermeer (1973) found that lakes where breeding loons were present were also used by successful anglers. Common loons were absent from many lakes and sloughs that offered poor fishing to anglers.

LIMITING FACTORS

Loon abundance and reproductive success is dependent upon the availability of undisturbed shoreline or island nesting sites. Fluctuations of water levels and other disturbances at nest sites have been responsible for nest failures, and therefore limit reproductive success. Protection of the forage base and water quality is essential.

Human Impacts

Heavy recreational use may be a key factor in the decline of loon productivity because the birds are susceptible to disturbance during nesting. Titus and Vandruff (1981) found that loons nesting on lakes where motorboats were absent had greater egg-hatching rates than those nesting on lakes where motorboats occurred. Vermeer (1973) found more breeding pairs in areas with fewer resorts, cottages, and campsites. Heimberger et al. (1983) showed that breeding success declined as the number of cottages within 150 m (492 ft) of nests increased. Lake size may affect the influence human disturbance has on loon nesting. Some studies have shown that loons have equal or greater reproductive success on larger lakes with substantial human disturbance than smaller lakes with little or no human disturbance (Jung 1991, Caron and Robinson 1994, Ruggles 1994). It appears that loons may acclimate to heightened disturbance levels while occupying the greater number of undisturbed coves and bays of larger lakes.

Loons appear susceptible to heavy metal poisoning (especially mercury in low pH lakes) through consumption of contaminated fish (Scheuhammer and Blancher 1994, Meyer et al. 1995). Fortunately, much of this mercury is sequestered into feathers during the molt and shed in the succeeding molt (Burger et al. 1994). However, heightened levels of mercury can negatively affect loon reproductive success (Burger et al 1994, Scheuhammer and Blancher 1994, Meyer et al. 1995).

MANAGEMENT RECOMMENDATIONS

Protection of loons and their habitat during pair-bonding, egg laying, and initial brood rearing (1 April through 15 July) is important for reproductive success. Brood-rearing areas or nurseries are also important to protect after 15 July. Because common loons may re-use nests from year to year, protection of known nesting and brood-rearing areas is essential. Camping on islands can adversely affect loon productivity and may cause nest abandonment (Ream 1976). Campers and other visitors should be prevented from approaching within 150 m (492 ft) of nesting sites from 1 April through 15 July. A 150 m (492 ft) disturbance buffer is also recommended for brood-rearing areas (nursery pools) from 15 July to 1 September (R. Spencer, personal communication). Building within 150 m (492 ft) of a loon nest should be avoided year-round to maintain a permanent buffer around nests.

The absence of suitable nesting islands may limit the breeding activity of common loons. In areas where natural islands are unavailable, artificial islands can be provided. McIntyre and Mathisen (1977) created nesting islands by obtaining sedge mats from boggy lakes and binding the mats' edges with poles. Cedar log rafts were also found to be effective. Artificial nest sites have been used in Washington, primarily in reservoirs with fluctuating water levels (R. Spencer, personal communication). As breeding pairs of loons are not abundant in Washington, protection of all nest sites is important. Consequently, reservoirs where loons nest should maintain constant water levels when loons are laying and incubating eggs (a 30 day period).

REFERENCES

Belant, J. L., and R. K. Anderson. 1991. Common loon, *Gavia immer*, productivity on a northern Wisconsin impoundment. Canadian Field Naturalist 105:29-33.

Burger, J., M. Pokras, R. Chafel, and M. Gochfeld. 1994. Heavy metal concentrations in feathers of common loons (*Gavia immer*) in the northeastern United States and age differences in mercury levels. Environmental Monitoring and Assessment 30:1-7.

Caron, J. A., and W. L. Robinson. 1994. Responses of breeding loons to human activity in Upper Michigan. Hydrobiologia 279/280:431-438.

Heimberger, M. D., D. Euler, and J. Barr. 1983. The impact of cottage development on common loon (*Gavia immer*) reproductive success in central Ontario, Canada. Wilson Bulletin 95:431-439.

Jung, R. E. 1991. Effects of human activities and lake characteristics on the behavior and breeding success of common loons. Passenger Pigeon 53:207-218.

McIntyre, J. W. 1975. Biology and behavior of the common loon (*Gavia immer*) with reference to its adaptability to a man-made environment. Dissertation, University of Minnesota, Saint Paul, Minnesota, USA.

____. 1983. Nurseries: a consideration of habitat requirements during the early chick-rearing period in common loons. Journal of Field Ornithology 54:247-253.

____, and J. E. Mathisen. 1977. Artificial islands as nest sites for common loons. Journal of Wildlife Management 41: 317-319.

Meyer, M. W., D. C. Evers, T. Daulton, and W. E. Braselton. 1995. Common loons (*Gavia immer*) nesting on low pH lakes in northern Wisconsin have elevated blood mercury content. Water, Air, and Soil Pollution 80:871-880.

Ream, C. H. 1976. Loon productivity, human disturbance, and pesticide residues in northern Minnesota. Wilson Bulletin 88:427-432.

Ruggles, A. K. 1994. Habitat selection by loons in southcentral Alaska. Hydrobiologia 279/280:421-430.

Scheuhammer, A. M., and P. J. Blancher. 1994. Potential risk to common loons (*Gavia immer*) from methylmercury exposure in acidified lakes. Hydrobiologia 279/280:445-455.

Strong, P. I. V., J. A. Bissonette, and J. S. Fair. 1987. Re-use of nesting and nursery areas by common loons. Journal of Wildlife Management 51:123-127.

Titus, J. R., and L. W. Vandruff. 1981. Response of the common loon (*Gavia immer*) to recreational pressure in the Boundary Waters Canoe Area northeastern Minnesota. Wildlife Monograph 79:5-59.

Vermeer, K. 1973. Some aspects of the nesting requirements of common loons in Alberta. Wilson Bulletin 85:429-435.

PERSONAL COMMUNICATIONS

Rocky Spencer, Area Wildlife Biologist
Washington Department of Fish and Wildlife
Mill Creek, Washington

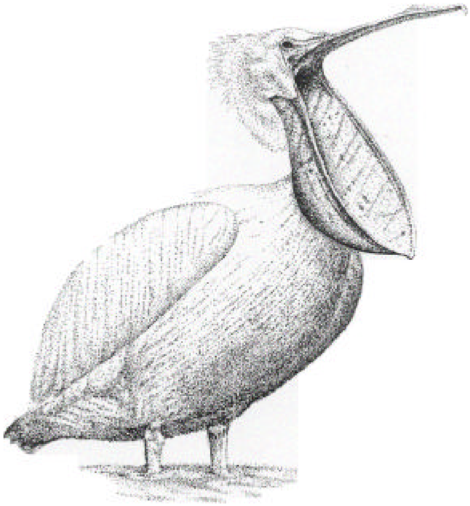
KEY POINTS

Habitat Requirements

- Common loons breed on large lakes in forested areas.
- A healthy fish population is required as a prey base.
- Nests are situated on shorelines, islands, or floating structures within 1.5 m (5 ft) of shore.
- Nests may be constructed on emergent vegetation, and nest sites may be reused.
- Common loons are very susceptible to nest disturbance. They are intolerant of recurrent disturbance within 150 m (492 ft) of nest sites.

Management Recommendations

- Protect known nest and nursery sites.
- Restrict disturbance of nest sites from 1 April to 15 July and brood-rearing nursery pools from 15 July to 1 September. Maintain a 150 m (492 ft) disturbance buffer around brood-rearing areas (nursery pools) from 15 July to 1 September.
- Erect no structures within 150 m (492 ft) of nesting sites. Avoid building within this distance year round to maintain a permanent buffer around nests.
- Provide artificial nesting islands (e.g., sedge mats and cedar log rafts) where appropriate (e.g., reservoirs).



American White Pelican

Pelecanus erythrorhynchos

Last updated: 1998

Written by Patrick J. Doran, Morie Whalen, Karen Riener, and Lisa Fitzner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

American white pelicans occur throughout the western, central, and southern parts of North America. These pelicans are colonial nesters, breeding primarily in the western and central United States and Canada, and wintering along the southern coast of the United States and in Mexico. Canada supports the largest population of breeding American white pelicans, with colonies located in Alberta, British Columbia, Manitoba, Ontario, and Saskatchewan. In the United States, breeding colonies are located in California, Colorado, Idaho, Minnesota, Montana, Nevada, North Dakota, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming (Ackerman 1994; Sidle et al. 1985; J. Annear, personal communication).

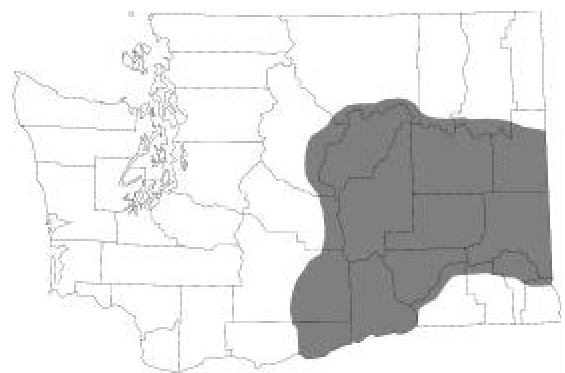


Figure 1. Range of the American white pelican, Pelecanus erythrorhynchos, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

The population can be roughly split into 2 groups based upon differences in their ranges. The western group, which includes American white pelicans occurring in Washington state (see Figure 1), breeds to the west of the Rocky Mountains and winters along the Pacific Coast from central California to Mexico, mainly along Baja California and the western coast of Mexico (U. S. Fish and Wildlife Service 1984). Additionally, small numbers of American white pelicans winter on inland waters in Oregon and Washington (U. S. Fish and Wildlife Service 1984; L. Fitzner, personal communication; R. Friesz, personal communication). The migratory route of the western population takes in all states west of the continental divide and Mexico (U. S. Fish and Wildlife Service 1984).

Historically, American white pelicans were known to occur and presumed to have bred in eastern Washington on inland waters such as Sprague and Moses Lakes (Dawson and Bowles 1909). The first nesting record is from 1926 at Moses Lake, Grant County (Brown 1926). Jewett et al. (1953) stated that the Moses Lake colony continued for several years. From 1926 through 1994 there were no published records of American white pelicans breeding in Washington. In 1994 a breeding colony was established on Crescent Island, which was constructed for nesting birds in the Columbia River, Walla Walla County in 1985 (Ackerman 1994). American white pelicans have continued to nest on Crescent Island up to the date of this publication. In 1994 an estimated 30 nests produced approximately 50 juveniles, and in 1996 an estimated 25 nests produced approximately 35 young (Ackerman 1997). Nests and young were not counted in 1995. However, breeding was confirmed on the island and numbers were estimated to be similar to those in 1994 (Ackerman 1997). In 1997, the colony initiated nesting on nearby Badger Island. After high water destroyed some of the nests, a portion of the colony returned to Crescent Island and initiated a second nesting attempt. At the time of this publication, American white pelicans were nesting on both Badger and Crescent Islands (Ackerman 1997).

In addition to the breeding colonies present on Crescent and Badger Islands, the inland waters of eastern Washington support a significant number of non-breeding American white pelicans throughout the year. Non-breeding American white pelicans can be found along the Columbia River from the Dalles through Chief Joseph pool. Numbers of these pelicans vary greatly during the summer, with peaks of up to 2000 birds observed in the potholes region of the Columbia Basin during late summer (R. Friesz, personal communication; J. Tabor, personal communication). Numbers of summer residents have declined substantially since 1990 (L. Fitzner, personal communication). Wintering concentrations, ranging from 40-300 birds, occur along the Columbia River from the mouth of the Walla Walla River to Priest Rapids (L. Fitzner, personal communication; E. Nelson, personal communication). Therefore, areas within Washington state may play an important regional role in sustaining non-breeding summer residents and birds which have dispersed from their breeding grounds in adjacent states and provinces.

RATIONALE

The American white pelican is a State Endangered species. In Washington, colonies of American white pelicans have disappeared from historical breeding areas (Dawson and Bowles 1909, Johnsgard 1955). Currently, only one breeding colony exists in Washington (Ackerman 1994, 1997). Suitable nesting habitat that is free from human disturbance is rapidly declining (Motschenbacher 1984), thus there are few opportunities for breeding populations of American white pelicans to become reestablished. Additionally, non-breeding and wintering populations occur in Washington throughout the year (R. Friesz, personal communication; L. Fitzner, personal communication).

HABITAT REQUIREMENTS

American white pelicans are colonial nesters that breed most often on isolated islands in freshwater lakes and occasionally on isolated islands in rivers. Islands free from human disturbance, mammalian predators, flooding, and erosion are required for successful nesting (U. S. Fish and Wildlife Service 1984, Koonz and Rakowski 1985). At 11 American white pelican breeding sites near Washington state, Motschenbacher (1984) reported a minimum nest island size of 0.3 ha (0.75 ac). The United States Fish and Wildlife Service (USFWS) recommends a minimum nest island size of 0.4 ha (1.0 ac) (U.S. Fish and Wildlife Service 1984). Preferred nesting substrates include gravel, sand, and soil (Evans and Knopf 1993). American white pelicans have also been known to nest on rocky outcroppings and dense stands of aquatic vegetation (e.g., hardstem bulrush [*Scirpus lacustris*]) (U. S. Fish and Wildlife Service 1984; Motschenbacher 1984). If vegetation is present within the nesting colony, it primarily consists of grasses, forbs, and shrubs (U. S. Fish and Wildlife Service 1984). At the Crescent Island colony in Washington, American white pelicans placed their nests on bare ground under willows (S. Ackerman, personal communication). Similar sites are used for loafing by both breeding and non-breeding birds.

American white pelicans require shallow water for foraging. Most feeding occurs between water depths of 0.3-2.5 m (1-8.3 ft) (Anderson 1991). Feeding mostly takes place along lake or river edges, in open areas within marshes, on or below rapids, and occasionally in deep waters of lakes and rivers (Evans and Knopf 1993). American white pelicans feed largely on nongame or "rough" fish, amphibians, and crustaceans (Brittell et al 1976, Lingle and Sloan 1980). Hall (1925) reported that adult pelicans consume 1.8 kg (4.8 lbs) of food per day. Therefore, an abundant prey base predominantly consisting of warm water fish is essential for American white pelican survival (Smith et al. 1984). Although foraging sites close to their breeding area are more advantageous than ones further away, American white pelicans are known to travel 50-80 km (31-50 mi) from nesting colonies to feed (Motschenbacher 1984, U.S. Fish and Wildlife Service 1984).

LIMITING FACTORS

The USFWS identifies 3 major factors that limit the success of breeding and non-breeding American White pelican populations: habitat destruction, utilization of wetlands and lakes for other purposes (e.g., irrigation, hydroelectricity, waterfowl production), and intentional or unintentional human disturbance of nesting colonies. They also cite several other potential factors that may limit American white pelican populations, including decreases or fluctuations in food supply and availability, shooting, mammalian predation at breeding colonies (especially coyotes), pesticide contamination, and powerline collisions (U.S. Fish and Wildlife Service 1984).

Habitat destruction and human disturbance appear to be the most important factors limiting American white pelican populations in Washington (Motschenbacher 1984). Currently, all 5 sites where breeding colonies were thought to have historically been located no longer exist or are in areas of high human activity (Motschenbacher 1984). Additionally, pool fluctuations on the Columbia River and other water bodies, which result in inconsistent water depths, may adversely affect habitat quality. Finally, American white pelicans are susceptible to pesticides and other toxic contaminants. Organochlorine pesticide residues and mercury concentrate in adult tissues and in pelican eggs (Evans and Knopf 1993). Aquatic pollution contribute to accumulations of toxic compounds in warm water fish species, which can adversely affect pelicans (Boellstorff et al. 1985; L. Blus, personal communication).

MANAGEMENT RECOMMENDATIONS

In Washington, management of American white pelican populations should focus on protection of breeding colonies and protection of feeding and loafing areas of both breeding and non-breeding birds.

Disturbance

Disturbance of nesting colonies may result in: abandonment of nests and colonies; egg breakage; depredation of nests by avian predators; exposure of young to temperature stress; and trampling of young (U. S. Fish and Wildlife Service 1984). In order to reduce the impacts of human disturbance at nesting sites, mangers should:

- Close nest islands to trespass during the breeding season from 15 March through 31 August (U. S. Fish and Wildlife Service 1984).
- Establish a buffer zone of 400-800 m (0.25-0.5 mi) and up to 1600 m (1.0 mi) from the nesting island which is closed to human activity such as boating (especially power boating), fishing, water skiing, discharge of fire arms, wildlife observation (Knopf 1975, U. S. Fish and Wildlife Service 1984).
- Restrict air traffic to an altitude of 610 m (2000 ft) above breeding colonies to reduce disruption of nesting (U. S. Fish and Wildlife Service 1984).
- Close channels with dikes to restrict boating/fishing in breeding areas, creating sanctuaries.
- Retain stable water levels during the nesting season so that flood waters do not inundate nests, and low water levels do not allow the emergence of mainland to island bridges that can be crossed by predators (Findholt and Diem 1988).
- Protect nesting areas and potential nesting islands from mammalian predators such as coyotes (U. S. Fish and Wildlife Service 1984).

In addition to protecting active nest colonies, such as the Crescent and Badger Island sites, land managers should identify and protect loafing/roosting and feeding areas of both breeding and non-breeding birds. The availability of adequate foraging areas is also vital to the success of American white pelican populations. These pelicans are known to commute between 50-80 km (31-50 mi) between nesting and foraging sites (U. S. Fish and Wildlife Service 1984). In areas surrounding American white pelican colonies or in primary feeding areas for non-breeding, wintering, or migrating birds, managers should:

- Identify and survey American white pelican foraging areas to determine presence and abundance of fish species that may serve as a prey base for pelican populations (U. S. Fish and Wildlife Service 1984).

- Maintain and manage American white pelican foraging areas for the prey base fish species (U. S. Fish and Wildlife Service 1984).
- Maintain shallow water between 0.3-2.5 m (1.0-8.3 ft.) in depth at foraging areas (U.S. Fish and Wildlife Service 1984). Deeper waters may be necessary where water level fluctuations occur.
- Maintain abundant fish populations and a diversity of water bodies, such as lakes, sloughs, rivers, and marshes (Smith et al. 1984, Findholt and Anderson 1995a,b).
- Limit disturbance at foraging areas from hunting and fishing activities, boating, and other recreational activities (U. S. Fish and Wildlife Service 1984).

Reestablishment of Breeding Colonies

With the recent establishment of breeding colonies in Washington, the presence of large numbers of non-breeding summer birds, and population increases on a continental scale, there exists the potential for American white pelicans to become regular breeders in this state. In order to reestablish American white pelican nesting sites in Washington, sanctuaries that protects the birds from human disturbance are needed (Motschenbacher 1984). The sanctuary should contain a nesting island of at least 0.1 ha (0.25 ac), and preferably 0.4 ha (1.0 ac) or larger (U. S. Fish and Wildlife Service 1984) if water level fluctuations are common. Additionally, protected foraging areas with a sufficient prey base must be provided. Buffer zones, which exclude all human activities including boating, fishing, and water skiing, should be established as suggested above.

Contaminants

American white pelicans are susceptible to pesticides and other toxic contaminants. Currently, pesticide and mercury levels are not thought to be a significant problem in American white pelican populations. However, the U.S. Fish and Wildlife Service (1984) recommends monitoring of such contaminants. Fish, pelican eggs, and other biota should be sampled and analyzed for pesticides, dioxins, and other toxicants. Sources of these pollutants should be identified and regulated if necessary. Biocides, including those used in fish rehabilitation programs, should be avoided in American white pelican feeding areas, especially those near nesting colonies (L. Blus, personal communication).

Avoid using any insecticide (Smith 1987) or herbicide (Santillo et al. 1989) in American white pelican nesting or foraging habitat. Organochlorine, organophosphate, and carbamate insecticides can be highly toxic to birds and fish and should be avoided (McEwen et al. 1972, Grue et al. 1983, Grue et al. 1986, Smith 1987). If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A, which lists contacts that may be helpful when assessing pesticides and their alternatives.

Appropriate buffer widths for insecticide spray application near sensitive riparian and wetland areas range from 30-500 m (100-1650 ft) (Kingsbury 1975, Payne et al. 1988, Terrell and Bytnar-Perfetti 1989). When possible, leave a 500 m (1650 ft) (Kingsbury 1975) buffer around American white pelican nesting and foraging areas that is devoid of pesticides (Brown 1978, Smith 1987). Larger buffer areas may be necessary in areas where pesticide runoff affects a large area.

REFERENCES

Ackerman, S. M. 1994. American white pelicans nest successfully at Crescent Island, Washington. Washington Birds 3:44-49.

____. 1997. Update: American white pelican colony. WOSNews 51. Washington Ornithological Society, October/November.

Anderson, J. G. T. 1991. Foraging behavior of the American white pelican (*Pelecanus erythrorhynchos*) in western Nevada. Colonial Waterbirds 14:166-172.

Boellstorff, D. E., H. M. Ohlendorf, D. W. Anderson, E. J. O'Neill, J. O. Keith, and R. M. Prouty. 1985. Organochlorine chemical residues in white pelicans and western grebes from the Klamath Basin, California. Archives of Environmental Contaminants 14:485-493.

Brittell, J. D., J. M. Brown, and R. L. Eaton. 1976. Marine shoreline fauna of Washington. Volume II. Washington Department of Game and Washington Department of Ecology, Olympia, Washington, USA.

Brown, D. E. 1926. Birds observed at Moses Lake, Grant County, Washington. Murrelet 7(3):48-51.

Brown, A. W. A. 1978. Ecology of pesticides. John Wiley and Sons, New York, New York, USA.

Dawson, W. L., and J. H. Bowles. 1909. The birds of Washington. Volume II. The Occidental Publishing Company, Seattle, Washington, USA.

Evans, R. M., and F. L. Knopf. 1993. American white pelican (*Pelecanus erythrorhynchos*). No. 57 *in* A. Poole and F. Gill, editors. The Birds of North America. Academy of National Science and American Ornithologists Union, Philadelphia, Pennsylvania, USA.

Findholt, S. L., and S. H. Anderson. 1995a. Diet and prey use patterns of the American white pelican (*Pelecanus erythrorhynchos*) nesting at Pathfinder Reservoir, Wyoming. Colonial Waterbirds 18:58-68.

____, and ____. 1995b. Foraging areas and feeding habitat selection of American white pelicans (*Pelecanus erythrorhynchos*) nesting at Pathfinder Reservoir, Wyoming. Colonial Waterbirds 18:47-57.

____, and K. L. Diem. 1988. Status and distribution of American white pelican nesting colonies in Wyoming USA: an update. Great Basin Naturalist 48:285-289.

Grue, C. E., W. J. Fleming, D. G. Busby, and E. F. Hill. 1983. Assessing hazards of organophosphate pesticides to wildlife. Transactions of North American Wildlife Natural Resource Conference 48:200-220.

____, L. R. DeWeese, P. Mineau, G. A. Swanson, J. R. Foster, P. M. Arnold, J. N. Huckins, P. J. Sheehan, W. K. Marshall, and A. P. Ludden. 1986. Potential impacts of agricultural chemicals on waterfowl and other wildlife inhabiting prairie wetlands: an evaluation of research needs and approaches. Transactions of the North American Wildlife and Natural Resource Conference 51:357-383.

Hall, E. R. 1925. Pelican versus fish in Pyramid Lake. Condor 27:147-160.

Jewett, S. G., W. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. Birds of Washington state. University of Washington Press, Seattle, Washington, USA.

Johnsgard, P. A. 1955. The relation of water level and vegetational change to avian populations, particularly waterfowl. Thesis, Washington State University, Pullman, Washington, USA.

Kingsbury, P. D. 1975. Effects of aerial forest spraying on aquatic fauna. *in* M. L. Prebble, editor. Aerial control of forest insects in Canada. Department of the Environment, Ottawa, Ontario, Canada.

Knopf, F. L. 1975. Spatial and temporal aspects of colonial nesting of white pelicans. Condor 81:353-363.

Koonz, W. H., and P. W. Rakowski. 1985. Status of colonial waterbirds nesting in southern Manitoba. Canadian Field-Naturalist 99:19-29.

Lingle, G. R., and N. F. Sloan. 1980. Food habits of white pelicans during 1976-1977 at Chase Lake National Wildlife Refuge, North Dakota. Wilson Bulletin 92:123-125.

McEwen, L. C., C. E. Knittle, and M. L. Richmond. 1972. Wildlife effects from grasshopper insecticides sprayed on short-grass range. Journal of Range Management 25:188-194.

Motschenbacher, M. D. 1984. The feasibility of restoring a breeding white pelican population in the state of Washington. Thesis, Washington State University, Pullman, Washington, USA.

Payne, N. J., B. V. Helson, K. M. S. Sundaram, and R. A. Flemming. 1988. Estimating buffer zone widths for pesticide applications. Pesticide Science 24:147-161.

Santillo, D. J., D. M. Leslie, Jr., P. W. Brown. 1989. Response of small mammals and habitat to glyphosate application on clearcuts. Journal of Wildlife Management 53:164-172.

Sidle, J. G., W. H. Koonz, and K. Roney. 1985. Status of the American white pelican: an update. American Birds 39:859-864.

Smith, G. J. 1987. Pesticide use and toxicology in relation to wildlife: organophosphorus and carbamate compounds. Research Publication Number 170, U.S. Fish and Wildlife Service, Washington, D.C., USA.
Smith M., T. Steinback, and G. Pampush. 1984. Distribution, foraging relationships and colony dynamics of the American white pelican (*Pelecanus erythrorhynchos*) in southern Oregon and northeastern California. Oregon Department of Fish and Wildlife Technical Report Number 83-0-04.
Terrell, C. R., and P. Bytnar-Perfetti. 1989. Water quality indicators guide: Surface waters. SCS-TP-161, U.S. Soil Conservation Service, Washington, D.C., USA.
United States Fish and Wildlife Service. 1984. Guidelines for the management of the American white pelican. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

PERSONAL COMMUNICATIONS

Scott Ackerman, Wildlife Biologist
U.S. Army Corps of Engineers
Pasco, Washington

John Annear, Biologist
Umatilla National Wildlife Refuge
Umatilla, Oregon

Lawrence Blus, Biologist
Patuxent Wildlife Research Center
Corvallis, Oregon

Lisa Fitzner, Area Wildlife Biologist
Washington Department of Fish and Wildlife
Yakima, Washington

Ron Friesz, Area Habitat Biologist
Washington Department of Fish and Wildlife
Ephrata, Washington

Eric Nelson, Wildlife Biologist
Umatilla National Wildlife Refuge
Umatilla, Oregon

Jim Tabor, Area Wildlife Biologist
Washington Department of Fish and Wildlife
Ephrata, Washington

KEY POINTS

Habitat Requirements

- Foraging occurs in shallow water 0.3-2.5 m (1.0-8.3 ft) deep.
- Breeding and stopover areas are clear of dense shrubbery or trees, include open aquatic habitats, and are free from human disturbance.
- American white pelicans nest on soil or sod.
- An abundant source of prey is essential, such as fish, amphibians, and crustaceans.

Management Recommendations

- Develop site-specific management plans for breeding areas.
- Identify, monitor, and protect primary feeding and loafing areas of breeding and non-breeding American white pelicans.
- Identify and survey American white pelican foraging areas to determine presence and abundance of fish species that may serve as a prey base for pelican populations.
- Maintain shallow water between 0.3-2.5 m (1.0-8.3 ft) in depth at foraging areas. Deeper waters may be necessary where water level fluctuations occur.
- Maintain or restore abundant fish populations in areas where American white pelicans feed.

- Prohibit boats and other human access within 400-800 m (0.25-0.5 mi) and up to 1,600 m (1 mi) of important foraging and breeding areas.
- Close nest islands to trespass during the breeding season from 15 March through 31 August.
- Restrict air traffic to an altitude of 610 m (2000 ft.) above breeding colonies to reduce disruption of nesting.
- Keep water levels stable during breeding season to protect nests from inundation or from predators which may cross land bridges during low water.
- Protect nesting areas and potential nesting islands from mammalian predators such as coyotes.
- Monitor for pesticides, dioxins, and other toxicants in prey fish.
- Avoid pesticide use in American white pelican habitat. If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A that lists contacts that may be helpful when assessing pesticides and their alternatives.
- When possible, leave a 500 m (1650 ft) buffer around American white pelican nesting and foraging areas that is devoid of pesticides. Larger buffer areas may be necessary in areas where pesticide runoff affects a large area.
- Appropriate buffer widths for insecticide spray application near sensitive riparian and wetland areas range from 30-500 m (100-1650 ft).
- Breeding sanctuaries should contain:

    - a nesting island of at least 0.1 ha (0.25 ac), and preferably 0.4 ha (1.0 ac) or larger if water level fluctuations are common.
    - protected foraging areas with sufficient prey
    - buffer zones that exclude human activities.

NOTE: This chapter was updated in March 2012

Great Blue Heron

Last updated: 2012

Written by Jeffrey M. Azerrad

GENERAL RANGE AND REGIONAL DISTRIBUTION

The Great Blue Heron's North American breeding range runs from southeast Alaska east to Nova Scotia and south to northwestern Mexico, the Yucatan Peninsula in Belize and Mexico, the West Indies, and Galapagos Islands (*7*). Herons overwinter from southern British Columbia, south to Venezuela.

Figure 1. The hatched area is the year-round range of the Great Blue Heron (*Ardea Herodias*) in Washington and British Columbia (*55*).

Herons are a permanent resident in all of Washington except the higher Cascade and Olympic ranges (Figure 1). In British Columbia, they are permanent residents along the entire coast and throughout Vancouver Island and the Haida Gwaii Archipelago[1]. They also are residents in south-central British Columbia. Although herons breed at elevations as high as 1,100 meters (3,600 ft; *14*), they mainly nest at lower elevations.

The region's largest colonies are within the range of the Pacific Great Blue Heron (*A. h. fannini*). This subspecies differs from inland herons and from herons near south-coastal Washington (*A. h. herodias*) in that they are smaller in size. They also generally begin breeding earlier in the spring (*54*). The range of these birds is isolated by the mountains east of Puget Sound and Georgia Basin. Pacific Great Blue Herons mostly occur close to the coast and inland along large rivers from Prince William Sound to Puget Sound (*54*).

[1] This publication was written in cooperation with the Great Blue Heron Working Group. Because the group is a made up of experts from Washington and British Columbia, we present information and guidance relevant to Washington and British Columbia.

RATIONALE

Great Blue Herons are highly vulnerable to human disturbance, predation, and competition for nesting habitat (*40*). Their habit of nesting in large groups makes herons especially susceptible to these types of impacts. A single event involving human disturbance can lead an entire colony to terminate a nesting attempt (*21*, *54*, *55*). Because herons breed in colonies of up to 500 nests (*21*), early termination of even one breeding attempt can lead to a considerable loss of offspring. This is especially a problem in Puget Sound and the Georgia Basin, where half the breeding population is concentrated into four large colonies (*21*). Recently the size of these large colonies in Puget Sound has increased as birds began to move out of smaller colonies (*22*).

Although herons are not a state-listed species in Washington, they are a species of special concern in British Columbia due to a decline in productivity, where the number of fledglings per active nest fell by nearly half since the 1970s (*54*). Although habitat loss and disturbance negatively impact individual colonies, we need more surveys to assess whether these factors are having an impact on regional heron populations.

HABITAT REQUIREMENTS

Great Blue Heron foraging, breeding, and pre-nesting habitats usually are in close proximity to each other (*24*). Foraging habitat often is adjacent to or within a few kilometers of the nesting colony. Before nesting begins, herons will often congregate close to where they nest. The inter-relationships among these habitats require consideration to effectively protect a nesting colony.

PRE-NESTING HABITAT

Prior to nesting, herons may gather in groups. Surveyors have observed pre-nesting groups close to many of the region's heron colonies (A. Eissinger and I. Moul, personal communications). There is some debate as to how prevalent these groups are in the region. Although birds may not exhibit this behavior at every colony, more survey and research during the pre-nesting period will help us better understand these habitats.

The breeding season begins when adult herons gather at these pre-nesting sites (*21*). Along the coast, herons may occupy these sites while waiting for the tides to descend enough for food to become accessible (I. Moul, personal communication). Although not all of a colony's nesting birds will be found in a pre-nesting congregation area, the number of birds seen at these sites seems to correspond to the size of the nearby colony (A. Eissinger, personal communication).

Herons form pre-nesting congregations in various types of habitats. They congregate in both vegetated areas and on built structures (e.g., rooftops near Stanley Park and in Seattle's Kiwanis Ravine). Although in interior British Columbia and eastern Washington far fewer pre-nesting groups have been reported, Gebauer and Moul (*24*) noted interior-nesting herons gathering at larger lakes, wetlands, and watercourses prior to nesting. In coastal areas, herons often congregate in large estuaries and mudflats (*24*). At one of Washington's largest colonies at Birch Bay, pre-nesting congregations occur in fallow fields adjacent to the colony. Herons also assemble in day roosts near colonies in the pre-nesting period (*21*).

BREEDING AND NESTING HABITAT

Great Blue Herons often assemble in large and conspicuous colonies. Although some will nest as isolated pairs, most form colonies of a few pairs to many hundreds of birds (*10*). Larger and more productive colonies tend to form near large areas of high quality foraging habitat (*5*, *25*, *27*, *31*), and especially near eelgrass beds (*11*, *54*). Although herons sometimes nest on the ground, human-made structures, cliffs, and in shrubs (*7*, *10*, *28*; H. Ferguson, personal communication), nesting mostly occurs in trees like alder, cedar, hemlock, pine, Douglas-fir (*Pseudotsuga menziesii*), spruce, hawthorn, bigleaf maple (*Acer macrophyllum*), and cottonwood (*Populus balsamifera*). A shortage of suitable trees may lead herons to nest in shrubs or near the ground (*28, 54*). In coastal Washington and British Columbia, nesting largely occurs in areas with deciduous trees (M. Tirhi and R. Vennesland, personal communications). In British Columbia's interior Columbia River Basin, herons showed no preference for nesting in conifer or deciduous trees (*35*).

Ideal nesting habitat typically consists of mature forest (*24*). Although most colonies are found in forests free of human disturbance, some nesting occurs in areas of persistent human activity (*10*). An explanation for this may be that some areas lack undisturbed forest close to foraging habitat. In these places herons may be forced to select a disturbed forest because it is close to rich foraging habitat (*31*). In some regions they may select the best available habitat when optimal habitat is altogether lacking. Some herons may also become more acclimated to people (*52*). Although herons nest in disturbed areas, the presence of people has been linked to reduced nesting productivity (*16*, *24*, *49*, *53*). Colony abandonment has also resulted from activities like land development and repeated human intrusions (*43*, *49, 53*).

Breeding Season Foraging Habitat

During the breeding season herons feed in the shallow margins of various coastal and freshwater habitats (*24*). Herons primarily nest near abundant sources of food (*31*). Although most colonies are within 3 kilometers (1.9 mi) of key foraging grounds, herons can nest anywhere within 10 kilometers (6.2 mi) of where they are foraging (*9*).

The presence of a nearby food source influences a colony in various ways. Food accessibility influences when a heron colony will begin breeding each year (*8*). Food also influences the size of nesting bird's clutch and brood (*41*, *42*, *47*). Although few have studied the relationship between food abundance and nesting, numbers of breeding herons likely decline with waning food supplies. A reliable food source also seems to affect reproductive performance (*10*, *31*).

Along the coast, eelgrass meadows and other estuarine ecosystems supply most of the food that adult and juvenile herons require during the breeding season (*10, 20*). These herons feed on various small fish and marine invertebrates (*10*) such as gunnels, sculpin, shiner perch, mud shrimp, isopods, and crabs. Butler (*9*) concluded that coastal-nesting herons forage most efficiently in late spring when the tides are at their lowest levels and when prey tends to be abundant (*10*). This timing also corresponds to when the energy demands of juvenile herons hit their peak (*1*). Although coastal herons rely mainly on marine and estuarine waters for foraging, freshwater habitats also serve as an important source of food (*24*).

In contrast to coastal herons, interior herons feed alone and in small groups. This may be a result of foraging in areas of less abundant food. In southeast British Columbia and eastern Washington, breeding herons feed in wetland complexes, large rivers and creeks, and small lakes (*35;* H. Ferguson, personal communication). In southeast British Columbia, palustrine wetland complexes comprise 40% of the waters near colonies, while rivers, small lakes, and reservoirs made up another 50% (*35*). Given the proximity, herons may have an affinity for feeding in these waters.

Non-breeding Season Foraging Habitat

Although breeding season foraging more directly influences heron nesting, areas used for foraging outside the breeding period are also important. In fall and early winter, adult and juvenile herons often prey on small mammals in fallow, freshly plowed, or mowed fields and in grasslands

(*9*, *24*; H. Ferguson and S. Pinnock, personal communications). Close to the coast, herons feed in ditches, old fields, marshes, and wetlands just following their dispersal from breeding areas (*10*). In October and November adults closer to the coast feed in marshes while juveniles feed in old-fields (*5*). These coastal herons later move back to tidal areas beginning in February and March. Great Blue Herons in interior areas forage along ice-free waters like creeks and lake shorelines. Non-breeding season foraging habitat may be a limiting resource for interior herons when frozen waterbodies or snow-covered fields restrict their access to prey (*24*).

LIMITING FACTORS

Activities like forestry and development have lead to the loss and degradation of heron habitat, disturbance to nesting and foraging grounds, and to direct mortality (*10*, *40*, *49*). Forest removal and urban and industrial development are the chief causes of habitat loss in the Pacific Northwest (*24*, *51, 60*). Increased human disturbance at breeding and foraging sites can lead to increased predation, lower breeding success, nest failure, and less efficient foraging (*10*, *24*, *53*). Although herons can nest in disturbed urban areas, disturbance can lead birds to terminate breeding attempts, especially when a disturbance occurs early in the nesting period or when it is a large or novel event (*37*, *52*).

Avian predators also kill herons and compete for habitat. Bald Eagles are the heron's primary predator (*10*, *24*, *53*). A sharp increase in eagle populations has lead to more colony incursions (*55*). In some areas, eagle predation and disturbance has lead to an increase in nest and colony failure (*13*, *53*). Depredation in particular appears on the rise in coastal heron colonies (*50*, *53*) and attacks on adult herons may be leading to the temporary or permanent colony abandonment (*21*). Annual monitoring of colonies in interior British Columbia has shown eagles to be a cause of mortality and depredation (*35*). Eagles may also affect colony size further from the coast (H. Ferguson, personal communication). Although the recent rise in Bald Eagle abundance following their recovery has apparently exacerbated impacts at heron colonies, historically herons persisted when eagles were more common than they are today (*46*). But because interactions now occur in an altered landscape, there is uncertainty as to how herons will respond to the increased influence of eagles.

Other birds also seem to impact herons. The considerable ecological overlap of Double-crested Cormorants (*Phalacrocorax auritus*) and herons in interior British Columbia and eastern Washington suggests they potentially compete for limited nesting habitat (*35*; D. Norman, personal communication). Crows and ravens also prey on heron eggs and young (*45*).

Climate change will likely influence heron nesting and distribution. While we still do not know how severe the impacts will be, rising sea level and sea temperatures could affect nesting and foraging resources. A rise in sea level could inundate shallow coastal marshes (*12*), displacing herons from rich foraging grounds. Changing weather may also alter wading bird distributions (*33*).

MANAGEMENT RECOMMENDATIONS

Heron Management Area

These recommendations are intended for use in what we have termed the Heron Management Area (HMA). An HMA consists of the nesting colony, year-round and seasonal buffer, and foraging habitat (Figure 2). The HMA core zone consists of the colony and year-round buffer. Pre-nesting congregation areas are also part of the HMA. You should protect all these areas as disturbance to any part of an HMA can harm a colony.

Figure 2. Depiction of all the components of a HMA.

The following guidelines will help you identify, map, and manage an entire HMA. We suggest you use the guidelines to protect any colony, no matter its size or status. Although you should not underestimate the value of smaller colonies, larger colonies generally merit highest priority. Give colonies with at least 20 nests close to coastal and estuarine habitat or along large rivers that drain into an estuary high priority (*30*). Since colonies inland tend to be smaller, regard all inland nesting aggregations as high priority.

Core Zone Identification and Mapping

You should gather baseline information when planning a project near a heron colony. Because gathering data can lead to serious disturbance including failed nesting attempts (*49*, *56*), you should only collect data in the core zone during the non-breeding season (Figure 3) when herons are absent. Although the non-breeding period generally runs from the beginning of September to mid-February, breeding activity can begin in late January and can conclude as late as mid-September (*21*; K. Stenberg, personal communication). Also, specific stages within the breeding season can vary geographically as well as from one colony to the next. For example, young in colonies south of Seattle often hatch in late March and fledge in June (*38*; K. Stenberg, personal communication). The fledging period in some colonies can also run for longer durations than the range shown in Figure 3 (K. Stenberg, personal communication). Because of this variability, draw on local knowledge of a colony to determine its true breeding period.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Non-breeding season		Pre-courtship, pre-nesting, and courtship		Eggs laying, incubation	Brooding	Large active young	Young fledge	Non-breeding season			

Figure 3. Chronology of the Great Blue Heron breeding and non-breeding periods (*6*, *10*, *20*, *21*).

Just after the breeding season is the ideal time for nest counts and collecting habitat data. When a non-breeding season survey is impossible, you should not collect data in the core zone before the brooding period because colonies are more sensitive at that time (*52*). Conduct breeding season surveys late in the day when birds are less likely to leave their nests (*56*).

Begin your survey by locating all trees and structures with nests. Mark all nest trees at the colony's outer perimeter with flagging. Then mark their location on a map. Also flag and map trees with canopies overlapping a nest tree. You will use the marked trees to identify the colony's boundary. Knowing the location of the boundary will also help with post-project monitoring.

Because some nests occur in trees with canopies that overlap with other trees, locate which of the overlapping trees are furthest from the center of the colony for each outer perimeter nest. Using these peripheral trees as your guide, delineate the colony's outer boundary (Figure 4). Although there will be some subjectivity as you map this boundary, these nests will serve as your primary guide.

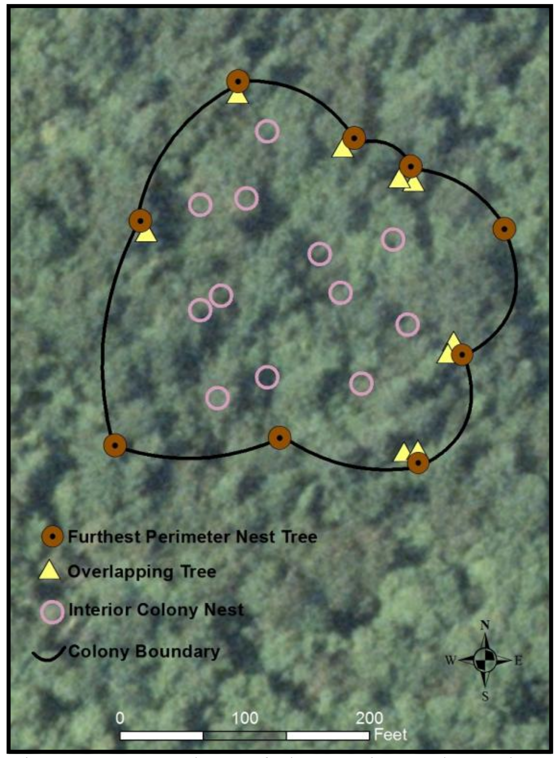


Figure 4. Boundary of the nesting colony demarcated using outer perimeter nests as a guide.

In some heron colonies outlying nests can be found in locations distant from where most of the colony's nests are concentrated. These satellite nests are typically represented by no more than a small handful of active or inactive nests located far[1] from the nearest neighboring nest in the heart of the colony. Although satellite nests are considered a part of the larger nesting colony, they usually will not be used to map the colony's outer boundary. But they should be protected. The best way to do this is by using them to identify the location of an alternate nesting stands. Alternate nesting stands serve important functions. We later discuss how to use satellite nests to identify a suitable location for an alternate nesting stand.

Buffers protect colonies by putting some distance between a colony and a potentially harmful activity (*3*, *7, 43*, *51*, *57*). Some heron colonies require a relatively wide buffer given people as far as 250 meters (820 ft) away can cause birds to flush, and in some instances terminate a nesting attempt (*3*). Consequently, anyone working on a project near an existing colony should designate a buffer area to protect the colony.

Because colonies closer to human activity may tolerate more disturbance than colonies in a more undisturbed area (*2, 52, 59*), our recommended buffer widths vary with the surrounding levels of development. To delineate the year-round buffer, draw a circle around each outer nest tree using the buffer distances in Table 1. The outermost edge of each circle forms the outer limit of the year-round buffer (Figure 5)[2].

---

[1] For the purpose of this publication, a satellite nest is any nest located a distance of no less than twice the length of the colony's year-round buffer from its nearest neighboring nest.

[2] Mapping needs periodic updating since colonies are dynamic and the outer boundary of a colony can move over time.

Table 1. Recommended buffers for nesting colonies

Year-round Buffers [a]			
Meters	**Feet**	**Setting**	**Percent built within a ¼ mile of the nest colony** [c]
300	984	Undeveloped	0 - 2%
200	656	Suburban/Rural	2 - 50%
60 [d]	197	Urban	≥ 50%
Seasonal Buffers [e]			
Meters	**Feet**	**Land Use Activity**	**Time of Year**
200	656	Unusually loud activities [f]	February to September
400	1,320	Extreme loud activities like blasting	

a Buffer guidelines based on *3*, *4*, *7*, *15*.
b Rationale for setting-specific buffers based on observed heron tolerance variations associated with land use levels (*49*, *52*)
c Cutoff percentages among undeveloped, urban, and suburban/rural as defined in *36*, *49*.
d When birds in an urban area exhibit behavior indicative of a low tolerance to people, assign the 300 meter buffer regardless of setting.
e Seasonal buffer begins at the outer edge of the year-round buffer when specified land uses occur near a colony in the breeding season.
f These activities generates sounds exceeding 92 decibels when the sound reaches the outer boundary of the nesting colony (*58*).

CORE ZONE MANAGEMENT

A colony with an adequate buffer and with room to move or expand increases its longevity and productivity (*16*, *21*). A buffer acts as a physical and visual barrier to potentially intrusive activities. Buffers can also protect nest trees from being blown down (*34*). The buffer area also provides habitat that birds can use when they need to move from one nest tree to another.

For the greatest protection, certain actions should not occur near a colony. Specifically, clearing vegetation, grading, and construction should never occur in the core zone (*24*, *49*, *51*). Trails should also be directed away from the core zone or be closed off to access in the breeding season.

Although these activities are not recommended in the year-round buffer, when you have exhaustedall options we strongly recommend you do the following when situating your project in a colony's core zone. First, you should site your project as far as possible from nests. You should also find a location where the nests will receive the greatest visual screening possible from all project distur-bances. Screeing is important as it helps ensure disturbance is minimized by removing visual cues (R. Vennesland, personal communication). Because disturbance is linked to reduced nesting prod- uctivity (*16, 24, 49, 53*), screening should provide some added protection. You should also carry out your project during the non-breeding season and mitigate for your project's infringement into the core zone.

Limited low impact recreation such as hiking, trail biking, or dog walking can occur in a core zone. However, these activities should only occur in the non-breeding season when no herons are present. Although we do not encourage any vegetation removal in the core zone, limited vegetation removal may be acceptable so long as it is part of a project primarily intended to enhance wildlife habitat (e.g., eradicating invasive understory vegetation) or to treat a fire-prone stand. Although vegetation removal may be okay in these limited instances, avoid these activities during the breeding season. Forest enhancement should also be done under the careful supervision of a wildlife biologist who understands heron behavior and ecology. When treating an overstocked or densely vegetated fire-prone stand, aim to avoid noticeable loss of visual screening to the nests.

We recommend using fences to exclude human entry into the colony's core zone (*16*, *51*). But with that in mind make sure the fence will not cut off access to other wildlife (see Fencing with Wildlife in Mind). Construct your fence in the non-breeding season and with minimal disturbance to vegetation. You can also plant of dense thickets of vegetation to keep people out of a colony's core zone (see Appendix B for thicket-forming plants). Place signs around the outer edge of the year-round buffer explaining why entry is discouraged. Although we encourage the use of fencing or a vegetation barrier, we recognize these may not be feasible options for colonies surrounded by multiple small landowners.

Great Blue Herons are less tolerant of disturbance in the pre-courtship and courtship periods (mid-February to mid-April). They progressively becoming less likely to leave or abandon a nesting attempt after their eggs hatch (*2*, *32*, *43*, *52*). Consequently, we discourage disturbance early in the breeding period. Where a core zone contains pre-existing structures like a home or a road, the type and level of use should not exceed intensities that customarily have occurred in the breeding period (*51*).

Any activity situated between the outer edges of the year-round and breeding season buffers should begin with a plan to identify where it will cause the least disturbance. Because herons seem most sensitive to actions in their line of sight, keep any work that will increase the presence of people, domestic animals, or vehicles out of view of the colony. To accomplish this, you should site your project where it will receive the greatest screening by way of vegetation or topography. Screening is especially vital when you have sited your project near the outer perimeter of the year-round buffer area. The best trees for screening will be at least as tall as a colony's tallest nesting tree. Whenever possible, these trees should also be of the same species as the dominant nesting trees. This way they will not only serve as a screen, but will provide the secondary benefit of being potential nesting trees.

Seasonal Buffer, Pre-nesting Areas, and Alternate Nest Sites

Other components of the HMA are the seasonal buffer, pre-nesting habitat, and alternate nesting stands. Identify these important areas whenever planning for a project in the vicinity of a colony. Because WDFW has not mapped pre-nesting congregation areas and alternate nesting stands in our Priority Habitat and Species database, you should identify these sites during the development of a habitat management plan (HMP).

Demarcate a seasonal "quiet" buffer of 200 meters (656 ft) if any unusual or loud activity will occur in the breeding season (Table 1; *3*). This seasonal buffer begins at the outer edge of the year-round buffer. If blasting (or any similarly loud activity) will occur in the breeding season, we recommend you designate a 400 meter buffer (1,320 ft; *48*).

The presence of a pre-nesting congregation of herons often signals the start to the breeding season. These congregations generally are close to the nesting colony (≤ 1 km) and are discernable by a concentration of birds outside the nesting colony between February and March, and as early as January. You should map any known pre-nesting use area. Because we know little as to how pre-nesting habitat disturbance affects a colony, you should take a precautionary approach to managing these areas. We recommend minimal disturbance of any area where herons congregate prior to nesting due to their greater sensitivity early in the breeding season (*2*, *52*, *57*).

Although our recommendations focus on protecting the active colony, you also should identify and conserve potential nesting stands to preserve active nesting colonies in an area. Nesting herons periodically relocate their colonies and alternate nesting stands provide places to relocate

(*51*). We recommend retaining several forested alternate nesting stands of at least 4 hectares (10 ac) with dominant trees at least 17 meters (56 ft) high near breeding colonies (*29, 39*).

There are several strategies for finding the ideal places for an alternate nesting stand. Because herons sometimes nest in outlying trees away from where most nesting birds are concentrated, alternate nesting stands can be centered on these remote satellite nests. The satellite nest typically is represented by one, two, or several active or inactive nests located well beyond the nearest neighboring nest. We recommend using satellite nests to site an alternate nesting stand when they are located at least twice the year-round buffer distance from the nearest neighboring nest.

Another strategy is using former heron colony sites. When these sites are near an active colony, they may be designated as alternate nesting stands. But before choosing a former nesting site, consider the circumstances of the former colony site's demise. Above all, it probably is not suitable to designate a former nesting site if the site was likely vacated because of a nearby disturbance with permanent (e.g., housing development) or long-term (e.g., clear cut) effects.

If you cannot find a former nesting site or satellite nest, identify all nearby forest stands where structure and tree species composition is similar to the active nesting stand. The alternate nesting stand should be within a kilometer of the active colony and within 3 kilometers (1.9 mi) of foraging habitat. Preferably this should be the same foraging habitat used by the active colony.

FORAGING HABITAT

Because breeding herons need nearby foraging habitat, conserving potential foraging habitat is key. Similar to pre-nesting concentration areas and alternate nesting habitat, identify foraging habitat when developing your HMP. Although some herons forage further away, most herons feed within 3 kilometers (1.9 mi) of their colony.

Map all bodies of water within a 3 kilometer (1.9 mi) radius of a nesting colony (up to 10 km from colonies with ≥100 nests) as an initial step to identify potential foraging habitat. The perimeter and shallow portion of waterbodies are especially important for foraging. Although herons will not feed along every nearby waterbody, these waters will likely include foraging habitat. For colonies in the outer coast, Puget Sound, and Georgia Basin, publicly available data can help you pinpoint potential marine nearshore foraging habitat (Table 2). WDFW's multiyear heron foraging count in Puget Sound gives a snapshot of foraging during the 2003-04 breeding season. This is the region's only survey specifically of nearshore marine and estuarine foraging habitat.

Land use activities along the nearshore can adversely affect habitat where herons feed in concentrations. These habitats include eelgrass and kelp beds, shorelines, and wetlands (*23*). Dredging, filling, grading, or otherwise altering nearshore and riparian habitat can interrupt feeding and harm food supplies (*23*). Therefore, we recommend you not disturb key foraging habitat between March and September (R. Butler, personal communication). To protect foraging habitat, establish adequate riparian buffers such as those recommended by Knutson and Naef (*34*). You should also minimize certain activities where herons feed:

- removal of aquatic vegetation, especially native eelgrass.
- use of all watercraft within 180 meters (590 ft) of shallow waters where herons forage (*44*).
- logging mature forest close to nearshore foraging habitat (*24*).
- removing perch trees adjacent to foraging areas (*51*).
- draining, filling, or dredging wetlands or marshes (*3*).
- building close to riparian shorelines (*34*).

In addition to these measures, the Aquatic Habitat Guidelines Working Group's recommendations offer ways of limiting nearshore disturbances from overwater structures, shoreline armoring, and riparian alterations in Puget Sound (see Envirovision et al. 2010). Because these activities affect the species that herons feed on, you should review this publication before beginning one of these activities within 3 kilometers of any Puget Sound heron colony.

Because inland herons tend to feed in a dispersed manner, their foraging habitat often is not as obvious as in coastal areas. Although inland breeding herons do not restrict their foraging at one or two areas of concentrated feeding, the shallow margins of lakes, rivers, and wetlands that they do use are still vital. In fact, these habitats not only are important to herons, but to most of the region's other species as well (*34*). Consequently, we recommend using WDFW's PHS Riparian management recommendations and Washington Department of Ecology's Wetland's Guidance Manual to protect riparian habitats along lakes, rivers, and wetlands.

Table 2. Sources of GIS data that can aid in locating potential nearshore Great Blue Heron foraging habitat.

Database [a]	Description	Data Limitations [b]	Acquiring Data
Washington			
Priority Habitat and Species database	Documented locations of eelgrass beds and other nearshore habitats.	• Database only includes a small subset of the locations of nearshore priority habitats in Washington.	PHS on the Web
Shorezone Washington	Inventory of Washington's saltwater shorelines from 1994-2000. Information was collected by helicopter at low tide.	• Not designed to capture small features. • Shoreline units divided based on geology, not biology. Thus, biotic elements (e.g., eelgrass) may occur in the middle of a unit, or span several units. • If biota is recorded as present, a user can be confident the feature was present during the flight. If a feature is *not* recorded, it is not necessarily absent.	Washington Department of Natural Resource Data Web Portal
WDFW Puget Sound Heron Foraging Count	Aerial foraging count carried out in Puget Sound from 2003-2004.	• A static dataset with no confirmed timeline for an update.	Contact Data Steward for WDFW's Washington Survey Data Management (WSDM) system
Skagit and Whatcom county Intertidal Habitat Inventories	Vegetation classified using multispectral imagery from 1995-1997: eelgrass, brown algae, kelp, green algae, mixed algae, salt marsh, spit and berm vegetation, and red algae.	• Vegetation type was classified using dominant vegetation. Other vegetation types may be present in abundances <30%. • Low density vegetative cover (<25%) likely escaped detection. • Subtidal vegetation that does not form a canopy may not be distinguished and conclusions regarding the presence or absence of this vegetation should not be drawn based on this data set. • Vegetation patches < 16 m^2 are likely not detected.	Washington Department of Natural Resource Data Web Portal
National Wetland Inventory	Information on the extent and status of wetlands in the United States.	• Prepared from analysis of high altitude imagery. • Accuracy of interpretation depends on image quality, experience of image analyst, and amount of ground-truthing conducted.	Wetlands Mapper
British Columbia			
Shorezone British Columbia	Tool for identifying coastal biological communities in BC	• Similar to Shorezone Washington data limitations.	ess.info@gov.bc.ca
Coastal Resource Information System	Locations of kelp and eelgrass beds in BC		British Columbia CRIS Web Portal
Eelgrass Bed Mapping Application	Locations of kelp and eelgrass beds in BC	• Details at www.cmnbc.ca/atlas_gallery/eelgrass-bed-mapping	Community Mapping Network
Eelgrass mapping review: eelgrass mapping initiatives in coastal BC	A report of known eelgrass mapping and monitoring projects in BC	• Surveys and mapping carried out after 2003 are not identified in the report. • Report likely to have inadvertently left out some pre-2003 eelgrass mapping efforts.	Dunster 2003

[a] These inventories should be used only as screening tools. They are not site-specific, and should not replace site-specific surveys. However, they can all complement site-specific surveys by providing regional context.

[b] Each of these databases represent a snapshot over a given time period and do not show changes in condition or status over time.

Former Nesting Colonies

Because herons occasionally move back to seemingly abandoned nesting sites, we recommend you protect these sites. In Washington, documented re-nesting has occurred in sites over 10 years after being "abandoned" (C. Anderson, personal communication). Although entry for uses that will not alter the look of the habitat like hiking and dog walking is okay when no nesting herons are present, all other recommendations applying to an active colony should remain in effect for at least 10 years after nesting has ceased at the site of any former colony.

Management of Urban Colonies

Although herons mostly nest away of urban settings, colonies occur in urban areas in Washington, British Columbia, and throughout the species' North American range. Herons may tolerate everyday human activities, but in general birds often suspend nesting when they perceive the activity is a threat (*17, 49*). Although we do not know the threshold for what constitutes a threat, a seemingly benign stimulus like a pedestrian can lead a colony to terminate a nesting attempt (*53*).

In this update to the Great Blue Heron management recommendations we have further recognized differences in managing urban versus non-urban colonies. The primary approach is the tiered set of buffers (Table 1). In urban and suburban landscapes project planners should learn of any existing disturbances before beginning a project near a heron colony. That way a planner can identify an appropriate size and scope for a project. As a rule of thumb, new activities should not add to the intensity of disturbance a colony has historically tolerated and adapted to.

To see if a project will increase the level of disturbance from historical levels, we recommend you begin by documenting the intensity of all existing disturbances. We do not recommend any new activities that will lead to an increase in the intensity of disturbance. An increase in intensity can occur when a new activity is sited closer to a colony than that of existing activities. Increased intensity can also happen when the magnitude of a proposed disturbance is out of pro-portion to all existing disturbances located the same distance from a colony. To illustrate this point, consider a colony where herons have historically persisted where the footprint of the closest home is 60 meters from the colony. If a new home is sited 30 meters away, this would constitute an increase in intensity because the new home's influence on the colony would be greater than that of the existing home. Other ways of increasing the intensity of disturbance include upzoning or changing or converting to a more intensive land use practice.

Where development already exists within our recommended year-round buffer zone (Table 1), we do not recommend any further infringement within this zone. Where further infringement will occur, new disturbances should not take place in the breeding season and we do not recommend large or novel events occurring at any time (*52*). Any further infringement should not happen without first developing a plan to mitigate for the loss of habitat.

Carrying out the Heron Recommendations

These guidelines are to be applied wherever herons nest in Washington. They may also be applicable throughout the heron's North American breeding range. To protect heron colonies, these guidelines should be incorporated into the regulatory and non-regulatory framework of local communities throughout the region. Another for way of protecting habitat is through land acquisition by organizations (e.g., land trusts) whose mission includes wildlife habitat conservation.

Two of Washington's laws most influential to regulating Great Blue Heron habitat at the local level are the Shoreline Management Act and the Growth Management Act. Counties and cities are encouraged to designate Great Blue Heron as a species of local importance and to adopt these management recommendations to support protection of this priority species.

Although effective heron conservation requires regulatory protections, non-regulatory incentives should also be put in place to protect herons. Some non-regulatory options in Washington include transfer of development rights[1] (TDR), current use taxation (via the development of a Public Benefit Rating System), and Conservation Futures. Local land trusts[2] can also help property owners protect heron habitat through incentives such as conservation easements.

Each of these options can protect herons by giving landowners monetary or other incentives to avoid harmful activities. Communities with TDR programs allow certain landowners to transfer their right to develop in exchange for monetary compensations. In this program landowners with important wildlife habitat could receive eligibility to transfer their development rights to a less environmentally sensitive location. Participants in a PBRS program could also receive an economic incentive for limiting certain land use activities for the purpose of protecting a colony. Conservation Futures or other conservation funding or easement programs may also be designed to give preference points to properties with nesting herons. Counties and cities should adopt some or all of these options as a way to balance regulatory with non-regulatory protections for the Great Blue Heron and other sensitive species.

While many local governments protect the nesting colony, habitats that indirectly benefit a colony sometimes go unprotected. To protect pre-nesting habitat, alternate nesting stands, and foraging habitat, incentives can provide a set of useful tools. Local governments should offer incentives to landowners who want to permanently protect any type of breeding season habitat. Specifically, proposals near breeding season habitat deserve high priority when choosing between candidates for new Conservation Futures sites. Land trusts should also consider these areas when developing their conservation portfolios.

Habitat Management Plans. – A habitat management plan (HMP) should be developed whenever a land use proposal is submitted for an area in or near the core zone of an HMA. An HMP is a detailed report that outlines and documents where there is habitat, any planned incursions or habitat impacts, and a strategy for limiting impacts. Using our management recommendations as a guide, an HMP should describe the:

- resources, including active or historical nesting sites, pre-nesting congregation areas, and potential foraging sites.
- past, present, and future land uses.
- habitat features and processes potentially impacted by the proposal.
- habitat enhancement or mitigation measures, including quantitative goals and objectives.
- objectives that carefully balance the needs of the species with that of the landowner.
- implementation plan with maps, as-built drawings, and operation and maintenance plan.
- specific prescriptions and project timing to best meet the species' needs and to promote the health of their habitat.
- a schedule for periodic monitoring, and a contingency plan with corrective actions if conservation or mitigation actions do not lead to a desired outcome.

[1] In Canada TDRs are more commonly referred to as Transfer of Development Credits.
[2] A list of land trusts in British Columbia can be found at http://landtrustalliance.bc.ca/members.html.

REFERENCES

1. Bennett, D. C., P. E. Whitehead, and L. E. Hart. 1995. Growth and energy requirements of hand-reared Great Blue Heron (*Ardea herodias*) chicks. Auk 112:201-209.

2. Bowman, I., and J. Siderius. 1984. Management guidelines for the protection of heronries in Ontario. Ontario Ministry of Natural Resources, Wildlife Branch, Toronto, Ontario.

3. B. C. Ministry of Environment. 2006. Develop with care: environmental guidelines for urban and rural land development in British Columbia. Victoria, British Columbia.

4. _____. 2008. Develop with care: Great Blue Heron fact sheet. Fact sheet number 11. Victoria, Victoria, British Columbia.

5. Butler, R. W. 1991a. Habitat selection and time of breeding in the Great Blue Heron (*Ardea herodias*). Ph.D. Dissertation. University of British Columbia, Vancouver, British Columbia.

6. _____. 1991b. A review of the biology and conservation of the Great Blue Heron (*Ardea herodias*) in British Columbia. Technical Report Series, Number 154. Canadian Wildlife Service, Delta, British Columbia.

7. _____. 1992. Great Blue Heron (*Ardea Herodias*). Number 25 *in* A. Poole, P. Stettenheim, and F. Gill, editors. The Birds of North America. American Ornithologists Union and Academy of Natural Science, Philadelphia, Pennsylvania.

8. _____. 1993. Time of breeding in relation to food availability of female Great Blue Herons (*Ardea herodias*). Auk 110:693-701.

9. _____. 1995. The patient predator: foraging and population ecology of the Great Blue Heron (*Ardea herodias*) in British Columbia. Occasional Paper Number 86. Canadian Wildlife Service, Ottawa, Ontario.

10. _____. 1997. The Great Blue Heron. University of British Columbia Press, Vancouver, British Columbia.

11. _____, and P. D. Baudin. 2000. Status and conservation stewardship of the Pacific Great Blue Heron in Canada. Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk 1:247-250.

12. _____, and R. G. Vennesland. 2000. Integrating climate change and predation risk with wading bird conservation research in North America. Waterbirds 23:535-540.

13. _____, P. E. Whitehead, A. M. Breault, and I. E. Moul. 1995 Colony effects on fledging success of Great Blue Herons (*Ardea herodias*) in British Columbia . Colonial Waterbirds 18: 159-65.

14. Campbell, R. W., N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, and M. C. E. McNall. 1990. The birds of British Columbia, Volume 1. Royal British Columbia Museum, Victoria, British Columbia.

15. Carney, K. M., and W. J. Sydeman. 1999. A review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22:68-79.

16. Carlson, B. A., and E. B. McLean. 1996. Buffer zone and disturbance types as predictors of fledging success in Great Blue Herons, *Ardea herodias*. Colonial Waterbirds 19:124–127.

17. City of Vancouver Parks and Recreation. 2006. Stanley Park heronry management plan. Vancouver, British Columbia.

18. del Hoyo, J., A. Elliott, and J. Sargatal. 1992. Handbook of the birds of the world. Volume 1. Lynx Edicions, Barcelona, Spain.

19. Dunster, K. 2003. Eelgrass mapping review: eelgrass mapping initiatives in coastal British Columbia. Report prepared for the Canadian Wildlife Service, Delta, British Columbia.

20. Eissinger, A.M. 1996. Great Blue Herons of the Salish Sea: a model plan for the conservation and stewardship of coastal heron colonies. Nahkeeta Northwest Wildlife Services, Bow, Washington.

21. _____. 2007a. Great Blue Herons in Puget Sound. Puget Sound Nearshore Partnership Report Number 2007-06. Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

22. _____. 2007b. Status and trends of Puget Sound Great Blue Heron breeding colonies. Proceedings of the 2007 Georgia Basin Puget Sound research conference, Vancouver, British Columbia.

23. Envirovision, Herrera, and AHG. 2010. Protecting nearshore habitat and functions in Puget Sound, an interim guide, Washington departments of Fish and Wildlife, Ecology, Natural Resources, Transportation, Community Trade and Economic Development, the Recreation and Conservation Office, and the Puget Sound Partnership.

24. Gebauer, M. B., and I. E. Moul. 2001. Status of the Great Blue Heron in British Columbia, Wildlife Working Report No. WR-102. Ministry of Environment, Lands and Parks - Wildlife Branch, Victoria, British Columbia.

25. Gibbs, J. P. 1991. Spatial relationships between nesting colonies and foraging areas of Great Blue Herons. Auk 108:764-770.

26. _____, and L. K. Kinkel. 1997. Determinants of the size and location of Great Blue Heron colonies. Colonial Waterbirds 20:1-7.

27. _____, S. Woodward, M. L. Hunter, and A. E. Hutchinson. 1987. Determinants of Great Blue Heron colony distribution in coastal Maine. Auk 104:38-47.

28. Henny, C. J. 1978. Great Blue Herons respond to nesting habitat loss. Wildlife Society Bulletin 6:35-37.

29. Jensen, K. E., and P. D. Boersma. 1993. Land development and human disturbance as factors in determining Great Blue Heron (*Ardea herodias*) colony size and location in the Puget Sound Region. Unpublished Report, University of Washington, Seattle, Washington.

30. Kelly, J. P. K. Etienne, C. Strong, M. McCaustland, and M. L. Parkes. 2007. Status, trends, and implications for the conservation of heron and egret nesting colonies in the San Francisco Bay Area. Waterbirds 455-478.

31. _____, D. Stralberg, K. Etienne, and M. McCaustland. 2008. Landscape influence on the quality of heron and egret colony sites. Wetlands 28: 257–275.

32. Kelsall, J. P. 1989. The Great Blue Herons of Point Roberts: history, biology, and management. Point Roberts Heron Preservation Committee, Points Roberts, Washington.

33. Kendall, M. A., M. T. Burrows, A. J. Southward, and S. J. Hawkins. 2004. Predicting the effect of marine climate change on the invertebrate prey of the birds of rocky shores. Ibis 146:40-47.

34. Knutson, K. L., and Naef, V. L. 1997. Management recommendations for Washington's priority habitats: Riparian. Washington Department of Fish and Wildlife, Olympia, Washington.

35. Machmer, M. M. 2009. Great Blue Heron and Bald Eagle inventory and stewardship in the Columbia Basin (2008-2009), Fish and Wildlife Compensation Program, Nelson, British Columbia.

36. Marzluff, J. M., R. Bowman, and R. Donnelly. 2001. A historical perspective on urban bird research: trends topics, and definitions. Pages 1-17 *in* J. M. Marzluff, R. Bowman, and R. Donnelly, Editors. Avian ecology and conservation in an urbanizing world. Kluwer Academic Press, Norwell, Massachusetts.

37. Moul, I. E. 1990. Environmental contaminants, disturbance and breeding failure at a Great Blue Heron colony on Vancouver Island. Master's Thesis, University of British Columbia, Vancouver, British Columbia.

38. Norman, D. M. 2001. The big sit: monitoring Great Blue Heron foraging sites, Everett to Point Roberts. Puget Sound Action Team, Olympia, Washington.

39. Parker, J. 1980. Great Blue Herons (*Ardea herodias*) in northwestern Montana: nesting habitat use and the effects of human disturbance. Master's Thesis, University of Montana, Missoula, Montana.

40. Parnell, J. F., D. G. Ainley, H. Blokpoel, B. Cain, T. W. Custer, J. L. Dusi, S. Kress, J. A. Kushlan, W. E. Southern, L. E. Stenzel, and B. C. Thompson. 1988. Colonial waterbird management in North America. Colonial Waterbirds 11:129-169.

41. Powell, G. V. N. 1983. Food availability and reproduction by Great White Herons (*Ardea herodias*): A food addition study. Colonial Waterbirds 6:138-147.

42. _____, and A. H. Powell. 1986. Reproduction by Great White Herons (*Ardea herodias*) in Florida Bay as an indicator of habitat quality. Biological Conservation 36:101-113.

43. Rogers J. A. Jr., and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9:89-99.

44. _____, and S. T. Schwikert. 2002. Buffer-zone distances to protect foraging and loafing waterbirds from disturbance by personal watercraft and outboard-powered boats. Conservation Biology 16: 216-224.

45. Simpson, K. 1984. Factors affecting reproduction in Great Blue Heron (*Ardea herodias*). Master's Thesis, University of British Columbia, Vancouver, British Columbia.

46. Suckley, G., and J. G. Cooper. 1860. The natural history of Washington Territory and Oregon. Bailliere Brothers, New York, New York.

47. Sullivan, J. P. 1988. Effects of provisioning rates and number fledged on nestling aggression in great blue herons. Colonial Waterbirds 11:220-226.

48. USDI. 2003. Biological opinion and letter of concurrence for effects to Bald Eagles, Marbled Murrelets, Northern Spotted Owls, Bull Trout, and designated critical habitat for Marbled Murrelets and Northern Spotted Owls from Olympic National Forest Program of activities for August 5, 2003, to December 31, 2008. FWS Reference Number 1-3-03-F-0833. Lacey, Washington.

49. Vennesland, R. G. 2000. The effects of disturbance from humans and predators on the breeding decisions and productivity of the Great Blue Heron. M.Sc. Thesis, Simon Fraser University, Burnaby, British Columbia.

50. _____. 2003. Coastal Great Blue Heron (*Ardea herodias fannini*) inventory and monitoring project: 2002 breeding season report and historical analysis. British Columbia Ministry of Water, Land and Air Protection, Nanaimo, British Columbia.

51. _____. 2004. Great Blue Heron (*Ardea herodias*). British Columbia Ministry of Water, Land and Air Protection, Victoria, British Columbia.

52. _____. 2010. Risk perception of nesting Great Blue Herons: experimental evidence of habituation. Canadian Journal of Zoology 88:81-89.

53. _____, and R. W. Butler. 2004. Factors influencing Great Blue Heron nesting productivity on the Pacific coast of Canada from 1998 to 1999. Waterbirds 27: 289-296.

54. _____, and _____. 2008. COSEWIC Assessment and update status report on the Great Blue Heron (*Ardea herodias fannini*) in Canada. Committee on the Status of Endangered Wildlife in Canada , Ottawa, Ontario.

55. _____, and _____. 2011. Great Blue Heron (*Ardea herodias*). Number 25 *in* A. Poole, Editor. The Birds of North America. Available at http://bna.birds.cornell.edu/bna/ (accessed 17 February 2012). Cornell Lab of Ornithology, Ithaca, New York.

56. _____, and D. M. Norman. 2006. Survey protocol: for measurement of nesting productivity at Pacific Great Blue Heron nesting colonies. Available at www.heronworkinggroup.org (accessed 27 December 2011).

57. Vos, K. K., R. A. Ryder, and W. D. Graul. 1985. Response of breeding Great Blue Herons to human disturbance in north central Colorado. Colonial Waterbirds 8:13-22.

58. Washington Department of Transportation. 2011. Biological assessment preparation for transportation projects: advanced training manual. Available at http://www.wsdot.wa.gov/Environment/Biology/BA/BAguidance.htm#Manual (accessed 9 March 2012). Olympia, Washington.

59. Webb, R. S., and L. S. Forbes. 1982. Colony establishment in an urban site by Great Blue Herons. Murrelet 63:91-92.

60. Werschkul, D. F., E. McMahon, and M. Leitschuh. 1976. Some effects of human activities on the Great Blue Heron in Oregon. Wilson Bulletin 88:660-662.

PERSONAL COMMUNICATIONS

Chris Anderson
Assistant District Wildlife Biologist
Washington Department of Fish and Wildlife
Mill Creek, Washington

Dr. Robert Butler, Ph.D.
President
The Pacific Wildlife Foundation
Port Moody, British Columbia

Ann Eissinger
Wildlife Biologist
Nahkeeta Northwest Wildlife Services
Bow, Washington

Howard Ferguson
District Wildlife Biologist
Washington Department of Fish and Wildlife
Spokane Valley, Washington

Ian Moul
B.C. Nature
Provincial Coordinator
Wildlife Tree Stewardship Program
Vancouver Island, British Columbia

Don Norman
Wildlife Biologist
Norman Wildlife Consulting
Shoreline, Washington

Sarah Pinnock
Wetlands Education Specialist
City of Hillsboro Parks and Recreation
Hillsboro, Oregon

Dr. Kate Stenberg, Ph.D.
Senior Urban Wildlife Scientist
CDM Smith
Bellevue, Washington

Michelle Tirhi
District Wildlife Biologist
Washington Department of Fish and Wildlife
Lakewood, Washington

Ross Vennesland
Species at Risk Recovery Specialist
Parks Canada
Vancouver, British Columbia

GLOSSARY

Breeding Season	This is the period when herons begin gathering in pre-nesting aggregations near the colony and concludes when young of the year have fledged.
Brood	A collective term for the offspring produced by an individual breeding female.
Brooding Period	The first days of a juvenile bird's life.
Clutch	Collection of eggs in a single nest.
Core Zone	This encompasses the area where herons are nesting as well as the adjacent year-round buffer zone.
Habitat Management Plan	A detailed report that outlines and documents the location of the important habitat area, any incursions or impacts into the habitat by a proposed land use action, and ways to limit any impacts to the habitat and to associated species.
Heron Management Area	This is the area that includes all key elements needed to sustain a colony of nesting Great Blue Herons. This includes the area where herons are nesting, year-round and seasonal buffer areas, the pre-nesting concentration area(s), and the foraging habitat that nesting herons are using during the breeding season.
Nesting Colony	The area where a group of heron nests are located.
Seasonal "Quiet" Buffer	An area just adjacent to the outer edge of the year-round buffer. Within this area certain loud activities such as blasting or the use of chain saws is not recommended.
Pre-nesting Habitat	Where herons gather in groups prior to initiating nesting. Pre-nesting often occurs along larger lakes, wetlands, watercourses, and fallow fields.
Year-round Buffer	An area set between the outer edge of the nesting colony and the inner perimeter of the seasonal buffer. Within this area most land use activities are not recommended at any time of the year.

Cavity Nesting Ducks

Barrow's Goldeneye -*Bucephala islandica*
Common Goldeneye - *Bucephala clangula*
Hooded Merganser - *Lophodytes cucullatus*
Bufflehead - *Bucephala albeola*
Wood Duck - *Aix sponsa*

Last updated: 2000

Written by Jeffrey C. Lewis and Don Kraege

GENERAL RANGE AND WASHINGTON DISTRIBUTION

These five species of cavity-nesting ducks vary in distribution. The breeding and wintering ranges of the Barrow's goldeneye (*Bucephala islandica)* and the bufflehead *(Bucephala albeola*) extend from Alaska to California. The wood duck (*Aix sponsa*) and hooded merganser (*Lophodytes cucullatus*) winter south of Alaska and breed from British Columbia southward. The common goldeneye winters from Alaska to California and breeds in isolated areas of Washington northward to Alaska (Bellrose 1976).

Washington is one of a very few states where all 5 species are known to breed (Matt Monda, personal communication). The Barrow's goldeneye is widespread and breeds within the Cascades and in north-central Washington (see Figure 1). A unique population of Barrow's goldeneye nest in cavities within the talus slopes and basalt cliffs surrounding Lake Lenore and Alkali Lake in central Washington (Matt Monda, personal communication). Buffleheads are only known to breed south of Spokane on Turnbull National Wildlife Refuge and at Big Meadow Lake in Pend Oreille County (see Figure 2; Smith et al. 1997). The common goldeneye breeds in a few isolated areas in northeastern Washington (see Figure 3). Breeding areas for hooded mergansers and wood ducks are more widespread, primarily in the western part of the state, but they also breed in eastern Washington where adequate habitat occurs (see Figure 4; Smith et al. 1997). In addition, large concentrations of

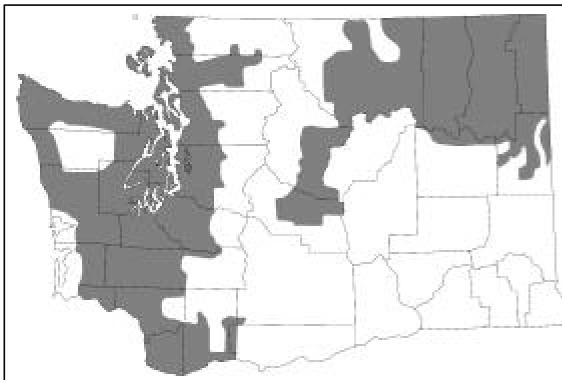


Figure 1. Breeding range of the Barrow's goldeneye (Bucephala islandica) in Washington. Map derived from GAP Analysis of Washington. Smith et al. 1997).

Figure 2. Breeding Distribution of the Bufflehead (Bucephala Clangula) in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).

breeding wood ducks occur in the Yakima valley (see Figure 5; Matt Monda, personal communication).

All five species can be found in larger numbers during migration. Though wood ducks typically winter further south than Washington, significant wintering numbers can be found in the Yakima Valley and the Columbia River estuary. Goldeneyes and buffleheads winter in large numbers on Puget Sound and larger rivers. Hooded Mergansers are less common but winter in a wide variety of habitats (Matt Monda, personal communication).

Figure 3. Breeding distribution of the common goldeneye in Washington. Map derived from GAP Anaylsis of Washington (Smith et al. 1997).

RATIONALE

Cavity-nesting ducks provide recreation to hunters and bird watchers, and they are vulnerable to loss of nesting habitat. These species require nesting cavities within trees and snags, which are commonly lost through commercial forestry, firewood cutting, and shoreline development. All but the wood duck exhibit low productivity and low population sizes, breed for the first time at an older age, and are poor pioneers of unoccupied habitats (Goudie et al. 1994). Common goldeneye and bufflehead are the least common breeding ducks in the state. Loss of suitable nesting sites will eliminate use of an area by breeding birds.

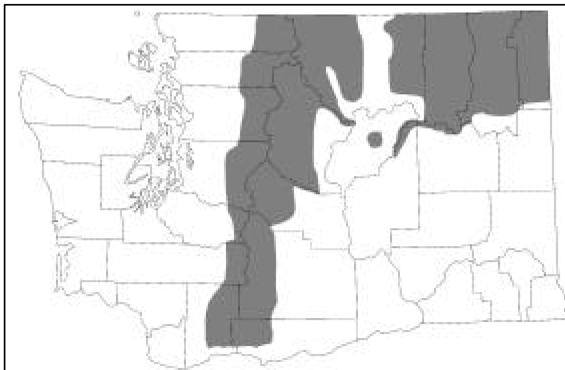


Figure 4. Breeding distribution of the hooded merganser (Lophodytes cucullatus) in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).

HABITAT REQUIREMENTS

In Washington, cavity-nesting ducks nest primarily in late-successional forests and riparian areas adjacent to low gradient rivers, sloughs, lakes, and beaver ponds (Thomas 1979, Brown 1985, Parker 1990). Animal matter can comprise over 75% of the diets of the hooded merganser, bufflehead, common goldeneye and Barrow's goldeneye. These species feed primarily on aquatic insects, mollusks, crustaceans, and small fish (Gauthier 1993, Dugger et al. 1994, Fitzner and Gray 1994, Eadie et al. 1995, Hepp and Bellrose 1995). Wood ducks up to 6 weeks old depend on animal matter, while older ducklings and adult wood ducks feed on aquatic and emergent plants, acorns, grain, and other seeds (Bellrose and Holm 1994).

Nest Site Characteristics

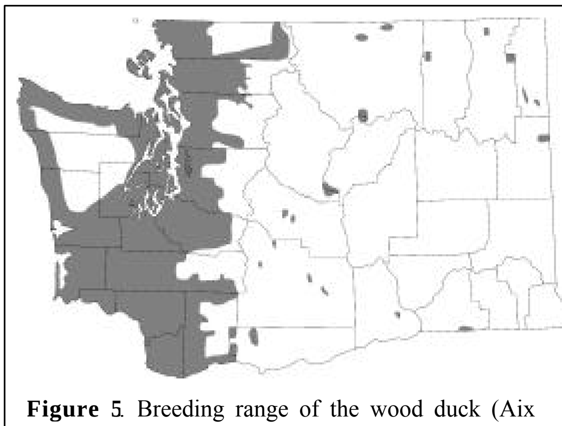


Figure 5. Breeding range of the wood duck (Aix sponsa) in Washington. Map derived from GAP Analysis of Washington (Smith et al. 1997).

These 5 species of ducks nest almost exclusively in tree cavities, which offer protection from weather and predators. They are secondary cavity nesters, using cavities created by large woodpeckers or by decay or damage to the tree. Cavity use is dependent on the proximity of suitable brood habitat, predator levels, and competition (and perhaps brood parasitism) from the other cavity-nesting species (Peterson and Gauthier 1985, Dugger et al. 1994, Eadie et al. 1995, Robb and Bookhout 1995). Nest site fidelity is common, especially at successful nests (Dow and Fredga 1984, Hepp and Kennamer 1992, Gauthier 1993, Dugger et al. 1994). Population levels of cavity-nesting ducks can be related to the availability of nesting sites (Dow and Fredga 1984, Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Hepp and Bellrose 1995).

In general, minimum cavity dimensions that will accommodate all 5 species include an entrance hole at least 9 cm (3.5 in) in diameter, with the internal cavity 25 cm (10 in) deep and 19 cm (7.5 in) in diameter (Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Robb and Bookhout 1995). The bufflehead, however, appears to prefer smaller cavity entrances (6.5 cm diameter [2.5 in]; flicker nests are ideal) which may reduce nest-site competition and brood parasitism from larger ducks (especially goldeneyes) (Gauthier 1993). Hooded mergansers have less specific nest-cavity preferences, but they prefer nest sites that are within or very near brood habitat (Dugger et al. 1994). Nest trees should have a diameter at breast height (dbh) of 30 cm (12 in) (Soulliere 1988), but all 5 species typically use nest trees >60 cm (24 in) dbh. These ducks will use tree cavities that occur above 20 m (66 ft), but they generally use cavities 2-15 m (6-49 ft) above the ground or water. The canopy around a cavity is generally open and does not overhang the entrance (Bellrose 1976). Optimal density of potential nest trees is 12.5/ha (5/ac) (Sousa and Farmer 1983).

Brood Habitat

Shallow wetlands within 0.8 km (0.5 mi) of cavities provide optimal brood habitat for all cavity-nesting ducks. Wood ducks typically use habitats with 50-75% overhanging woody vegetation and/or emergent vegetation for brood escape cover (Sousa and Farmer 1983); all 5 species use downed logs or low islands for loafing (Webster and McGilvrey 1966, Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Hepp and Bellrose 1995). Both goldeneye species and the bufflehead typically use more open water with less emergent vegetation as brood habitat (Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995). Common goldeneyes prefer acidic and fishless waters where there is little or no competition from fish for aquatic insects (Gauthier 1993, Poysa and Virtanen 1994, Eadie et al. 1995).

LIMITING FACTORS

Population levels of cavity-nesting ducks can be limited by the availability of suitable nesting sites, adequate brood escape cover, foraging areas, nest predation, and nest parasitism (Dow and Fredga 1984, Gauthier 1993, Bellrose and Holm 1994, Dugger et al. 1994, Eadie et al. 1995, Hepp and Bellrose 1995). Human disturbance of nesting ducks may affect productivity. Destruction of cavity trees can eliminate these species from an area (Matt Monda, personal communication).

The use of herbicides or pesticides near wetlands may affect cavity-nesting ducks by lowering the numbers of invertebrates, and by adversely affecting aquatic and emergent vegetation. All of these ducks are known to accumulate toxins in their tissues, especially in areas where toxins are elevated, such as downstream from mines, pulp and paper mills (Blus et al. 1993, Swift et al. 1993, Vermeer et al. 1993, Champoux 1996).

MANAGEMENT RECOMMENDATIONS

An adequate supply of nest cavities is the key to supporting populations of cavity-nesting ducks in Washington. Land management activities designed to promote healthy populations of these 5 duck species should ensure a continuous supply of available nest cavities.

Snags and cavity trees near suitable wetlands should be preserved and created to achieve a minimum density of 12.5 potential nest cavities/ha (5/ac) (McGilvrey 1968). Snags and cavity trees should have a minimum diameter of 30 cm (12 in), although a diameter of 60 cm (24 in) is preferred (McGilvrey 1968).

In general, the following nest cavity characteristics will accommodate all five species and should be considered when evaluating potential nest sites:

- an elliptical entrance hole at least 9 cm (3.5 in) in diameter (buffleheads may prefer smaller cavity entrances that are 6.5 cm diameter [2.5 in])
- an internal cavity 25 cm (10 in) deep and 19 cm (7.5 in) in diameter (Gauthier 1993, Dugger et al. 1994, Eadie et al. 1995, Robb and Bookhout 1995)
- cavities 2-15 m (6-49 ft) above the ground or water are generally preferred, although cavities above 20 m (66 ft) in trees will be used
- the canopy around a cavity should be open and not overhang the entrance (Bellrose 1976)

Large woody debris and downed logs should be present, as well as low islands for breeding and brood use (McGilvrey 1968). Flooded timber should not be logged, and woody vegetation along the shores of nesting and brood areas should be retained. In some situations, flooding standing or downed timber may be used to create snags and brood habitat (McGilvrey 1968).

Predator-proof nest boxes for cavity nesting ducks can be used in areas where natural cavity sites are limited but other habitat requirements are met (Bellrose 1976). However, it is unknown how nest boxes affect natural selection or species fitness over time. In some situations, it may not be suitable to consider nest boxes as permanent substitutes for natural cavities. The decision to provide nest boxes to supplement existing cavities or nest boxes should consider occupancy rates of existing suitable nest sites.

Wood duck boxes should be designed and placed following the recommendations of Bellrose and Holm (1994). Boxes for the other four species should follow the guidelines provided by Lumsden et al. (1980) and Gauthier (1993). Nest boxes for cavity nesting ducks are commonly made out of rough-cut lumber. Other materials that can be used include sheet metal and slab wood (Bellrose and Holm 1994).

To minimize the impacts of brood parasitism, predation, and starling use, nest boxes for wood ducks should be placed far enough apart so that one is not visible from the other. (Bellrose and Holm 1994, Semel and Sherman 1995). Bellrose and Holm (1994) recommend a minimum of 46 m (150 ft) between nest box structures. Nest box placement can affect clutch size, rates of brood parasitism, and hatching success in wood ducks. Traditionally placed nest boxes that are grouped together with highly visible entrances often suffer from higher rates of brood parasitism and produce less ducklings over time than nest boxes placed in trees out of sight of each other (Bellrose 1976, Semel and Sherman 1995).

In areas supporting wood ducks, mast-producing (nut producing) trees and shrubs, such as oaks (*Quercus garryana*) and hazelnuts (*Corylus cornuta*), should be maintained.

The use of pesticides or herbicides may negatively affect these species. If pesticide or herbicide use is planned for areas where cavity-nesting ducks occur, refer to Appendix A for useful contacts to help assess the use of pesticides, herbicides, and their alternatives.

REFERENCES

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

____, and D. J. Holm. 1994. Ecology and management of the wood duck. Stackpole Books, Harrisburg, Pennsylvania, USA.

Blus, L. J., C. J. Henny, D. J. Hoffman, and R. A. Grove. 1993. Accumulation and effects of lead and cadmium on wood ducks near a mining and smelting complex in Idaho. Ecotoxicology 2:139-154.

Brown, E. R., technical editor. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington, Volumes 1 and 2. R6-F&WL-192-1985. USDA Forest Service, Pacific Northwest Region, Portland, Oregon, USA.

Champoux, L. 1996. PCBs, dioxins and furans in hooded merganser (*Lophodytes cucullatus*), common merganser (*Mergus merganser*), and mink (*Mustela vison*) collected along the St. Maurice River near La Tuque, Quebec. Environmental Pollutants 92:147-153.

Dow, H., and S. Fredga. 1984. Factors affecting reproductive output of the goldeneye duck. Journal of Animal Ecology 53:679-692.

Dugger, B. D., K. M. Dugger, and L. H. Fredrickson. 1994. Hooded merganser (*Lophodytes cucullatus*). Number 98 *in* A. Poole and F. Gill, editors. The Birds of North America, American Ornithologists Union and Academy of Natural Science, Philadelphia, Pennsylvania, USA.

Eadie, J. M., M. L. Mallory, and H. G. Lumsden. 1995. Common goldeneye (*Bucephala clangula*). Number 170 *in* A. Poole and F. Gill, editors. The Birds of North America. American Ornithologists Union and Academy of Natural Science, Philadelphia, Pennsylvania, USA.

Fitzner, R. E., and R. H. Gray. 1994. Winter diet and weights of Barrow's and common goldeneyes in southcentral Washington. Northwest Science 68:172-177.

Gauthier, G. 1993. Bufflehead (*Bucephala albeola*). Number 67 *in* A. Poole and F. Gill, editors. The Birds of North America. American Ornithologists' Union and Academy of Natural Science, Philadelphia, Pennsylvania, USA.

Goudie, R. I., A. V. Kondratyev, S. Brault, M. R. Petersen, B. Conant, and K. Vermeer. 1994. The status of sea ducks in the North Pacific Rim: toward their conservation and management. Transactions of North American Wildlife and Natural Resources Conference 59:27-49.

Hepp, G. R., and F. C. Bellrose. 1995. Wood duck (*Aix sponsa*). Number 169 *in* A. Poole and F. Gill, editors. The Birds of North America. American Ornithologists Union and Academy of Natural Science, Philadelphia, Pennsylvania, USA.

____, and R. A. Kennamer. 1992. Characteristics and consequences of nest-site fidelity in wood ducks. Auk 109:812-818.

Lumsden, H. G., R. E. Page, and M. Gunthier. 1980. Choice of nest boxes by common goldeneye in Ontario. Wilson Bulletin 92:497-505.

McGilvrey, F. 1968. A guide to wood duck production habitat requirements. Bureau of Sport Fish and Wildlife Research, Publication number 60.

Parker, R. 1990. Statewide waterfowl survey and inventory: waterfowl productivity: July 1, 1989, through June 30, 1990. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.

Peterson, B., and G. Gauthier. 1985. Nest site use by cavity-nesting birds of the Cariboo Parkland, British Columbia. Wilson Bulletin 97:319-331.

Poysa, H., and J. Virtanen. 1994. Habitat selection and survival of common goldeneye (*Bucephala clangula*) broods - preliminary results. Hydrobiologia 279/280:289-296.

Robb, J. R., and T. A. Bookhout. 1995. Factors influencing wood duck use of natural cavities. Journal of Wildlife Management 59:372-383.

Semel, B., and P. W. Sherman. 1995. Alternative placement strategies for wood duck nest boxes. Wildlife Society Bulletin 23:463-471.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith and K. M. Dvornich, editors. Washington State GAP analysis - final report. Seattle Audubon Society Publications in Zoology Number 1, Seattle, Washington, USA.

Soulliere, G. 1988. Density of suitable wood duck nest cavities in a northern hardwood forest. Journal of Wildlife Management 52:86-89.

Sousa, P., and A. Farmer. 1983. Habitat suitability index models: wood duck. U.S. Fish and Wildlife Service, FWS/OBS82/10.43.

Swift, B. L., R. E. Foley, and G. R. Batcheller. 1993. Organochlorines in common goldeneyes wintering in New York. Wildlife Society Bulletin 21:52-56.

Thomas, J. W. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Forest Service, Agricultural Handbook Number 553.

Vermeer, K., W. J. Cretney, J. E. Elliott, R. J. Norstrom, and P. E. Whitehead. 1993. Elevated polychlorinated dibenzodioxin and dibenzofuran concentrations in grebes, ducks, and their prey near Port Alberni, British Columbia, Canada. Marine Pollutants Bulletin 26:431-435.

Webster, C., and F. McGilvrey. 1966. Providing brood habitat for wood ducks. Pages 70-75 *in* J. B. Trefethen, editor. Wood duck management and research: a symposium. Wildlife Management Institute, Washington, D.C., USA.

PERSONAL COMMUNICATION

Matt Monda, Biologist
Washington Department of Fish and Wildlife
Ephrata, Washington

KEY POINTS

Habitat Requirements

- Cavity-nesting ducks use natural cavities with minimum entrance size of 9 cm (3.5 in) in diameter and minimum internal dimensions of 25 cm (10 in) deep and 19 cm (7.5 in) diameter. Smaller entrances (~6.5 cm [2.5 in]) are preferred by buffleheads.
- Nest trees usually have a minimum dbh of 30 cm (12 in), although 60 cm (24 in) is preferred.
- Natural cavities 2-15 m (6-49 ft) above ground or water are typically used by all 5 species; however, use of cavities over 20 m (66 ft) is not unusual.
- Optimal density of potential nest cavities is 12.5/ha (5/ac), within 0.8 km (0.5 mi) of suitable brood habitat.
- Ideal wood duck brood habitat consists of shallow wetlands with 50-75% cover and abundant downed logs or low islands. Goldeneyes, buffleheads, and to some extent hooded mergansers do not require the amount of emergent vegetation typical of wood duck brood habitat.

Management Recommendations

- Predator-proof nest boxes for cavity nesting ducks can be used in areas where natural cavity sites are limited but other habitat requirements are met. However, in some situations, it may not be suitable to consider nest boxes as permanent substitutes for natural cavities. The decision to provide nest boxes to supplement existing cavities or nest boxes should consider occupancy rates of existing suitable nest sites.
- Wood duck boxes should be designed and placed following the recommendations of Bellrose and Holm (1994). Boxes for the other four species should follow the guidelines provided by Lumsden et al. (1980) and Gauthier (1993).
- To minimize the impacts of brood parasitism, predation, and starling use, nest boxes for wood ducks should be placed far enough apart so that one is not visible from the other. Bellrose and Holm (1994) recommend a minimum of 46 m (50 yd) between nest box structures.
- Snags and cavity trees 30 cm (12 in) (60 cm [24 in] preferred) near suitable wetlands should be maintained to achieve a minimum density of 12.5 potential nest cavities/ha (5/ac).
- Mast-producing trees and shrubs (e.g., oaks, hazelnuts) should be maintained.
- Large woody debris and downed logs should be present, as well as low islands for breeding and brood use.
- Avoid logging flooded timber and leave woody vegetation along the shores of nesting and brood areas. In some situations, flooding standing or downed timber may be used to create snags and brood habitat.
- The use of pesticides or herbicides may negatively affect these species. If pesticide or herbicide use is planned for areas where cavity-nesting ducks occur, refer to Appendix A for contacts useful for assessing pesticides, herbicides and their alternatives.

Harlequin Duck

Histrionicus histrionicus

Last updated: 1999

Written by Jeffrey C. Lewis and Don Kraege

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Harlequin ducks winter along the Pacific Coast from the Aleutian Islands to northern California and along the Atlantic Coast. Their breeding and summer range extends from the coastal mountains of Alaska to California, along the northern Rocky Mountains to northwestern Wyoming, and along the north Atlantic Coast, southern Greenland, and Iceland (Bellrose 1980).

Figure 1. Range of the harlequin duck, *Histrionicus histrionicus*, in Washington. Map derived from the literature.

In Washington, harlequins historically breed in the Olympic Mountains, the Cascades, and the Blue and Selkirk Mountains (see Figure 1; Jewett et al. 1953, Schirato 1994); however, their presence in the Blue Mountains is now in question (Schirato 1994). Wintering areas include northern Puget Sound, northern Hood Canal, the Strait of Juan de Fuca, San Juan Islands, and the outer coast. Significant numbers of harlequins that breed in Washington molt and winter in the Strait of Georgia, British Columbia (I. Goudie, personal communication). Also, some harlequins that molt and winter in Washington breed in interior British Columbia, Alberta, Idaho, Wyoming, and Montana.

RATIONALE

The harlequin duck is a Washington State Game species that provides year-round recreation for consumptive and non-consumptive users. This species is limited by low productivity, older age at sexual maturity, and low intrinsic rate of population growth (Goudie et al. 1994). They are also sensitive to human disturbance (Cassirer and Groves 1994), which is likely to decrease their productivity.

HABITAT REQUIREMENTS

During the nesting season (April-June), adult harlequin ducks require fast-flowing water with loafing sites nearby. Streams usually have substrate that ranges from cobble to boulder, with adjacent vegetated banks. They have been found more often at distances >50 m (164 ft) from roads or trails, and in stream reaches with mature and old growth forest cover (Cassirer and Groves 1994). Whereas harlequins generally appear to avoid certain types of human disturbances, some anecdotal evidence has shown that individuals may use and even nest in areas that are regularly visited by humans (Cassirer et al. 1993). Harlequins often nest on the ground (Bengtson 1972), however, cavities in trees and cliff faces also serve as nest sites (Cassirer et al. 1993). Midstream loafing sites are an important part of suitable habitat (Cassirer and Groves 1994). Since adult females show fidelity to nest sites, it is unlikely that they will relocate to new nesting areas once they are disturbed (Wallen and Groves 1989). However, radio-tagged harlequins have used new nest sites after a nest failure the previous year (Cassirer et al. 1993).

Broods remain near nesting areas for the first few weeks after hatching, then move downstream during the summer (Kuchel 1977, Wallen 1987, Cassirer and Groves 1989). Broods prefer low-gradient streams with adequate macroinvertebrate fauna (Bengtson and Ulfstrand 1971). Preferred prey include crustaceans, molluscs, and aquatic insects (Cottam 1939). Aquatic insect larvae appear to make up the bulk of the diet for juveniles and for adults during the breeding season (Cassirer and Groves 1994).

During winter, harlequins forage and loaf along boulder-strewn shores, points, gravel substrates, and kelp beds. Prey species occur chiefly on rock substrate (70%) and gravel substrate (22%) (Vermeer 1983). Most wintering harlequins occur within 50 m (164 ft) of shore in saltwater areas (Gaines and Fitzner 1987).

LIMITING FACTORS

Low benthic macroinvertebrate abundance may limit the productivity of harlequin ducks (Bengtson annd Ulfstrand 1971). Human disturbance discourages nesting at traditional sites and thereby decreases productivity. A high tendency for individuals to breed at the same location year after year may result in a separation of populations with little chance to replenish stable or declining populations. Populations are highly sensitive to additional mortality from such causes as hunting, oil pollution, or food contamination. Additional mortality sources exceeding 5% appear to be unsustainable (Goudie et al. 1994).

MANAGEMENT RECOMMENDATIONS

Maintain woody debris and riparian vegetation in and adjacent to streams. A 50 m (164 ft) buffer along nesting streams is necessary to recruit suitable large organic debris for loafing sites and to ensure cover for nesting females and protective cover from predators (Murphy and Koski 1989). A larger buffer may be necessary on second growth stands. Logging activity in the riparian corridor should be avoided (Cassirer and Groves 1989, 1994).

Stream alterations that would cause greater surface runoff, changing water levels, or lower macroinvertebrate levels should be avoided (Kuchel 1977).

Human disturbance should be managed during the breeding and brood-rearing season (April-August). To limit disturbance, trails or roads should be farther than 50 m (164 feet) from streams used by harlequin ducks and should not be visible from the stream (Cassirer and Groves 1989). Fishing, rafting, and canoeing activities should be limited on streams used by nesting harlequins (Wallen 1987), especially in streams <20 m (66 ft) in width. The April through August nesting and brood-rearing period are the critical months to reduce disturbance.

Rocky shoreline areas used during winter should be protected. Disturbances at traditional coastal molting sites should be limited.

REFERENCES

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Bengston, S. 1972. Breeding ecology of the harlequin duck, *Histrionicus histrionicus*, in Iceland. Ornis Scandinavica 3:1-19.

____, and S. Ulfstrand. 1971. Food resources and breeding frequency of the harlequin duck *Histrionicus histrionicus* in Iceland. Oikos 22:235-239.

Cassirer, E. F., and C. R. Groves. 1989. Breeding ecology of harlequin ducks (*Histrionicus histrionicus*) of the Kaniksu National Forest, Idaho. Idaho Department of Fish and Game, Boise, Idaho, USA.

____, and C. R. Groves . 1994. Ecology of harlequin ducks in northern Idaho. Unpublished Report, Idaho Department of Fish and Game, Boise, Idaho, USA.

____, G. Schirato, F. Sharpe, C. R. Groves, and R. N. Anderson. 1993. Cavity nesting by harlequin ducks in the Pacific Northwest. Wilson Bulletin 105:691-694.

Cottam, C. 1939. Food habits of North American diving ducks. U.S. Department of Agriculture Technical Bulletin 643.

Gaines, B. L., and R. Fitzner. 1987. Winter diet of the harlequin duck at Sequim Bay, Puget Sound, Washington. Northwest Science 61:213-215.

Goudie, R. I., A. V. Kondratyev, S. Brault, M. R. Petersen, B. Conant, and K. Vermeer. 1994. The status of sea ducks in the North Pacific Rim: toward their conservation and management. Transactions of the North American Wildlife and Natural Resource Conference 59:27-49.

Jewett, S. G., W. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. Birds of Washington state. University of Washington, Seattle, Washington, USA.

Kuchel, C. R. 1977. Some aspects of the behavior and ecology of harlequin ducks in Glacier National Park, Montana. Thesis, University of Montana, Missoula, Montana, USA.

Murphy, M. L., and K. U. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal of Fish Management 9:427-436.

Schirato. G. 1994. Population and distribution of harlequin ducks in Washington state. Page 18 *in* B. C. Galiano, editor. Proceedings of the Second Harlequin Duck Symposium, Harlequin Duck Working Group.

Vermeer, K. 1983. Diet of the harlequin duck in the Strait of Georgia, British Columbia. Murrelet 64:54-57.

Wallen, R. L. 1987. Habitat utilization by harlequin ducks in Grand Teton National Park. Thesis, Montana State University, Bozeman, Montana, USA.

____, and C. R. Groves. 1989. Distribution, breeding biology, and nesting habitat of harlequin ducks in northern Idaho. Unpublished Report, Idaho Department of Fish and Game, Boise, Idaho, USA.

PERSONAL COMMUNICATIONS

Ian Goudie, Wildlife Biologist
Canadian Wildlife Service
Delta, British Columbia

KEY POINTS

Habitat Requirements

- In the summer, adult harlequin ducks require fast-flowing streams with clear water, loafing sites, and dense bank vegetation.
- Broods require low gradient streams with an adequate macroinvertebrate food supply.
- During the nesting season, harlequin ducks require areas with little or no human disturbance.
- Harlequin ducks winter along rocky marine shorelines, frequently using kelp beds.

Management Recommendations

- Manage human disturbance during the breeding and brood-rearing season (April-August).
- Protect rocky shoreline areas used during winter. Limit potential disturbance at traditional coastal molting sites.
- Maintain woody debris and riparian vegetation in and adjacent to streams.
- A 50 m (164 ft) buffer along nesting streams is necessary to recruit suitable large organic debris for loafing sites. A larger buffer may be necessary on second growth stands. Provide nesting and hiding cover within this buffer.
- Logging activity in the riparian corridor should be avoided.
- Stream alterations that would cause greater surface runoff, change water levels, affect water quality, or lower macroinvertebrate levels should be avoided.
- To limit disturbance, trails or roads should be farther than 50 m (164 ft) from streams used by harlequin ducks, and should not be visible from the stream. Also fishing, rafting, and canoeing activity should be limited on streams used by nesting harlequins, especially if such streams are <20 m (66 ft) wide.

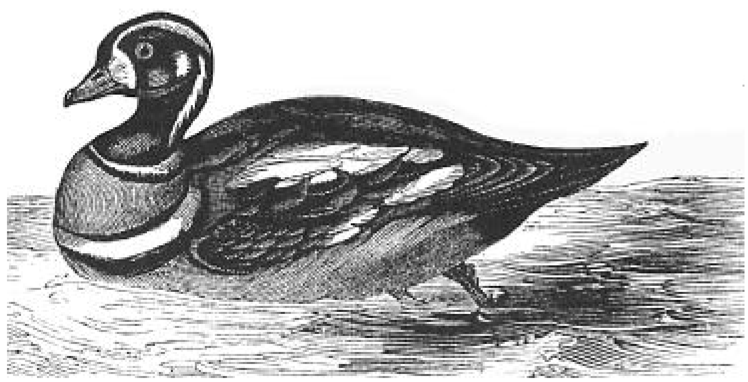


Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; http://www.royalbcmuseum.bc.ca/

Northern Goshawk

Accipiter gentilis

Last revised: 2003

Written by Steven M. Desimone and David W. Hays

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The northern goshawk (*Accipiter gentilis)* is holarctic in distribution, occupying a wide variety of boreal and montane forest habitats throughout Eurasia and North America (Palmer 1988, Johnsgard 1990). Three subspecies of the goshawk are recognized in North America (Johnsgard 1990, James and Palmer 1997), but only the northern goshawk (*A.g. atricapillus*) is known in Washington.

Figure 1. Shaded areas contain the general forest conditions that could provide potential suitable habitat for the northern goshawk (*Accipiter gentilis)* in Washington.

Northern goshawks can occur in all forested regions of Washington (see Figure 1). As of 2003, there were 338 documented breeding territories in the state (Washington Department of Fish and Wildlife [WDFW], unpublished data). The exact number is not known, because monitoring is not currently being conducted. The number of historical breeding sites lost due to habitat alteration and the number of new territories in suitable habitat are also unknown. About 50% of the documented breeding territories occur in the eastern Cascades, 27% in the western Cascades, 12% in other forested areas of northeast and southeast Washington, and 10% in the Olympic Peninsula (WDFW, unpublished data). Breeding birds formerly occurred in the Puget trough (Jewett et al. 1953). Less than one percent of recent breeding records have been recorded from this area and southwest Washington (south of the Puget Sound and west to the coast). Wintering goshawk populations in Washington include resident birds (Bloxton 2002; WDFW, unpublished data) and migrants that move into the state during winters when food shortages occur in their territories (Squires and Reynolds 1997). Overall, densities of territorial pairs in Washington appear to be lower than elsewhere in the western United States (Table 1) but this is partly dependent on habitat quality.

Table 1. Density estimates of northern goshawk territories in the western United States. Forest management in the study areas ranged from intensive to minimal timber harvest.

Study	Number of pairs	Mean distance (km) to nearest-neighbor	Density (territories/ 1000 ha)	Spacing (ha/pair)	Reference
Western Washington industrial forest	3	-	0.04-0.13	-	Bosakowski et al. 1999
Upper Yakima River, Washington	1 4 5	- - -	0.1 [a, b] 0.5 [a, c] 0.5 [a, d]	9091 2083 1852	Wagenknecht et al. 1998
Eastern Oregon National Forests	20	4.4	0.7	1538	DeStefano et al. 1994
Eastern Oregon	4	5.6	-	2750	Reynolds and Wight 1978
Klamath National Forest, California	21	3.3	0.6 - 1.1	1750 - 935	Woodbridge and Detrich 1994
North Kaibab NF, Arizona	100	2.5	2.0	491	Reynolds 1997, Reynolds and Joy 1998

[a] Estimate calculated with one year of survey data in each forest type; [b] Open Douglas-fir/ponderosa pine; [c] mixed conifer-lodgepole pine; [d] mixed Douglas-fir, grand fir, western hemlock

RATIONALE

The northern goshawk is a Federal Species of Concern and State Candidate species in Washington because of concerns about its population status. Although a decline in populations of northern goshawks has been suggested based on reduced nesting in areas of extensive harvest of mature forest (Crocker-Bedford 1990, 1995; Ward et al. 1992), Kennedy (1997) found no evidence to support the contention that goshawk populations in the western United States were declining, increasing, or stable. Kennedy (1997) acknowledged, however, that population declines might not be apparent due to insufficient sampling techniques. In Washington, goshawks appear to have been largely extirpated from urbanized landscapes and from some areas that are moderately developed or intensively managed for timber on short rotations (WDFW, unpublished data). There are no studies evaluating the population status of the goshawk in the Pacific Northwest. Because goshawks build multiple nests within nesting territories that are often used by other raptor species (Moore and Henny 1983, Buchanan et al. 1993; S. Desimone, unpublished data), the loss of goshawks might indirectly affect other forest species.

HABITAT REQUIREMENTS

Research in western North America suggested that the home range of breeding goshawks can be split into three functional divisions: the nest area or areas, the post-fledging family area (PFA), and the foraging area; the sum of these areas compose a northern goshawk's home range (Reynolds et al. 1992) (Figure 2). Habitat information relevant to each of these scales is provided below.

Nest Area

The nest area (in some studies referred to as the *nest stand*) is composed of one to several forest stands that contain the active and alternate nest structures (Figure 2). Usually occupied by breeding goshawks from March until

September, nest area boundaries are determined by the movement and behavior of the adults and newly fledged young, and by the locations of prey plucking areas and roosts that are usually within the nest area. (Reynolds et al. 1982). The term “occupied” is defined by the presence of at least one adult goshawk in the area or territory during a breeding season surveys (Desimone 1997; Finn et al. 2002a, b). The size of nest areas ranged between 8-12 ha (20-30 ac) (Reynolds 1983, Crocker-Bedford and Chaney 1988, Reynolds et al. 1992), but other studies suggest that nest areas can be larger (39 ha [96 ac; Finn et al. 2002a] up to 115 ha [284; Woodbridge and Detrich 1994]).

Within the nest area, the nest site is defined for this document as the immediate vicinity surrounding the nest tree, usually = 1.0 ha (2.5 ac; see McGrath et al. 2003). Goshawks in Washington nest almost exclusively in coniferous forest, although a few nests have been found in smaller aspen (*Populus* spp.) groves within the larger coniferous forest landscape in Okanogan County, Washington (WDFW, unpublished data; S. Desimone, personal observation).

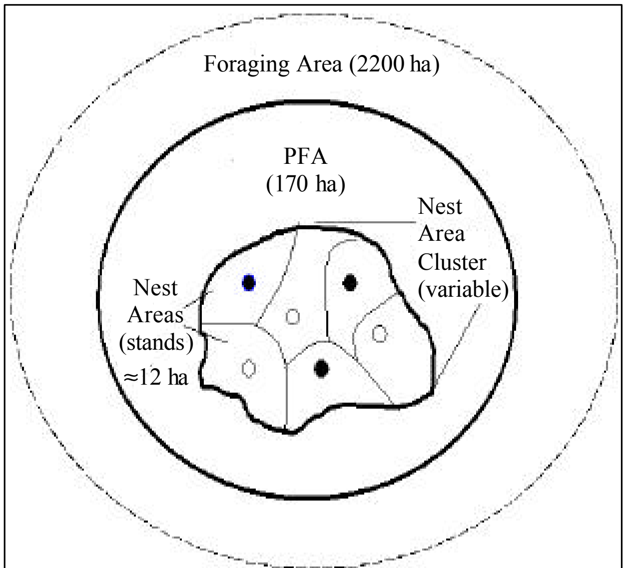


Figure 2. An idealized diagram (not to scale) for management of the breeding home range of the northern goshawk. Filled circles represent a possible nest site (i.e., tree where nest is located); open circles are nest sites within replacement nest areas (suitable or developing stands). Scale sizes represent averages. The Foraging Area of 2200 ha does not include the PFA and Nest Areas (i.e., 2200+170+72 = 2442 ha = total Home Range).

Stand age. Studies in North America indicate that goshawks typically select mature or old forest habitat for nesting (Reynolds et al. 1982, Moore and Henny 1983, Fleming 1987, Crocker-Bedford and Chaney 1988, McGrath 1997, Daw and DeStefano 2001; Finn et al. 2002a, b). Research in Washington and Oregon has shown links between nest stand occupancy and forest stand age. Finn et al. (2002a) found late-seral forest consistently averaged 64-75% of the nest areas (39 ha [96 ac]), PFA (177 ha [437 ac]) and home ranges (1886 ha [4660 ac]) of occupied goshawk territories on the Olympic Peninsula, and the average age of trees at occupied nest stands in managed and unmanaged forest were 147 years (95% CI 97-198) (Finn et al. 2002b). These forests are generally characterized by large sawtimber, >50% canopy closure, two or more canopy layers, gaps in the canopy, abundance of large diameter crowns, and the presence of shade tolerant trees. Most goshawk nests in eastern Washington (Finn 1994, McGrath 1997; J. Buchanan, unpublished data) and Oregon (Reynolds et al. 1982, Desimone 1997, Daw and DeStefano 2001, McGrath et al. 2003) were in mature or older forest. In eastern Oregon, Daw and DeStefano (2001) showed that goshawk nest stands were negatively associated with regenerating and young (average diameter at breast height [dbh]: 12-22 cm [5-9 in]) forest at the nest stand scale (10 ha [25 ac]). In east-central Washington and eastern Oregon, McGrath (1997) determined that increasing the amount of early-seral forest by 1% within specified areas surrounding the nest tree would decrease the odds of the site being suitable for nesting by 10%.

Finn (unpublished data) studied landscape patterns and habitat patch features around 25 goshawk nests in the upper Yakima River basin from 1992-1996. They found that the landscape surrounding nests was more homogeneous and contained less seedling/sapling and forest edge than what was available at the combined nest areas scale (32 ha [79 ac]) and at the post-fledging family area scale (210 ha [519 ac]). At the foraging range scale (3,566 ha [8,812 ac]), no differences were found between areas used by goshawks versus other areas in the landscape.

Tree density. Goshawk nest areas generally have a high density of large trees. On the Olympic Peninsula, the average diameter of trees within occupied nest areas was 59 cm (23 in; 95% CI 51 - 67cm) (Finn et al. 2002b). These stands had more large-diameter (≥63cm [25.7 in; 95% CI 22-59 cm]) trees than unoccupied historic nest areas. In the Olympic Peninsula and western Cascades, dominant and co-dominant trees in nesting stands averaged 43-48 cm (17-19 in) dbh and generally exceeded 27 m (89 ft) in height (Fleming 1987). On average, there were 482 trees/ha (195 trees/acre) >6 cm dbh (2.4 in) within nest stands in eastern Oregon (Reynolds et al. 1982). Finn (1994) found that goshawk nest stands contained more snags and down woody material, had greater basal area, and an increased number of tree species than random plots in Okanogan County, Washington.

Canopy attributes. Researchers have used various methods to measure forest canopy and this may influence the ability to compare different data sets. Despite this, the overwhelming majority of stands used by nesting goshawks have relatively closed canopies (i.e., >50%) and are often characterized by multiple canopy layers. In western Washington, Fleming (1987) found goshawk nests in stands with an average canopy closure of about 60-65%. Additionally, nest stands had one to three canopy layers with generally poor development of understory vegetation. Similarly, Finn et al. (2002b) found that canopy closure in occupied nest areas averaged 78% in the Olympic Peninsula. Occupied nest areas had relatively greater canopy depth (i.e., the difference between the average maximum and minimum overstory height; Finn et al. 2002a) as compared to unoccupied historic nest areas. The odds of occupancy at historical nest areas increased with increasing overstory canopy depth (Finn et al. 2002a). Greater canopy depth coupled with low shrub density best discriminated occupied nest areas versus unoccupied historic nest areas (Finn et al. 2002a). This research also showed that occupancy of a stand by goshawks decreased by 47% with each 10% increase in understory shrub cover. Overall, increasing early-seral forest cover was associated with decreasing goshawk occupancy at historical nest stands on the Olympic Peninsula (Finn et al. 2002a).

Canopy attributes east of the Cascades are relatively similar to the previously discussed west-side attributes. Goshawk nest stands in eastern Oregon typically had multi-layered canopies with green foliage occurring a few meters to over 40 m (131 ft) above the ground, and the tops of understory trees overlapped with the lower crowns of overstory trees (Reynolds et al. 1982). In Okanogan County, average overstory canopy closure in nest stands was 75% (Finn 1994), and canopy closure in the eastern Cascades averaged 74% in stands where spotted owls exploited goshawk nests for breeding (J. Buchanan, personal communication). In east-central Washington, canopy closure averaged 73% (McGrath 1997). In eastern Oregon, mean canopy closure was 60% (Reynolds et al. 1982) and 88% (Moore and Henny 1983) within nest stands.

Size. The sizes of goshawk nest areas in the Pacific Northwest are variable. On the Olympic Peninsula, occupied goshawk nest areas averaged 33 ha (82 ac) (range: 12-69 ha [30-170 ac]) (Finn et al. 2002b). The conclusions of Finn et al. (2002a) indicated that the composition of nest areas was largely (about 67%) late-seral forest.

In eastern Oregon, Reynolds and Wight (1978) found that the size of nest areas or stands varied with topography and the availability of large trees in dense patches of at least 10 ha (25 ac). Woodbridge and Detrich (1994) found that goshawk territories in northern California contained one to five different forested nesting stands (average = 2). These nest stands were homogeneous in composition, age, and structure relative to the surrounding forest (Woodbridge and Detrich 1994). Stands <10 ha (25 ac) typically contained one or two nests that were occasionally occupied by goshawks, whereas stands >20 ha (49 ac) often contained several nests that were frequently occupied (Woodbridge and Detrich 1994).

Spacing and number of nests. Established pairs of goshawks have multiple nest areas that are often structurally similar within a home range (Reynolds et al. 1992). Goshawks may build =10 nest structures within a territory that can be occupied over multiple generations (Crocker-Bedford 1990; S. Joy and T. Fleming, personal communications). In western Washington, the distance between alternate nests of the same territory averaged 536 m (1759 ft) (S. Finn, unpublished data). In more arid forested habitats such as pine and mixed conifer, the average distance between alternate nests within a territory ranged between 245 and 273 m (804-896 ft) (Reynolds et al. 1994, Woodbridge and Detrich 1994, Desimone 1997).

Nest tree and nest site. Nest structures in western Washington are often in Douglas-fir (*Pseudotsuga menziesii*), with western hemlock (*Tsuga heterophylla*) used to a lesser extent (Fleming 1987, Finn 2000). Nests in deciduous trees are uncommon (Fleming 1987; S. Finn and T. Bloxton, unpublished data). Deciduous trees used for nesting west of the Cascade mountain crest (e.g., red alder [*Alnus rubra*]) were generally found in the sub-canopy and isolated in coniferous forest stands comprised of less than 2% deciduous species (Finn et al. 2002b). Goshawks in eastern Washington and Oregon nest in Douglas-fir, ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), grand fir (*Abies grandis*) and occasionally aspen (Finn 1994, McGrath 1997; WDFW, unpublished data). In areas of heavy mistletoe infection, goshawks will use mistletoe “brooms” as a nesting substrate (Moore and Henny 1983, Buchanan et al. 1993, Finn 1994). They may also occasionally nest in dead trees (Moore and Henny 1983; S. Desimone, unpublished data). Average nest tree size in the Pacific Northwest is >53 cm (21 in) dbh (range: 25-172 cm [10-68 in]) (Moore and Henny 1983, Fleming 1987, Bull and Hohmann 1994, McGrath et al. 2003; S. Finn, unpublished data). Goshawks build fairly large, bulky stick nests (about 0.6-0.9 m [2-3 ft] outside diameter), and nest placement is usually in the lower third of the forest canopy and relatively close to the tree trunk (Reynolds et al. 1982, McGrath 1997, Finn 2000).

Basal area at the nest site is usually higher than that of the surrounding stand. McGrath (1997) measured vegetation attributes around 82 active goshawk nests in eastern Oregon and central Washington east of the Cascade crest. At the nest site scale (1 ha [2.5 ac]), higher basal area best discriminated nest sites from random sites. Nest sites had higher average basal area/tree, and greater live stem density compared to random sites (McGrath 1997). In Montana and northern Idaho, 0.04 ha (0.1 ac) plots around nest sites (n=17) had an average of about 6 trees/plot that were >30 cm dbh (64 trees/ac >12 in) (Hayward and Escano 1989). In northeastern Oregon, Moore and Henny (1983) reported an average of 208 trees/ha >32 cm dbh (84 trees/ac >13 in) surrounding 34 nests.

Goshawks pluck the hair or feathers of their prey before consuming or bringing it to the nest for incubating/brooding females or young. Consequently, established ‘plucking posts’ (i.e., perches used to pluck captured prey) may be present within the nest area and are typically within 100 m (328 ft) of an active nest (S. Desimone, unpublished data).

Water and topography. It is unclear whether goshawks prefer to nest close to water, but close proximity to water may improve nesting conditions in drier forest types based on the results of several studies (see Reynolds et al. 1982, Hargis et al. 1994, Squires and Reynolds 1997). Bathing by a brooding goshawk in hot dry climates may help to maintain proper humidity in the nest during incubation, and may aid in thermoregulation (Hennessy 1978). However, Crocker-Bedford and Chaney (1988) found no association with water in Arizona where actual breeding density was high. Overall, goshawk nests in western Washington generally averaged >200 meters (654 ft) from perennial water (WDFW, unpublished data). On the Olympic Peninsula, water bodies were an average of 232 m (761 ft) from nest sites (S. Finn, unpublished data). Other studies found that goshawk nests were generally within 200-300 m (656-984 ft) of permanent water sources in Idaho (Hayward and Escano 1989), northeastern Oregon (Bull 1992), and in the eastern Cascades of Washington (McGrath 1997). However, McGrath (1997) found that eastern Oregon nest sites averaged =335 m (1099 ft) from water. Goshawk nests in east-central Washington and Oregon were generally associated with low topographic position (i.e., lower 1/3 or bottom of drainage; McGrath et al. 2003; J. Buchanan, personal communication), most likely because the larger trees at lower elevations provided a more favorable microclimate. McGrath et al. (2003) found only a single nest near a ridge top east of the Cascades, and Bull (1992) found no goshawk nests near ridge tops in eastern Oregon.

Nest area cluster. Woodbridge and Detrich (1994) suggested that the aggregate of all nest stands and alternate nests within a goshawk pair’s territory form a “cluster” of nest stands (i.e, “nest stand cluster”; see Figure 2). For this document, the aggregate of nest areas will be referred to as the “Nest Area Cluster” (NAC). A pair’s NAC generally does not overlap with NACs of neighboring territories. NACs are variable in size and their size is believed to be less than that of the PFA (Woodbridge and Detrich 1994). It is possible the NAC coincides with PFAs, but this has not been verified. The occupancy of nesting stands (or nesting areas) by marked territorial adults was used as a basis for the NAC concept (Woodbridge and Detrich 1994).

On the Klamath National Forest in California, NACs ranged between 11 and 114 ha (26-282 ac) (Woodbridge and Detrich 1994). Occupancy rates of clusters <20 ha (49 ac) were typically less than 50%. However, occupancy at clusters that were 40 ha (99 ac) and 41-61 ha (100-151 ac) were 75-80% and about 90%, respectively, and nearly 100% of clusters >61 ha (151 ac) were occupied. Overall, long-term territory occupancy was positively correlated with the size of clusters and with larger proportions of mature forest (Woodbridge and Detrich 1994). This larger percent of area in older forest appears to provide more opportunities to maximize a pair’s chance of maintaining occupancy.

Mid- and late-successional habitat is strongly associated with goshawk sites at the NAC scale. In eastern Oregon, Desimone (1997) found that substantial amounts of mid- (average dbh of 23-53 cm [9-21 in]) and late-successional (average dbh >53 cm [21 in]) forest at the NAC scale (52 ha [128 ac]) were important to the persistence of goshawks in historic territories. Occupied areas during that study had more forest area with these characteristics than historic territories without goshawks. Within the 52 ha (128 ac) surrounding historic nests, habitat around recently occupied sites was not significantly different from occupied historic sites at the time they were last known to be active. The historic sites where no goshawks were located had significantly lower amounts of combined mid-age and late-successional forest within the NAC. It was concluded that recent site conditions within the NAC that most resembled the historic conditions contributed to the persistence of goshawks in a territory over time (Desimone 1997).

Post-fledging Family Area

The Post-fledging Family Area (PFA) contains the nest area(s) and is an area of concentrated use by adult females and developing juveniles after fledging and prior to natal dispersal (Reynolds et al. 1992, Kennedy et al. 1994). The PFA surrounds and includes nest area habitat (Kennedy et al. 1994), and provides foraging opportunities for adult females and fledgling goshawks, as well as hiding cover for fledglings (Reynolds et al. 1992). The parameters used to calculate the PFA included the average core area used by nesting females as well as the average distance juveniles dispersed from the nest tree over a specified time period (Kennedy et al. 1994). PFAs in New Mexico were high-use core areas used by breeding females that averaged 168 ha (415 ac; Kennedy et al. 1994), and may have corresponded to the defended areas of goshawk pairs (Reynolds et al. 1992). Similarly, high-use areas of adult breeding females (post-hatching) in western Washington averaged about 143 ha (353 ac) (S. Finn, unpublished data). These values are similar to the average of 168 ha (415 ac) reported by Kennedy et al. (1994) for core-use areas of breeding females.

Studies on the use of habitats by northern goshawks in the PFA indicate the importance of structurally complex forests. McGrath (1997) measured structural stages on the eastern Cascades within 83 and 170 ha (205 and 420 ac) areas around recently active nests. He found that "stand initiation phase" (clearcut/sapling stage) accounted for 7% (range 0-23%) of the 83 ha (205) plot and 10% of the 170 ha (420) plot; both values were significantly smaller than random sites. In the southwestern United States, the PFA contained 40% (by area) mature and old forest with >40% canopy closure (Reynolds et al. 1992). In eastern Oregon (with forest types similar to the southwestern U.S.) PFAs consisted of an average of 22% (Desimone 1997) and 29% (Daw and DeStefano 2001) dense canopy, late-seral (>50% canopy closure and =20 trees/ha >53cm) forest. In western Washington, PFAs contained an average of 72% (95% CI = 59-84) mature (>10% of trees >53 cm [21 in] dbh) coniferous forest (Finn et al. 2002a). PFAs consisted of forests with a dense cover of trees and an abundant number of snags and down logs (Reynolds et al. 1992).

Foraging Areas (breeding season) and Home Range

Foraging areas are the various habitats where goshawks secure prey. Foraging areas also define the goshawk's home range during the breeding season. Home range (HR) size estimates for goshawk pairs in western states (other than Washington) ranged between 569-3774 ha (1400-9321 ac) (Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994, Kennedy et al. 1994). The average HR size on managed forest landscapes in western Washington was 3710 ha (9164 ac) (range 844 to 10,730 ha [2084-26500 ac]) (Bloxton 2002). Males generally had larger HRs than females, while HRs of non-breeders tended to be larger than that of breeders. Two years of unusually wet conditions was thought to partly explain variability in foraging distances from nests of male goshawks (Bloxton 2002).

Goshawks forage in a variety of forest types. Limited information describing goshawk foraging habitat is available for Washington. Bloxton (2002) found that goshawks tended to hunt in stands with larger diameter (= 50 cm [20 in]) trees, and they avoided stands in the sapling and pole stages. Kill sites had greater basal area (average = 52 m^2/ha), snag density (average = 77 snags/ha = 13 cm dbh [31 snags/ac =5 in]), large tree density (average = 62 trees/ha >50 cm dbh [25 snags/ac = 20 in]) and higher average dbh (32 cm [13 in]) than random sites. Bloxton (2002) reported that a disproportionately high number of goshawk kill sites were in forests with a 25-36 cm (10-14 in) quadratic mean dbh (Qdbh; i.e., the dbh of a tree with average basal area in a stand) as well as in mature (35-51 cm [14-20 in] Qdbh) and old-growth (>51 cm [20 in] Qdbh) structural classes. Also, 96% of kill sites had canopy closures = 60% (average = 77%). Bloxton (2002) noted that young (< 30 years) forests generally did not provide appropriate conditions (i.e., large trees with well developed canopies, adequate flight space beneath the canopy) for goshawk hunting.

In ponderosa pine forests of northern Arizona, breeding male goshawks preferred to forage in mature forests with higher basal areas and higher densities of trees >41 cm (16 in) dbh (Beier and Drennan 1997). In winter, foraging sites used by the same birds had higher canopy closure and more trees between 20-40 cm (8-16 in) dbh as compared to random sites (Drennan and Beier 2003). Based on these findings, one could conclude that in landscapes where the coverage of older forest has decreased, foraging areas and home ranges would become larger and territories more widely spaced (see Crocker-Bedford 1998).

Goshawks in the Cascade Range of northern California selected closed canopy mature and old-growth stands for foraging (>51 cm [21 in] average dbh and >40% canopy closure) (Austin 1993). Greater basal area, more large trees (>46 cm [18 in] dbh), and higher canopy closure characterized areas of goshawk use in eastern California as compared to random sites (Hargis et al. 1994).

Studies in the western United States (Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994, Desimone 1997, Patla 1997, Daw and DeStefano 2001; Finn et al. 2002a, b) indicate that mid- to late-successional forested habitats comprise a significant proportion of the total home range area. Average habitat composition of the HR (1886 ha [4660]) was 64% (95% CI 54-78) "late-seral" forest on the Olympic Peninsula (Finn et al. 2002a). Historical goshawk sites were more likely to be occupied in landscapes (i.e., home ranges) dominated by large uniform patches in late-seral stages.

Diet

Goshawks are considered opportunistic foragers (Beebe 1974), as exhibited by the wide range of prey taken in the United States (Squires and Reynolds 1997). Douglas' squirrel (*Tamiasciurus douglasii*), grouse, and snowshoe hare (*Lepus americanus*) were the most frequently represented prey species (representing 54% of all prey in the eastern slope of the Cascade range and Okanogan county and 41% in the Olympic peninsula and west slope of Cascade range) (Watson et al. 1998). Chipmunks (*Tamias* spp.), northern flying squirrel (*Glaucomys sabrinus*), Steller's jay (*Cyanocitta stelleri*), northern flicker (*Colaptes auratus*) and small woodpeckers (Picidae) each constituted >3% of the goshawks diet by frequency. Passerine bird species (e.g., American robin [*Turdus migratorius*]) accounted for 28% of west-side and 18% of the east-side prey by frequency (Watson et al. 1998). Goshawks in the northeastern Cascades took the highest proportions of grouse, while those in the Olympics took the fewest. Combined grouse and snowshoe hare accounted for the majority of all prey biomass consumed. Similar prey species and ratios were documented in eastern Oregon (Reynolds and Meslow 1984, Bull and Hohman 1994, Cutler et al. 1996).

In northeastern Washington and the Blue Mountains, the red squirrel (*T. hudsonicus*) replaces the Douglas' squirrel as an important food item (Hayward and Escano 1989, Patla 1997; D. Base and S. Fitkin, personal communications). In Klickitat County, a western gray squirrel (*Sciurus griseus*) was observed being taken by an immature goshawk in ponderosa pine/Garry oak (*Quercus garryana*) habitat (M. Linders, personal communication).

Bloxton (2002) studied goshawk foraging behavior and prey use among 15 territories in an intensively managed forest landscape in western Washington. He found that grouse (ruffed and blue combined) and band-tailed pigeon (*Columbia fasciata*) were the predominant prey by frequency, followed by Steller's jay, snowshoe hare, thrushes (Turdidae), woodpeckers, Douglas' squirrel, northern flying squirrel, other rodents, and birds. Grouse and hares probably represented the majority of biomass consumed.

Given the importance of snowshoe hare in Washington goshawk diets, it is possible that goshawk territory occupancy could fluctuate in response to cyclical changes in snowshoe hare abundance (e.g., see Doyle and Smith 1994). However, the variety of prey species identified suggests that Washington's goshawks are not dependent on hare and grouse abundance because of opportunistic feeding on other prey species (Watson et al. 1998).

Dispersal

Dispersal data for adult goshawks in the western U.S. is limited. The cycling population patterns of snowshoe hare and grouse are believed to influence periodic southward movement of goshawks from northern Canada (Squires and Reynolds 1997). Although some goshawks appear to disperse short distances during the non-breeding season, most populations are believed to be non-migratory (Johnsgard 1990, Squires and Reynolds 1997, Bloxton 2002, Drennan and Beier 2003). These short-distance movements are likely a response to prey availability during winter (Keane and Morrison 1994, Reynolds et al. 1994, Squires and Ruggiero 1995, Drennan and Beier 2003; T. Bloxton, personal communication). In western Washington, female goshawks had higher winter site fidelity to their breeding areas compared to their mates (Bloxton 2002). Adult northern goshawks are not believed to make significant movements to seek new breeding sites (Detrich and Woodbridge 1994, Doyle and Smith 1994, Reynolds and Joy 1998).

Limited information is available about dispersal patterns in Washington. In one unpublished study, four immature goshawks were captured, marked, and released near Chelan, Washington, in autumn; they occupied transitional areas between coniferous forest and either subalpine parkland or lower elevation shrub-steppe savannah. Monitored until their deaths (average survival time: 13 weeks), they remained within 150 km of their banding site (J. Smith, personal communication).

LIMITING FACTORS

Generally, the two most significant limiting factors to the long-term productivity and survival of raptors are the availability of suitable prey and nesting habitat (Newton 1979). Although the effects of timber harvesting on goshawks in the United States are not fully understood, there is evidence to suggest that harvest impacts nest site selection (Reynolds 1989, Crocker-Bedford 1990, Ward et al. 1992, Woodbridge and Detrich 1994, Desimone 1997; Finn 2002a, b), and potentially, nesting rates (Crocker-Bedford 1990, 1995). In addition, nesting goshawks appear to be largely absent from some extensive forested landscapes in western Washington that have been intensively managed on rotations =50 years (WDFW, unpublished data). Fragmentation of suitable habitat potentially increases interaction with competing raptors (e.g., red-tailed hawks [*Buteo jamaicensis*], great horned owls [*Bubo virginianus*]) (Moore and Henny 1983, Crocker-Bedford and Chaney 1988, Crocker-Bedford 1990, Kenward 1996). The impact of regulated falconry on wild raptor populations is thought to be minimal (Conway et al. 1995, Kenward 1997, Mosher 1997), but is largely unknown for goshawks (Squires and Reynolds 1997).

MANAGEMENT RECOMMENDATIONS

Management recommendations for goshawks in Washington before the publication of this volume largely relied on the Northern Goshawk Scientific Committee's (GSC) recommendations developed for forests in the southwestern United States (Reynolds et al. 1992). The GSC recommendations were prescriptions that reflected a balance of different forest age classes to provide "desired forest conditions" needed to sustain goshawk populations and an adequate prey population in the U.S. Forest Service's (USFS) Southwestern Region (Reynolds et al. 1992). Many of the following recommendations for Washington are still based, at least in part, on the GSC guidelines because there is currently limited information for northern goshawks in the Pacific Northwest. However, where appropriate, some of the following prescriptions are based on recent research in western Washington.

Certain general forest types listed in the GSC guidelines may be similar to some forest types in eastern Washington (e.g., ponderosa pine and higher elevation mixed conifer) and the guidelines may be more applicable to these forest types east of the Cascade crest (S. Desimone, personal observation; R. Anthony and R. Reynolds, personal communications). Although eastern Washington vegetation data have not been fully evaluated in goshawk studies, some information exists that can be used to make limited comparisons (see Finn 1994, McGrath 1997). However, the GSC guidelines have not been assessed in Washington, particularly for moist forest types west of the Cascade crest (e.g., western hemlock/Douglas-fir and Sitka spruce zones). Also, eastern Washington lodgepole pine, moist Douglas-fir/grand fir/western larch, and true fir/Engelmann spruce (*Picea engelmannii*) forest stands have not been assessed. Overall, the GSC does not recommend applying specific management prescriptions outside of the southwestern United States. Rather, they recommend the application of general GSC model concepts elsewhere (R. Reynolds, personal communication). In addition, Anthony and Holthausen (1997) caution that the appropriateness of the PFA and foraging area estimates need to be tested for applicability to the Pacific Northwest.

Nest Areas

Nest areas should be approximately 12 ha (30 ac) in size (Reynolds et al. 1992). At least three suitable nest areas should be protected per home range (Reynolds et al. 1992). In addition, at least three replacement areas should be present per home range, for a total of 72 ha (180 ac) (Table 2). If only one nest area is known, additional stands and replacement areas within the PFA management areas should be identified and protected. Alternate nest areas selected by managers should be structurally similar to known nest areas (Reynolds et al. 1992). Replacement nest areas are needed because goshawk nest areas are subject to disturbances such as fire and windthrow. Selection of nest areas should prioritize active or most recent nest areas over historical areas. Nest areas should be delineated using known nests and plucking posts where possible. In mixed conifer and ponderosa pine forests of eastern Washington, data from Table 2 can be evaluated with stand-specific and area data to estimate local habitat needs. All nest areas should be located within approximately 0.8 km (0.5 mi) of the goshawk pair's adjacent nest areas (Reynolds et al. 1992).

Table 2. Size recommendations for areas within goshawk home range as reported by the Goshawk Scientific Committee (Reynolds et al. 1992).

Attribute	Home Range Components		
	Nest Area	**PFA**	**Foraging Area** [a]
Total areas	6	1	1
Suitable nest areas	3	N/A	N/A
Replacement nest areas	3	N/A	N/A
Size in hectares (acres)	12 (30) each	170 (420)	2,185 (5,400)
Management season	Oct - Feb	Oct - Feb	Oct - Feb

[a] Foraging area figures do not include the nest areas and PFA.

Human presence should be minimized in active nest areas during the nesting season (1 March - 30 September) (Reynolds et al. 1992). Broadcasting calls for survey purposes should not be implemented until June 1 (for recommended survey protocol guidelines and information, contact WDFW's goshawk specialist in Olympia). Data on human disturbances are lacking; however, in the absence of such data, the disturbance guidelines established for other raptors should be observed: activities such as road building, logging, site preparation and herbicide and pesticide application should not occur within 0.8 km (0.5 mi) of active nests during the nesting season (e.g., Washington Forest Practices Board 2001). On known occupied territories, if the active nest is not located during the year of management activity, then a 0.8 km (0.5 mi) radius from the geographic center of previous known nest sites should be protected. Road densities should be minimized in the vicinity of nest areas and should be managed within the context of adaptive management (a systematic process for continually improving management practices by learning from the outcomes of earlier practices) (Reynolds et al. 1992).

An average canopy closure of 70-80% for both western and eastern Washington nest areas should be retained (McGrath 1997, Finn et al. 2002b). Activities conducted within suitable and replacement nest areas should be limited to those designed to enhance stand development and maintain habitat structure (Reynolds et al. 1992). Selective overstory removal, patch harvests, or clearcut harvests resulting in complete removal of trees or the reduction of large stem density and canopy volume over a landscape compromises goshawk nesting habitat (Ward et al. 1992, Crocker-Bedford 1995, Desimone 1997; Finn et al. 2002a, b). Activities in nest areas that are detrimental to desired nesting structure for goshawks should not occur at any time in areas managed for goshawks (Reynolds et al. 1992). All intact forest patches in late stages of forest development within the nest area should be retained (Daw and DeStefano 2001, Henjum et al. 1996). Fidelity of some goshawks to nest areas in winter (T. Bloxton, personal communication) underscores the importance of protecting mature and old forested habitat in nest areas to sustain resident prey populations.

No overstory or regeneration harvest should take place within the NAC at any time (Woodbridge and Detrich 1994, Desimone 1997, Daw and DeStefano 2001). For the Olympic Peninsula, controlled understory thinning to enhance development of stands for desirable nest characteristics should be carefully monitored so that dominant overstory trees are not removed and deep overstory canopy attributes are maintained (see Finn et al. 2002b); average canopy closure should remain =70%. Thinning may help younger stands develop characteristics conducive to nest habitat sooner than if left unmanaged. However, their potential for use by goshawks will be negated if the newly enhanced stands are not allowed to exist over an extended time period (e.g., 20-70 years) beyond a harvest rotation age (depending on stand age and site conditions). Thinning and stand enhancements for nest areas should be done within the context of local forest conditions and within an adaptive management framework.

Post-fledging Family Area (PFA)

The size of the PFA should be approximately 170 ha (420 ac) in addition to the identified suitable and replacement nest areas (Reynolds et al. 1992). This area should be delineated and centered on active and alternate nest areas (i.e., the nest area cluster [Woodbridge and Detrich 1994]), and include as much mature and old forest as possible (Desimone 1997, Daw and DeStefano 2001).

In western Washington and moist forests east of the Cascade crests, canopy closure in the PFA should average ≥70% (Finn et al. 2002a, b), and ≥60% in the drier pine-dominated forests east of the Cascades (Finn 1994, McGrath 1997, Wagenknecht et al. 1998). Preference should be given to stands that are similar in structure to the nest area (Reynolds et al. 1992, Daw and DeStefano 2001). Forest management should emphasize the retention and enhancement of complex forest structure and desirable canopy closure (Finn et al. 2002a, b). PFA attribute information for eastern Washington forests is virtually unknown; therefore, forest management should avoid reducing or further fragmenting existing late-seral forest in PFAs (Beier and Drennan 1997, Daw and DeStefano 2001) until more data are collected. If possible, the PFA should not contain >10% seedling/sapling or early forest cover (Finn et al. 2002a). Retaining snags and down logs will likely enhance goshawk prey abundance (Reynolds et al. 1992).

Foraging Area (Home Range)

The GSC recommends that 60% of the foraging habitat be equally divided between mid-aged (20%), mature (20%), and old (20%) successional classes of forest by area based on work in the southwestern United States (Reynolds et al. 1992). These percentages might not be adequate in western Washington, because the average proportion of late-seral forest in foraging areas was at least 1.5 times that of the southwest in certain forest types (Finn et al. 2002a). In addition, goshawks made most kills in mature and older closed-canopy forest in western Washington (Bloxton 2002). Goshawks also occupied landscapes where ≥54% of the foraging area (i.e., home range) was comprised of late-seral forest, and averaged no more than 11% seedling/sapling or early forest stages (Finn et al. 2002a). Based on these findings, it is recommended at least 60% of the foraging area be retained in mature and old forest. This is in addition to the mature and old forest area that should be retained in nest areas and PFAs.

Snags are important resources for sheltering birds and mammals that are goshawk prey. Large-diameter snags and logs should be retained within managed goshawk foraging areas to provide cover for important prey species. While no information exists for goshawk foraging areas in ponderosa pine forests in eastern Washington, we recommend the retention of at least 5 large (≥ 46 cm dbh [18 in], ≥ 9.1 m [30 ft] in height) snags/ha (2 large snags/ac), and at least 7 large (≥ 30 cm [12 in] diameter, ≥ 2 m [7 ft] in length) downed logs/ha (3 logs/ac) based on the guidelines of Reynolds et al. (1992). At least 7 large snags/ha (3/ac) with at least 12 large downed logs/ha (5/ac) should be retained in interior-fir forests (Reynolds et al. 1992). These criteria are recommended until more local information is obtained for eastern Washington.

Few studies have documented snag abundance within goshawk home range habitat in western Washington. Foraging habitat patches should be structurally similar to mimic suitable nesting habitat as well as the habitat of preferred prey. Based on Bloxton (2002), average snag density in intensively managed habitats should average 14 snags/ha >30 cm (6 snags/ac >12 in); however, additional research is needed.

Landscape Management

Planning in Pacific Northwest forests should occur at the landscape scale because site-by-site management will not maintain viable populations (Kennedy 1991, Bright-Smith and Mannan 1994, Hargis et al. 1994). Conservation and management strategies should consider multiple spatial scales (e.g., watershed, forest-wide, territory, etc.) and potential overlap between adjacent territories. Emphasis should be placed on retaining vegetative diversity and sufficient amounts of mature forested habitat for goshawk nesting and foraging (Crocker-Bedford 1990, Reynolds et al. 1992, Bright-Smith and Mannan 1994, Hargis et al. 1994, Beier and Drennan 1997, Crocker-Bedford 1998, Finn et al. 2002a, Drennan and Beier 2003).

Because of limited information on the habitat requirements of goshawks (especially in eastern Washington), it is recommended that habitat manipulations occur using adaptive management techniques. More direct observational data of goshawk habitat use will be required to develop management plans, predict the species distribution, and aid in the assessment of habitat for goshawks on a landscape-level in eastern Washington (Dewhurst et al. 1995, Braun et al. 1996).

Forest Management

Although largely untested, recommendations for silvicultural manipulations within goshawk home ranges have been proposed. The GSC recommended forest manipulations to benefit goshawk prey (Reynolds et al. 1992). Merrill (1989) and Lilieholm et al. (1993, 1994) recommended the use of a stand density index to manage goshawk habitat in Utah and Idaho. They provided recommendations on desirable stand conditions as well as some specific examples of stand management.

Forest stands in lower elevations of western Washington begin to develop suitable nesting habitat characteristics at about 50 years (Bosakowski et al. 1999, Finn et al. 2002b). However, current timber rotations on industrial lands are approximately 35-50 years (Finn et al. 2002b; F. Silvernail, personal communication). The net result may be the sustained loss of suitable nesting and foraging habitat in intensively managed forests in Washington. We concur with researchers (e.g., Merrill 1989; Lilieholm et al. 1993, 1994; Bloxton 2002, Finn et al. 2002a) who recommend that portions of intensively managed forested landscapes surrounding existing late-seral forest patches be allowed to mature beyond industrial rotational ages (e.g., 70-120 years on the Olympic peninsula and lowland western Washington) to benefit goshawks. Such practices would ensure that some suitable nesting and foraging habitat is available across the managed landscape. Existing occupied marbled murrelet (*Brachyramphus marmoratus*) habitat, which is composed primarily of late forest structure (Ralph et al. 1995), may potentially provide some interim goshawk nest sites (WDFW, unpublished data). However, the potential of these patches to provide adequate PFA and foraging habitat to sustain potential goshawk nest areas is limited to the size and adjacency of mature forests that are within the range of the murrelet in western Washington (i.e., generally within 80 km [50 mi] of marine waters).

To promote the development of nest habitat in western Washington, managers should thin young (30-35 years) conifer stands by removing the understory trees to a density of 345-445 trees/ha (140-180 trees/ac) (Finn et al. 2002a). This forest practice will accelerate tree growth and should eventually result in a deep overstory canopy and a low density of shrub cover if the stand is allowed to mature beyond 50-70 years.

Because goshawks have a strong fidelity to high quality nest areas, there can be a temporal lag before birds respond to habitat changes (T. Bloxton, unpublished data; S. Desimone, personal observation). Abandonment of a nest area following timber management depends on the proximity, timing, and extent of the habitat removal. Habitat assessment models and change detection (e.g., McGrath 1997, Desimone 1997) can evaluate the effects of management on site suitability. However, these processes sometimes lead to an overestimation of suitable habitat if the assumptions of the model are not explicitly addressed (McGrath 1997). A landscape-scale habitat model is currently being developed for predicting nesting habitat for goshawks in Washington (S. Finn, personal communication).

Falconry

The impact of removing wild goshawks for falconry is thought to be negligible (Squires and Reynolds 1997). Of the various hawk species captured, Kenward (1997) estimated that 50-93% are eventually lost or released back into the wild. In Washington, falconry permit holders reported 64 northern goshawks taken from the wild between 1990 and 2002; one immature escaped and one adult died in captivity between 1998 and 2002 (WDFW, unpublished data). As the data are relatively sparse for Washington birds, the removal of northern goshawks from the wild for falconry should continue to be closely monitored.

REFERENCES

Anthony, R. G., and R. S. Holthausen. 1997. Applying concepts of the Southwest goshawk management plan to the Pacific Northwest: What do we need to know? Presented at Ecology and Management for Northern Goshawks in Eastside Forests of the Pacific Northwest Workshop, Spokane, Washington, USA.

Austin, K. 1993. Habitat use and home range size of breeding northern goshawks in the southern Cascades. Thesis, Oregon State University, Corvallis, Oregon, USA.

Beebe, F. L. 1974. Field studies of the Falconiformes of British Columbia. Number 17. Occasional Papers of the British Columbia Provincial Museum, Victoria, British Columbia, Canada.

Beier, P., and J. E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. Ecological Applications 7:564-571.

Bloxton, T. 2002. Prey abundance, space use, demography, and foraging habitat of northern goshawks in western Washington. Thesis, University of Washington, Seattle, Washington, USA.

Bosakowski T., B. McCullough, F. J. Lapsansky, and M. E. Vaughn. 1999. Northern goshawks nesting on a private industrial forest in western Washington. Journal of Raptor Research 33:240-244.

Braun, C. E., J. H. Enderson, M. R. Fuller, Y. B. Linhart, and C. D. Marti. 1996. Northern goshawk and forest management in the southwestern United States. Wildlife Society Technical Review 96-2.

Bright-Smith, D. J., and R. W. Mannan. 1994. Home range and habitat characteristics of male northern goshawks. Studies in Avian Biology 16:58-65.

Buchanan, J. B., L. L. Irwin, and E. L. McCutchen. 1993. Characteristics of spotted owl nest trees in the Wenatchee National Forest. Journal of Raptor Research 27:1-7.

Bull, E. L. 1992. Northern goshawks in northeastern Oregon. Unpublished Report, USDA Forest Service, Pacific Northwest Research Station, La Grande, Oregon, USA.

____, and J. E. Hohmann. 1994. Breeding biology of northern goshawks in northeastern Oregon. Studies in Avian Biology 16:103-105.

Conway, C. J., S. H. Anderson, D. E. Runde, and D. Abbate. 1995. Effects of experimental nestling harvest on prairie falcons. Journal of Wildlife Management 59:311-316.

Crocker-Bedford, D. C. 1990. Goshawk reproduction and forest management. Wildlife Society Bulletin. 18:262-269.

____. 1995. Northern Goshawk reproduction relative to selection harvest in Arizona. Journal of Raptor Research 29:42-43.

____. 1998. The value of demographic and habitat studies in determining the status of northern goshawks (*Accipiter gentiles atricapillus*) with special reference to Crocker-Bedford (1990) and Kennedy (1997). Journal of Raptor Research 32:329-336.

____, and B. Chaney. 1988. Characteristics of goshawk nesting stands. Pages 210-217 *in* R. L., Glinski, B. C. Pendleton, M. B. Moss, M. N. LeFranc, Jr., B. A. Millsap, and S. W. Hoffman, editors. Proceedings of the Southwest Raptor Management Symposium and Workshop. National Wildlife Federation Scientific Technical Series, Washington D.C., USA.

Cutler, T. L., R. J. Steidl, and S. DeStefano. 1996. Diets of northern goshawks in Oregon. Unpublished Report, Oregon Cooperative Wildlife Research Unit, Corvallis, Oregon, USA.

Daw, S. K., and S. DeStefano. 2001. Forest characteristics of northern goshawk nest stands and post-fledging areas in Oregon. Journal of Wildlife Management 65:59-65.

Desimone, S. M. 1997. Occupancy rates and habitat relationships of northern goshawks in historic nesting areas in Oregon. Thesis, Oregon State University, Corvallis, Oregon, USA.

DeStefano, S., S. K. Daw, S. M. Desimone, and E. C. Meslow. 1994. Density and productivity of northern goshawks: implications for monitoring and management. Studies in Avian Biology 16:88-91.

Detrich, P. J., and B. Woodbridge. 1994. Territory fidelity, mate fidelity, and movements of color-marked northern goshawks in the southern Cascades of California. Studies in Avian Biology 16:130-132.

Dewhurst, S. M., W. W. Covington, and D. B. Wood. 1995. Developing a model for adaptive ecosystem management: Goshawk management on Arizona's Kaibab plateau. Journal of Forestry 93:35-41.

Doyle, F. I., and J. M Smith. 1994. Population responses of northern goshawks to the 10-year cycle in numbers of snowshoe hares. Studies in Avian Biology 16:122-129.

Drennan, J. E., and P. Beier. 2003. Forest structure and prey abundance in winter habitat of northern goshawks. Journal of Wildlife Management 67:177-185.

Finn, S. P. 1994. Northern goshawk nest stand characteristics in Okanogan County, Washington. Unpublished Report, Washington Department of Fish and Wildlife, Ephrata, Washington, USA.

____. 2000. Multi-scale habitat influences on northern goshawk occupancy and reproduction on the Olympic Peninsula, Washington. Thesis, Boise State University, Boise, Idaho, USA.

____, J. Marzluff, and D. E. Varland. 2002a. Effects of landscape and local habitat attributes on northern goshawk site occupancy in western Washington. Forest Science 48:1-10.

____, D. E. Varland, and J. Marzluff. 2002b. Does northern goshawk breeding occupancy vary with nest-stand characteristics on the Olympic Peninsula, Washington? Journal of Raptor Research 36:265-279.

Fleming, T. L. 1987. Northern goshawk status and habitat associations in western Washington with special emphasis on the Olympic Peninsula. Unpublished Report. USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington, USA.

Hargis, C. D., C. McCarthy, and R. D. Perloff. 1994. Home ranges and habitats of northern goshawks in eastern California. Studies in Avian Biology 16:66-74.

Hayward, G. D., and R. E. Escano. 1989. Goshawk nest-site characteristics in western Montana and northern Idaho. Condor 91:476-479.

Henjum, M.G., D.A. Perry, J. R. Carr, D.L. Bottom, J.C. Bednarz, S.G. Wright, S.A. Beckwitt, and E. Beckwitt. 1996. Maintaining ecological integrity of inland forest ecosystems in Oregon and Washington. Wildlife Society Bulletin 24(2): 227-232.

Hennessy, S. P. 1978. Ecological relationships of *Accipiter gentilis* in northern Utah, with special emphasis on the effects of human disturbance. Thesis, Utah State University, Logan, Utah, USA.

James, M., and B. K. Palmer. 1997. 90-day finding for a petition to list the northern goshawk in the contiguous United States west of the 100th meridian: supplementary background information. Federal Register 62:50892-50896.

Jewett, S. G., S. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. The birds of Washington state. University of Washington Press, Seattle, Washington, USA.

Johnsgard, P. A. 1990. Hawks, eagles, and falcons of North America. Smithsonian Institution Press. Washington, D.C., USA.

Keane, J. J., and M. L. Morrison. 1994. Northern goshawk ecology: effects of scale and levels of biological organization. Studies in Avian Biology 16:3-11.

Kennedy, P. L. 1991. Reproductive strategies of northern goshawks and Cooper's hawks in north-central New Mexico. Dissertation, Utah State University, Logan, Utah, USA.

____. 1997. The northern goshawk (*Accipiter gentilis atricapillus*): Is there evidence of a population decline? Journal of Raptor Research 31:95-106.

____, J. M. Ward, G. A. Rinker, and J. A. Gessaman. 1994. Post-fledging areas in northern goshawk home ranges. Studies in Avian Biology 16:75-82.

Kenward, R. E. 1996. Goshawk adaptation to deforestation: Does Europe differ from North America? Pages 233-243 *in* D. Bird, D. Varland, and J. Negro, editors. Raptors in human landscapes: adaptations to built and cultivated environments. Academic Press, San Diego, California, USA.

____. 1997. Inferring sustainable yields for raptor populations. Journal of Raptor Research 31:295-296.

Lilieholm, R. J., W. B. Kessler, and K. Merrill. 1993. Stand density index applied to timber and goshawk habitat objectives in Douglas-fir. Environmental Management 17:773-779.

____, J. N. Long, and S. Patla. 1994. Assessment of goshawk nest area habitat using stand density index. Studies in Avian Biology 16:18-23.

McGrath, M. T. 1997. Northern goshawk habitat analysis in managed forest landscapes. Thesis, Oregon State University, Corvallis, Oregon, USA.
____, S. DeStefano, R. A. Riggs, L. L. Irwin, and G. J. Roloff. 2003. Spatially explicit influences on northern goshawk nesting habitat in the interior Pacific Northwest. Wildlife Monograph 154:1-63
Merrill, K. 1989. Silvicultural prescription for development of goshawk habitat. Thesis, Utah State University, Logan, Utah, USA.
Moore, R. K., and C. J. Henny. 1983. Nest site characteristics of three co-existing accipiter hawks in northeastern Oregon. Raptor Research 17:65-76.
Mosher, J. A. 1997. Falconry harvest in the United States. Journal of Raptor Research 31:294-295.
Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota, USA.
Palmer, R. S. 1988. Northern Goshawk *Accipiter gentilis*. Handbook of North American birds. Volume 4: diurnal raptors. Yale University Press, New Haven, Connecticut, USA.
Patla, S. M. 1997. Nesting ecology and habitat of the northern goshawk in undisturbed and timber harvest areas on the Targhee National Forest, Greater Yellowstone Ecosystem. Thesis, Idaho State University, Pocatello, Idaho, USA.
Ralph, C. J., G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, technical editors. 1995. Ecology and conservation of the marbled murrelet. USDA Forest Service General Technical Report PSW-GTR-152. Arcata, California, USA.
Reynolds, R. T. 1983. Management of western coniferous forest habitat for nesting accipiter hawks. USDA Forest Service General Technical Report RM-102, Rocky Mountain and Range Experiment Station, Fort Collins, CO, USA
____. 1989. Accipiters. Pages 92-101 *in* B. G. Pendleton, editor. Proceedings of the Western Raptor Management Symposium and Workshop. Number 12. National Wildlife Federation Technical Series, Washington, D.C., USA.
____. 1997. Ecology and population biology of northern goshawks on the Kaibab Plateau, Arizona. Presented at Ecology and management for northern goshawks in eastside forests of the Pacific Northwest Workshop, Spokane, Washington, USA.
____, R. T. Graham, M. H. Reiser, R. L. Bassett, P. L. Kennedy, D. A. Boyce, G. Goodwin, R. Smith, and E. L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. USDA Forest Service General Technical Report GTR-RM-217. Fort Collins, Colorado, USA.
____, and S. M. Joy. 1998. Distribution, territory, occupancy, dispersal, and demography of northern goshawks on the Kaibab Plateau, Arizona. Final Report for Arizona Game and Fish Heritage Project Number 194045. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
____, ____, and D. G. Leslie. 1994. Nest productivity, fidelity, and spacing of northern goshawks in Arizona. Studies in Avian Biology 16:106-113.
____, ____, and H. M. Wight. 1982. Nesting habitat of co-existing Accipiter in Oregon. Journal of Wildlife Management 46:124-138.
____, and E. C. Meslow. 1984. Partitioning of food and niche characteristics of co-existing Accipiter during breeding. Auk 101:761-779.
____, and H.M. Wight. 1978. Distribution, density, and productivity of accipiter hawks breeding in Oregon. Wilson Bulletin 90:182-196.
Squires, J. R., and L. F. Ruggiero. 1995. Winter movements of northern goshawks that nested in south-central Wyoming. Journal of Raptor Research 29:5-9.
____, and R. T. Reynolds. 1997. Northern Goshawk (*Accipiter gentiles*). Number 298 *In in* A. Poole and F. Gill, editors. The Birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.
Wagenknecht J.F., S.P. Finn, and L. Stream. 1998. Northern goshawk breeding ecology in the Upper Yakima River basin, 1994 to 1996. Unpublished Report, Washington Department of Fish and Wildlife, Yakima, Washington, USA.
Ward, L.Z., D.K Ward and T.J. Tibbitts. 1992. Canopy density analysis at goshawk nesting territories on the North Kaibab Ranger District, Kaibab National Forest. Final Report, Arizona Department of Fish and Game, Phoenix, Arizona, USA.
Washington Forest Practices Board. 2001. Forest Practices Rules: Title 222 Washington Administrative Code. Washington Department of Natural Resources, Olympia, Washington, USA.

Watson, J. W., D. W. Hays, S. P. Finn, and P. Meehan-Martin. 1998. Prey of breeding northern goshawks in Washington. Journal of Raptor Research 32:297-305.

Woodbridge, B., and P. J. Detrich. 1994. Territory occupancy and habitat patch size of northern goshawks in the southern Cascades of California. Studies in Avian Biology 16:83-87.

PERSONAL COMMUNICATIONS

Robert Anthony, Unit Leader
Oregon Cooperative Wildlife Research Unit
Corvallis, Oregon

Dana Base, Wildlife Biologist
Washington Department of Fish and Wildlife
Colville, Washington

Thomas K. Bloxton, Wildlife Biologist
University of Washington
Seattle, Washington

Joseph Buchanan, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

Sean Finn, Wildlife Biologist
U.S. Geological Survey
Boise, Idaho

Scott Fitkin, Wildlife Biologist
Washington Department of Fish and Wildlife
Winthrop, Washington

Tracy Fleming, Wildlife Biologist
National Council for Air and Stream Improvement
Vancouver, Washington

Suzanne Joy, Wildlife Biologist
U.S. Forest Service
Fort Collins, Colorado

Mary Linders, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

Jeff Smith, Director of Research
HawkWatch International
Salt Lake City, Utah

Richard Reynolds, Wildlife Research Biologist
U.S. Forest Service
Fort Collins, Colorado

Frank Silvernail, Forester
Crown-Pacific Corporation
Port Angeles, Washington

KEY POINTS

Habitat Requirements

- Home ranges for breeding goshawks can be split into three functional divisions: the nest area or areas, post-fledgling family area (PFA), and foraging area.
- Nest areas are composed of one or several forest stands that contain active or alternate nest structures that are usually occupied by goshawks between March and September.
- Nest areas are typically located in mature or old coniferous forest with a high density of large trees. Additionally, nest areas primarily are composed of stands with a closed canopy and multiple canopy layers.
- Nests are often found in Douglas-fir in western Washington and in Douglas-fir, ponderosa pine, western larch, lodgepole pine, and grand fir east of the Cascades.
- Nest areas typically have a higher basal area than that of surrounding forest east of the Cascade crest.
- Plucking posts are usually found within 100 m (328 ft) of active nests.
- Goshawks apparently prefer to nest close to water and at low topographic positions.
- All nests and alternate nests of a pair form a cluster that generally does not overlap with clusters of neighboring territories.
- The PFA is an area of concentrated use by adult females and developing juvenile goshawks.
- PFAs are typically comprised of complex forest structure and typically contain mature and old forest
- Foraging areas are where goshawks secure prey and it defines their home range during the breeding season. Goshawks forage in a variety of forest types.
- Goshawks are considered opportunistic foragers, as exhibited by the wide range of prey taken.

- Goshawks are believed to be non-migratory

Management Recommendations

- Protect at least three nest areas and three alternate nest areas per home range. Each nest area should be at least 12 ha (30 ac) in size, and selected nest areas should be structurally similar to known nest areas.
- Minimize human disturbance in active nest areas between March 1st – September 30th.
- Retain an average canopy closure of 70-80% and maintain forest in late stages of forest development.
- Limit all overstory or regeneration harvest and increase harvest rotation length in nest area clusters.
- Delineate and center areas to managed as PFAs on active and alternate nests. PFAs should be approximately 170 ha (420 ac) and include as much old and mature forest as possible.
- Manage PFAs for $\geq$ 70% canopy closure in western Washington and for moist forests east of the Cascade crest. Drier forests east of the Cascade crest should have $\geq$ 60 canopy closure.
- Avoid removing late-seral forest in PFAs, and retain snags and downed logs.
- Retain at least 60% of foraging habitat in mid-aged (20%), mature (20%), and old (20%) forest successional classes.
- Large diameter snags and logs should be retained in goshawk foraging areas.
- Retain at least 5 large ($\geq$ 46 cm dbh [18 in], $\geq$ 9.1 m [30 ft] in height) snags/ha (2 large snags/ac), and at least 7 large ($\geq$ 30 cm [12 in] diameter, $\geq$ 2 m [7 ft] in length) downed logs/ha (3/ac) in foraging areas comprised of ponderosa pine forest in eastern Washington. At least 7 large snags/ha (3/ac) with at least 12 large downed logs/ha (5/ac) should be retained in interior-fir forests.
- Conservation of goshawk habitat should be managed on a landscape-scale and multiple spatial scales (e.g., watershed, forest-wide, territory, etc.)
- Forest management should consider increasing timber harvest rotations (e.g., 70-120 years in western Washington lowlands and Olympic peninsula) because intensively managed forest appear to negatively impact goshawks.
- Thin young (30-35 years) conifer stands to a density of 345-445 trees/ha (140-180/ac) to promote the development of nesting habitat in western Washington. If allowed to mature beyond 50-70 years, this practice should result in preferred forest conditions.
- Closely monitor the impact of the removal of northern goshawks from the wild for falconry purposes.

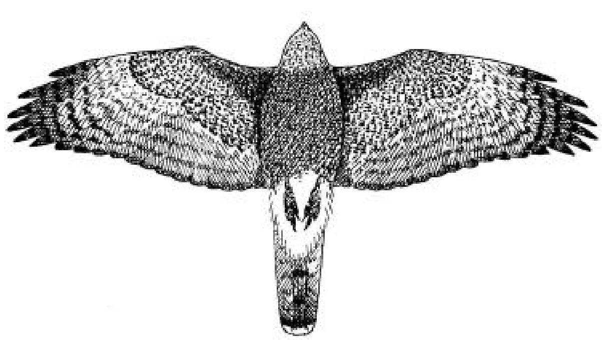


Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; http://royalbcmuseum.bc.ca/

Ferruginous Hawk

Buteo regalis

Last updated: 1999

Written by Scott Richardson, Morie Whalen, Dinah Demers, and Ruth Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Ferruginous hawks inhabit the arid, open country of 17 western states and 3 Canadian provinces during the breeding season. They winter primarily in Mexico and the southwestern and southcentral United States (American Ornithologists' Union 1983, Olendorff 1993).

Ferruginous hawks breed in the Lower Columbia Basin and surrounding arid lands of southeast Washington (see Figure 1). The Washington breeding range includes Adams, Benton, Columbia, Douglas, Franklin, Garfield, Grant, Kittitas, Lincoln, Walla Walla, Whitman, and Yakima counties.

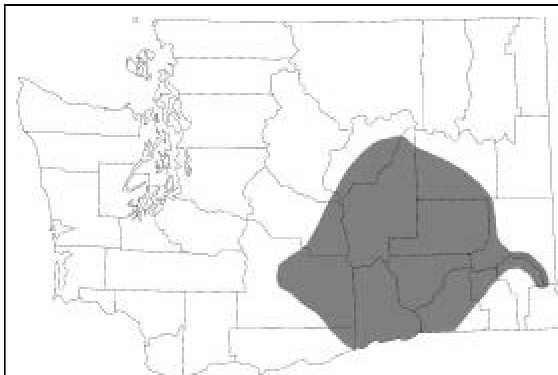


Figure 1. Breeding range of the ferruginous hawk, *Buteo regalis,* in Washington. Map derived from WDFW data files and GAP Analysis of Washington (Smith et al. 1997).

RATIONALE

The ferruginous hawk, a State Threatened species, is an uncommon breeding species and rare winter visitor east of the Washington Cascades (Washington Department of Fish and Wildlife 1996). Uncultivated land is a major component of ferruginous hawk habitat (Lokemoen and Duebbert 1976; Schmutz 1984, 1987; Olendorff 1993). Loss of uncultivated land and the prey base it supports (Howard and Wolfe 1976, Woffinden and Murphy 1977) may limit the frequency and success of ferruginous hawk nesting efforts. This species is also sensitive to human disturbance, particularly early in the breeding cycle (Smith and Murphy 1978, Schmutz 1984, White and Thurow 1985, Olendorff 1993). The amount of undisturbed natural habitat within the ferruginous hawk's Washington range has been reduced, which may make the population vulnerable.

HABITAT REQUIREMENTS

Ferruginous hawks are obligate grassland or desert-shrub nesters (Woffinden and Murphy 1989). In Washington, they frequent shrub-steppe in the channeled scablands, as well as juniper-savannah areas of the Columbia Basin.

Nesting

Landscapes comprised primarily of shrub-steppe, native prairie, haylands, and pasture are favored for nesting, while cropland is avoided (Howard 1975, Gilmer and Stewart 1983, Schmutz 1984, Roth and Marzluff 1989). Most nests are found in areas with a high proportion of grassland, shrubland, and juniper forest and a low proportion of wheatland, although nests can be found in areas with 50% to 100% wheatland within 3 km (1.9 mi) (Bechard et al. 1990). Ferruginous hawk populations decline consistently once cultivated land exceeds 30% of the area (Schmutz 1987, 1989). This species' nesting requirements may not be adequately accommodated in areas where native grasses are replaced by dense and tall cultivated crops (Schmutz 1987).

In Washington, ferruginous hawks nest on rock outcrops, steep low cliffs, ledges on hills, in some canyons, in isolated trees [juniper (*Juniperus* spp.), black locust (*Robinia pseudoacacia*) and others], and on powerline towers or other artificial structures (Washington Department of Fish and Wildlife 1996).

Ferruginous hawks are sensitive to disturbance; pairs may abandon nests even when mildly disturbed during nest building or incubation (1 March through 31 May) (Smith and Murphy 1978, White and Thurow 1985, Olendorff 1993, Washington Department of Fish and Wildlife 1996). Furthermore, disturbed nests fledge fewer young, and they often are not reoccupied the year following disturbances (White and Thurow 1985). Rather than becoming acclimated to repeated disturbance, ferruginous hawks become sensitized and flush at greater distances (White and Thurow 1985), which may result in increased clutch or brood mortality due to exposure, predation, starvation, or nest desertion.

Ferruginous hawks typically nest farther from human habitations than closely related raptor species (Schmutz 1984, Gaines 1985). In South Dakota, occupied nest sites were significantly farther from human activity as opposed to sites selected at random (Lokemoen and Duebbert 1976). Nests located in physically remote areas or on posted land tend to fledge more young than nests in areas where human access is not limited (Olendorff and Stoddart 1974).

Food

The diet of ferruginous hawks consists primarily of small- to medium-size mammals and, to a lesser extent, snakes, birds, and insects (Olendorff 1993). Northern pocket gophers appear to dominate the diet of Washington ferruginous hawks. Other rodents, snakes, and insects are also common prey (Washington Department of Fish and Wildlife 1996).

Density of major prey species may influence productivity and limit ferruginous hawk populations (Howard and Wolfe 1976). In years of food scarcity, many nesting territories may be left vacant, territorial pairs may fail to nest, clutch sizes may be reduced, or productivity may decline (Woffinden and Murphy 1977, Smith et al. 1981).

Home Range

The average home range for ferruginous hawks in the western states is 7.0 km^2 (2.7 mi^2), but size varies with habitat conditions and prey availability (Olendorff 1993). Some home ranges in Washington are considerably larger (i.e., mean = 79 km^2 [49 mi^2] for 7 males), mainly due to long-distance foraging flights (Leary 1996).

LIMITING FACTORS

Ferruginous hawks may be limited by availability of suitable nesting sites in undisturbed habitats supporting adequate prey populations (Olendorff and Stoddart 1974, Lokemoen and Duebbert 1976, Smith and Murphy 1978, Schmutz 1984, Schmutz et al. 1984, Schmutz 1987).

MANAGEMENT RECOMMENDATIONS

Habitat Protection

Landowners should protect at least half of the native shrub-steppe within ferruginous hawk home ranges (Gilmer and Stewart 1983, Schmutz 1984).

Disturbance

Brief human access and intermittent ground-based activities should be avoided within a distance of 250 m (820 ft) of nests during the hawks' most sensitive period (1 March to 31 May) (White and Thurow 1985). Prolonged activities (0.5 hr to several days) should be avoided, and noisy, prolonged activities should not occur, within 1 km (0.6 mi) of nests during the breeding season (1 March to 15 August) (Suter and Joness 1981). Construction or other developments near occupied nests should be delayed until after the young have dispersed (Konrad and Gilmer 1986), which generally occurs about a month after fledging (Olendorff 1993; A. Jerman, unpubl. data).

Spatial and temporal buffers should be tailored to the individual hawks involved (Knight and Skagen 1988), based on factors such as line-of-sight distance between nest and disturbance, nest structure security, history of disturbance, observed responses, and nest elevation in relation to the disturbance.

Natural Nest Structures

Isolated trees should be protected from cattle rubbing by surrounding them with stick piles or fences. Old, unoccupied nest trees should not be cut for at least 10 years after they have been abandoned by ferruginous hawks. Junipers and black locusts may be planted to provide future nest sites.

In areas where natural nesting materials are in short supply, sagebrush stems and other large sticks may be provided in the vicinity of potential nest structures.

After the dispersal of young, the amount of material in nests may be reduced to avoid having nest-site competitors (e.g., great horned owls) usurp the nests prior to the hawks' return.

Artificial Nest Structures

Artificial nest structures are an effective tool for encouraging successful ferruginous hawk nesting (Tigner et al. 1996). Such structures can be especially valuable if prey populations are adequate, disturbances are minimal, and nest sites are thought to be limiting. However, they may also enhance populations or productivity under other conditions.

Commonly, artificial structures are platforms mounted on poles, trees, or cliffs. Poles should be buried at least 1 m (3.3 ft) deep and should be located away from watering holes, gates, and other areas where livestock congregate. Platforms should be approximately 1 m^2 (10.8 ft^2) to allow space for 3 or 4 nestlings to lie down during strong winds. The structure should allow adult hawks to anchor nest materials. Shade is not required. Specifications for cliff nest structures are available from the Spokane office of the Bureau of Land Management.

Although largely beneficial, artificial structures may attract undesirable or competitive species and are prone to increased disturbance due to their conspicuousness (Howard and Hilliard 1980, Suter and Joness 1981).

Prey

Ferruginous hawks will benefit from land-use practices that ensure an adequate prey base. Landowners should protect shrub-steppe and grassland habitats that harbor significant populations of small mammals and other prey. Habitat conversions, especially through chemical application, should be discouraged where ferruginous hawks occur. Developments (e.g., oil, gas, or geothermal exploration; pipeline and road construction; campgrounds;

interpretive facilities) should be kept at least 400 m (¼ mi) from important prey concentrations, such as ground squirrel colonies (Suter and Joness 1981). Pesticides and rodenticides should not be used within this 400 m area. Appendix A provides useful contacts to help assess the use of pesticides, herbicides, and their alternatives.

Range management activities such as chaining, disking, and brush burning may be detrimental to prey populations and should be avoided. In areas where chaining cannot be avoided, brush may be windrowed to provide nesting and cover for prey species. Reseeding of native plant species after chaining or burning promotes habitat stability and is beneficial to ferruginous hawk prey populations (Olendorff 1993).

REFERENCES

American Ornithologists' Union. 1983. Check-list of North American birds. Sixth edition. Allen Press, Washington, D.C, USA.

Bechard, M. J., R. L. Knight, D. G. Smith, and R. E. Fitzner. 1990. Nest sites and habitats of sympatric hawks (*Buteo* spp.) in Washington. Journal of Field Ornithology 61:159-170.

Gaines, R. C. 1985. Nest site selection, habitat utilization, and breeding biology of the ferruginous hawk in central North Dakota. Thesis, North Dakota State University, Fargo, North Dakota, USA.

Gilmer, D. S., and R. E. Stewart. 1983. Ferruginous hawk populations and habitat use in North Dakota. Journal of Wildlife Management 47:146-157.

Howard, R. P. 1975. Breeding ecology of the ferruginous hawk in northern Utah and southern Idaho. Thesis, Utah State University, Logan, Utah, USA.

____, and M. Hilliard. 1980. Artificial nest structures and grassland raptors. Raptor Research 14:41-45.

____, and W. L. Wolfe. 1976. Range improvement practices and ferruginous hawks. Journal of Range Management 29:33-37.

Knight, R. L., and S. K. Skagen. 1988. Effects of recreational disturbance on birds of prey: a review. Pages 355-359 *in* R. L. Glinski, B. G. Pendleton, M. B. Moss, M. N. LeFranc, Jr., B. A. Millsap, and S. W. Hoffman, editors. Proceedings of the southwest raptor management symposium and workshop. Science and Technology Series No. 11. National Wildlife Federation, Washington D.C., USA.

Konrad, P. M., and D. S. Gilmer. 1986. Post-fledging behavior of ferruginous hawks in North Dakota. Raptor Research 20:35-39.

Leary, A. W. 1996. Home ranges, core use areas, and dietary habits of ferruginous hawks in southcentral Washington. Thesis, Boise State University, Boise, Idaho, USA.

Lokemoen, J. T., and H. F. Duebbert. 1976. Ferruginous hawk nesting ecology and raptor populations in northern South Dakota. Condor 78:464-470.

Olendorff, R. R. 1993. Biology and management of ferruginous hawk (*Buteo regalis*): a review. Occasional Papers Number 1. Raptor Research and Technical Assistance Center, U.S. Bureau of Land Management, Boise, Idaho, USA.

____, and J. W. Stoddart, Jr. 1974. Potential for management of raptor populations in western grasslands. Pages 47-88 *in* F. N. Hamerstrom, Jr., B. E. Harrell, and R. R. Olendorff, editors. Management of raptors. Raptor Research Report No. 2., Raptor Research Foundation, Vermillion, South Dakota, USA.

Roth, S. D., Jr., and J. M. Marzluff. 1989. Nest placement and productivity of ferruginous hawks in western Kansas. Transactions of Kansas Academic Sciences 92:132-148.

Schmutz, J. K. 1984. Ferruginous and Swainson's hawk abundance and distribution in relation to land use in southeastern Alberta. Journal of Wildlife Management 48:1180-1187.

____. 1987. The effect of agriculture on ferruginous and Swainson's hawks. Journal of Range Management 40:438-330.

____. 1989. Hawk occupancy of disturbed grasslands in relation to models of habitat selection. Condor 91:362-371.

Schmutz, J. K., R. W. Fyfe, D. A. Moore, and A. R. Smith. 1984. Artificial nest sites for ferruginous and Swainson's hawks. Journal of Wildlife Management 48:1009-1013.

Smith, D. G., and J. R. Murphy. 1978. Biology of the ferruginous hawk in central Utah. Sociobiology 3:79-95.

____, J. R. Murphy, and N. D. Woffinden. 1981. Relationships between jackrabbit abundance and ferruginous hawk reproduction. Condor 83:52-56.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington State. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith and K. M. Dvornich, editors. Washington State Gap Analysis-Final Report. Seattle Audubon Society Publications in Zoology Number 1, Seattle, Washington, USA.
Suter, G. W., II, and J. L. Joness. 1981. Criteria for golden eagle, ferruginous hawk and peregrine falcon nest site protection. Raptor Research 15:12-18.
Tigner, J. R., M. W. Call, and M. N. Kochert. 1996. Effectiveness of artificial nesting structures for ferruginous hawks in Wyoming. Pages 137-146 *in* D. W. Bird, D. E. Varland, and J. J. Negro, editors. Raptors in human landscapes, Academic Press, New York, New York, USA.
White, C. M., and T. L. Thurow. 1985. Reproduction of ferruginous hawks exposed to controlled disturbance. Condor 87:14-22.
Washington Department of Fish and Wildlife. 1996. Washington state recovery plan for the ferruginous hawk. Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Woffinden, N. D., and J. R. Murphy. 1977. Population dynamics of the ferruginous hawk during a prey decline. Great Basin Naturalist 37:411-425.
____, and ____. 1989. Decline of a ferruginous hawks population: a 20-year summary. Journal of Wildlife Management 53:1127-1132.

PERSONAL COMMUNICATIONS

Aimee Jerman, Thesis Candidate
Boise State University
Boise, Idaho

CONTACTS

Bureau of Land Management
Spokane District Office
1103 N. Fancher
Spokane, WA, 99212-1275
Phone: (509) 536-1200
FAX: (509) 536-1275
E-Mail: or130mb@or.blm.gov

KEY POINTS

Habitat Requirements

- Sparse, short vegetation in steppe and shrub-steppe habitats is preferred by ferruginous hawks.
- Ferruginous hawks avoid nesting in heavily cultivated lands.
- Ferruginous hawks in Washington generally nest on rock outcrops, steep cliffs, isolated trees, or artificial platforms.
- Ferruginous hawks feed primarily upon a variety of small- to medium-size mammals.

Management Recommendations

- Encourage surrounding landowners to protect 50% or more of the shrub-steppe within ferruginous hawk home ranges.
- Avoid disturbance within 250 m (820 ft) of nests from 1 March through 31 May.
- Delay development near occupied nests until one month after young hawks fledge.

- Avoid construction within 1.6 km (1 mi) of nest sites.
- Install "No Trespassing" signs to prevent harassment.
- Fence isolated trees which show signs of abuse from livestock (e.g., rubbing, soil erosion).
- Retain trees and shrubs greater than 1 m (3.3 ft) in height and within 1.6 km (1 mi) of one another.
- Plant trees, especially junipers and black locusts, in isolated situations.
- Avoid cutting nest trees for at least 10 years after they are abandoned.
- Construct artificial nest structures where nest sites are limited.
- Remove some material from nests in the autumn to prevent nest loss to competitive species or weathering during the non-nesting season.
- Preserve remaining steppe and shrub-steppe habitat types that harbor significant populations of hares, rabbits, and small- and medium-size rodents.
- Maintain a "no disturbance" buffer of 400 m (¼ mi) around periphery of ground squirrel colonies and other prey concentrations.
- Avoid spray application of pesticides when possible. For spray application near ground squirrel colonies, add additional width to the 400 m (¼ mi) buffer to account for pesticide drift. Refer to Appendix A for contacts useful in assessing pesticides, herbicides, and their alternatives.
- Plant 5 m (16 ft) buffer of rye around edge of agricultural crops to protect against rodent damage.
- Avoid chaining, disking, and brush burning where prey species are concentrated or affected. Windrow brush where chaining or disking is necessary.

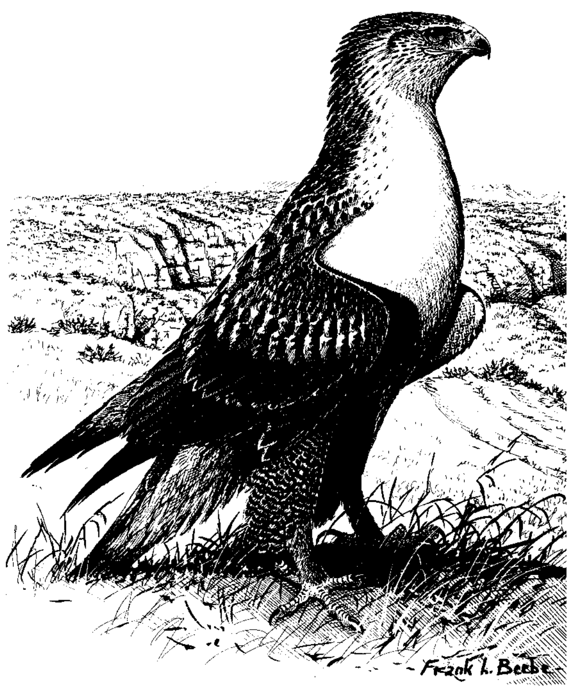


Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; http://www.royalbcmuseum.bc.ca/

Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; http://www.royalbcmuseum.bc.ca/

Golden Eagle

Aquila chrysaetos

Last updated: 2003

Written by Jim Watson and Morie Whalen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Golden eagles are distributed throughout much of the northern hemisphere (Kochert et al. 2002). In Washington, golden eagles nest throughout much of the state, but are most common in the north-central highlands transitional area between montane and shrub-steppe habitats (see Figure 1). Scattered nest sites are found in more arid portions of eastern Washington and west of the Cascades where the species is uncommon (Larrison and Sonnenberg 1968). The migratory status of nesting golden eagles in Washington has not been studied; observations of golden eagles along the upper Columbia River suggest they remain at nest sites throughout the winter (Knight et al. 1979).

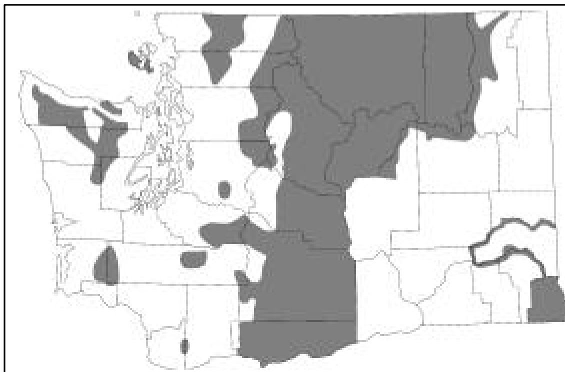


Figure 1. General range of the golden eagle, *Aquila chrysaetos,* in Washington. Map derived from Washington Department of Fish and Wildlife Heritage data files and GAP Analysis of Washington.

RATIONALE

The golden eagle is a State Candidate species. This species is vulnerable to population declines due to habitat loss and disturbance, loss of foraging areas, and through direct human-caused mortality (Franson et al. 1995, Kochert et al. 2002).

HABITAT REQUIREMENTS

Golden eagles are commonly associated with open, arid plateaus deeply cut by streams and canyons, western shrub-steppe and grassland communities and transition zones between shrub, grassland and forested habitat (De Smet 1987, Marzluff et al. 1997). Nests generally are located on cliffs and are occasionally located in trees (Anderson and Bruce 1980, Menkens and Anderson 1987, Kochert et al 2002). Golden eagles use the same territory annually but may use alternate nests in different years. This species uses an average of 2-3 alternate nests (range: 1-14 alternate nests) (Snow 1973). Individual eagles mature and may establish territories and breed during their fifth summer but are capable of breeding earlier in life (Kochert et al. 2002).

Although they are more common east of the Cascades, golden eagles are sometimes found in mature and old-growth forests near the edges of clearcuts in western Washington (Anderson and Bruce 1980). Golden eagle nesting was observed in the San Juan Island archipelago (<10 pairs) during the 1970s and 1980s (Washington State Wildlife Heritage Database). Bruce et al. (1982) found that golden eagle tree nests in western Washington were generally smaller than bald eagle nests, were placed at or below canopy height, and were located no more than 500 m (1,600 ft) from large clearcuts (<10 years old) or open fields. In another study, bald eagle nests were located at or above the canopy on the interior of a stand and were closer to water than golden eagle nests (Anderson and Bruce 1980).

Shrub-steppe and native grassland communities provide important foraging habitat for the golden eagle (Marzluff et al. 1997, Kochert et al. 2002). Small to medium-sized mammals such as hares (*Lepus* spp.), ground squirrels (*Citellus* spp.), marmots (*Marmota* spp.), mountain beaver (*Aplodontia rufa*) and birds (e.g., pheasant, grouse) are important prey for golden eagles (McGahan 1967, Olendorff 1976, Bruce et al. 1982, Steenhof and Kochert 1988, Marzluff et al. 1997). Based on a survey of prey remains at 74 nests in eastern Washington, yellow-bellied marmots were the most important prey of nesting golden eagles, whereas carrion was regularly consumed in fall and winter (Marr and Knight 1983). Golden eagles nesting on large cliffs in the Columbia Basin commonly capture rock doves (*Columba livia*) that roost on canyon walls (J. Watson, personal observation). Jackrabbits and ground squirrels were historically more abundant in the Northwest (Richardson et al. 2001, Yensen and Sherman 2003) and likely were a more significant source of prey for the golden eagle. Extensive poisoning of ground squirrels in the 1980s, and possibly other factors (S. Zender, personal communication), significantly reduced Townsend's (*Citellus townsendi*) and Washington ground squirrel (*Citellus washingtoni*) populations in Washington (Washington State Wildlife Heritage Database) to the degree that they are being reviewed for status listing. Several researchers (Bates and Moretti 1994, Steenhof et al. 1997, McIntyre 2002) have found increased productivity in golden eagles in years with a higher abundance of hare. McIntyre (2002) and Steenhof et al. (1997) found that golden eagle reproduction was related to prey abundance, with more pairs producing eggs and increased numbers of young fledged when prey numbers were higher. Some eagles conserve energy by suspending their breeding activity when food supplies decrease (Steenhof et al. 1997, McIntyre 2002).

Densities of golden eagles in the western states range from one pair per 34 km^2 to 251 km^2 (13-96 mi^2) (Phillips et al. 1984). In Wyoming, prime golden eagle habitat as defined by high population densities consisted of a mixture of cliffs and trees suitable for nesting and open habitat with abundant and diverse prey (Phillips et al. 1984). Home range size, size of core areas, and travel distances can vary dramatically based on habitat composition, potential prey abundance and individual preferences (Marzluff et al. 1997).

LIMITING FACTORS

Golden eagle populations appear to be limited by habitat availability and disturbance, adequate prey populations (e.g., large rodents, rabbits and hares), and the availability of undisturbed nest sites (Olendorff and Stoddard 1974, Beecham and Kochert 1975, Kochert and Steenhof 2002). Direct mortality is increased by poisoning from lead and other contaminants, power line electrocutions, collision with wind turbines, and shooting (Phillips 1986, Harlow and Bloom 1989, Craig et al. 1990, Wingfield 1991, Leptich 1994, Avian Power Line Interaction Committee 1996, Hunt et al. 1997, Hoover 2002). Breeding success is limited by reduced habitat availability and decreased prey populations resulting from habitat conversion (Murphy 1977).

MANAGEMENT RECOMMENDATIONS

Factors affecting golden eagle habitat and populations have not been extensively studied in Washington, but studies have been conducted throughout western North America, and the following reflect the findings of these studies. These recommendations generally apply to conditions east of the Cascade Range because very few North American studies have been conducted in high rainfall zones.

In general, golden eagle habitat should be managed to improve native vegetation and maintain native prey populations (e.g., jackrabbits, ground squirrels) (Andersen 1991). Management of grassland habitats can influence prey density, diversity and availability (Andersen 1991). In general, certain prey species decrease with reduced herbaceous cover and foliage height diversity (Kochert 1989). Prey such as jackrabbits and ground squirrels, are believed to be moderately tolerant to grazing but they disappear where habitat is overgrazed (i.e., repeated grazing that exceeds the recovery capacity of the vegetation and creates or perpetuates a deteriorated plant community). Severely damaged native grassland can be restored by removing livestock, using controlled burning or chaining to remove trees and invasive shrubs, and reseeding with native grasses (Kochert 1989). However, fire management should be conducted only after developing a professional fire management plan (see Washington State University Cooperative Extension Service in Appendix A), especially in low rainfall zones, where exotic vegetation (e.g., Cheatgrass [*bromus tectorum*]) often becomes dominant (Knick and Rotenberry 1995).

Burning and other techniques that reduce shrub stand density should be avoided in healthy shrub-steppe communities, such as those dominated by sagebrush, in order to maintain existing prey populations (Kochert et al. 1999, Kochert et al. 2002).

Few studies have documented the effects of habitat fragmentation on raptors. However, in several states, raptors survived only on large habitat patches (Robinson 1991). In arid regions, golden eagles require large expanses of undisturbed shrub habitat (Marzluff et al. 1997). Therefore, it is recommended that shrub stands be preserved within 3 km (1.9 mi) of golden eagle nests (Kochert et al. 1999). This distance accounted for 95% of eagle movements measured during the breeding season in western Idaho (Marzluff et al. 1997). Large-scale conversion of eagle foraging habitat should be avoided because it reduces prey abundance and availability. This is particularly important where prey are concentrated, such as at ground squirrel colonies. Many types of development that remove vegetation from localized areas, including oil, gas, and geothermal exploitation; power line, pipeline and road construction; and the development of campgrounds and other facilities may result in loss of habitat for certain prey species (Suter and Joness 1981).

Although empirical evidence is limited, recreation and other human activities near nests appear to cause breeding failure (Kochert et al. 2002). Rock climbing as well as development activities on or near cliffs containing nests should be avoided (De Smet 1987). Avoiding these activities is especially important during the nesting period of 15 February to 15 July (Beebe 1974; R. Friesz, personal communication). The establishment of buffer zones surrounding nests, wide enough to include 90-95% of flushing distances, is generally an accepted technique to reduce disturbance to nesting raptors (Olendorff and Stoddart 1974, Suter and Joness 1981, Mersmann and Fraser 1990). Buffer widths may be adjusted on a case by case basis (with the assistance of a professional wildlife biologist), depending on factors that may influence a pairs' response to a particular disturbance, such as influence of terrain on the "line of sight" distance, security of the nest, history of disturbance, and elevation of the disturbance relative to the nest (Suter and Joness 1981; K. Steenhof, personal communication).

Holmes et al. (1993) found that wintering golden eagles are more likely to flush when approached by a human on foot than by a vehicle. They suggested that a buffer zone of 300 m (980 ft) would prevent flushing by 90% of eagles.

Golden eagles often have wing spans that are greater than the distances between conductive materials on power poles, which increases their probability of electrocution (Harness and Wilson 2001). Power lines and poles in any nesting or feeding area should be constructed so birds cannot make simultaneous contact between any two items of conductive equipment. Once an electrocution problem is identified on any existing structures, utility managers should ensure these are quickly retrofitted or modified to eliminate bird loss (Avian Power Line Interaction Committee 1996, Harness and Wilson 2001). Because multiple-phase transformers are believed to be associated with a disproportionate number of eagle electrocutions (Harness and Wilson 2001), the construction of this form of transformer should be avoided.

Rabbits and ground squirrels are important prey for golden eagles and have been targeted in control efforts. Rodent control should not occur within eagle foraging areas because it reduces the prey base (Eaton 1976, Phillips 1986, Young 1989). Shooting and rodenticides should be replaced by wildlife repellents for use in agricultural damage control. Two very effective jackrabbit/hare repellents available are trinitrobenzene-aniline (TNB-A), and zinc tetramethyl thiuram disulfide (TMTD) (Besser and Welch 1959). Another effective jackrabbit/hare repellent for use in orchards consists of a rosin and ethyl alcohol mixture (Cardinell 1958).

Because ground squirrels are an important prey of golden eagles (Kochert et al. 2002), spray application of pesticides near squirrel colonies should be avoided. If pesticides are to be sprayed, an additional buffer area should be used to prevent drift into the protected area. Droplet size, volume of compound and meteorological conditions should be factored into the buffer width (Kingsbury 1975, Brown 1978, Payne et al. 1988). Payne et al. (1988) describes a method for estimating buffer zone widths for pesticide application. In addition, pesticide use should be avoided during the ground squirrel breeding season, from early March to late May, and during the critical foraging time before estivation (dormancy period), mid-August through September (Carlson et al. 1980).

Organochlorine, organophosphate, and carbamate insecticides can be highly toxic to raptors and mammals, and their use in areas inhabited by golden eagles should be avoided (McEwen et al. 1972; Balcom 1983; Grue et al. 1983, 1986; Smith 1987; Hooper et al. 1989). If insecticides must be used, synthetic pyrethroid compounds may be an alternative. For example, permethrin is low in toxicity to raptors and mammals and bio-degrades rapidly (Grue et al. 1983, Smith and Stratton 1986). Repellents can be used with pesticides to deter golden eagle prey species from treated areas (Blus et al. 1989). If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A for contacts to assist in assessing the use of chemicals and their alternatives.

From collection and clinical analysis of dead or dying golden eagles, toxic lead poisoning has been recently identified as a potential source of adult golden eagle mortality in eastern Washington (J. Watson, personal observation). Craig et al. (1990) and Craig and Craig (1995) found elevated levels of lead in golden eagles in southern Idaho and believed this may be a more serious problem than previously thought. The source of contamination is under investigation. If bullet fragments and lead shot prove to be the source of contamination, hunter removal of carcasses and gut piles from the field, or conversion to the now widely available and ballistically comparable non-toxic ammunition (e.g., tungsten-alloy shot, solid copper bullets) might substantially reduce lead exposure (G. Hunt, personal communication).

REFERENCES

Avian Power Line Interaction Committee. 1996. Suggested practices for raptor protection on power lines: the state of the art in 1996. Edison Electric Institute/Raptor Research Foundation, Washington D.C.

Andersen, D. E. 1991. Management of North American grasslands for raptors. Pages 203-210 *in* B. Giron Pendleton and D. L. Krahe, editors. Midwest Raptor Management Symposium and Workshop. National. Wildlife Federation, Washington D.C.

Anderson, R. J., and A. M. Bruce. 1980. A comparison of selected bald and golden eagle nests in western Washington. Pages 117-120 *in* R. L. Knight, editor. Proceedings of the Washington Bald Eagle Symposium, Washington Department of Game, Seattle, Washington, USA.

Balcom, R. 1983. Secondary poisoning of red-shouldered hawks with carbofuran. Journal of Wildlife Management 47:1129-1132.

Bates, J. W., and M. O. Moretti. 1994. Golden eagle *(Aquila chrysaetos)* population ecology in eastern Utah. Great Basin Naturalist 54:248-255.

Beebe, F. L. 1974. Field studies of Falconiformes (Vultures, Eagles, Hawks, and Falcons) of British Columbia. British Columbia Provincial Museum, Victoria, British Columbia, Canada.

Beecham, J. J., and M. N. Kochert. 1975. Breeding biology of the golden eagle in southwestern Idaho. Wilson Bulletin 87:506-513.

Besser, J. F., and J. F. Welch. 1959. Chemical repellents for the control of mammal damage to plants. Transactions of the North American Wildlife Conference 24:166-173

Blus, L. J., C. S. Staley, C. J. Henny, G. W. Pendleton, E. H. Craig, and D. K. Halford. 1989. Effects of organophosphorous insecticides on sage grouse in southeastern Idaho. Journal of Wildlife Management. 53:1139-1146.

Brown, A. W. A. 1978. Ecology of pesticides. John Wiley & Sons, New York, New York, USA.

Bruce, A. M., R. J. Anderson, and G. T. Allen. 1982. Observation of golden eagles nesting in western Washington. Raptor Research 16:132-134.

Cardinell, H. A. 1958. An effective repellent for European hares in Brazil. Journal of Wildlife Management 22:435-436.

Carlson, L., G. Geupel, J. Kjelmyr, J. MacIvor, M. Morton, and N. Shishido. 1980. Geographic range, habitat requirements and a preliminary population study of *Spermophilus washingtoni*. Final Technical Report, National Science Foundation Student Originated Studies Program.

Craig, E. H., and T. H. Craig. 1995. Lead levels in golden eagles in southeastern Idaho. Journal of Raptor Research 29:54-55.

Craig, T. H., J. W. Connelly, E. H. Craig, T. L. Parker. 1990. Lead concentrations in golden and bald eagles. Wilson Bulletin 102:130-133.

De Smet, K. D. 1987. Status report on the golden eagle (*Aquila chrysaetos*). Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario, Canada.

Eaton, R. L. 1976. Golden eagle. Pages 82-118 *in* J. D. Brittell, J. David, J. M. Brown, R. L. Eaton, and C. A. Starika, editors. Marine Shoreline Fauna of Washington Vol. II. Washington Department of Game and Washington Department of Ecology, Olympia, Washington, USA.

Franson, J. C., L. Sileo, and N. J. Thomas. 1995. Causes of eagle deaths. Page 68 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C., USA.

Grue, C. E., L. R. DeWeese, P. Mineau, G. A. Swanson, J. R. Foster, P. M. Arnold, J. N. Huckins, P .J. Sheehan, W. K. Marshall, and A. P. Ludden. 1986. Potential impacts of agricultural chemicals on waterfowl and other wildlife inhabiting prairie wetlands: an evaluation of research needs and approaches. Transactions of the North American Wildlife and Natural Resource Conference 51:357-383.

____, W. J. Fleming, D. G. Busby, and E. F. Hill. 1983. Assessing hazards of organophosphate pesticides to wildlife. Transactions of the North American Wildlife and Natural Resource Conference 48:200-220.

Harlow, D. L., and P. H. Bloom. 1989. Buteos and the golden eagle. Pages 102-110 *in* Proceedings of the Western Raptor Management Symposium and Workshop. National Wildlife Federation, Washington, D.C.

Harness, R. E., and K. R. Wilson. 2001. Electric-utility structures associated with raptor electrocutions in rural areas. Wildlife Society Bulletin 29: 612-623.

Holmes, T. L., R. L. Knight, L. Stegall, and G. R. Craig. 1993. Responses of wintering grassland raptors to human disturbance. Wildlife Society Bulletin 21:461-468.

Hooper, M. J., P. J. Detrich, C .P. Weisskopf, and B. W. Wilson. 1989. Organophosphorous insecticide exposure in hawks inhabiting orchards during winter dormant spraying. Bulletin of Environmental Contaminant Toxicology 42:651-659.

Hoover, S. 2002. Response of red-tailed hawks and golden eagles to topographical features, weather, and abundance of a dominant prey species at the Altamont Pass Wind Resource Area, California: April 1999-December 2000. National Renewable Energy Laboratory, Golden, Colorado, USA.

Hunt, W.G., R.E. Jackman, T.L. Brown, D.E. Driscoll and L. Culp. 1997. A population study of golden eagles in the Altamont Pass Wind Resource Area; second-year progress report. Predatory Bird Research Center, Long Marine Laboratory, University of California, Santa Cruz, California, USA.

Kingsbury, P. D. 1975. Effects of aerial forest spraying on aquatic fauna. *in* M. L. Prebble, editor. Aerial control of forest insects in Canada. Ministry of the Environment, Ottawa, Ontario, Canada.

Knick, S. T., and J. T. Rotenberry. 1995. Landscape characteristics of fragmented shrub-steppe habitats and breeding passerine birds. Conservation Biology 9:1059-1071.

Knight, R. L., J. B. Athearn, J. J. Brueggeman, and A. W. Erickson. 1979. Observations on wintering bald and golden eagles on the Columbia River, Washington. The Murrelet 60:99-105.

Kochert, M. N. 1989. Responses of raptors to livestock grazing in the western United States. Pages 194-203 *in* Proceedings of the Western Raptor Management Symposium. National Wildlife Federation, Washington, D.C.

____, and K. Steenhof. 2002. Golden eagles in the U.S. and Canada: status, trends, and conservation challenges. Journal of Raptor Research 36:32-40.

____, ____, L. B. Carpenter, and J. M. Marzluff. 1999. Effects of fire on golden eagle territory occupancy and reproductive success. Journal of Wildlife Management 63:773-780.

____, ____, C. L. McIntyre, and E. H. Craig. 2002. Golden eagle (*Aquila chrysaetos*). No. 684 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Larrison, E. J., and K. G. Sonnenberg. 1968. Washington birds: their location and identification. Seattle Audubon Society, Seattle, Washington, USA.

Leptich, D. J. 1994. Agricultural development and its influence on raptors in southern Idaho. Northwest Science 68:167-171.

Marr, N. V., and R. L. Knight. 1983. Food habits of golden eagles in eastern Washington. Murrelet 64:73-77.
Marzluff, J. M., S. T. Knick, M. S. Vekasy, L. S. Schueck, and T. J. Zarriello. 1997. Spatial use and habitat selection of golden eagles in southwestern Idaho. Auk 114:673-687.
McEwen, L. C., C. E. Knittle, and M. L. Richmond. 1972. Wildlife effects from grasshopper insecticides sprayed on short-grass range. Journal of Range Management 25:188-194.
McGahan, J. 1967. Quantified estimates of predation by a golden eagle population. Journal of Wildlife Management 31:496-501.
McIntyre, C. L. 2002. Patterns in nesting area occupancy and reproductive success of golden eagles (Aquila chrysaetos) in Denali National Park and Preserve, Alaska, 1988-99. Journal of Raptor Research 36:50-54.
Menkens, G. E., Jr., and S. H. Anderson. 1987. Nest site characteristics of a predominantly tree-nesting population of golden eagles. Journal of Field Ornithology 58:22-25.

Mersmann, T. J., and J. D. Fraser. 1990. Management of raptor foraging habitat in the southeast. Proceedings of the southeast raptor management symposium and workshop. National Wildlife Federation Science and Technical Series Number 14. Baltimore, Maryland, USA.
Murphy, J. R. 1977. Status of eagle populations in the western United States. *In* R. D. Chancellor, editor, Proceedings of the World Conference on Birds of Prey, Vienna, Austria.
Olendorff, R. R. 1976. The food habits of North American golden eagles. American Midland Naturalist 95:231-236.
____, and J. W. Stoddard, Jr. 1974. The potential for management of raptor populations in western grasslands. Pages 47-88 *in* F. N. Hamerston, Jr., B. E. Harrell, and R. R. Olendorff, editors. Management of raptors. Raptor Research Foundations Raptor Research Report Number 2, Vermillion, SD, USA.
Payne, N. J., B. V. Helson, K. M. S. Sundaram, and R. A. Flemming. 1988. Estimating buffer zone widths for pesticide applications. Pesticide Science 24:147-161.
Phillips, R. 1986. Current issues concerning management of golden eagles in western U.S.A. Denver Wildlife Research Center, U.S. Fish and Wildlife Service Birds of Prey Bulletin Number 3, Sheridan, Wyoming, USA.
____, T. P. McEneaney, and A. E. Beske. 1984. Population densities of breeding golden eagles in Wyoming. Wildlife Society Bulletin 12:269-273.
Richardson, S.A., A.E. Potter, K.L. Lehmkuhl, R. Mazaika, M.E. McFadzen, and R. Estes. 2001. Prey of ferruginous hawks breeding in Washington. Northwestern Naturalist. 82:58-64.
Robinson, S. K. 1991. Effects of habitat fragmentation on Midwestern raptors. Pages 195-202 *in* B. Giron Pendleton and D. L. Krahe, editors. Midwest Raptor Management Symposium and Workshop. National Wildlife Federation, Washington D.C.
Smith, G. J. 1987. Pesticide use and toxicology in relation to wildlife: organophosphorus and carbamate compounds. U.S. Fish and Wildlife Service Research. Publication Number 170, Washington, D.C.
Smith, T. M., and G. W. Stratton. 1986. Effects of synthetic pyrethroid insecticides on nontarget organisms. Residue Reviews 97:93-120.
Snow, C. 1973. Golden eagle. Habitat Management Series for unique or endangered species. Bureau of Land Management Technical Report Number 7. Denver, Colorado, USA.
Steenhof, K., and M. N. Kochert. 1988. Dietary responses of three raptor species to changing prey densities in a natural environment. Journal of Animal Ecology 57-37-48.
____, ____, and T. L. McDonald. 1997. Interactive effects of prey and weather on golden eagle reproduction. Journal of Animal Ecology 66:350-362.
Suter, G. W., and J. L. Joness. 1981. Criteria for golden eagle, ferruginous hawk, and prairie falcon nest site protection. Journal of Raptor Research 15:12-18.
Wingfield, G. A. 1991. Central plains buteos and golden eagle. Pages 60-68 *in* B. G. Pendleton and D. L. Krahe, editors. Midwest Raptor Management Symposium and Workshop. National Wildlife Federation, Washington D. C.
Yensen, E., and P. W. Sherman. 2003. Ground-dwelling squirrels of the Pacific Northwest. U.S. Fish and Wildlife Service, Boise, Idaho, USA.
Young, L. S. 1989. Effects of agriculture on raptors in the western U.S. Pages 209-218 *in* Proceedings of the Western Raptor Management Symposium and Workshop. National Wildlife Federation, Washington, D.C.

PERSONAL COMMUNICATIONS

Ron Friesz, Wildlife Biologist
Washington Department of Fish and Wildlife
Ephrata, Washington

Karen Steenhof, Wildlife Research Biologist
U.S. Geological Survey, Biological Resource Division
Forest and Rangeland Ecosystem Science Center
Snake River Field Station
Boise, Idaho

Grainger Hunt, Senior Scientist
Peregrine Fund
McArthur, California

Steve Zender, District Wildlife Biologist
Washington Department of Fish and Wildlife
Chewelah, Washington

KEY POINTS

Habitat Requirements

- Commonly associated with open, arid plateaus deeply cut by streams and canyons, western shrub-steppe and grassland communities and transition zones between shrub, grassland and forested habitat. Nests usually located on cliffs and trees.
- Use the same territory annually, but have an average of 2-3 alternative nests used in different years.
- Although yellow-bellied marmots are the most important prey of nesting golden eagles, jackrabbits and ground squirrels were probably the most significant historical prey for eagles in the Northwest.
- Carrion is important prey during the fall and winter.
- Home range size, size of core areas, and travel distances can vary dramatically based on habitat composition, potential prey abundance, and individual preferences.

Management Recommendations

- Manage golden eagle habitat to improve native vegetation and maintain native prey populations
- Restore severely damaged grassland (e.g., non-shrub) habitat with controlled burning or chaining of trees and invasive shrubs, followed by reseeding with native grasses.
- Preserve shrub-dominated habitat (i.e., sagebrush) within 3 km (1.9 mi) of golden eagle nests and avoid practices that remove shrub cover (i.e., chaining or burning).
- Avoid new development and human activities near nest sites (especially between 15 February and 15 July).
- Designate spatial buffer areas to protect nests and juvenile eagles.
- Construct or modify power lines and poles so birds cannot make simultaneous contact between any two items of conductive equipment and avoid construction of multiple-phase transformers.
- Avoid rodent control within eagle foraging areas.
- Avoid using organochlorine, organophosphate, and carbamate insecticides in eagle habitat and prey concentration areas.

Bald Eagle

IMPORTANT MESSAGE

May 2011

The Washington Fish and Wildlife Commission amended the bald eagle protection rules (WAC 232-12-292), removing the requirement that landowners develop bald eagle management plans. This decision was mainly the result of the species' recovery and its downlisting to Sensitive status in Washington state. If at any point the bald eagle is listed as an endangered or threatened species (federally or by Washington state), the requirement to develop a management plan will be restored.

The Department removed the bald eagle chapter from this publication because it was specifically written to provide guidance on developing bald eagle management plans. Now that the state no longer requires a plan, the responsibility for bald eagle management has shifted from the Washington Department of Fish and Wildlife to the U.S. Fish and Wildlife Service (USFWS).

For information about federal requirements and guidelines, please go the USFWS Pacific Region's bald eagle website at http://www.fws.gov/pacific/eagle/.

Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; http://www.royalbcmuseum.bc.ca/

Prairie Falcon

Falco mexicanus

Last updated: 1999

Written by David W. Hays and Frederick C. Dobler

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The breeding range of the prairie falcon extends southward from central British Columbia through much of the western United States (Snow 1974), and reaches as far south as San Luis Potosi in northern Mexico (Lanning and Hitchcock 1991).

Prairie falcons winter throughout their breeding range, as far south as central Mexico and as far east as the Mississippi River (American Ornithologists' Union 1957).

Figure 1. General breeding range of the prairie falcon, *Falco mexicanus*, in Washington

In Washington, prairie falcons have been known to breed in all central and eastern counties except Pend Oreille County (see Figure 1; Parker 1972). Prairie falcons winter throughout their breeding range in Washington, but the largest wintering populations are found in the central Columbia Basin (Grant, Adams, Franklin, Walla Walla, and Benton counties). Reports of prairie falcons wintering in western Washington have also been reported (Decker and Bowles 1930, F. Dobler, unpublished data).

RATIONALE

Prairie falcons are of recreational importance in Washington, and are vulnerable to habitat loss and degradation. Prairie falcons nest on cliffs, and depend on steppe and shrub-steppe habitats that support abundant prey. There is a limited number of suitable cliffs in Washington, and steppe and shrub-steppe ecosystems in this state are rapidly being converted to agriculture. Human habitation close to cliffs limits their use by prairie falcons, as do agricultural practices that reduce available prey.

HABITAT REQUIREMENTS

Prairie falcons inhabit the arid environments of eastern Washington and nest on cliffs usually associated with native steppe and shrub-steppe habitat (Denton 1975). Often this habitat is intermixed with agricultural lands (Denton 1975). Typically, the landscape is treeless, but its edges include shrub-land that may contain a few conifers. Prairie falcon habitat in Washington does not differ markedly from other areas described in the literature (Fowler 1931, Skinner 1938, Enderson 1964, Denton 1975).

Prairie falcons use a wide variety of cliffs. Along the Columbia, Snake, and Yakima rivers, they commonly nest on basalt cliffs up to 122 m (400 ft) tall. They also use scant escarpments raised only 6 m (20 ft) above sloping canyon walls. In North Dakota, Allen (1987) found prairie falcons using cliffs ranging from 3-35 m (10-115 ft) tall, with a mean of 11 m (36 ft), and 5-500 m (16-1,649 ft) in length, with a mean of 103 m (338 ft). In Mexico, Lanning and Hitchcock (1991) found the range of cliff heights used by prairie falcons to be between 25 m and 130 m (92-427 ft) tall, with a mean of 65 m (213 ft). Runde and Anderson (1986), summarized data from 8 studies on prairie falcons, and reported a combined cliff height range of 2-154 m (6.5-505 ft), with a mean of 29 m (95 ft). They also summarized the aspect of the cliff lines, and reported that although prairie falcons may use cliffs facing any aspect, they tend to use cliffs with a southerly aspect.

Nest sites are often on a sheltered ledge or in a pothole in the cliff. Runde and Anderson (1986) found that 97% of their sites in Wyoming had overhead protection. Other studies (Enderson 1964, Leedy 1972, Platt 1974, Ogden and Hornocker 1977) generally found this same trend. Use of abandoned stick nests built by other raptors (particularly golden eagle [*Aquila chrysaetos*] or raven [*Corvus corvus*]) is well documented (Decker and Bowles 1930, Bent 1938, Williams 1942, Webster 1944, Enderson 1964, Brown and Amadon 1968, Hickman 1971). Use of artificial nests by prairie falcons has been documented in North Dakota, but long-term successful nesting was limited (Mayer and Licht 1995).

In Oregon, Denton (1975) found that most nest sites were located at elevations between 60 and 2530 m (200-8300 ft), in habitats typified by undulating topography and moderately xeric vegetation. This was comprised of juniper (*Juniperus* spp.), big sagebrush (*Artemisia tridentata*), and bunchgrass (*Agropyron spicatum* and *Festuca idahoensis*) associations, which were sometimes degraded where cheatgrass (*Bromus tectorum*) replaced native grasses. He also reported that of 63 nest sites, 76% were within 400 m (0.25 mi) of a water source, 32% bordered agricultural land, 62% were within 800 m (0.5 mi) of a road, but only 15% were within 800 m (0.5 mi) of human habitation.

Foraging territories surround prairie falcon nest sites, and studies have reported a wide variety of home range sizes during the breeding season. In Idaho, home range size varied between 26-142 km^2 (10-55 mi^2) (U. S. Bureau of Land Management 1979), in Southern California between 31-78 km^2 (12-30 mi^2) (Harmata et al. 1978), and in Northern California between 34-389 km^2 (13-150 mi^2) (Haak 1982). Squires et al. (1993) found that prairie falcons typically foraged within 10 km (6 mi) of nest sites during the breeding season, and that habitats closer to nesting sites were preferred. Males had the larger home ranges and traveled greater distances from their nests while hunting than did females.

Prairie falcons forage on a variety of prey, including birds and small mammals. Prey abundance largely determines diet composition. Some studies have found that prairie falcons foraged primarily on mammalian prey (Ogden and Hornocker 1977), whereas others found that avian prey predominated (Marti and Braun 1975, Becker 1979, Boyce 1985). In Wyoming, thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) were found in 91% of pellets analyzed, western meadowlark (*Sturnella neglecta*) in 56%, and horned lark (*Eremophila alpestris*) in 23% (Squires et al. 1989). In Idaho, Townsend's ground squirrels (*S. townsendii*) were prey items in at least 98% of the aeries, with western meadowlark and horned lark present in 13% and 22%, respectively (Ogden and Hornocker 1977). Steenhof and Kochert (1988) found ground squirrels to be the primary prey during the breeding season in Idaho's Snake River Birds of Prey Natural Area.

Less is known about prairie falcon food habits during winter, though small mammals and birds continue to play a major role. Horned larks are the main food for prairie falcons in winter wheat areas (Snow 1974, Beauvais and Enderson 1992) and in the Snake River Birds of Prey Natural Area (Prokop 1995). Wintering prairie falcons have also been observed hunting microtine rodents in harvested hay fields and chasing upland game birds and rock doves (Beauvais and Enderson 1992). The home range size in winter is less than what is reported for the nesting season, ranging between 12-68 km^2 (4.6-26 mi^2) (Beauvais and Enderson 1992). Prokop (1995) reported that home range size did not vary between sexes in winter.

LIMITING FACTORS

In Washington, prairie falcons are limited by the availability of cliffs suitable for nesting that are adjacent to steppe and shrub-steppe habitats (Denton 1975). Prey abundance within their home ranges also limits prairie falcons. Ground squirrels, western meadowlarks (*Sturnella neglecta*), and horned larks (*Eremophila alpestris*) are important prey (Marti and Braun 1975, Ogden and Hornocker 1977, Becker 1979, Boyce 1985). Human habitation near nesting cliffs limits prairie falcon use, as do agricultural practices that reduce available prey (Denton 1975). In winter, the availability of avian prey, particularly horned larks, is important to the survival of resident prairie falcons (Snow 1974).

MANAGEMENT RECOMMENDATIONS

Homes and other sources of human activity should be placed no closer than 805m (2640 ft) from prairie falcon nest sites (Denton 1975). Prairie falcons commonly occur where human habitation is absent. As difficult as it may be to protect existing nest sites, creating new sites suitable for continued, long-term use may be even more difficult (Mayer and Licht 1995).

Native steppe and shrub-steppe habitats should be maintained near prairie falcon nesting sites to ensure falcon survival and nesting success. These habitats are important for maintaining populations of the prairie falcons' prey. Studies of shrub-steppe in Washington indicate that the western meadowlark and the horned lark are the most common shrub-steppe birds (Dobler 1996). They are also the 2 most common bird species in prairie falcon diets (Squires et al. 1989). In addition, *Spermophilus* ground squirrels are commonly associated with native steppe and shrub-steppe habitats, and they also make up a significant portion of the prairie falcon's diet (Ogden and Hornocker 1977, Steenhof and Kochert 1988).

Widespread rodent control should not occur within prairie falcon foraging areas, because ground squirrels are common prey items, and foraging prairie falcons may depend on food located a great distance from the nest (Haak 1982). The foraging area is approximated by using the dimensions of the home range, which can be as large as 389 km^2 (150 mi) (Haak 1982). If rodenticides or other chemical treatments are planned for areas where prairie falcons exist, refer to Appendix A for contacts that can assist in assessing chemical treatments and their alternatives.

REFERENCES

Allen, G. T. 1987. Prairie falcon aerie site characteristics and aerie use in North Dakota. Condor 89:187-190.

American Ornithologists Union. 1957. The American Ornithologists' Union Checklist of North American birds. Lord Baltimore Press, Baltimore, Maryland, USA.

Beauvais, G., and J. E. Enderson. 1992. Home range, habitat use and behavior of prairie falcons wintering in east-central Colorado. Journal of Raptor Research 26:13-18.

Brown, L., and D. Amadon. 1968. Eagles, hawks and falcons of the world. McGraw-Hill, New York, New York, USA.

Becker, D. M. 1979. A survey of raptors on national forest land in Carter County, Montana. USDA Forest Service Final Report, 1977-79.

Bent, A. C. 1938. Life histories of North American birds of prey. Part 2. Orders Falconiformes and Strigiformes. Smithsonian Institution, U.S. National Museum Bulletin 170.

Boyce, D. A. Jr. 1985. Prairie falcon prey in the Mohave Desert, California. Raptor Research 19:128-134.

Decker, F. R., and J. H. Bowles. 1930. The prairie falcon in the state of Washington. Auk 47:25-31.

Denton, S. J. 1975. Status of prairie falcons breeding in Oregon. Thesis, Oregon State University, Corvallis, Oregon, USA.
Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Research Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Enderson, J. H. 1964. A study of the prairie falcon in the central Rocky Mountain region. Auk 81:332-352.
Fowler, F. H. 1931. Studies of food and growth of the prairie falcon. Condor 33:193-203.
Haak, B. A. 1982. Foraging ecology of prairie falcons in Northern California. Thesis, Oregon State University, Corvallis, Oregon, USA.
Harmata, A. R., J. E. Durr, and H. Geduldig. 1978. Home range, activity patterns, and habitat use of prairie falcon nesting in the Mohave Desert. U.S. Bureau of Land Management Report, Contract YA-512-ct8-43.
Hickman, G. L. 1971. Prairie falcons and red-tailed hawks rearing young in inactive golden eagle nests. Condor 73:490.
Lanning, D. V., and M. A. Hitchcock. 1991. Breeding distribution and habitat of prairie falcons in northern Mexico. Condor 93:762-765
Leedy, R. R. 1972. Status of the prairie falcon in western Montana: special emphasis on possible effects of chlorinated hydrocarbon insecticides. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana, USA.
Marti, C. P., and C. E. Braun. 1975. Use of tundra habitats by prairie falcons in Colorado. Condor 77:213-214.
Mayer, P. M., and D. S. Licht. 1995. Persistance and use of artificial prairie falcon aeries in North Dakota. Wildlife Society Bulletin 23:532-534.
Ogden, V. T., and M. G. Hornocker. 1977. Nesting density and success of Prairie Falcons in southwestern Idaho. Journal of Wildlife Management 41:1-11.
Parker, R. C. 1972. Prairie falcon management in Washington state. Unpublished Report, Washington Department of Game, Olympia, Washington, USA.
Platt, S. W. 1974. Breeding status of the prairie falcon in northern New Mexico. Thesis, Oklahoma State University, Stillwater, Oklahoma, USA.
Prokop, R. S. 1995. Wintering ecology of prairie falcons in the Snake River Birds of Prey National Conservation Area. Journal of Raptor Research 29:64-65.
Runde, D. E., and S. H. Anderson. 1986. Characteristics of cliffs and nest sites used by breeding prairie falcons. Raptor Research 20: 21-28.
Skinner, M. P. 1938. Prairie falcon. Pages 18-42 *in* A. C. Bent, editor. Life histories of North American birds of prey. Part 2. Smithsonian Institution, U. S. National Museum Bulletin 170.
Snow, C. R. 1974. Habitat management series for unique or endangered Species. Prairie falcon. U.S. Bureau of Land Management, Technical Note 8.
Squires, J. R., S. H. Anderson, and R. Oakleaf. 1989. Food habits of nesting prairie falcons in Campbell County, Wyoming. Journal of Raptor Research 23:157-161.
____, ____, and ____. 1993. Home range size and habitat-use patterns of nesting prairie falcons near oil developments in northeastern Wyoming. Journal of Field Ornithology. 62:191-194.
Steenhof, K., and M. N. Kochert. 1988. Dietary responses of three raptor species to changing prey densities in a natural environment. Journal of Animal Ecology 57:37-48.
United States Bureau of Land Management. 1979. Snake River birds of prey special research report to the Secretary of Interior. U.S. Bureau of Land Management, Boise, Idaho, USA.
Webster, H. Jr. 1944. A survey of the prairie falcon in Colorado. Auk 61:609-616.
Williams, R. B. 1942. Notes on the prairie falcon. Wyoming Wildlife 7:12-15.

KEY POINTS

Habitat Requirements

- Prairie falcons inhabit the arid environments of eastern Washington, nesting on cliffs in arid steppe and shrub-steppe habitat.
- Prairie falcons use a wide variety of cliffs, from those made of basalt that are 122 m (400 ft) tall to scant escarpments raised only 6 m (20 ft) above sloping canyon walls.

- Nest sites are often on a sheltered ledge or in a pothole in the cliff, and prairie falcons often use abandoned stick nests built by other raptors.
- Most nest sites are located over 800 m (.5 mi) from human habitation.
- Most nests occur within one-quarter mile of water.
- Prairie falcon nest sites are located within foraging territories. Breeding home range can be as large as 389 km^2 (150 mi^2).
- Prairie falcons forage on a variety prey common to shrub-steppe environments. Ground squirrels (*Spermophilus* spp.), western meadowlarks and horned larks are primary prey items during the breeding season.

Management Recommendations

- Human habitation limits the use of nesting cliffs and should not occur within 800 m (0.5 mi) of known nests.
- Steppe and shrub-steppe habitats should be maintained within the range of prairie falcons to provide a sufficient prey base.
- Widespread control of ground squirrels and other rodents should be limited to areas outside of prairie falcon foraging areas. If rodenticides or other chemical treatments are being considered in areas with prairie falcons, refer to Appendix A for contacts useful when assessing chemical treatments and their alternatives.

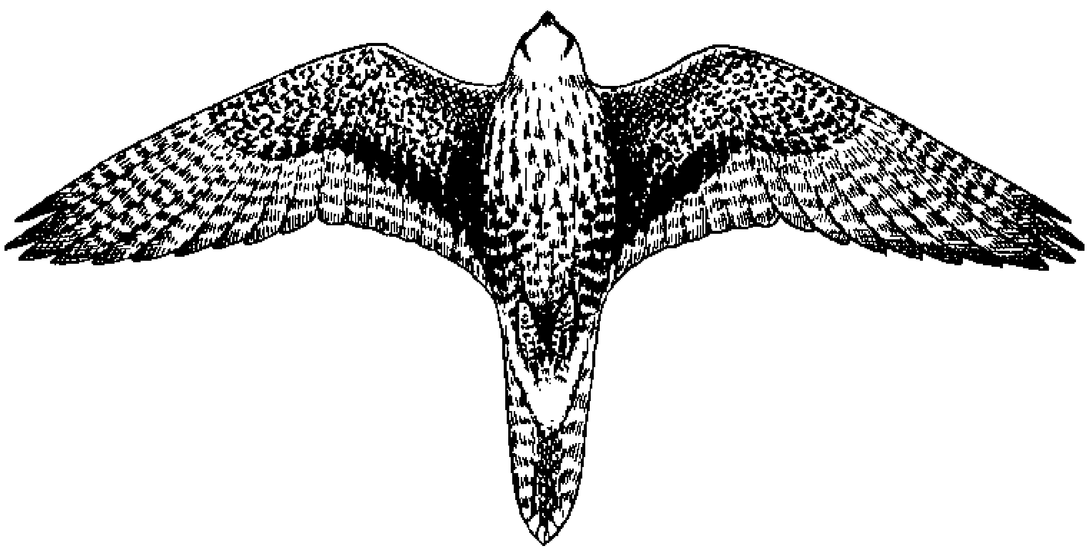


Illustration by Frank L. Beebe; used with permission of Royal British Columbia Museum; http://www.royalbcmuseum.bc.ca/

Peregrine Falcon removed from Priority Habitat and Species list in 2016

Illustrations by Frank L. Beebe; used with permission of Royal British Columbia Museum; http://royalbcmuseum.bc.ca/

Peregrine Falcon

Falco peregrinus

Last updated: 1999

Written by David W. Hays and Ruth L. Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Peregrine falcons occur nearly worldwide. In Washington, nesting may occur in all but the driest parts of the state (see Figure 1). Naturally occurring breeding sites are verified along the outer coast, in the San Juan Islands, and in the Columbia Gorge. Young birds have been introduced in unoccupied historical habitat in Skamania, Lewis, Spokane, Asotin, and Yakima counties.

Figure 1. Washington distribution of the peregrine falcon, *Falco peregrinus.* Dark shading indicates breeding areas. Light shading indicates wintering areas. Map derived from Washington Department of Fish and Wildlife data files.

RATIONALE

The peregrine falcon is a State Endangered[1] species. Peregrine falcon populations have increased in Washington since chlorinated hydrocarbon pesticides were banned in the United States, and through the success of reintroduction programs. Their numbers and distribution are still limited however, due primarily to the lingering effects of pesticides and the lack of suitable nesting sites. Nest sites need to be in close proximity to adequate food sources and free from human disturbance.

HABITAT REQUIREMENTS

Peregrine falcons usually nest on cliffs, typically 45 m (150 ft) or more in height. They will also nest on off-shore islands and ledges on vegetated slopes. Eggs are laid and young are reared in small caves or on ledges. Nest sites are generally near water. The birds are sensitive to disturbance during all phases of the nesting season (1 March through 30 June) (Pacific Coast American Peregrine Falcon Recovery Team 1982, Towry 1987). Disturbance can cause desertion of eggs or young, and later in the breeding season can cause older nestlings to fledge prematurely.

Peregrines feed on a variety of smaller birds that are usually captured on-the-wing. Hunting territories may extend to a radius of 19-24 km (12-15 mi) from nest sites (Towry 1987).

[1] On April 12, 2002, the Washington Fish and Wildlife Commission downlisted the species from endangered to sensitive

In winter and fall, peregrines spend much of their time foraging in areas with large shorebird or waterfowl concentrations, especially in coastal areas (Dekker 1995). At least 3 western Washington areas support significant numbers of winter resident peregrines annually: the Samish Flats, Grays Harbor, and the Sequim area (Dobler 1989).

LIMITING FACTORS

Peregrine falcon populations declined worldwide as a result of sublethal doses of chlorinated hydrocarbon pesticides, especially DDT and dieldrin. Chemical contamination of the prey base resulted in reduced eggshell thickness, and consequently poor hatching success and survival of young peregrines (Snow 1972). Although these chemicals are now banned in the United States, eggshell thinning and other effects of pesticide contamination are still seen in some peregrine pairs (Peakall and Kiff 1988). Contamination probably results from consuming prey species that winter in countries that continue to use DDT and other organochlorine pesticides, from persistent pesticide residue remaining at the breeding grounds, or from current, illegal use of these chemicals in the United States (Henny et al. 1982, Stone and Okoniewski 1988).

Additionally, peregrines may be limited in some parts of their range by availability of nesting sites in proximity to an adequate food source.

MANAGEMENT RECOMMENDATIONS

Breeding peregrine falcons are most likely to be disturbed by activities taking place above their nest (eyrie) (Herbert and Herbert 1969, Ellis 1982). Ellis (1982) recommended buffer zones of "no human activity" around peregrine falcon breeding sites in Arizona that ranged from 0.8 km to 4.8 km (0.5-3.0 mi), with wider buffer zones recommended for activities above the breeding cliff. These buffer distances were based on incidental observations of peregrine responses to various disturbances. In Washington, buffer zones of 4.8 km (3.0 mi) may not be necessary. However, human access along the cliff rim should be restricted within 0.8 km (0.5 mi) of the nest from March through the end of June (F. Dobler, personal communication). Human activities on the face of, or immediately below, nest cliffs should be restricted from 0.4-0.8 km (0.25-0.5 mi) of the nest during this time (F. Dobler, personal communication). Where falcon nests are already established in proximity to humans there is no need to eliminate trails, picnic grounds, or other facilities except where the birds are evidently disturbed by the human activities. However, further facilities should not be established within 0.4-0.8 km (0.25-0.5 mi) of the eyries (Ellis 1982). Cliff tops above the eyrie should remain undeveloped.

Ellis (1982) suggested that logging be curtailed within 1.6 km (1 mi) of occupied peregrine eyries in Arizona. In Washington, forest practices are reviewed by the Department of Fish and Wildlife when occurring within 0.4 km (0.25 mi) of an eyrie during any season, and within 0.8 km (0.5 mi) of an occupied eyrie during the breeding season (Washington Administrative Code 222-16-080, 1,f).

Eyries occurring within non-forested lands, and those eyries not subjected to forest practices or forest practice rules, should be similarly considered through the development of a site specific peregrine management plan when activities near nests are considered. Male peregrines require perches within sight of the eyrie. Preserve all major perches around the nest and on ridges or plateaus above the nest by retaining all snags and large trees (F. Dobler, personal communication).

Aircraft should not approach closer than 500 m (1,640 ft) above a nest (Fyfe and Olendorff 1976). Closer approaches may cause peregrines to attack planes or may cause a frantic departure from the nest. Falcons startled from the eyrie have been known to damage eggs or nestlings (Nelson 1970).

Powerlines and other wires may be serious hazards to peregrine falcons. Wherever possible, powerlines should be routed away from eyries (Olsen and Olsen 1980).

Applications of pesticides that could potentially affect passerine birds should be avoided around occupied peregrine eyries during the breeding season. Some chemicals such as organochlorines, organophosphates, strychnine, and carbofuran can impact birds by causing toxicosis or death, or by contaminating their tissues. Other pesticides may be less toxic to birds, but will increase mortality of young passerines by directly reducing their food supply, thus indirectly reducing the prey available to peregrines (Driver 1991). Reduced or contaminated food sources will negatively affect peregrine falcons. Appendix A provides useful contacts to help assess the use of pesticides, herbicides, and their alternatives.

Wetlands, especially intertidal mudflats, estuaries, and coastal marshes, are key feeding areas in winter. Wetlands used regularly by peregrine falcons at any time of the year should receive strict protection from filling, development, or other excessive disturbances that could alter prey abundance. Do not apply pesticides to areas where winter prey species congregate. Lead shot should not be used in waterfowl areas where peregrine falcons feed. Peregrines can tolerate human presence at wintering sites if they are not harassed and if abundant prey remains.

Maintain all large trees and snags in areas where peregrine falcons feed in winter. These perches are important for roosting and for hunting at terrestrial sites. Snags and debris located on mud flats should also be left for winter perching and roosting.

REFERENCES

Dekkar, D. 1995. Prey capture by peregrine falcons wintering on southern Vancouver Island, British Columbia. Journal of Raptor Research 29:26-29.

Dobler, F. C. 1989. Wintering peregrine falcon (*Falco peregrinus*) habitat utilization near Sequim, Washington. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.

Driver, C. J. 1991. Potential impacts of pesticide applications to fish and wildlife in forest environments. Draft Report, Washington Department of Wildlife, Battelle Pacific Northwest Laboratories, Richland, Washington, USA.

Ellis, D. H. 1982. The peregrine falcon in Arizona: Habitat utilization and management recommendations. Institute for Raptor Studies, Research Report Number 1.

Fyfe, R.W., and R. R. Olendorff. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service, Occasional Paper Number 23.

Henny, C. J., F. P. Ward, K. E. Riddle, and R. M. Prouty. 1982. Migratory peregrine falcons, Falco peregrinus, accumulate pesticide in Latin America during winter. Canadian Field Naturalist 96:333-338.

Herbert, R. A., and K. G. S. Herbert. 1969. The extirpation of the Hudson River peregrine falcon population. Pages 133-154 *in* J. J. Hickery, editor. Peregrine falcon populations: their biology and decline. University Wisconsin Press, Madison, Wisconsin, USA.

Towry, R. K. 1987. Wildlife habitat requirements. Pages 73-210 *in* R. L. Hoover and D. L. Wills, editors. Managing Forested Lands for Wildlife. Colorado Division of Wildlife, Denver, Colorado, USA.

Nelson, R. W. 1970. Some aspect of the breeding behavior of peregrine falcons on Langara Island, B.C. Thesis, University of Calgary, Calgary, Alberta, Canada.

Olsen, J., and P. Olsen. 1980. Alleviating the impacts of human disturbance on the breeding peregrine falcon: Public and recreational lands. Corella 4:54-57.

Pacific Coast American Peregrine Falcon Recovery Team. 1982. Pacific Coast recovery plan for the American peregrine falcon, Falco peregrinus anatum. U.S. Fish and Wildlife Service, Denver, Colorado, USA.

Peakall, D. B., and L. F. Kiff. 1988. DDE Contamination in Peregrines and American Kestrels and its effect on reproduction. Pages 337-350 *in* T. J. Cade, J. E. Enderson, C. G. Thelander and C. M. White, editors. Peregrine Falcon Populations: Their management and recovery. The Peregrine Fund, Boise, Idaho, USA.

Snow, C. 1972. Habitat management series for endangered species, Report Number 1: American peregrine falcon (*Falco peregrinus anatum*) and Arctic peregrine falcon (*Falco peregrinus tundrius*). U.S. Bureau of Land Management Technical Note.

Stone, W. B., and J. C. Okoniewski. 1988. Organochlorine pesticide-related mortalities of raptors and other birds in New York, 1982-1986. Pages 429-438 *in* T. J. Cade, J. E. Enderson, C. G. Thelander and C. M. White, editors. Peregrine Falcon Populations: Their management and recovery. The Peregrine Fund, Boise, Idaho, USA.

Peregrine Falcon removed from Priority Habitat and Species list in 2016

PERSONAL COMMUNICATIONS

Frederick C. Dobler, Area Wildlife Biologist
Washington Department of Fish and Wildlife
Ephrata, Washington

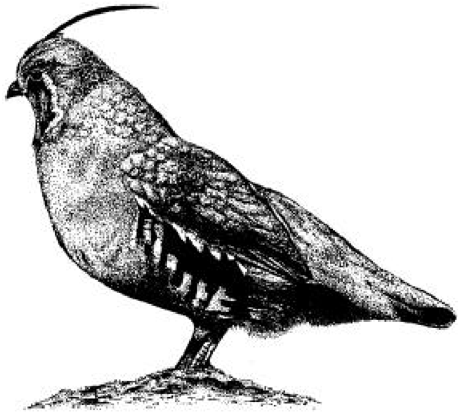
KEY POINTS

Habitat Requirements

- Peregrine falcons nest in cliffs that are 45 m (150 ft) or more in height.
- Peregrines feed on a variety of smaller birds.
- Hunting territories may extend to a radius of 24 km (15 mi) from nest sites.
- These falcons winter along coastal areas with large shorebird or waterfowl concentrations.

Management Recommendations

- Avoid disturbance during the breeding season (March through June); restrict access to cliff rims where nests are built within 0.8 km (0.5 mi) and within 0.4 km (0.25 mi) of cliff faces.
- Avoid forest practices within 0.8 km (0.5 mi) of eyrie cliffs during the breeding season. If logging does occur, retain all trees on top of the cliff ridge.
- Develop site management plans for Eyries when considering land uses outside of forested environments or for non-forest practice activities.
- Preserve all major perches around nests by retaining all snags and large trees.
- Aircraft should not approach closer than 500 m (1,500 ft) above a nest.
- Route powerlines away from eyries.
- Avoid applying pesticides that affect birds near eyries. Refer to Appendix A for contacts useful in assessing pesticides, herbicides, and their alternatives.
- Avoid applying pesticides to areas where winter prey species congregate.
- Do not use lead shot in peregrine winter feeding areas.
- Maintain large trees and snags as perches in winter peregrine feeding localities.



Mountain Quail

Oreortyx pictus

Last updated: 1999

Written by David A. Ware, Michelle Tirhi, and Becky Herbig

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The mountain quail ranges from southwestern British Columbia, through Washington and central Idaho south to the mountainous regions of California, Nevada, and Baja California (American Ornithologists' Union 1983). Mountain quail have been introduced into Alabama, British Columbia, Colorado, Hawaii, Idaho, Montana, Nebraska, Nevada, and Oregon (Heekin 1991). Mountain quail also have been introduced into Washington; however, along the Columbia and Snake rivers there are scattered populations that may be extensions of Oregon flocks (see Figure 1).

Figure 1. Range of the mountain quail, *Oreortyx pictus*, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

The healthiest populations of mountain quail in western Washington appear in Kitsap County (B. Tweit, personal communication). Localized populations also persist in logged areas of Grays Harbor, Thurston, and Mason counties (G. Shirato, personal communication). Incidental sightings have been reported on Fort Lewis, Pierce County (J. Stevenson, personal communication) and in Cowlitz, Jefferson, King, Lewis, Pacific, Pierce, Snohomish, Asotin, Columbia, Garfield, Kittitas, and Klickitat counties (Brennan 1989; Kessler 1990; B. Tweit, personal communication; G. Shirato, personal communication). Scattered sightings have also been reported along the southern portion of Hood Canal and in Skamania County (Hunn and Mattocks 1980), as well as in western Yakima County (L. Stream, personal communication). Many of the localized sightings are thought to be the result of captive flocks being released by hobbyists.

RATIONALE

Mountain quail are uncommon game birds that are at the edge of their range in Washington. Eastern Washington populations are thought to have declined in recent years largely from declining habitat quality. Because of their secretive nature and reliance on brushy habitats that are usually associated with riparian zones, they are not capable of extensive movements away from suitable patches of habitat. Once these habitats are degraded or removed, mountain quail become isolated from other habitat that may be available.

HABITAT REQUIREMENTS

Mountain quail are associated with mixed evergreen-deciduous forests, regenerating clearcuts, forest and meadow edges, chaparral slopes, shrub-steppe, and mixed forest/shrub areas, characteristically in overgrown brushy areas (Johnsgard 1973, American Ornithologists' Union 1983, Brennan 1989, Crawford 1989, Kessler 1990). Tall, dense cover is a requirement for the majority of activities throughout the year (Johnsgard 1973, Gutiérrez 1975) and mountain quail are seldom found far from this cover (Brennan 1993).

In western Washington, mountain quail may be found at sea level in areas cleared for development that contain stands of Scotch broom (*Cytisus scoparius*) and madrone (*Arbutus* spp.) (G. Shirato, personal communication). In arid regions, such as in southeastern Washington, typical habitat consists of deciduous shrub thickets below talus and cliffs, and alder (*Alnus* spp.) thickets along streams (Yocom and Harris 1953, Brennan et al. 1987). In such arid settings, free-flowing water is essential (Ormiston 1966, Leopold 1972, Gutierrez 1975) and mountain quail are often found in close proximity to both water and escape cover (Brennan et al. 1987). Mountain quail commonly inhabit slopes of 20-60% (Miller 1950, Gutiérrez 1980) and have been observed using slopes of 60-110% (P. Heekin, personal communication).

Nesting

In spring, mountain quail seek brush, hardwood, and conifer communities for nesting (R. Gutiérrez, personal communication). Johnsgard (1973) and Kessler (1990) characterized nesting cover as large shrubs and young trees in dense clusters. Nests are typically well concealed and situated beneath roots, brush, grass clumps, bank edges, or at the base of a dead shrub in patches of live shrubs (P. Heekin, personal communication). Miller (1950) reported a mean vegetational height of 0.5 m (1.6 ft) at nest sites. Nests may also be found next to rocks or logs. Some birds nest in their winter range and others move to higher ground, such as forest or farmland edges (Ormiston 1966). In Idaho, nests were located between 713 m and 1,426 m (2,340-4,680 ft) on slopes 60-110% (P. Heekin, personal communication). Nests were situated in relatively open stands of conifer/mountain shrub cover having a fairly dense understory.

Brood Rearing

In mid-summer, mountain quail broods move to the cool, moist bottoms of draws and canyons (Ormiston 1966). Such movements may be related to the availability of preferred foods within the daily cruising range of water (Ormiston 1966, Gutiérrez 1975). In Idaho, broods 2 to 3 weeks old were located in relatively open cover, often on or near game trails (P. Heekin, personal communication).

Winter

In late fall, mountain quail often migrate to lower elevation winter range (Bent 1963, Johnsgard 1973). They winter in brushy thickets, canyons, and along the borders of farms and woodlands (Yocom and Harris 1953) where mixed trees, shrubs, and herbs exist (Kessler 1990). Mountain quail remain below the snow-line, moving up or down in elevation depending on weather conditions (Ormiston 1966). In Idaho, the mean straight-line distance moved from nest site to winter range was 648 m (2,126 ft) (P. Heekin, personal communication).

Loafing and Roosting Cover

Loafing and roosting cover consists of dense vegetation approximately 2-3 m (5-6 ft) in height (Miller 1950). Mountain quail in west-central Idaho have been observed night roosting in hawthorn (*Crataegus* spp.) trees 3-4 m (10-13 ft) above ground level and loafing at the base of dead shrubs (P. Heekin, personal communication).

Escape Cover

Escape cover is typically 1.5-2 m (5-6.5 ft) high with fairly dense growth (Miller 1950). Where this cover type is not available, quail use slopes of 36% or more to escape (Johnsgard 1973). Trees, such as ponderosa pine (*Pinus ponderosa*), firs (*Abies* spp.), and oaks (*Quercus* spp.) may also be important.

Food

Mountain quail feed primarily on vegetable matter (Ormiston 1966, Rue 1973 *in* Heekin 1991); animal matter typically comprises <5% of the diet (J. Crawford, personal communication). Food species for mountain quail include lotus (*Lotus* spp.), smooth sumac (*Rhus glabra*), hackberry (*Celtis* spp.), serviceberry (*Amelanchier* spp.), grape (*Vitis* spp.), gooseberry (*Ribes* spp.), elderberry (*Sambucus* spp.), snowberry (*Symphoricarpos* spp.), manzanitas (*Arctostaphylos* spp.), nightshade (*Solanum* spp.), chickweed (*Stellaria* spp.), blue-eyed Mary (*Collinsia* spp.), hawthorn (*Crataegus* spp.), sweet clover (*Trifolium* spp.), thistle (*Cirsium* spp.), ragweed (*Ambrosia* spp.), teasel (*Dipsacus* spp.), scotchbroom, fringecup (*Lithophragma* spp.), composite seeds (*Madia* spp.), poison oak (*Rhus diversoloba*), geranium (*Geranium* spp.), and lupine (*Lupinus* spp.) (Yocom and Harris 1953, Ormiston 1966, Kessler 1990). Mast (tree seed) is eaten in abundance and includes the seeds of pines, Douglas fir (*Pseudotsuga menziesii*), and black locust (*Robinia pseudoacacia*). Acorns, legumes, tubers, roots, and weed seeds may also be consumed. Ormiston (1966) observed seeds of grasses, hawthorn, pines, sweet clover, thistles, ragweed, and teasel in the fall diet in Idaho. The winter diet is comprised of seeds of large annuals and perennials and fruits of woody species such as hawthorn, acorn meats, pine seeds, and greens (Ormiston 1966, Johnsgard 1973).

LIMITING FACTORS

An inadequate food supply caused by habitat loss throughout mountain quail range is considered a major limiting factor (Miller 1950; R. Gutiérrez, personal communication). The loss of winter habitat from dams and water impoundments, residential development, intensive agriculture, and the deterioration of wintering and breeding grounds as a result of overgrazing also limits mountain quail (Brennan 1990, P. Heekin, personal communication). Timber harvest does not appear to limit mountain quail if the cut site is allowed natural regrowth and invasion by brush species (R. Gutiérrez, personal communication). Excessive timber harvest [>200-400 ha (500-1,000 ac)] may negatively impact mountain quail (Leopold 1977; R. Gutiérrez, pers. comm.); however, this has not been proven (R. Gutiérrez, personal communication).

Water has been reported as a limiting factor (Rahm 1938, Ormiston 1966, Gutiérrez 1975, Miller and Stebbins 1964 *in* Gutiérrez 1975) and may be a problem in southeastern Washington (Kessler 1990). An increased water supply due to greater rainfall has resulted in higher breeding success in arid regions (Gutiérrez 1975, 1980; Brennan et al. 1987). The loss of riparian habitat in arid portions of mountain quail range is a serious threat to their stability (R. Gutiérrez, personal communication).

MANAGEMENT RECOMMENDATIONS

Habitat preservation is the key to mountain quail management in Washington (Kessler 1990). In eastern Washington, mountain quail persist in relatively isolated populations interconnected by corridors of riparian brush communities. These corridors serve as avenues for dispersal and movement between breeding and wintering habitat, as well as provide food and cover in close proximity to water sources (Brennan 1993). Removal of riparian brush communities should be avoided within the range of the mountain quail. The burning of decadent shrub fields should be avoided unless performed as a mosaic burn (P. Heekin, personal communication).

Herbicides that destroy brushy habitat should be avoided where management for mountain quail is a priority. Landowners are encouraged to use integrated pest management that targets specific pests or noxious weeds, pest population thresholds to determine when to use pesticides or herbicides, and crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). Appendix A provides useful contacts to help assess the use of pesticides, herbicides, and their alternatives.

The interspersion of shrubby cover [covering 20-50% of the ground area (Miller 1950)] should be given major consideration. Ideal habitat consists of a variety of plants at various heights (Miller 1950). The creation of edges between cover types is of lesser importance in habitat management (Miller 1950, Gutiérrez 1975). Management should protect and/or provide a variety of micro-habitats within the mountain quail range including mixed evergreen-deciduous forests, openings, forest and meadow edges, chaparral slopes, shrub-steppe, and mixed forest-shrub areas. Tall, dense cover in close proximity to water should receive priority in management consideration.

Clearcutting extremely large blocks of coniferous and deciduous forests [>200 ha (500 ac)] should be avoided where mountain quail are known to exist. Land managers should be encouraged to replant logged areas with a variety of tree species or allow natural regeneration of sites (J. Crawford,personal communication; R. Gutiérrez, personal communication). Small harvested areas; selective harvest which maintains several mature, standing trees; harvest which retains slash and/or slash piles; and harvested sites which are not subject to broadcast burning have been beneficial to mountain quail in west-central Idaho (P. Heekin, personal communication).
Every effort should be made to protect or provide water sources within mountain quail range, especially along riparian corridors. Livestock use of riparian corridors should be avoided as heavy grazing by sheep and cattle may be detrimental to mountain quail habitat (Gutiérrez 1975). Where water is lacking, watering devices should be installed (Miller 1950). Water devices should be placed in or near heavy cover to reduce predation (P. Heekin, personal communication).

Public education programs targeting habitat removal and water diversion issues associated with residential development are desirable where mountain quail management is priority (P. Heekin, personal communication). Furthermore, mountain quail are often attracted to and concentrate at bird feeders during the winter months. The concentration of birds at these sites increases the threat of predation by both natural and introduced predators. People that maintain bird feeders should be discouraged from placing feeders in open areas which are highly visible to predators (P. Heekin, personal communication).

REFERENCES

American Ornithologists' Union. 1983. Check-list of North American birds: sixth edition. American Ornithologists' Union, Washington, D.C., USA.

Bent, A. C. 1963. Life histories of North American gallinaceous birds. Reprint of 1932 edition, U.S. National Museum Bulletin 162. Dover Publications, New York, New York, USA.

Brennan, L. A. 1989. Report on a survey of mountain quail habitat in eastern Oregon, southeastern Washington, western Idaho, and northern Nevada. Unpublished Report, Chukar Found, Boise, Idaho, USA.

____. 1990. What happened to the mountain quail in Idaho? Quail Unlimited 9:42-43, 69.

____. 1993. Strategic plan for quail research in the United States: introduction and background. Pages 160-169 *in* K. E. Church and T. V. Dailey, editors. Quail III: Proceedings of the National Quail Symposium. Missouri Department of Conservation, Jefferson City, Missouri, USA.

____, W. M. Block, and R. J. Gutierrez. 1987. Habitat use by mountain quail in northern California. Condor 89:66-74.

Crawford, J. A. 1989. Mountain quail in Oregon: a special report. Unpublished Report, Oregon Department of Fish and Wildlife, Portland, Oregon, USA.

Gutiérrez, R. J. 1975. A literature review and bibliography of the mountain quail, *Oreortyx pictus*. USDA Forest Service Species Report, California Regional Office, San Francisco, California, USA.

____. 1980. Comparative ecology of the mountain and California quail in the Carmel Valley, California. Living Bird 18:71-93.

Heekin, P. E. 1991. Movements, habitat use, and population characteristics of mountain quail in west-central Idaho. Research Proposal, University of Idaho, Moscow, Idaho, USA.

Hunn, E. S., and P. W. Mattocks. 1980. Northern Pacific Coast Region: kites through Turkeys. American Birds 34:808.

Johnsgard. P. A. 1973. Grouse and Quails of North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Kessler, R. 1990. The status of mountain quail, *Oreortyx pictus*, in Washington State. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.
Leopold, A. S. 1972. Wildlife of Mexico: the game birds and mammals. University of California Press, Berkeley, California, USA.
____. 1977. The California quail. University of California Press, Berkeley, California., USA.
Miller, E. V. 1950. The life history and management of mountain quail in California. Project W-19-R. California Department of Fish and Game, Sacramento, California, USA.
Ormiston, J. H. 1966. The food habits, habitat and movement of mountain quail in Idaho. Thesis, University of Idaho, Moscow, Idaho, USA.
Rahm, R. 1938. Quail range extension in the San Bernardino National Forest. California Fish and Game 24:133-158.
Stinson, E. R., and P. T. Bromley. 1991. Pesticides and wildlife: a guide to reducing impacts on animals and their habitat. Virginia Department of Game and Inland Fisheries, Richmond, Virginia, USA.
Yocom, C. F., and S. W. Harris. 1953. Food habits of mountain quail (*Oreortyx pictus*) in eastern Washington. Journal of Wildlife Management 17:204-207.

PERSONAL COMMUNICATIONS

John A. Crawford, Professor of Wildlife Ecology
Department Fish and Wildlife
Oregon State University
Corvallis, Oregon

Patricia E. Heekin, Graduate Student
University of Idaho
Moscow, Idaho

Jim D. Stevenson, Fish and Wildlife Biologist
Fort Lewis Army Base
Fort Lewis, Washington

Bill Tweit, Wildlife Biologist
Washington Department of Wildlife
Olympia, Washington

Ralph J. Gutiérrez
Professor of Wildlife Management
Department of Wildlife
Humboldt State University
Arcata, California

Greg Shirato, Wildlife Biologist
Washington Department of Wildlife
Aberdeen, Washington

LeRay Stream, Wildlife Biologist
Washington Department of Wildlife
Yakima, Washington

CONTACTS

Dave Ware, Upland Bird Section Manager
Wash. Department of Fish and Wildlife
600 Capitol Way N
Olympia, WA 98501
(360) 902-2509

U.S. Natural Resource Conservation Service
316 W. Boone Ave., Suite 450
Spokane, WA 99201-2348
(509) 353-2354

U. S. Fish and Wildlife Service
3704 Griffin Lane SE
Suite 102
Olympia, WA 98501-2192
(360)753-9440

KEY POINTS

Habitat Requirements

- Mountain quail are associated with mixed evergreen-deciduous forests; regenerating clearcuts, selective cuts, and seed-tree cuts; forest and meadow edges; chaparral slopes; shrub-steppe; and mixed forest/shrub areas.
- Mountain quail require tall, dense cover over 20-50% of the area.
- A source of free-flowing water such as that found in riparian zones is critical to mountain quail occupying arid regions.
- Mountain quail nest in brush, shrubs, hardwood, and conifer communities.
- Loafing and roosting cover consists of dense vegetation approximately 2-3 m (5-6 ft) in height.
- Mountain quail winter in brushy thickets, along canyons, and about farms and woodland borders.
- Mountain quail feed on fruits, mast, acorns, legumes, tubers, roots, and seeds of grasses, weeds, flowering plants, and insects.

Management Recommendations

- Tall, dense cover (covering 20-50% of the ground area) in close proximity to water sources should be retained in areas where mountain quail management is a priority.
- Protect riparian brush communities within the range of the mountain quail.
- Encourage the use of integrated pest management within the mountain quail primary management zone. Refer to Appendix A for contacts useful when assessing pesticides, herbicides, and their alternatives.
- The burning of decadent shrub fields should be avoided unless performed as a mosaic burn.
- Public education should be encouraged where managing for mountain quail is a priority, and should target habitat removal and water diversion issues associated with residential development. The avoidance of placing bird feeders in open areas highly visible to predators should also be addressed.
- Minimize livestock use of riparian habitat.
- Protect or provide a variety of micro-habitats.
- Avoid clearcutting large areas of coniferous and deciduous forests (>500 ac).
- Encourage the planting of multiple tree and shrub species and/or allowing natural regeneration in areas subject to timber harvest.
- Install watering devices where water is lacking in or near dense cover.

Chukar

Alectoris chukar

Last revised: 1999

Written by David A. Ware and Michelle Tirhi

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Chukars are native to Asia, the Middle East, and southern Europe. They have been introduced into rocky, arid, mountainous areas from southern British Columbia south to Baja California and east to western Colorado (Udvardy 1977, Dunn et al. 1987). In southern Alberta, Arizona, New Mexico, and South Dakota only remnant populations exist (Johnsgard 1973).

In Washington, chukars are mainly found along deep river canyons in the arid regions east of the Cascade Mountains. The primary management zone includes portions of the middle and upper Columbia River and its tributaries, the Banks Lake area, the lower Yakima River and its tributaries, and the eastern portion of the Snake River (see Figure 1).

Figure 1. The primary management zones for chukar, *Alectoris chukar*, in Washington.

RATIONALE

The chukar, a recreationally important game bird, is one of the most popular upland game species in Washington. From 1991 to 1995, an average of 8,000 hunters a year reported pursuing chukars in Washington. Habitat is limited by the availability of talus or rocky slopes.

HABITAT REQUIREMENTS

Chukars flourish in mesic (moist) and semi-arid portions of shrub-steppe habitat characterized by steep, rocky, dry slopes (Galbreath and Moreland 1953, Christensen 1954, Molini 1976, Oelklaus 1976, Carmi-Winkler et al. 1987). The habitat is described as dense to open, with non-spiny shrubs, perennial and annual grasses, and forbs (Molini 1976). Galbreath and Moreland (1953) and Molini (1976) identified the optimum range as 50% sagebrush

(*Artemisia* spp.)-cheatgrass (*Bromus tectorum*)-bunchgrass (*Agropyron* spp.); 45% talus slope, rock outcrops, cliffs, and bluffs; 5% brushy creek bottoms and swales; and steep slopes (up to 40).

In Washington, chukar habitat consists of talus areas containing bromegrasses, bunchgrasses, and sagebrush at elevations of 175-1,220 m (575-4,000 ft) (Moreland 1950). Oelklaus (1976) found Douglas hackberry (*Celtis douglasii*) communities, smooth sumac (*Rhus glabra*) stands, and poison ivy (*Toxicodendron* spp.) clones along rivers and riparian corridors used extensively by chukars throughout the Snake and Columbia river canyons. Chukars are apparently not agricultural inhabitants and typically exist in areas unoccupied by other upland birds (Moreland 1950). Big sagebrush (*Artemisia tridentata*) is the predominant shrub and cheatgrass brome the predominant grass throughout the chukar range (Galbreath and Moreland 1953, Molini 1976). However, a variety of native and non-native shrubs and grasses are used.

Nesting

Most chukar nests are located under low-growing scabland sagebrush, 90-120 m (300-400 ft) above creek bottoms in heavy sagebrush areas mixed with bunch- and bromegrasses (Galbreath and Moreland 1953). Hens may also seek more gentle terrain in which to nest (Alkon 1983).

Roosting, Loafing, and Dusting Sites

Chukars typically roost and loaf on the ground beneath sagebrush, under rock outcrops, or in open rocky areas (Christensen 1970). Chukars often roost on peninsulas. Rock outcrops, Douglas hackberry, and smooth sumac communities may be used for loafing (Oelklaus 1976) depending on availability. Dusting is very important and occurs alongside trails and roads, or near water sites (Christensen 1970).

Food

Chukars feed primarily on exotic grasses and the seeds of weedy forbs (Galbreath and Moreland 1953, Bohl 1957, Christensen 1970, Kam et al. 1987). Cheatgrass (both seeds and leaves) is the most important yearly food item for chukars throughout their range (Galbreath and Moreland 1953, Harper et al. 1958, Christensen 1970). In Washington, cheatgrass and wheat comprise the main diet of the chukar year-round (Galbreath and Moreland 1953). When chukars are in close proximity to agricultural fields, they may feed on available grains, seeds, and green shoots (Sandfort 1954, Christensen 1970). Insects are an important source of food during the summer and early fall (W. Molini, personal communication).

Water

The summer range of the chukar depends upon the distribution and availability of water (Galbreath and Moreland 1953, Christensen 1970). Oelklaus (1976) consistently found chukars concentrated around rivers and tributaries in Idaho. Oelklaus (1976) also found chukars moving away from tributaries that dried up in the summer and fall to those that remained. In eastern Washington, chukars have been observed feeding on ripe fruits of hawthorne (*Crataegus* spp.), common chokecherry (*Prunus virginiana*), and serviceberry (*Amelanchier* spp.) in July and August in part to fulfill their water needs (Galbreath and Moreland 1953).

LIMITING FACTORS

Grasses, particularly cheatgrass, and water are the 2 components necessary for chukar survival (Oeklaus 1976). Severe winters may limit local populations and have been known to adversely effect chukar populations in Nevada, Idaho (Christensen 1970), and Washington (Galbreath and Moreland 1953). Low precipitation, especially droughts, are deleterious to these birds (Christensen 1958).

MANAGEMENT RECOMMENDATIONS

Of primary importance in maintaining good chukar production is the availability of green grasses, especially cheatgrass (Christensen 1958). Chukars rely on sagebrush stands within semi-arid sagebrush grasslands (Galbreath and Moreland 1953). Reduction of sagebrush within primary chukar management zones should be avoided. Management practices that significantly impact insect populations will likely decrease chukar numbers and should be avoided (W. Molini, personal communication).

The summer range of the chukar depends on the availability of water. Therefore, water improvement and development can be used to expand their distribution and possibly increase the chukar population (Christensen 1970). The protection and improvement of existing water supplies should receive priority in chukar habitat management (Christensen 1970). This would include reconstructing livestock watering troughs and other watering developments to insure a permanent water supply for chukars and other wildlife. Providing escape ramps and supplemental bird drinking basins to stock water tanks used by livestock would also benefit chukars. Gallinaceous guzzlers [1,300 L (350 gal)] placed within 45 m (148 ft) of steep, rocky escape cover or near the bottom of draws, gullies, and/or ravines provide the most benefits to chukars (W. Molini, personal communication). Chukars require some form of protective cover around water sources. Therefore, plant shrub cover around watering devices (Galbreath and Moreland 1953).

Douglas hackberry communities, sumac stands, and poison ivy clones along rivers and riparian corridors throughout the range of the chukar should be retained (Oelklaus 1976). Landowners and land managers are encouraged to use integrated pest management that targets specific pests or noxious weeds, uses pest population thresholds to determine when to use pesticides or herbicides, and utilizes crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). For more information on integrated pest management, refer to Appendix A, for contacts to help assess the use of pesticides, herbicides, and their alternatives.

REFERENCES

Alkon, P. U. 1983. Nesting and brood production in an Israeli population of chukars *Alectoris chukar; Aves, Phasianidae*. Israel Journal of Zoology 32:185-193.

Bohl, W. H. 1957. Chukars in New Mexico 1931-1957. Project W-58-R. Bulletin Number 6. New Mexico Department of Game and Fish, Santa Fe, New Mexico, USA.

Carmi-Winkler, N., A. A. Degen and B. Pinshow. 1987. Seasonal time-energy budgets of free-living chukars in the Negev Desert, Israel. Condor 89:594-601.

Christensen, G. C. 1954. The chukar partridge in Nevada. Project W-8-R. Biology Bulletin Number 1. Nevada Fish and Game Commission, Reno, Nevada, USA.

____. 1958. The effects of drought and hunting on the chukar partridge. Transactions of the North American Wildlife Conference 23:329-341.

____. 1970. The chukar partridge: Its introduction, life history, and management. Project W-8-R, W-43-R, W-48-1. Biology Bulletin Number 4. Nevada Department of Fish and Game, Reno, Nevada, USA.

Dunn, J. L., G. E. Watson, and J. P. O'Neill, compilers. 1987. Field guide to the birds of North America. National Geographic Society, Washington, D.C. USA.

Galbreath, D. S., and R. Moreland. 1953. The chukar partridge in Washington. Project W-38-R. Biology Bulletin Number 11. Washington Department of Game, Olympia, Washington, USA.

Harper, H. T., B. H. Harry, and W. D. Bailey. 1958. The chukar partridge in California. California Fish and Game Journal 44:5-50.

Johnsgard, P. A. 1973. Grouse and quails of North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Kam, M., A. A. Degen, and K. A. Nagy. 1987. Seasonal energy water and food consumption of Negev chukars and sand partridges. Ecology 68:1029-1037.

Molini, W. A. 1976. Chukar partridge: species management plan. Nevada Department of Fish and Game, Reno, Nevada, USA.

Moreland, R. 1950. Success of chukar partridge in the state of Washington. 15th North American Wildlife Conference, Wildlife Management Institute, Washington, D.C., USA.

Oelklaus, W. F. 1976. Chukar partridge dispersion along the middle and lower Snake River and Columbia Rivers. Thesis, University of Idaho, Moscow, Idaho, USA.
Sandfort, W. W. 1954. Evaluation of chukar partridge range in Colorado. Conference Proceedings of the Western Association of State Game and Fish Commissions 34:244-250.
Stinson, E. R., and P. T. Bromley. 1991. Pesticides and wildlife: a guide to reducing impacts on animals and their habitat. Virginia Department of Game and Inland Fisheries, Richmond, Virginia, USA
Udvardy, M. D. F. 1977. The Audubon Society field guide to North American birds. Alfred A. Knopf, Incorporated, New York, New York, USA.

PERSONAL COMMUNICATIONS

W.A. Molini, Director
Nevada Department of Wildlife
Reno, Nevada, USA

CONTACTS

Dave Ware, Upland Game Section Manager
Washington Department of Fish and Wildlife
600 N. Capitol Way
Olympia, WA 98501
(360) 902-2509

U. S. Fish and Wildlife Service
3704 Griffin Lane SE
Suite 102
Olympia, WA 98501-2192
(360)753-9440

Washington State University Cooperative Extension Service
921 Lakeridge Drive SW
Room 216
Olympia, WA 98502
(360)786-5445

U.S. Natural Resource Conservation Service
316 W. Boone Ave.
Suite 450
Spokane, WA 99201-2348
(509) 353-2354

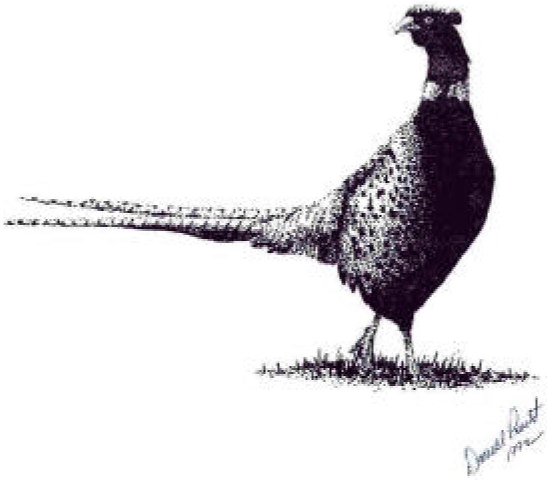
KEY POINTS

Habitat Requirements

- Chukars inhabit dense to open portions of shrubland associated with perennial and annual grasses and forbs.
- Optimum range is 50% sagebrush-cheatgrass-bunchgrasses; 45% talus slope, rock outcrops, cliffs, and bluffs; 5% brushy creek bottoms and swales; and steep slopes (up to 40).
- Big sagebrush and cheatgrass predominate throughout the chuckar's range.
- Chukars nest under low-growing scabland sagebrush, 90-120 m (300-400 ft) above creek bottoms in heavy sagebrush areas mixed with bunch- and bromegrasses.
- Chukars roost and loaf on the ground beneath sagebrush or under rock outcrops, in Douglas hackberry and in smooth sumac communities.
- Chukars dust alongside trails and roads or near water sites.
- Chukars feed mostly on cheatgrass as well as grains, seeds, and green shoots when available.

Management Recommendations

- Protect sagebrush in semi-arid sagebrush grasslands used by chukars.
- Management practices which significantly impact insect populations will likely decrease chukar numbers and should be avoided.
- Protect and/or improve existing water supplies throughout chukar range.
- Provide escape ramps and supplemental bird drinking basins to stock water tanks used by livestock.
- Gallinaceous guzzlers [1,300 L (350 gal)] placed within 45 m (148 ft) of steep, rocky escape cover or near the bottom of draws, gullies, and/or ravines provides the most benefits to chukars.
- Plant shrub cover around watering devices.
- Retain Douglas hackberry communities, sumac stands, and poison ivy clones along rivers and riparian corridors.
- Encourage the use of integrated pest management within the chukar primary management zone. For more information on integrated pest management, refer to Appendix A for contacts useful in assessing pesticides, herbicides, and their alternatives.



Ring-necked Pheasant

Phasianus colchicus

Last updated: 1999

Written by David A. Ware and Michelle Tirhi

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The ring-necked pheasant is native to Asia and has been extensively introduced throughout North America. Ring-necked pheasants range from central Canada through the northern United States and southward into New Mexico, Texas, Louisiana, and Mississippi (Dumke et al. 1984, Dahlgren 1988, Droege and Sauer 1990).

Ring-necked pheasants are found in most agricultural areas throughout Washington. However, they are only considered a priority species within the primary management zone delineated by Washington Department of Fish and Wildlife's Game Division (see Figure 1).

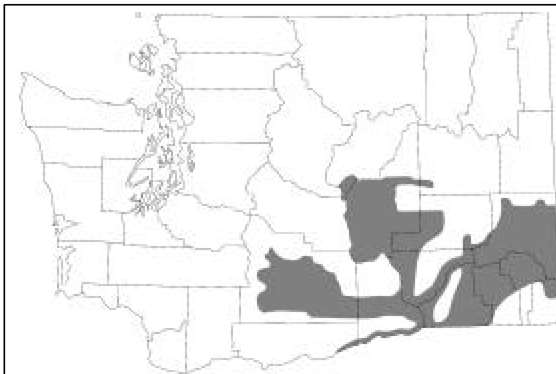


Figure 1. Primary management zone of the ring-necked pheasant, *Phasianus colchicus*, in Washington. Map developed by Washington Department of Fish and Wildlife Game Division.

RATIONALE

The ring-necked pheasant, a recreationally important game species, is the most popular upland game bird in Washington. Ring-necked pheasants are currently the focus of a major habitat restoration program. Pheasants are dependent on agricultural habitats and they thrive in non-crop vegetation around cultivated crops. As shrub-steppe habitats were converted to agriculture, pheasant populations grew. However, with today's improved farming technology and management practices, pheasants have undergone a tremendous decline as indicated by harvest surveys (Washington Department of Fish and Wildlife 1996). This has resulted in significant declines in hunter numbers and associated recreation. There were over 110,000 pheasant hunters in 1981. In 1995, that number declined to 29,000. Pheasant harvest declined from over 500,000 to 70,000 birds from 1981 to 1995.

HABITAT REQUIREMENTS

Ring-necked pheasants require permanent retention-type cover to sustain populations and use a variety of agricultural cover types. In Washington, prime cover occurs near irrigated farmlands containing cattail patches (*Typha* spp.) mixed with willow (*Salix* spp.) (Blatt 1975, Foster et al. 1984). Riparian/shrub tree bottoms in dryland wheat areas of eastern Washington that are not grazed by livestock also provide excellent habitat. Thickets and shrubs provide shelter and shade; woody plants and thorny shrubs provide escape cover; wetland areas and weedy patches provide roost and loaf sites; and cattail, willow, and bulrush sloughs (*Scirpus* spp.) provide escape and thermal cover during winter. Fence rows, roadside ditches, and field edges with adequate vegetation provide travel corridors. In Britain, pheasants have been observed roosting in trees and in ditches in areas void of trees (D. Hill, personal communication).

Where adequate habitat exists, pheasants may spend their entire life in an area approximately 256 ha (640 ac) in size. Prime ring-necked pheasant habitat contains approximately 25-50% uncultivated land and 50-75% cultivated land (having 20-75% small grain crops and/or 30-40% field corn crops) (Warner et al 1984).

Roadsides, canals, and drainage banks have good potential for pheasants and other upland wildlife (Joselyn and Tate 1972, Snyder 1974, Varland 1985, Warner et al. 1987). The use of such linear cover depends on the proximity to other prime breeding habitats (Warner and Joselyn 1986), the density and height of cover (Wiegers 1959, Hoffman 1973, Warner et al. 1987), and the width of linear cover (Linder et al. 1960, Gates and Hale 1975).

Nesting and Brood Rearing

Undisturbed cover provides the best nesting and brood rearing habitat. Areas containing new vegetation are preferred; where this is lacking, residual vegetation is used. Alfalfa, wheat, and grass hayfields are often selected as nest sites (Galbreath and Ball 1969; Snyder 1982, 1984). This choice of nesting habitat is the most precarious due to harvest and cultivation. Pastures, woodlots, orchards, row crops, wetlands, and untilled sites adjacent to cropland are also used for nesting (Gates 1970; J. Tabor, personal communication). Ring-necked pheasants typically nest in the tallest [15 cm (6 in) residual cover and 25 cm (10 in) for current growth] herbaceous vegetation available (Washington Department of Wildlife 1987). In Britain, Hill (personal communication) has observed pheasants nesting under area of bramble (*Rubus* spp.) intertwined with grasses that provides both open ground cover and overhead concealment. Nest predation actually increased when nests were situated in clumps of obvious vegetation (D. Hill, personal communication). In Wisconsin, undisturbed grasslands or hayfields with adequate residual cover and wetlands provide key nesting and brood-rearing habitat (Gatti 1983).

Roadsides could provide important nesting areas if managed properly (Trautman 1982, Warner and Joselyn 1986, Hill and Robertson 1988). Warner et al. (1987) commonly found pheasants nesting on roadsides when prime nesting habitat was unavailable. Haensly et al. (1987) cautioned that strip cover, such as that found at roadsides, may also have a higher rate of predation in comparison to more extensive habitats used for nesting.

Brood-rearing habitat includes shrubs, tree rows, grain fields (corn or sorghum), and cool-season grasses (Nelson et al. 1990), which provide both dense hiding cover and adequate food supplies. Optimal brood-rearing habitat contains a high proportion of broad-leaved plants which are a key source of insects and seeds. Optimal brood-rearing habitat also provides overhead concealment from predators and open space at ground level for ease of movement of chicks. Broods typically range over large areas and various vegetative communities in search of food during the first 2 weeks of life (D. Hill, personal communication). Often areas containing the highest densities of preferred foods are avoided, such as weed fields (D. Hill, personal communication).

Roosting

Roosting takes place in grasslands and stubble fields except during severe winter weather when low, herbaceous vegetation (Labisky 1956, Robertson 1958), cattails, and marshy vegetation are preferred (Olsen 1977). In Washington's Columbia Basin, wet meadows containing rush (*Juncus* spp.) are used throughout the year as roosting sites (J. Tabor, personal communication).

Loafing

Loafing areas contain minimal ground cover but dense overhead concealment, such as bushy vegetation, ragweed (*Ambrosia* spp.), or summercypress (*Kochia* spp.). These areas usually provide dusting sites, sunlight, or shade depending upon the needs of the pheasant (Ginn 1962).

Winter

Ideal winter habitat provides food and woody plants for cover (Hill and Robertson 1988). In South Dakota, wetlands lacking snow accumulation are ideal wintering sites (A. Leif, personal communication). In Washington, pheasants mainly winter in dense willow stands and cattail patches on sites 2-6 ha (5-15 ac) in size which are within 1 km (0.6 mi) of cultivated crops (Blatt 1975, Foster et al. 1984). In Great Britain, the highest density of wintering pheasants are located in small woodlots with convoluted boundaries which maximizes the edge:area ratio with surrounding tilled land (D. Hill, personal communication). Multi-row shelterbelts, windbreaks, fencerows, and shrub-type cover which is not grazed by livestock also provide good winter cover.

Food

Ring-necked pheasants feed primarily on cultivated grains, including corn, wheat, barley, peas, and oats (Trautman 1952, DeSimone 1975, Hill and Robertson 1988). Beans, rice, and sorghum are eaten in smaller quantities. Weed and grass seeds are also important food items, especially when waste grain is unavailable (Hiatt 1947, Trautman 1952, Olsen 1977, Wise 1986). In winter, wild fruits are consumed and may include the fruits of chokecherry (*Aronia* spp.), wild rose (*Rosa* spp.), snowberry (*Symphoricarpos* spp.), hawthorn (*Crataegus* spp.), and serviceberry (*Amelanchier* spp.). Insects and gastropods are eaten in small quantities by adults. Insects are consumed in larger quantities by hens during the breeding season and by chicks and juveniles (Loughrey and Stinson 1955; Korschgen 1964; Olsen 1977; A. Leif, personal communication). Species eaten include grasshoppers, snails, beetles, ants, cutworms, crickets, plant bugs, and sawfly larvae. During egg laying, hens consume large amounts of snail shells and high calcium grit to help in egg shell production (Wise 1986).

LIMITING FACTORS

Loss of permanent nesting and winter cover on irrigated lands is the primary factor limiting the ring-necked pheasant (Kimball et al. 1956 in Allen 1956, Washington Department of Game 1957, MacMullan 1961, Blatt 1975, Burger 1988, Hart 1990). Specific problems include the loss of cattail and willow stands, woody plants, windbreaks, and brushy fencerows (Warner et al. 1984). Pesticides have been shown to lower chick production (Labisky and Lutz 1967, Borg et al. 1969 in Potts 1986) and chick viability, (Rudd and Genelly 1956) as well as degenerate the nervous system.

MANAGEMENT RECOMMENDATIONS

Irrigated farmlands within the Columbia Basin Project, the Yakima Valley, and riparian areas in south Whitman, northern Garfield, Columbia, and Walla Walla counties should be considered high priority areas for ring-necked pheasants. Optimal feeding and wintering areas are 1 km (0.6 mi) (Hart 1990) to 1.2 km (0.75 mi) apart (Blatt 1975). Hill (personal communication) recommends maintaining many small plots of woodland with a maximum distance of 500-750 m (1,600-2,500 ft) between woodlots and permanent winter cover. On public lands, legumes and/or native grasses should be planted as nesting cover and shrubs and woody plants as winter cover. Multi-species food plots should be established near permanent cover. At the landscape level, habitat management for pheasants should include a mosaic of different crops and residual cover interspersed with plots of permanent cover (D. Hill, personal communication).

Fence rows, waterways, cattail and willow patches, thickets, shrubs, and other woody plants on irrigated private farmlands should be protected and enhanced. Farmers should be encouraged to delay alfalfa cutting 1 week or longer to increase nesting success (Hartman and Fisher 1984) and/or grow winter wheat, seed alfalfa, or grass seed crops. Strips of standing corn should be left in fields for winter food. Undisturbed grasslands and hayfields containing residual cover should be preserved (Gatti 1983). Where these components are lacking, the provision of large, square-shaped fields 4-32 ha (10-80 ac) in close proximity [3 km (2 mi)] to winter cover would enhance pheasant nesting and brood-rearing (Gatti 1983). Private landowners may also be encouraged to retire lands of marginal grazing or crop value, especially lands with moderate to high erosion risks (Gatti 1983).

Livestock grazing should be restricted or excluded on isolated tracts throughout pheasant range, in riparian areas, in woody cover, and on prime wintering, nesting, and roosting grounds (Wechsler 1986; Hart 1990; J. Tabor, personal communication). Fences should be constructed around ponds to exclude cattle and increase nesting cover.

In areas of low precipitation, protect or plant dense stands of warm- and cool-season grasses and legumes for nesting (Warner and Joselyn 1986). If weed control on these areas is necessary, mow between 1 August and 1 September (late summer) to allow hens to bring off a brood and allow vegetation to regrow prior to winter dormancy (Hoffman 1973, Wechsler 1986, Hart 1990).

Pesticide spraying should be avoided within prime pheasant habitat (Hoffman 1973). Where spraying is unavoidable, use a spot spraying technique verses blanket spraying (Wechsler 1986). Incorporate 6 m (20 ft) strips around the perimeter of cereal grain fields which would not receive chemical treatment (Potts 1986; A. Leif, personal communication). Landowners are encouraged to use integrated pest management that targets specific pests or noxious weeds, pest population thresholds to determine when to use pesticides or herbicides, and crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991; L. Peterson, personal communication). See Appendix A for useful contacts for assistance when assessing pesticides, herbicides, and their alternatives.

REFERENCES

Allen, D. L., editor. 1956. Pheasants in North America. The Stackpole Company, Harrisburg, Pennsylvania and Wildlife Management Institute, Washington, D.C., USA.

Blatt, D. D. 1975. Pheasant retention habitat acquisition and development. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.

Burger, G. V. 1988. 100 years of ringnecks: an historical perspective on pheasants in North America. Pages 1-26 *in* D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. Pheasants: symptoms of wildlife problems on agricultural lands. The Wildlife Society, Northcentral Section, Bloomington, Illinois, USA.

Dahlgren, R. B., 1988. Distribution and abundance of the ring-necked pheasant in North America. Pages 29-43 *in* D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. Pheasants: symptoms of wildlife problems on agricultural lands. The Wildlife Society, Northcentral Section, Bloomington, Illinois, USA.

DeSimone, R. M. 1975. Interspersion of cover types as related to pheasant use on a game management area in south-central Montana. Project W-120-R-5, 6 and 7, Study GB-18.1, Job 1. Montana Department of Fish, Wildlife, and Parks, Helena, Montana, USA

Droege S., and J. R. Sauer, 1990. Northern bobwhite, gray partridge, and ring-necked pheasant population trends (1966-1988) from the North American Breeding Bird Survey. Pages 2-20 *in* K. E. Church, R. E. Warner, and S. J. Brady, editors. Perdix V: gray partridge and ring-necked pheasant workshop. Kansas Department of Wildlife and Parks, Emporia, Kansas, USA.

Dumke, R. T., R. B. Stiehl, and R. B. Kahl, 1984. Questionnaire survey results; population status, harvest, and game farm programs for gray partridge and ring-necked pheasants in North America. Pages 175-192 *in* R. T. Dumke, R. B. Stiehl, and R. B. Kahl, editors. Perdix III: gray partridge and ring-necked pheasant workshop. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

Foster, J. H., W. E. Tillett, W. L. Myers, and J. C. Hoag. 1984. Columbia basin wildlife/irrigation development study. REC-ERC-83-6. U.S. Department of Interior, Bureau of Reclamation, Ephrata, Washington., USA.

Galbreath, D. S., and C. C. Ball. 1969. Columbia Basin pheasant nesting studies in alfalfa and sagebrush areas. Pages 105-111 *in* Anonymous. Game Bird Management 1969-1970. Washington Department of Wildlife, Olympia, Washington, USA.

Gates, J. M. 1970. Recommendations for a scattered wetlands program of pheasant habitat preservation in southeast Wisconsin. Research Report Number 63. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

____, and J. B. Hale. 1975. Reproduction of an east-central Wisconsin pheasant population. Technical Bulletin Number 85. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

Gatti, R. C. 1983. Ring-necked pheasants. Draft species management guidelines, chapter 39. Wisconsin Department of Natural Resources, Research Center, Monona, Wisconsin, USA.

Ginn, W. E. 1962. The ring-neck pheasant in Indiana. P-R bulletin Number 6. Indiana Division of Fish and Game, Indianapolis, Indiana, USA.
Haensly, T. F., J. A. Crawford, and S. M. Meyers. 1987. Relationships of habitat structure to nest success of ring-necked pheasants. Journal of Wildlife Management 51:421-425.
Hart, C. M. 1990. Management plan for the ring-necked pheasant in California. Project W-65-R. California Department of Fish and Game, Sacramento, California, USA.
Hartman, F. E., and R. Fisher. 1984. Pheasant nesting success with delayed hay mowing in Pennsylvania: preliminary results. Pages 110 to 116 *in* R. T. Dunke, R. B. Stiehl, and R. B. Kahl, editors. Proceedings of Perdix III/Gray partridge and ring-necked pheasant workshop, Campbellsport, Wisconsin, USA.
Hiatt, R. W. 1947. The relation of pheasants to agriculture in the Yellowstone and Big Horn River Valleys of Montana. Project 1-R. Montana Fish and Game Department, Wildlife Restoration Division, Helena, Montana, USA.
Hill, D., and P. Robertson, 1988. The pheasant: ecology, management, and conservation. BSP Professional Books, London, England.
Hoffman, D. M. 1973. Pheasant nest site selection. Special Report number 32. Colorado Division of Wildlife, Denver, Colorado, USA.
Joselyn, G. B., and G. I. Tate. 1972. Practical aspects of managing roadside cover for nesting pheasants. Journal of Wildlife Management 36:1-11.
Korschgen, L. J. 1964. Foods and nutrition of Missouri and Midwestern pheasants. Transactions of the North American Wildlife Conference 29:159-181.
Labisky, R. F. 1956. Behavior and movements of pheasants. Project W-30-R-11, Job 1. Illinois Department of Conservation, Springfield, Illinois, USA.
____, and R. W. Lutz. 1967. Response of wild pheasants to solid-block applications of aldrin. Journal of Wildlife Management 31:13-24.
Linder, R. L., D. L. Lyon, and C. P. Agee. 1960. An analysis of pheasant nesting in south-central Nebraska. Transactions. North American Wildlife Conference 25:214-230.
Loughrey, A. G., and R. H. Stinson. 1955. Feeding habits of juvenile ring-necked pheasants on Pelee Island, Ontario. Canadian Field-Naturalist 69:59-65.
MacMullan, R. A. 1961. Ring-necked pheasant habitat management in the United State. Transactions. North American Wildlife and Natural Resources Conference 26:268-272.
Nelson, D. R., R. O. Kimmel, and M. J. Frydendall. 1990. Ring-necked pheasant and gray partridge brood habitat in roadsides and managed grasslands. Pages 103 to 119 *in* K. E. Church, R. E. Warner, and S. J. Brady, editors. Perdix V: gray partridge and ring-necked pheasant workshop. Kansas Department of Wildlife and Parks, Emporia, Kansas, USA.
Olsen, D. W., 1977. A literature review of pheasant habitat requirements and improvement methods. Publication 77-7, project W-65-R-D-25, job B-8. Utah Department of Natural Resources, Salt Lake City, Utah, USA.
Potts, G. R. 1986. The partridge: pesticides, predation, and conservation. Collins Professional and Technical Books, London, England.
Robertson, W. D. 1958. Investigation of ring-necked pheasants in Illinois. Technical Bulletin Department of Conservation, Springfield, Illinois, USA.
Rudd, R. L., and R. E. Genelly. 1956. Pesticides: their use and toxicity in relation to wildlife. Game bulletin number 7. California Department of Fish and Game, Sacramento, California, USA.
Snyder, W. D. 1974. Pheasant use of roadsides for nesting in Northeast Colorado. Special Report Number 36. Colorado Division of Wildlife, Denver, Colorado, USA.
____. 1982. Evaluation of nesting cover preferences for pheasants in relation to wheat farming methods. Final Report, project W-37-R-35, job 22. Oregon Department of Fish and Wildlife, Portland, Oregon, USA.
____. 1984. Ring-necked pheasant nesting ecology and wheat farming in the High Plains. Journal of Wildlife Management 48:878-888.
Stinson, E. R., and P. T. Bromley. 1991. Pesticides and wildlife: a guide to reducing impacts on animals and their habitat. Virginia Department of Game and Inland Fisheries, Richmond, Virginia, USA.
Trautman, C. G. 1952. Pheasant food habitats in South Dakota. Technical Bulletin Number 1. South Dakota Department of Game, Fish, and Parks, Pierre, South Dakota, USA.
____. 1982. History, ecology, and management of the ring-necked pheasant in South Dakota. South Dakota Department of Game, Fish, and Parks, Pierre, South Dakota, USA.
Varland, K. 1985. Why roadsides for wildlife. Minnesota Volunteer 2:3-8.

Warner, R. E., S. L. Etter, G. B. Joselyn, and J. A. Ellis. 1984. Declining survival of ring-necked pheasant chicks in Illinois agricultural ecosystems. Journal of Wildlife Management 48:82-88.

____, and G. B. Joselyn. 1986. Responses of Illinois ring-necked pheasant populations to block roadside management. Journal of Wildlife Management 50:525-532.

____, G. B. Joselyn , and S. L. Etter. 1987. Factors affecting roadside nesting by pheasants in Illinois. Wildlife Society Bulletin 15:221-228.

Washington Game Department. 1957. Ten years of pheasant management, 1946-1956. Game Management and Land Management Division, Olympia, Washington, USA.

Washington Department of Fish and Wildlife. 1996. 1996 Game status and trend report. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Washington Department of Wildlife. 1987. Documentation of evaluation criteria for Conservation Reserve Program (CRP) lands in relation to ring-necked pheasant habitat quality. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.

Wechsler, C. 1986. The pheasant in Minnesota. Minnesota Department of Natural Resources, Madelia, Minnesota, USA.

Wiegers, H. L. 1959. A survey of roadsides: their status and value to nesting game birds. Project W-32-R-1 and 2, job 1-58 and 59. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Wise, S. 1986. The ring-necked pheasant (*Phasianus colchicus*). PUBL-WM-014, 86. Wisconsin Department of Natural Resources, Bureau of Wildlife Management, Madison, Wisconsin, USA.

PERSONAL COMMUNICATIONS

David Hill, Managing Director
Ecoscope: Applied Ecologists
Cambridge, Great Britain

Anthony Leif, Wildlife Biologist
South Dakota Dept. of Game, Fish and Parks
Huron, South Dakota

Jim Tabor, Area Wildlife Biologist
Washington Department of Fish and Wildlife
Ephrata, Washington

Les R. Peterson, Southern Regional Ecologist
Wisconsin Department of Natural Resources
Monona, Wisconsin

CONTACTS

Dave Ware, Upland Game Section Manager
Washington Department of Fish and Wildlife
600 N. Capitol Way
Olympia, WA 98501
(360) 902-2509

U.S. Fish and Wildlife Service
3704 Griffin Lane SE
Suite 102
Olympia, WA 98501-2192
(360) 753-9440

Washington State University
Cooperative Extension Service
921 Lakeridge Drive SW, Room 216
Olympia, WA 98502
(360) 786-5445

USDA Natural Resource Conservation Service
316 W. Boone Ave.
Suite 450
Spokane, WA 99201-2348
(509) 353-2354

KEY POINTS

Habitat Requirements

- Irrigated farmlands containing cattail patches mixed with willow and ungrazed riparian/shrub tree habitat in dryland wheat areas provide suitable retention cover for ring-necked pheasants.
- Ring-necked pheasant habitat contains approximately 25-50% idle land and 50-75% cultivated land (having 20-75% small grain crops and/or 30-40% field corn crops).
- Pheasants nest in undisturbed cover (May-July) found in alfalfa and wheat fields, grass hayfields, pastures, woodlots, orchards, row crops, wetlands, roadsides, and untilled areas adjacent to cropland.
- Nests are placed in tall, dense herbaceous vegetation [minimum15 cm (6 in) residual cover and 25 cm (10 in) current growth].
- Brood rearing habitat includes shrubs, tree rows, grain fields (corn or sorghum), and cool-season grasses with an abundance of broad-leaved plants and insects for chicks.
- Pheasants roost in grasslands, stubble fields, cattails, marshy vegetation, and wet meadows containing rush.
- Preferred loafing areas contain minimal ground cover and dense overhead concealment.
- Pheasants winter in dense willow stands and cattail patches 2-6 ha (5-15 ac) in size and 1 km (0.6 mi) from cultivated crops. Multi-row shelterbelts, windbreaks, fencerows, ungrazed shrub-type cover, and wetland vegetation also provides key wintering habitat.
- Pheasants feed primarily on cultivated grains, including corn, wheat, barley, peas and oats, weed and grass seeds, wild fruits, and insects.

Management Recommendations

- Optimal feeding and wintering areas are 1-1.2 km (0.6-0.75 mi) apart, preferably 500-750 m (1,600-2,500 ft).
- Plant legumes and/or native grasses as nesting cover and shrubs and woody plants as winter cover.
- Establish multi-species food plots (>2 acres in blocks) near permanent cover.
- Manage strip cover (roadsides, canals, and drainage banks) in areas of medium to high precipitation [>25 cm (10 in)]. Maintain or plant dense stands of warm- and cool-season grasses and legumes in areas of low precipitation. If weed control is necessary, mow between 1 August and 1 September.
- Discourage the removal and annual burning of fence rows, waterways, cattail and willow patches, thickets, shrubs, and other woody plants on irrigated private farmlands.
- Encourage farmers to delay alfalfa cutting to increase nesting time and/or grow other less hazardous crops.
- Leave scattered, standing grain in fields for winter food.
- At the landscape level, habitat management for pheasants should include a mosaic of different crops and residual cover, interspersed with tracts of permanent cover.
- Livestock grazing should be restricted and/or excluded on isolated tracts, woody cover, riparian areas, and on wintering grounds. Restrict livestock by placing fences around ponds.
- Avoid the use of pesticides within prime pheasant habitat where possible. Refer to Appendix A when assessing pesticides, herbicides, and their alternatives.
- Use spot spraying (verses blanket spraying) where spraying pesticides is unavoidable and establish a 6 m (20 ft) conservation headland (buffer) around the perimeter of cereal fields.
- Encourage the use of integrated pest management within the ring-necked pheasant primary management zone.

Blue Grouse

Dendragapus obscurus

Last updated: 1998

Written by David A. Ware

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Blue grouse are found throughout western North America, including the offshore islands of British Columbia, Canada. Their range extends from the southern portions of Alaska and the Yukon, south along the Pacific Coast to northern California. The range continues east, encompassing the Cascade and Sierra Nevada mountains of the Pacific Northwest and California, and the northern and central Rocky Mountains from Canada to Arizona (Aldrich 1963, Johnsgard 1973).

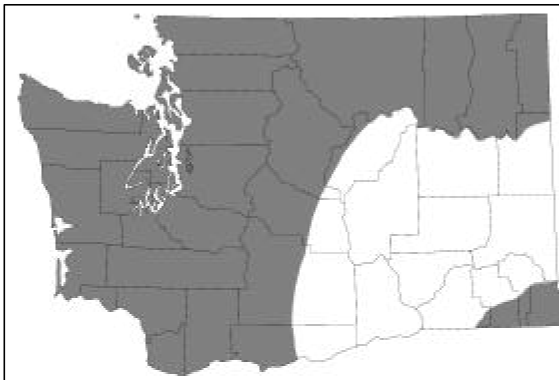


Figure 1. General range of the blue grouse, Dendragapus obscurus, in Washington. Map derived from Washington Department of Fish and Wildlife data files.

In Washington, blue grouse are found in mountainous areas wherever open coniferous forests are present (see Figure 1; Soil Conservation Service 1969). They are closely associated with true fir (*Abies* spp.) and Douglas fir (*Pseudotsuga menziesii*) forests (Johnsgard 1973). Hunter survey results from the 1995 season indicated that blue grouse were harvested from all counties except Adams, Benton, Franklin, Grant, Island, San Juan, and Whitman (Washington Department of Fish and Wildlife 1996).

RATIONALE

The blue grouse is a recreationally important species that is vulnerable to habitat loss or degradation.

HABITAT REQUIREMENTS

Blue grouse breed in open foothills and are closely associated with streams, springs, and meadows. Much of the food they require comes from the succulent vegetation that grows in these areas. During spring and summer blue grouse use stream bottoms and areas with gentle slopes (Washington Department of Game 1961). In the fall they migrate to higher elevations where they spend the winter feeding on fir needles (Soil Conservation Service 1969). Large fir trees are a food source for wintering blue grouse and are required for roost sites. Blue grouse exhibit strong site fidelity to their wintering areas (Cade 1984).

Diet

True fir and Douglas fir needles constitute 60% of blue grouse diet west of the Cascade Mountains (Beer 1943). In other areas they are often supplemented with larch (*Larix* spp.) and pine (*Pinus* spp.) needles (Boag 1963). Important forbs and grasses in drier climates include balsamroot (*Balsamorhiza* spp.), buckwheat (*Eriogonum* spp.), dwarf mistletoe (*Phoradendron* spp.), dandelion (*Taraxacum* spp.), false dandelion (*Agoseris* spp.), strawberry (*Fragaria* spp.), clover (*Trifolium* spp.), sedge (*Carex* spp.), daisy or fleabane (*Erigeron* spp.), knotweed (*Polygonum* spp.), manzanita or bearberry (*Arctostaphylos* spp.), huckleberry (*Vaccinium* spp.), pussy toes (*Antennaria* spp.), elderberry fruit (*Sambucus* spp.), hawksbeard (*Crepis* spp.), dock (*Rumex* spp.), starwort (*Stellaria* spp.), and lupine (*Lupinus* spp.) (Beer 1943, Boag 1963). A study on Vancouver Island indicated that 90% of adult blue grouse diets consisted of bracken fern (*Pteridium aquilinum*), willow (*Salix* spp.), Oregon grape (*Berberis* spp.), blackberry (*Rubus* spp.), huckleberry, salal (*Gaultheria* spp.), and cat's ear (*Hypochaeris* spp.) (Johnsgard 1973). Insects are also an important food source, especially for young chicks during their first 10 days of life (Beer 1943).

Breeding Areas

Conifer thickets, their edges, and adjacent clearings are characteristic of high quality breeding habitat for blue grouse. Selective logging and small clearcuts have the potential to produce good blue grouse habitat by creating uneven aged timber stands with numerous 20-60 year-old thickets (Martinka 1972). Nests are usually located near logs or under low tree branches in open timber (Johnsgard 1973). Smith (1990) found that in Idaho, nesting occurs in brushy areas and that sites with tall sagebrush were preferred.

Mussehl (1962) stated that broods use areas with high plant density and diversity and high canopy coverage. Bare ground should be less than 11%, and the average effective height of grass and forbs should be 20 cm (8 in). Grass and forb cover in areas of highest use range from 53-85%. The forb component of high use areas is 11-41%. Typically, broods feed within 90 m (295 ft) of brush/tree cover. As the broods get older, they switch to riparian areas and shrubby vegetation (Mussehl 1962).

LIMITING FACTORS

Reforestation practices that include high density replanting, herbicide application, and fertilization result in rapid tree canopy closure which reduces blue grouse use (Bendell and Elliott 1967, Zwickel and Bendell 1985). In drier areas, intense grazing of open lowland forests reduces the quality and availability of breeding habitat (Mussehl 1962, Seaburg 1966, Zwickel 1972).

MANAGEMENT RECOMMENDATIONS

Streams, springs, and wet meadows should be safeguarded from potential damage due to livestock grazing and logging operations. Lush vegetation, shrubs, and deciduous trees associated with such areas should be retained for blue grouse brooding and feeding habitat. Grazing should be managed for maximum forb production. The grazing intensity should be light enough to allow grass/forb vegetation to reach a standing height of 20 cm (8 in) (Mussehl 1962, Seaburg 1966). Preferred brooding areas for blue grouse include grass and forb communities that are up to 30 cm (12 in) high. Moderate grazing from May through August or grazing deferred until after 1 August, preserves nesting, brooding, and feeding cover (Soil Conservation Service 1969). Heavy grazing on lower slopes can be deleterious to blue grouse habitat (Johnsgard 1973).

Reforestation activities should address the needs of blue grouse. Succession is naturally rapid, but it is accelerated by dense plantings of Douglas fir. Allowing the tops of hills and low-productivity sites to remain unplanted would be beneficial to blue grouse as breeding areas (Johnsgard 1973, Zwickel and Bendell 1985). Forbs should always be included in seed mixes when reseeding forest land and range where blue grouse occur (Seaburg 1966). Mussehl

(1962) showed that blue grouse preferred sites composed of at least 11% forbs. Openings in densely forested areas such as Vancouver Island, Canada, are important to blue grouse. Logging activity and fire in the low to mid-elevations can open up the forest canopy which may improve breeding habitat.

Cade (1984) recommended using clearcuts smaller than 250 m (820 ft) across and leaving at least 40 trees/ha (16 trees/ac) that have a minimum 24 cm (9 in) diameter on wintering areas. Selective cuts or long rotations greater than 60 years are also better for wintering blue grouse than clearcuts (Cade and Hoffman 1990). Winter roost areas should be retained, including mature, mistletoe-laden Douglas fir thickets near ridges (R. McKeel, personal communication; M. Quinn, personal communication).

REFERENCES

Aldrich, J. W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management 27:529-545.

Beer, J. 1943. Food habits of the blue grouse. Journal of Wildlife Management 7:32-44.

Bendell, J. F., and P. W. Elliott. 1967. Behavior and the regulation of numbers in blue grouse. Canadian Wildlife Service.

Boag, D. 1963. Significance of location, year, sex, and age to the autumn diet of blue grouse. Journal of Wildlife Management 27:555-562.

Cade, B. S. 1984. Winter habitat preferences and migration patterns of blue grouse in Middle Park Colorado. Colorado Fish and Game (W-37-R) 01-03-045.

____, and R.W. Hoffman. 1990. Winter use of Douglas fir forests by blue grouse in Colorado. Journal of Wildlife Management 54:471-479.

Johnsgard, P. A. 1973. Grouse and quails of North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Martinka, R. R. 1972. Structural characteristics of blue grouse territories in southwestern Montana. Journal of Wildlife Management 36:428-510.

Mussehl, T. W. 1962. Some physical characteristics of ground vegetation used by blue grouse broods. Unpublished Report. Montana Fish and Game, Helena, Montana, USA.

Seaburg, K. 1966. The big blue grouse. Montana Wildlife. July: 23-27.

Smith, R. B. 1990. Forest grouse management plan. Pages 40-46 *in* Upland Game Management Plan 1991-1995. Idaho Department of Fish and Game, Boise, Idaho, USA.

Soil Conservation Service. 1969. Habitat management for blue grouse. U.S. Soil Conservation Service, Spokane, Washington, USA.

Washington Department of Game. 1961. Population study of blue grouse, north central Washington. W64-R-3. Washington Department of Game, Olympia, Washington, USA.

Washington Department of Fish and Wildlife. 1996. 1995 Game Harvest Report. Wildlife Management Program, Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Zwickel, F. C. 1972. Some effects of grazing on blue grouse during summer. Journal of Wildlife Management 36:631-634.

____, and J. F. Bendell. 1985. Blue grouse-effects on and influences of a changing forest. The Forestry Chronicle 61:185-188.

PERSONAL COMMUNICATIONS

Roger McKeel, Wildlife Program Manager
Washington Department of Fish and Wildlife
Yakima, Washington

Mark Quinn, Wildlife Program Manager
Washington Department of Fish and Wildlife
Ephrata, Washington

CONTACTS

Washington State University Cooperative Extension Service
921 Lakeridge Drive SW
Room 216
Olympia, WA 98502
(360)786-5445

U.S. Natural Resource Conservation Service
316 W. Boone Ave.
Suite 450
Spokane, WA 99201-2348
(509) 353-2354

Dave Ware
Washington Department of Fish and Wildlife
600 N. Capitol Way
Olympia, WA 98501
(360) 902-2509

U. S. Fish and Wildlife Service
3704 Griffin Lane SE
Suite 102
Olympia, WA 98501-2192
(360) 753-9440

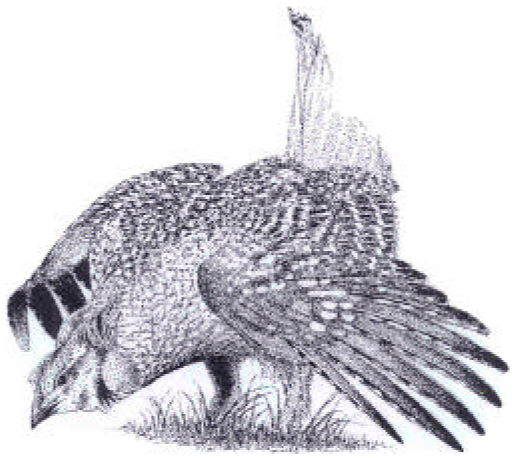
KEY POINTS

Habitat Requirements

- Blue grouse use open, low- to mid- elevation forests for breeding areas. They can be found in close association with streams, springs, and meadows.
- Forest openings <250 m (820 ft) best allow for blue grouse movement across them.
- Areas where vegetation is comprised of 11-40% broadleaf plants (forbs) are preferred.
- Rangeland with vegetation averaging 20 cm (8 in) tall provides brood rearing habitat from May through August.
- Broods use areas with high plant density and diversity and high canopy coverage.
- Insects are an important food source for very young chicks (<10 days old).
- Needles from true fir (*Abies* spp.) and Douglas fir (*Pseudotsuga menziesii*) are an important food source.
- Blue grouse winter in true fir and Douglas fir forests at higher elevations.

Management Recommendations

- Streams, springs, and wet meadows should be safeguarded from potential damage due to livestock grazing and logging operations. Lush vegetation, shrubs, and deciduous trees associated with such areas should be retained for blue grouse brooding and feeding habitat.
- Grazing should be light so that an effective height of 20 cm (8 in) for grasses and forbs is maintained from May through August, or grazing should be postponed until after 1 August.
- Timber harvest in areas known to contain wintering or breeding blue grouse should be restricted to selective cutting or clearcuts smaller than 250 m (820 ft).
- At least 40 trees/ha (16/ac) with diameters >24 cm (9 in) should be left standing when timber harvest occurs in areas inhabited by blue grouse.
- Revegetation efforts should aim for a high percentage of forbs and a variety of trees rather than single plantings that include 1 or 2 species.
- Known winter roosts should be retained, including mature Douglas fir thickets near ridges.



Sharp-tailed Grouse

Tympanuchus phasianellus

Last updated: 2003

Written by Michael A. Schroeder and Michelle Tirhi

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Sharp-tailed grouse (*Tympanuchus phasianellus*) were originally found throughout substantial portions of central and western North America, including a large portion of Canada and Alaska (Hays et al. 1998). Although there are 6 subspecies of sharp-tailed grouse in North America, only the Columbian subspecies (*T. p. columbianus*) is found in Washington. Columbian sharp-tailed grouse were originally distributed in shrub-steppe, steppe, and meadow-steppe habitats from southern British Columbia, through northeastern California, Utah, Colorado, Wyoming and western Montana (Yocom 1952, Jewett et al. 1953, Aldrich and Duvall 1955, Aldrich 1963, Daubenmire 1970).

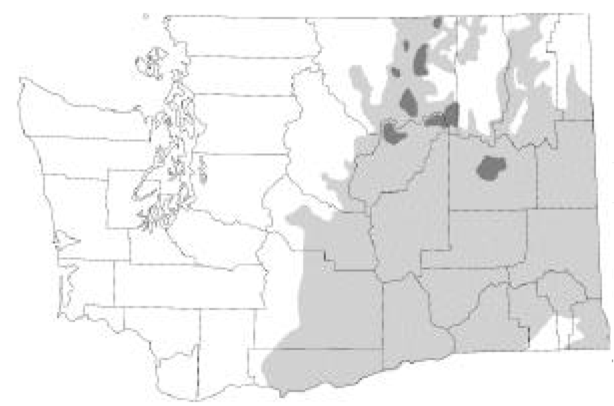


Figure 1. Current (dark) and pre-settlement (light) range of the sharp-tailed grouse, *Tympanuchus phasianellus*, in Washington. Map derived from Schroeder et al. 2000.

The current range of sharp-tailed grouse in Washington is restricted to eight small, isolated populations in the north-central portion of the state (see Figure 1; Washington Department of Fish and Wildlife 1995, Hays et al. 1998, Schroeder et al. 2000). The largest of these remaining populations is near the Swanson Lakes Wildlife Area in Lincoln County, Nespelem in Okanogan County, and the Tunk-Siwash valleys in the Okanogan River valley (Schroeder et al. 2000). Sporadic sightings outside these primary distribution areas have been reported in Lincoln, Douglas, Okanogan and Asotin counties (Schroeder et al. 2000). Sharp-tailed grouse management areas are currently being designated by the Department of Fish and Wildlife that include portions of Okanogan, Lincoln, Douglas, Chelan and Grant counties (Stinson, in preparation; see also Washington Department of Fish and Wildlife 1995).

RATIONALE

The Columbian sharp-tailed grouse was petitioned for federal listing as a threatened or endangered species under the Endangered Species Act, but the petition was rejected by the U.S. Fish and Wildlife Service after it was determined that populations in southeastern Idaho, north-central Utah, and northwestern Colorado were relatively robust (Warren 2000). Although the sharp-tailed grouse is classified as a game species in Washington, hunting was suspended in 1988 (Washington Department of Fish and Wildlife 1995); the grouse is currently listed as a state-threatened species (Hays et al. 1998). The distribution of sharp-tailed grouse in Washington has severely decreased since pre-settlement times due to the conversion of native habitat to cropland and to the degradation and fragmentation of remaining shrub- and grass-dominated habitats (Schroeder et al. 2000). Approximately 76% of Washington's sharp-tailed grouse habitat has been lost to conversion since the late 1800s (Schroeder et al. 2000). Protection and enhancement of remaining habitats is critical to the long-term management and survival of this species in Washington (Washington Department of Fish and Wildlife 1995).

HABITAT REQUIREMENTS

General Vegetation

Sharp-tailed grouse depend on grass-dominated habitats intermixed with patches of deciduous trees and shrubs for food and cover throughout the year (Connelly et al. 1998). In Washington, sharp-tailed grouse were historically associated with shrub-steppe, steppe, and meadow-steppe (hereafter referred to collectively as shrub-steppe), riparian, and mountain shrub habitats (Daubenmire 1970, Zeigler 1979, Giesen and Connelly 1993, Schroeder et al. 2000). Sharp-tailed grouse habitat is characterized by a high diversity and quantity of shrubs including common chokecherry (*Prunus virginiana*), bittercherry (*Prunus emarginata*), water birch (*Betula occidentalis*), serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpos* spp.), hawthorn (*Crataegus* spp.), wild rose (*Rosa* spp.), aspen (*Populus tremuloides*), big sagebrush (*Artemisia tridentata*), three-tipped sagebrush (*Artemisia tripartita*), and antelope bitterbrush (*Purshia tridentata*) (Washington Department of Fish and Wildlife 1995). Herbaceous vegetation often includes bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus* spp.), yellow salsify (*Tragopogon dubius*), milkvetch (*Astragalus* spp.), and yarrow (*Achillea* spp.) (Jones 1966, Zeigler 1979, Oedekoven 1985, Marks and Marks 1988, Meints 1991, Washington Department of Fish and Wildlife 1995).

Breeding Display Grounds (leks)

During spring, males congregate on display sites (leks) to breed with females (Connelly et al. 1998). Leks are typically located on knolls and ridges with relatively sparse vegetation (Hart et al. 1952, Rogers 1969, Oedekoven 1985). Leks are typically surrounded by nesting habitat, often outward from the lek to a distance of about 2 km (1.2 mi) (Marks and Marks 1988, Giesen and Connelly 1993). There is no evidence that lek habitat is limiting, especially because males have been observed displaying on a variety of sites that comprise a range of plant conditions (e.g., croplands, roads, native rangelands grazed by livestock) (Hays et al. 1998).

Nesting and Brood Rearing

Sharp-tailed grouse are ground nesters, preferring relatively dense cover provided by clumps of shrubs, grasses and/or forbs (Ammann 1963, Hillman and Jackson 1973, Meints et al. 1992). Residual grasses and forbs from the previous year's growth are particularly important for concealment and protection of nests and broods (Hart et al. 1952, Parker 1970, Zeigler 1979, Oedekoven 1985, Meints et al. 1992, Giesen and Connelly 1993, Hays et al. 1998). In research studies, visual obstruction readings (VOR; i.e., quantitative measure of vertical plant cover) were found to be greater at nest sites than at random sites (Kobriger 1980, Marks and Marks 1987, Meints 1991, McDonald 1998).

In Washington, McDonald (1998) found that litter cover, bare ground, and visual obstruction differed between nest and random sites within 5 meters of nests. Litter cover and visual obstruction were significantly greater at nest sites, while bare ground was significantly less at nest sites. McDonald (1998) found VOR readings of 24 cm (9.5 in) within 5 m (20 ft) of all nests, and successful nest sites had higher VOR readings than unsuccessful nests (28 cm vs. 23 cm). In addition, litter cover at successful nest sites was greater than 80 percent.

Fields enrolled in agricultural set-aside programs (e.g., federal Conservation Reserve Program [CRP]) are often used by nesting grouse (Sirotnak et al. 1991, McDonald 1998, Schroeder et al. 2000). After eggs hatch, hens with broods move to areas where succulent vegetation and insects can be found (Hamerstrom 1963, Bernhoft 1967, Sisson 1970, Gregg 1987, Marks and Marks 1987, Klott and Lindzey 1990). In late summer, riparian areas and mountain-shrub communities are preferred (Giesen 1987).

Winter

Throughout winter, patches of deciduous trees and shrubs in upland and riparian areas provide food and protective cover (Zeigler 1979, Oedekoven 1985, Marks and Marks 1988, Meints 1991, Giesen and Connelly 1993). Although sharp-tailed grouse will feed on cultivated grain crops in Washington, deciduous shrubs and trees (e.g., water birch) appear to be critical when snow conditions are such that access to wheat is restricted (Zeigler 1979).

Food

Food items consumed by sharp-tailed grouse in spring and summer include wild sunflower (*Helianthus* spp.), common chokecherry, sagebrush, serviceberry, salsify, dandelion (*Taraxacum* spp.), bluegrass (*Poa* spp.), and brome (*Bromus* spp.) (Marshall and Jensen 1937, Hart et al. 1952, Jones 1966, Parker 1970). Although juvenile and adult grouse consume insects, chicks consume the greatest quantity of insects during the first few weeks of life (Parker 1970). The fruits, seeds, and buds of deciduous trees and shrubs (e.g., chokecherry, serviceberry, snowberry, wild rose, hawthorn, aspen, and water birch) and wheat and corn where available, are consumed throughout the winter (Marshall and Jensen 1937, Buss and Dziedzic 1955, Marks and Marks 1988, Giesen and Connelly 1993).

LIMITING FACTORS

The conversion of native shrub-steppe habitat to cropland over most of the pre-settlement range of sharp-tailed grouse is the primary cause of long-term population declines (Buss and Dziedzic 1955, Hays et al. 1998, Schroeder et al. 2000). Grassland habitat has decreased from 25% of the eastern Washington landscape to 1%, while shrub-steppe has decreased from 44% to 16% (McDonald and Reese 1998). Remaining areas of suitable habitat are relatively small and highly fragmented. Within the currently occupied range of sharp-tailed grouse, the degradation, removal and fragmentation of winter habitat appears to be the most significant limiting factor (Hays et al. 1998). Specific management concerns include grazing, removal of native shrubs and trees in riparian and mountain shrub communities, urban development, orchard development, fire, and permanent flooding of historic wintering habitat by dams along the Columbia River system (Oedekoven 1985, Giesen 1987, Marks and Marks 1987, Washington Department of Fish and Wildlife 1995, Connelly et al. 1998, Schroeder et al. 2000).

MANAGEMENT RECOMMENDATIONS

Conversion of Shrub-Steppe

Most of the remaining shrub-steppe habitats are characterized by relatively shallow soil; hence, they are usually undesirable for crop production (Dobler et al. 1996, Jacobson and Snyder 2000, Vander Haegen et al. 2001). Nevertheless, additional conversion of shrub-steppe habitat for development and/or crop production within sharp-tailed grouse management areas should be discouraged (Washington Department of Fish and Wildlife 1995). The retention of remaining shrub-steppe in Douglas, Lincoln and Okanogan counties is especially important (Washington Department of Fish and Wildlife 1995).

Vegetation Removal

Vegetation removal should be discouraged within 2 km (1.2 mi) of active or potential lek sites, especially during the breeding season (Giesen and Connelly 1993, Washington Department of Fish and Wildlife 1995). In some cases, limited sagebrush treatment that improves the productivity and diversity of desirable grasses, forbs, and shrubs, with careful pre-treatment assessment and post-treatment management, might be considered (Washington Department of

Fish and Wildlife 1995). Deciduous shrubs and trees in sharp-tailed grouse habitat should be retained (Giesen and Connelly 1993). In addition, manipulation of vegetation that reduces or disturbs riparian habitats should not occur within 100 m (328 ft) of streams, including dry and intermittent streams (Giesen and Connelly 1993, Washington Department of Fish and Wildlife 1995). Vegetative cover should be maintained at a visual obstruction reading of 24 cm (9.5 in) within nesting habitat (McDonald 1998).

Fire

Controlled burning should not be considered for any type of sharp-tailed grouse habitat unless the action is part of a carefully considered overall plan to restore shrub-steppe habitat and the likelihood of beneficial results for the species is high (Washington Department of Fish and Wildlife 1995). Any fire plan should carefully consider the potential spread of weeds and exotic annuals, loss of sagebrush, response of existing vegetation to different fire intensities and seasons, and the conditions of adjacent lands (Washington Department of Fish and Wildlife 1995). Fire can be used to improve grassland habitat and control invasion by conifer species (Giesen and Connelly 1993, Hays et al. 1998). Livestock control following planned burns and wildfires is essential to permit the establishment of native shrubs and herbaceous vegetation (Brown 2000). Because the availability of critical wintering habitat is likely the most significant limiting influence on sharp-tailed grouse (Washington Department of Fish and Wildlife 1995), any burning conducted in wintering habitat should be done with extreme caution as a means to restore habitat, and only very small portions of wintering habitat should be burned during any given season.

Grazing and Browsing

Large herbivores (wild and domestic) can significantly influence and alter plant community composition and structure to varying degrees among different ecosystems (Daubenmire 1940, Augustine and McNaughton 1998, Opperman and Merenlender 2000). The forbs and bunchgrasses native to shrub-steppe in Washington are most likely not adapted to severe grazing because large grazing animals were presumably not present in large numbers for several thousand years prior to the introduction of domestic livestock (Mack and Thompson 1982, Lyman and Wolverton 2002).

Over-grazing (i.e., repeated grazing that exceeds the recovery capacity of the vegetation and creates or perpetuates a deteriorated plant community) is often detrimental to sharp-tailed grouse habitat (Yocom 1952, Sisson 1970, Zeigler 1979, Klott and Lindzey 1990, Giesen and Connelly 1993, Washington Department of Fish and Wildlife 1995). Management for sharp-tailed grouse habitat should be conducted to establish a relatively lush composition of perennial bunchgrasses and forbs (McDonald 1998), and grazing management should maintain habitat in good to excellent ecological condition as defined by the Natural Resources Conservation Services technical guidelines (Ulliman et al. 1998). In shrub-steppe habitats, it is difficult to provide acceptable levels of visual obstruction in nesting and brood-rearing habitats with more than light grazing (Sisson 1976, McDonald 1998). Consequently, light grazing ($\leq$25% removal of annual herbaceous growth; [Holechek et al. 1999, Galt et al. 2000]) or no grazing may by necessary for habitat improvement (McDonald 1998). It is especially important that these levels of grazing not be exceeded in areas where habitat restoration is the objective (Galt et al. 2000), during drought years (Holechek et al. 2003), and/or following fires (Brown 2000).

Light grazing combined with rest rotation on a yearly basis may be compatible with sharp-tailed grouse management (Giesen and Connelly 1993). No grazing may be necessary where the habitat has been previously degraded and habitat restoration is the goal (Kirsch et al. 1973, McDonald 1998). Cattle can also harm nests through trampling (McDonald 1998). McDonald (1998) recommends deferring grazing until July (after the nesting season) in sharp-tailed grouse habitat in Washington. Livestock use of riparian areas should be managed or eliminated to minimize the loss of associated shrubs and trees (Giesen and Connelly 1993, Paulson 1996). Grazing is discouraged in areas where encroachment by noxious weeds is a problem. If necessary, wildlife resource agencies may consider means of reducing the impacts of wild ungulates on grouse habitat that might include the alteration of supplemental feeding programs, adjustments to hunting regulations, and temporary fencing.

Biological soil crusts are a common feature of many shrub-steppe plant communities, particularly in the lowest precipitation zones (Belnap et al. 2001). Biological crusts are comprised of lichens, mosses, cyanobacteria, green algae, microfungi, and other bacteria that might indirectly benefit grouse through aiding nitrogen fixation of plants, increasing the nutrient value of plants, increasing native plant germination rates, and by inhibiting the expansion of exotic species including cheatgrass (Belnap et al. 2001; J. Belnap, personal communication). These organisms form a living soil crust that is easily damaged by grazing (Daubenmire 1940, Mack and Thompson 1982, Belnap et al. 2001). Belnap et al. (2001) describes grazing practices that can help reduce damage to biological soil crusts. Although most soil crust studies were conducted in more arid environments, precipitation levels in some of these studies rival the drier areas of eastern Washington. Research is needed to fully understand the ecological function, impacts of disturbance, and the means to reduce impacts to biological crusts in eastern Washington's shrub-steppe.

Chemical Treatments

Herbicides and insecticides may negatively affect sharp-tailed grouse habitat by removing forbs and deciduous shrubs used for cover and by eliminating insects used for food (Oedekoven 1985, Hays et al. 1998). Land managers should be encouraged to use integrated pest management that targets specific pests or noxious weeds, to use pest population thresholds to determine when to use pesticides or herbicides, and to use crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). For more information on alternatives such as integrated pest management, contact the county Washington State University Cooperative Extension Service or the USDA Natural Resource Conservation Service. Additional contacts are found in Appendix A.

Human Disturbance

All mechanical, physical and audible disturbances should be avoided during the breeding season (March through June) within 2 km (1.2 mi) of active lek sites (Giesen and Connelly 1993). Wind turbines should not be located in habitat known to be occupied by sharp-tailed grouse because this species avoids vertical structures and is sensitive to habitat fragmentation (U.S. Fish and Wildlife Service 2003). In known grouse habitat, avoid placing turbines within 8 km (5 mi) of known leks (U.S. Fish and Wildlife Service 2003). Viewing and censusing sharp-tailed grouse leks should be conducted in a way that minimizes disturbance of birds. If public interest in viewing leks is high, agencies should consider providing and supervising viewing opportunities, perhaps with specific viewing blinds. If public use appears to be impacting breeding behavior, closures and/or timing restrictions may be necessary on public lands.

Predation

Predator management should include the use of facilities that minimize perching by raptors (e.g., perch guards; Bureau of Land Management et al. 2000), removal of artificial nest sites for predators such as the common raven (*Corvus corax*), and control of dumps and/or livestock feeding stations that may concentrate and/or enhance predator populations (Washington Department of Fish and Wildlife 1995). Raptor-proofing techniques might include placing power-lines underground, covering horizontal surfaces (e.g., ledges) and other structures with steeply angled slanting boards or sheets metal, or placing low-voltage, electrically charged wires over perching structures. Because sharp-tailed grouse rely on grass and shrub cover for concealment from predators, activities that reduce tall residual grass and shrubs, especially in nesting areas, should be avoided (Giesen and Connelly 1993). In general, management that retains or produces good quality grouse habitat should be used as the most cost-effective tool for minimizing the negative effects of predation (Schroeder and Baydack 2001).

Conservation and Restoration

Research has shown that sharp-tailed grouse depend on deciduous trees/shrubs for winter food and that the lack of winter habitat may be a limiting factor in some areas (Marks and Marks 1988, Giesen and Connelly 1993, Schroeder et al. 2000). Therefore, planting appropriate vegetation in suitable sites (e.g., along streams, draws, or springs), preferably within 6.5 km (4 mi) of actual or potential breeding habitat (Meints et al. 1992) should occur in areas marked for conservation or restoration. These considerations should be included in the guidelines for future agricultural set-aside and/or conservation programs (such as CRP). Recommended deciduous shrub and tree species include water birch, aspen, chokecherry, hawthorn, snowberry and serviceberry (Washington Department of Fish and Wildlife 1995). Management practices to rejuvenate or increase mountain shrub communities within breeding complexes should be restricted to $\leq$25% of this cover type annually. Shrub-steppe restoration and enhancement in areas where this native habitat has been removed (e.g., croplands) or degraded may benefit sharp-tailed grouse (Washington Department of Fish and Wildlife 1995). Restoration would include seeding with a combination of native shrubs, perennial forbs and bunchgrasses. Land management should also include the control of noxious weeds that compete with native vegetation.

Agricultural set-aside programs (such as the Conservation Reserve Program, Grassland Reserve Program) in sharp-tailed grouse areas should be supported (Washington Department of Fish and Wildlife 1995). The set aside programs should be structured to promote growth of a diversity of perennial bunchgrasses and forbs, annual retention of residual cover, and restoration of deciduous shrubs (Hays et al. 1998, Boisvert 2002). The use of species of limited habitat value like smooth brome (*Bromopsis inermis*) and intermediate/pubescent wheatgrass (*Thinopyrum intermedium*) should be discouraged (Boisvert 2002, A. Sands personal communication).

Local and regional government programs should be reviewed to ensure they address long-term conservation of sharp-tailed grouse populations and habitat. Specifically, critical areas protection that falls under Washington's Growth Management Act are intended to protect State Threatened, Endangered and Sensitive species and can be an effective conservation tool. Local development regulations could require mitigation standards and provide incentives to reduce impacts from projects that potentially affect sharp-tailed grouse habitat. Many resource agencies, including Washington Department of Fish and Wildlife, have staff that can provide assistance in critical areas planning.

REFERENCES

Aldrich, J. W. 1963. Geographic orientation of American tetraonidae. Journal of Wildlife Management 27:529-545.

____, and A. J. Duvall. 1955. Distribution of American gallinaceous game birds. United States Fish and Wildlife Service, Circular 34, Washington, D.C., USA.

Ammann, G. A. 1963. Status and management of sharp-tailed grouse in Michigan. Journal of Wildlife Management 27:802-809.

Augustine, D. J., and S. J. McNaughton. 1998. Ungulate effects on the functional species composition of plant communities: Herbivore selectivity and plant tolerance. Journal of Wildlife Management 62:1165-1183.

Belnap, J., J. H. Kaltenenecker, R. Rosentreter, J. Williams, S. Leonard, and D. Eldredge. 2001. Biological soil crusts: ecology and management. Technical Reference 1730-2, USDI Bureau of Land Management and U.S. Geological Survey.

Bernhoft, L. S. 1967. Habitat preference of the sharp-tailed grouse. Project W-67-R-7, Job 21, Report A-329, North Dakota State Game and Fish Department, Bismark, North Dakota, USA.

Boisvert, J. H. 2002. Ecology of the Columbian sharp-tailed grouse associated with conservation reserve program and reclaimed surface mine lands in northwestern Colorado. Thesis, University of Idaho, Moscow, Idaho, USA.

Brown, J. K. 2000. Ecological principles, shifting fire regimes and management considerations. Pages 185-204 *in* J. K. Smith, editor. Wildland fire in ecosystems: effects of fire on flora, volume 2. U.S. Forest Service General Technical Report RMRS-42-VOL-2, Ogden, Utah, USA.

Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Forest Service, Oregon Department of Fish and Wildlife, and Oregon Department of State Lands. 2000. Greater Sage-Grouse and Sagebrush-Steppe Ecosystems management guidelines. Portland, Oregon, USA.

Buss, I. O., and E. S. Dziedzic. 1955. Relation of cultivation to the disappearance of the Columbian sharp-tailed grouse from southeastern Washington. Condor 57:185-187.

Connelly, J. W., M. W. Gratson, and K. P. Reese. 1998. Sharp-tailed grouse (*Tympanuchus phasianellus*). Number 354 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Daubenmire, R. F. 1940. Plant succession due to overgrazing in the *Agropyron* bunchgrass prairie of southeastern Washington. Ecology 21:55-64.

____. 1970. Steppe vegetation of Washington. Bulletin EB 1446. Washington State University Cooperative Extension, Pullman, Washington, USA.

Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Phase One Completion Report, Washington Department of Fish and Wildlife, Olympia, WA, USA.

Galt, D., F. Molinar, J. Navarro, J. Joseph, and J. Holechek. 2000. Grazing capacity and stocking rate. Rangelands 22:7-11.

Giesen, K. M. 1987. Population characteristics and habitat use by Columbian sharp-tailed grouse in northwest Colorado. Final Report, Project W-37-R, Colorado Division of Wildlife, Denver, Colorado, USA.

____, and J. W. Connelly. 1993. Guidelines for management of Columbian sharp-tailed grouse habitats. Wildlife Society Bulletin 21:325-333.

Gregg, L. 1987. Recommendations for a program of sharptail habitat preservation in Wisconsin. Research Report 141, Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

Hamerstrom, F. N., Jr. 1963. Sharptail brood habitat in Wisconsin's northern pine barrens. Journal of Wildlife Management 23:793-802.

Hart, C. M., O. S. Lee, and J. B. Low. 1952. The sharp-tailed grouse in Utah: Its life history, status, and management. Project 37-R, number 3, Utah State Department of Fish and Game, Salt Lake City, Utah, USA.

Hays, D. W., M. J. Tirhi, and D. W. Stinson. 1998. Washington State status report for the sharp-tailed grouse. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Hillman, C. N., and W. W. Jackson. 1973. The sharp-tailed grouse in South Dakota. No. 3, G125 73 0001, South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, USA.

Holechek, J. L., H. Gomez, F. Molinar, and D. Galt. 1999. Grazing studies: what we've learned. Rangelands 21(2)12-16.

____, D. Galt, J. Joseph, J. Navarro, G. Kumalo, F. Molinar, and M. Thomas. 2003. Moderate and light cattle grazing effects on Chihuahuan desert rangelands. Journal of Range Management 56:133-139.

Jacobson, J. E., and M. C. Snyder. 2000. Shrubsteppe mapping of eastern Washington using Landsat Satellite Thematic Mapper data. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Jewett, S. G., W. G. Taylor, W. T., Shaw, and A. W. Aldrich. 1953. Birds of Washington State. University of Washington Press, Seattle, Washington, USA.

Jones, R. E. 1966. Spring, summer, and fall foods of the Columbian sharp-tailed grouse in eastern Washington. Condor 68:536-540.

Kirsch, L. M., A. T. Klett, and H. W. Miller. 1973. Land use and prairie grouse population relationships in North Dakota. Journal of Wildlife Management 37:449-453.

Klott, J. H., and F. G. Lindzey. 1990. Brood habitats of sympatric sage grouse and Columbian sharp-tailed grouse in Wyoming. Journal of Wildlife Management 54:84-88.

Kobriger, J. 1980. Habitat use by nesting and brooding sharp-tailed grouse in southwestern North Dakota. North Dakota Outdoors 43:2-6.

Lyman, R. L., and S. Wolverton. 2002. The late pre-historic-early historic game sink in the northwestern United States. Conservation Biology 16:73-85.

Mack, R. N., and J. N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. American Naturalist 119:757-773.

Marks, S. J., and V. S. Marks. 1987. Habitat selection by Columbian sharp-tailed grouse in west-central Idaho. U.S. Bureau of Land Management, Boise District, Idaho, USA.

____, and ____. 1988. Winter habitat use by Columbian sharp-tailed grouse in western Idaho. Journal of Wildlife Management 52:743-746.

Marshall, W. H., and M. S. Jensen. 1937. Winter and spring studies of the sharp-tailed grouse in Utah. Journal of Wildlife Management 1:87-99.

McDonald, M. W. 1998. Ecology of the sharp-tailed grouse in eastern Washington. Thesis, University of Idaho, Moscow, Idaho, USA.

____, and K. P. Reese. 1998. Landscape changes within the historical distribution of Columbian sharp-tailed grouse in eastern Washington: is there hope? Northwest Science 72:34-41.

Meints, D. R. 1991. Seasonal movements, habitat uses, and productivity of Columbian sharp-tailed grouse in southeastern Idaho. Thesis, University of Idaho, Moscow, Idaho, USA.

____, J. W. Connelly, K. P. Reese, A. R. Sands, and T. P. Hemker. 1992. Habitat suitability index procedures for Columbian sharp-tailed grouse. Idaho Forest, Wildlife and Range Experiment Station, Bulletin 55.

Oedekoven, O. O. 1985 Columbian sharp-tailed grouse population distribution and habitat use in south central Wyoming. Thesis, University of Wyoming, Laramie, Wyoming, USA.

Opperman, J. J., and A. M. Merenlender. 2000. Deer herbivory as an ecological constraint to restoration os degraded riparian corridors. Restoration Ecology 8:41-47.

Parker, T. L. 1970. On the ecology of sharp-tailed grouse in southeastern Idaho. Thesis, Idaho State University, Pocatello, Idaho, USA.

Paulson, G. C. 1996. Livestock grazing: effects on woody riparian plant communities used by wintering Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*), Lake Creek, Washington. Thesis, Eastern Washington University, Cheney, Washington, USA.

Rogers, G. E. 1969. The sharp-tailed grouse in Colorado. Project W-37-R, Colorado Game, Fish, and Parks Division, Denver, Colorado, USA.

Schroeder, M. A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24-32.

____, D. W. Hays, M. A. Murphy, and D. J. Pierce. 2000. Changes in the distribution and abundance of Columbian sharp-tailed grouse in Washington. Northwestern Naturalist 81:95-103.

Sirotnak, J. M., K. P. Reese, J. W. Connelly, and K. Radford. 1991. Characteristics of Conservation Reserve Program fields in southeastern Idaho associated with upland bird and big game habitat use. Project W-160-R, Idaho Department of Fish and Game, Boise, Idaho, USA.

Sisson, L. H. 1970. Vegetational and topographic characteristics of sharp-tailed grouse habitat in Nebraska. Project W-38-R-3, Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

____. 1976. The sharp-tailed grouse in Nebraska. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Stinson, E. R., and P. T. Bromley. 1991. Pesticides and wildlife: a guide to reducing impacts on animals and their habitat. Virginia Department of Game and Inland Fish, Richmond, Virginia, USA.

Ulliman, M. J., A. Sands and T. Hemker. 1998. Idaho Columbian Sharp-tailed Grouse Conservation Plan (Draft), Unpublished Report, Idaho Department of Fish and Game, Boise, Idaho, USA.

U.S. Fish and Wildlife Service. 2003. Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines. [available at: http//www.fws.gov/r9dhcbfa/windenergy.htm], Washington, D.C. USA.

Vander Haegen, W. M., S. M. McCorquodale, C. R. Peterson, G. A. Green, and E. Yensen. 2001. Wildlife communities in eastside shrubland and grassland habitats. Pages 292-316 *in* D. H. Johnson and T. A. O'Neil, Managing Directors. Wildlife-Habitat Relationships in Oregon and Washington. University of Oregon Press, Corvallis, Oregon, USA.

Warren, C. 2000. Endangered and threatened wildlife and plants; 12-month finding for a petition to list the Columbian sharp-tailed grouse as threatened. Federal Register 65:60391-60396.

Washington Department of Fish and Wildlife. 1995. Washington state management plan for Columbian sharp-tailed grouse. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Yocom, C. F. 1952. Columbian sharp-tailed grouse (*Pedioecetes phasianellus columbianus*) in the State of Washington. American Midland Naturalist 48:185-192.

Zeigler, D. L. 1979. Distribution and status of the Columbian sharp-tailed grouse in Eastern Washington. Completion Report, Project W-70-R-18, Washington Department of Wildlife, Olympia, Washington, USA.

PERSONAL COMMUNICATIONS

Alan Sands, Stewardship Ecologist
The Nature Conservancy - Idaho Field Office
Boise, Idaho

Jayne Belnap, Soil Ecologist
United States Geological Survey
Biological Resources Division
Moab, Utah

CONTACTS

Michael A. Schroeder
Washington Department of Fish and Wildlife
P.O. Box 1077
Bridgeport, Washington 98813
(509) 686-2692

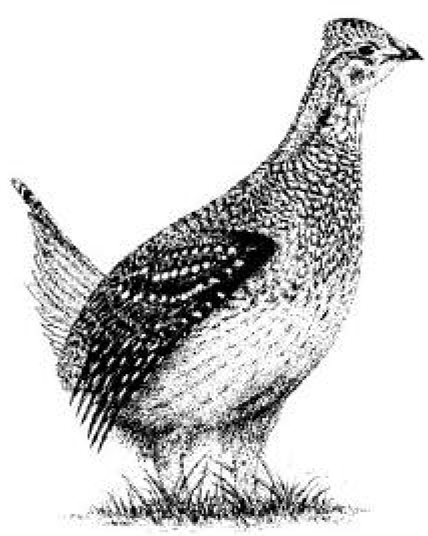
Mick Cope
Washington Department of Fish and Wildlife
600 Capitol Way N.
Olympia, Washington 98501
(360) 586-2755

U. S. Fish and Wildlife Service
510 Desmond Drive SE, Suite 102
Lacey, Washington 98503
(360) 753-9440

Washington State University Cooperative Extension Service
Hulbert 411
Pullman, Washington 98502
(509) 335-2837

U.S. Agriculture Stabilization and Conservation Service
Evergreen Plaza Building, Room 502
711 Capitol Way
Olympia, Washington 98501-1278
(360) 753-9454

Foster Creek Conservation District
103 North Baker Street
P.O. Box 428
Waterville, Washington 98858
(509) 745-8362



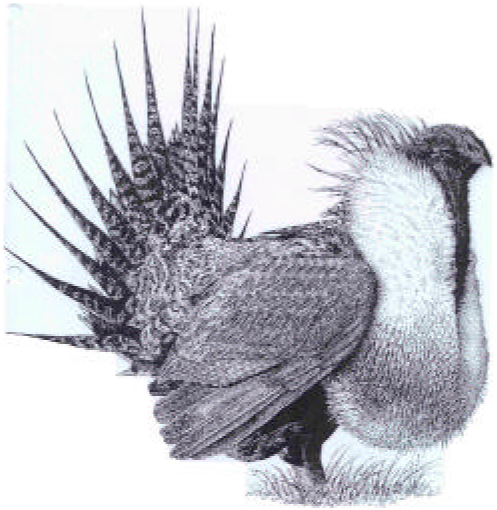
KEY POINTS

Habitat Requirements

- Sharp-tailed grouse occupy a variety of habitats in eastern Washington, including steppe, meadow-steppe, shrub-steppe, riparian, and mountain shrub.
- Buds, seeds, and fruits of chokecherry, serviceberry, snowberry, wild rose, hawthorn, aspen, and water birch are important winter food species for sharp-tailed grouse.
- Residual perennial bunchgrasses and forbs are the preferred nesting habitat of sharp-tailed grouse. Residual herbaceous growth from the previous growing season is a necessary component of sharp-tailed grouse nesting habitat.
- Sharp-tailed grouse depend on grass-dominated habitats intermixed with patches of deciduous trees and shrubs for food and cover throughout the year.

Management Recommendations

- Vegetation manipulation should be avoided (herbicide application, burning, mechanical treatment) for reasons other than sharp-tailed grouse habitat improvement within 2 km (1.2 mi) of active or potential lek sites, within 100 m (328 ft) of streams, or within winter habitat.
- Conversion of shrub-steppe habitat should be avoided within sharp-tailed grouse management areas.
- Vegetative cover should be maintained at a visual obstruction reading of 24 cm (9.5 in) within nesting habitat.
- Controlled burning should be avoided within any type of sharp-tailed grouse habitat unless the action is part of a carefully considered overall plan to restore shrub-steppe habitat and the likelihood of beneficial results for the species is high.
- Grazing management that improves and/or maintains habitat in good to excellent condition should be supported.
- Light grazing levels ($\leq$25% removal of annual herbaceous growth) or cessation of grazing to improve habitat conditions should be maintained.
- Grazing should be managed or eliminated within riparian areas to minimize the loss of associated shrubs and trees.
- Herbicide and insecticide use should be discouraged where sharp-tailed grouse occur, and encourage the use of integrated pest management.
- All physical and audible disturbances should be avoided from March through June within 2 km (1.2 mi) of active lek sites.
- Native shrubs and perennial native forbs and bunchgrasses should be reseeded to restore sharp-tailed grouse habitat.
- Land managers should control noxious weeds and prevent noxious weed encroachment in suitable sharp-tailed grouse habitat.
- The use of agricultural set aside programs (e.g., Conservation Reserve Program, Grassland Reserve Program) should be supported in sharp-tailed grouse areas dominated by cropland.



Greater Sage-Grouse

Centrocercus urophasianus

Last updated: 2003

Written by Michael A. Schroeder, Derek Stinson and Michelle Tirhi

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Greater sage-grouse (*Centrocercus urophasianus*) are closely tied to the distribution of big sagebrush (*Artemisia tridentata*) throughout much of their range (Schroeder et al. 1999). Prior to settlement by people of European descent, sage-grouse were distributed from southern British Columbia, Alberta, and Saskatchewan to eastern California, northern Arizona, and western portions of Oklahoma, Kansas, Nebraska, South Dakota and North Dakota. The core of the distribution was in Washington, Oregon, Nevada, Idaho, Utah, Colorado, Wyoming and Montana. The newly described Gunnison sage-grouse (*Centrocercus minimus*) was found primarily in northwestern New Mexico, southeastern Utah, and southwestern Colorado (Young et al. 2000).

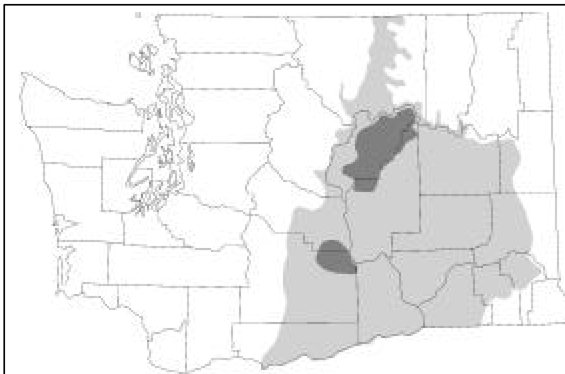


Figure 1. Current (dark) and pre-settlement (light) range of the greater sage-grouse, *Centrocercus urophasianus*, in Washington. Map derived from Schroeder et al. 2000.

Sage-grouse historically occurred throughout the shrub-steppe and meadow-steppe (hereafter referred to collectively as shrub-steppe) communities of eastern Washington (Yocom 1956, Schroeder et al. 2000). They were observed in abundance in 1805 by members of the Lewis and Clark expedition near the confluence of the Columbia and Snake Rivers (Zwickel and Schroeder 2003). Currently, the state has two relatively isolated breeding populations; one in Douglas-Grant Counties (. 650 grouse), and one in Kittitas-Yakima Counties (. 350 grouse) (see Figure 1; M. Schroeder, personal observation). Sporadic sightings outside the primary distribution have been reported in Benton, Yakima, Kittitas, Grant, Lincoln and Okanogan Counties. Sage-grouse management areas are currently being mapped and include portions of Yakima, Kittitas, Benton, Grant, Douglas, Lincoln and Okanogan Counties (Stinson, in preparation; see also Washington Department of Fish and Wildlife 1995).

RATIONALE

Greater sage-grouse in the state of Washington became a candidate for federal listing as threatened under the Endangered Species Act after a recent petition for listing precipitated a status review (Warren 2001). Although the sage-grouse is classified as a game species in Washington, hunting was terminated in 1988 (Washington Department of Fish and Wildlife 1995); they currently are listed as a state-threatened species (Hays et al. 1998). The distribution of sage-grouse in Washington has been dramatically reduced since pre-settlement times due to the conversion of shrub-steppe to cropland, and the degradation and fragmentation of the remaining habitat (Schroeder et al. 2000). Conserving, restoring and enhancing remaining habitat is critical to the survival of this species (Washington Department of Fish and Wildlife 1995).

HABITAT REQUIREMENTS

General Vegetation

Sage-grouse depend on sagebrush (*Artemisia* spp.), primarily big sagebrush, for food and cover throughout the year in Washington (Schroeder et al. 1999). Other important cover species include threetip sagebrush (*Artemisia tripartita*), stiff sagebrush (*Artemisia rigida*), rabbitbrush (*Chrysothamnus* spp.), bitterbrush (*Purshia tridentata*) and gray horsebrush (*Tetradymia canescens*) (Washington Department of Fish and Wildlife 1995). Common grasses and forbs include Sandberg bluegrass (*Poa sandbergii*), bluebunch wheatgrass (*Pseudoroegneria spicata*), needle-and-thread (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), Idaho fescue (*Festuca idahoensis*), prickly lettuce (*Lactuca serriola*), yellow salsify (*Tragopogon dubius*), milkvetch (*Astragalus* spp.), and microseris (*Microseris* spp.). Relatively dense shrub cover is important during winter and, and a combination of shrub, grass, and forb cover is important during the nesting season (Connelly et al. 2000).

Breeding Display Grounds (leks)

During spring, males congregate on display sites (leks) to breed with females (Schroeder et al. 1999). Leks are typically located in open areas near relatively dense stands of sagebrush (> 20% canopy coverage) used for food and escape cover (Dalke et al. 1963, Autenrieth 1981, Emmons and Braun 1984, Roberson 1984, Klebenow 1985). In north-central Washington, most documented leks are in wheatfields (M. Schroeder, personal observation). Sage-grouse leks are often located near nesting areas (Wallestad and Pyrah 1974, Berry and Eng 1985, Connelly et al. 1988, Gibson 1996). The typical distance between nests and the nearest leks ranges from 1.3 to 3.4 km (0.8 to 2.1 mi) (Wallestad and Pyrah 1974, Petersen 1980, Autenrieth 1981, Wakkinen et al. 1992, Fischer et al. 1993). In the fragmented shrub-steppe of eastern Washington, the nest-lek distance averages 5.1 km (3.2 mi) (Schroeder 1994). Typical characteristics of productive habitat are 15-25% sagebrush coverage in both arid and mesic (moist) sites; $\geq$ 15% perennial grass/forb cover on arid site; $\geq$ 25% perennial grass/forb cover on mesic sites (Connelly et al. 2000). Grass/forb cover tends to be higher in Washington (Schroeder 1994, Sveum et al. 1998a).

Nesting and Brood Rearing

Sage-grouse commonly nest in habitat containing sagebrush approximately 30-80 cm (12-31 in) in height, and relatively tall (>20 cm [8 in]), dense (> 40% grass and forb cover) herbaceous cover (Gray 1967, Wallestad and Pyrah 1974, Crawford and DeLong 1993, Gregg et al. 1994, Schroeder 1995, Sveum 1995, Connelly et al. 2000, Livingston and Nyland 2002). Although sage-grouse prefer to nest under sagebrush, they will nest under other plant species (Klebenow 1969, Wallstad and Pyrah 1974, Connelly et al. 1991). Nest success is directly related to higher horizontal and vertical cover at the nest site (Wallestad and Pyrah 1974, Gregg 1991, Connelly et al. 2000). In Washington, sage-grouse select nest sites that contain thicker and taller vegetation as opposed to other regions (Schroeder 1994, Sveum et al. 1998a). At the Yakima Training Center, Livingston and Nyland (2002) found that at the site level, females usually selected shrubs that provided overhead nest concealment and were surrounded by heavy bunchgrass cover >18 cm (7 in) in height.

Broods prefer open sagebrush-dominated habitats with an abundance of insects and succulent forbs (Klebenow 1969, Peterson 1970, Wallestad 1975, Klott and Lindzey 1990, Drut et al. 1994, Sveum et al. 1998b). As plants mature and dry, hens move their broods to habitats with green vegetation such as wet meadows, irrigated farmland or areas at higher elevations (Oakleaf 1971, Connelly et al. 1988, Klott and Lindzey 1990, Fischer et al. 1996, Connelly et al. 2000). Brood habitats in Washington also include areas enrolled in the federal Conservation Reserve Program (Conservation Reserve Program unpublished data).

Winter

Sagebrush provides escape cover and a majority of the dietary requirements for sage-grouse in winter (Connelly et al. 2000). They prefer sagebrush $\geq$25 cm (10 in) high above the ground or snow, with 10-30% canopy coverage (Eng and Schladweiler 1972, Wallestad and Schladweiler 1974, Wallestad 1975, Autenrieth 1981, Connelly et al. 2000). Good wintering areas are found at a variety of elevations, and include windswept ridges and sagebrush flats (Eng and Schladweiler 1972, Wallestad and Schladweiler 1974, Wallestad 1975, Autenrieth 1981). Winter habitat selection is often dependent on snow-depth (Hays et al. 1998). During winter, Robertson (1991) reported that migratory sage-grouse in southeastern Idaho made average daily movements of 752 m (2467 ft) and occupied an area >140 km^2 (54 mi^2). Wallestad (1975) reported that winter home range size varied between 11 and 31 km^2 (4-12 mi^2) in Montana.

Food

Sagebrush is a crucial component of the sage-grouse diet year-round, particularly during late autumn, winter and early spring (Remington 1983, Remington and Braun 1985, Welch et al. 1988, 1991; Myers 1992). Forbs are important food items for sage-grouse during spring, summer and early autumn; especially for hens prior to egg laying (Wallestad et al. 1975, Barnett and Crawford 1994, Drut et al. 1994). Pre-laying hens require a diet of forbs rich in calcium, phosphorus and protein in order to produce healthy clutches (Barnett and Crawford 1994). Thus, the condition of breeding habitats used by pre-laying hens plays an important role in overall reproductive success (Barnett and Crawford 1994, Coggins 1998).

Broods feed heavily on insects during their first weeks of life (Klebenow and Gray 1968, Peterson 1970, Johnson and Boyce 1990, Drut et al. 1994, Pyle and Crawford 1996). As chicks grow, they eat more forbs, gradually switching to a diet that consists primarily of forbs (Peterson 1970). Forbs consumed include desert parsley (*Lomatium* spp.), hawksbeard (*Crepis* spp.), prickly lettuce, common dandelion (*Taraxacum officinale*), mountain dandelion (*Agoseris* spp.), western yarrow (*Achillea millefolium*), pale agoseris (*Agoseris glauca*), clover (*Trifolium* spp.), yellow salsify, everlasting (*Antennaria* spp.), vetch (*Vicia* spp.), milkvetch, alfalfa (*Medicago sativa*), aster (*Aster* spp.) and long-leaf phlox (*Phlox longifolia*) (Wallestad et al. 1975, Drut et al. 1994, Barnett and Crawford 1994). The availability of forbs and insects influences sage-grouse chick survival (Johnson and Boyce 1991).

LIMITING FACTORS

In Washington, the lack of extensive good quality shrub-steppe vegetation limits sage-grouse (Washington Department of Fish and Wildlife 1995, Hays et al. 1998, Schroeder et al. 2000). Habitat loss, degradation and fragmentation of shrub-steppe can be attributed to land conversion, development, grazing, sagebrush removal and burning, erosion, mining, military activity, noise, power lines and roads (Klebenow 1972, Braun 1986, Swenson et al. 1987, Hofmann 1991, Remington and Braun 1991, Washington Department of Fish and Wildlife 1995, Schroeder et al. 2000).

MANAGEMENT RECOMMENDATIONS

Conversion of Shrub-Steppe

The reduction in sage-grouse numbers and distribution is primarily attributed to the loss, fragmentation, and degradation of shrub-steppe habitat through land conversion and mismanagement (Braun 1998). Most of the remaining shrub-steppe habitats are characterized by relatively shallow soil; hence they are usually undesirable for crop production (Dobler et al. 1996, Jacobson and Snyder 2000, Vander Haegen et al. 2000). Nevertheless, further conversion of shrub-steppe habitat within sage-grouse management areas should be strongly discouraged (Washington Department of Fish and Wildlife 1995). Despite the importance of shrub-steppe to many declining Species of Concern, conversion of shrub-steppe habitat on public and private lands is continuing (Hays et al. 1998). Conservation of shrub-steppe habitat in and around croplands in Douglas County is also extremely important because these sites are a source of sagebrush seed that germinate on the extensive lands that are enrolled in the Federal Conservation Reserve Program in this county (Hays et al. 1998).

Sagebrush Alteration

Removal or alteration of sagebrush should be avoided within sage-grouse management areas, particularly near leks, brood-rearing and in nesting and wintering areas (Connelly et al. 2000). Sage-grouse depend upon sagebrush stands for most of their life needs throughout the year, therefore sagebrush should not be eradicated (Connelly et al. 2000). Sagebrush should not be removed within 300 m (984 ft) of sage-grouse foraging sites along riparian areas, meadows, lakes, and farmlands (Connelly et al. 2000). Sagebrush removal should not occur where live sagebrush cover is <25% in nesting areas, and <30% in wintering areas (Connelly et al. 2000). Sagebrush should also not be controlled on slopes ≥ 20% and/or on slopes with shallow soils where big sagebrush is <30 cm (12 in) in height (Call and Maser 1985). Anyone planning to remove sagebrush should carefully consider the method of removal (fire, mechanical means, herbicides), amount removed, species removed, post-removal management, mitigation measures, and the effects on the sage-grouse population (see references in contact section for assistance).

Fire

Wildfires pose a substantial threat to sage-grouse in Washington and occupied habitat should be a high priority for fire suppression and prevention (Connelly et al. 2000). Prescribed fire has been used to reduce sagebrush that in turn increases grass and forb cover (Pyle and Crawford 1996). However, Wambolt et al. (2002) pointed out that there is no empirical evidence demonstrating the benefits of fire to sage-grouse.

Where fire is used as a management tool to restore potential habitat, controlled burns are recommended in late April to early May when fuels left from the prior growing season are able to carry a relatively cool fire (Autenrieth 1981). These prescribed fires should be ≤ 50 ha in size and cover less than 20% of an area used by sage-grouse during winter within any 20–30 year interval (depending on estimated recovery time for the sagebrush habitat) (Connelly et al. 2000). Because the availability of critical wintering habitat is likely the most significant limiting influence on sage-grouse, any burning conducted in wintering habitat should only be done with extreme caution as a means to restore habitat, and only very small portions of wintering habitat should be burned during any given season (Connelly et al. 2000). Avoid using fire without including plans to control cheatgrass competition in the understory (e.g., through the use of a pre-emergent herbicide [e.g., Oust®, Plateau®]) where an increase of or an invasion by cheatgrass (*Bromus tectorum*) is likely (Connelly et al. 2000). Annual grassland establishment following fire is very detrimental to sagebrush habitat integrity (Young and Longland 1996). In addition, habitat recovery following a fire may require several decades before sagebrush regrowth is sufficient to support sage-grouse (Connelly et al. 2000). Changes in livestock management (e.g., exclusion, change in season and/or intensity of use) following planned burns and wildfires is essential to the reestablishment of native shrubs and forbs (Beck and Mitchell 2000).

Fire should not be used in breeding habitat dominated by Wyoming big sagebrush (Connelly et al. 2000). Controlled burning should not be considered for any type of sage-grouse habitat unless the action is part of a carefully considered overall plan to restore shrub-steppe habitat and the likelihood of beneficial results for the species is high (Washington Department of Fish and Wildlife 1995).

Grazing and Browsing

Livestock grazing has been a common use of shrub-steppe lands within the range of sage-grouse in Washington (Hays et al. 1998). Although it is difficult to document positive effects of livestock grazing on sage-grouse, the existence of healthy sage-grouse populations in areas long grazed suggests that certain grazing levels may be compatible with sage-grouse populations (Wambolt et al. 2002). Vegetation characteristics of sage-grouse breeding, brood-rearing, and winter habitats (Table 1) should be used as guidelines in developing livestock grazing management plans, but these plans should also consider the long-term sustainability of the habitat, the likelihood of drought, and the potential for expansion of noxious weeds.

Light grazing in sage-grouse habitat should be managed for optimum growth and reproduction of native sagebrush, forbs and grasses (Table 1) (Beck and Mitchell 2000). The type and stocking rates of livestock, season of use, and grazing duration should be carefully planned based on available forage resources, and monitored on a site specific basis, with the goal of providing optimal sage-grouse habitat (Beck and Mitchell 2000) and long-term sustainability. This is particularly important in nesting areas, where sage-grouse are dependent on residual cover for concealment from predators. During drought periods ($\geq$ 2 consecutive years), it may be necessary to reduce stocking rates or change livestock management practices if herbaceous height requirements for cover (Table 1) during the nesting and brood-rearing periods are not met (Gregg et al. 1994, Sveum 1995, Connelly et al. 2000, Livingston and Nyland 2002).

Biological soil crusts are a common feature of many shrub-steppe plant communities, particularly in the lowest precipitation zones (Belnap et al. 2001). Biological crusts are comprised of lichens, mosses, cyanobacteria, green algae, microfungi, and other bacteria that might indirectly benefit grouse through aiding nitrogen fixation of plants, increasing the nutrient value of plants, increasing native plant germination rates, and by inhibiting the expansion of exotic species including cheatgrass (Belnap et al. 2001; J. Belnap, personal communication). These organisms form a living soil crust that is easily damaged by livestock grazing (Daubenmire 1940, Mack and Thompson 1982, Belnap et al. 2001). Belnap et al. (2001) describes grazing practices that can help reduce damage to biological soil crusts. Although most soil crust studies were conducted in more arid environments, precipitation levels in some of these studies rival the drier areas of eastern Washington. Research is needed to fully understand the ecological function, impacts of disturbance, and the means to reduce impacts to biological crusts in eastern Washington's shrub-steppe.

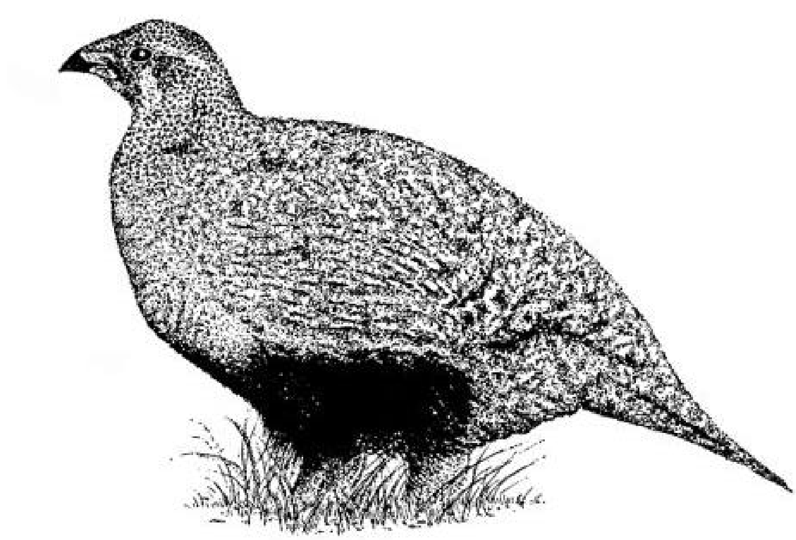


Table 1. Characteristics of sagebrush communities needed for productive sage-grouse habitat (Connelly et al. 2000).

	Breeding		Brood-rearing		Winter [e]	
	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)
Mesic (moist) sites [a]						
Sagebrush	40 – 80	15 – 25	40 – 80	10 – 25	25 – 35	10 – 30
Grass-forb	> 18 [c]	$\geq$ 25 [d]	variable	> 15	N/A	N/A
Arid sites [a]						
Sagebrush	30 – 80	15 – 25	40 – 80	10 – 25	25 – 35	10 – 30
Grass-forb	> 18 [c]	$\geq$ 15 [d]	variable	> 15	N/A	N/A
Area [b]	> 80		> 40		> 80	
Approximate period of use	late winter – late spring		late spring – early autumn		autumn – late winter	
General characteristics	Open areas surrounded by sagebrush.		Open sagebrush-dominated habitats with an abundance of insects/succulent forbs.		Areas that allow sagebrush access under various snow conditions.	

a. Mesic and arid sites should be defined on a local basis; annual precipitation, herbaceous understory, and soils should be considered (Tisdale and Hironaka 1981, Hironaka et al. 1983).
b. Percentage of seasonal habitat needed with indicated conditions.
c. Measured as "droop height"; the highest naturally growing portion of the plant.
d. Coverage should exceed 15% for perennial grasses and 10% for forbs; values should be substantially greater if most sagebrush has a growth form that provides little lateral cover (Schroeder 1995).
e. Values for height and canopy coverage are for shrubs exposed above snow.

Wild (as well as domestic) herbivores can significantly influence and alter plant community composition and structure to varying degrees among different ecosystems (Augustine and McNaughton 1998, Opperman and Merenlender 2000). The forbs and bunchgrasses native to shrub-steppe in Washington are not tolerant to intensive and prolonged grazing because large grazing animals were presumably not present in large numbers for several thousand years prior to the introduction of domestic livestock (Mack and Thompson 1982, Lyman and Wolverton 2002). In some instances, the exposure of sagebrush communities to deer (*Odocoileus* spp.) and elk (*Cervus elaphus*) browsing can suppress the production, germination and survival of sagebrush and increase the production of annual plant species (McArthur et al. 1988, Singer and Renkin 1995), potentially influencing grouse habitat. If necessary, wildlife resource agencies may consider means of reducing the impacts of wild ungulates on grouse habitat that might include altering supplemental feeding programs, adjusting hunting regulations, and temporary fencing.

The effects of livestock grazing on shrub-steppe vegetation largely depend on the timing, frequency, and intensity of grazing. Over-grazing (i.e., repeated grazing that exceeds the recovery capacity of the vegetation and creates or perpetuates a deteriorated plant community) should be discouraged within sage-grouse management areas (Washington Department of Fish and Wildlife 1995, Beck and Mitchell 2000, Connelly et al. 2000). Frequent heavy grazing (i.e., removal of >50% of current year's growth) deteriorates the species composition and structure of native plant communities (Holechek et al. 1999). Although light grazing of healthy shrub-steppe may not cause habitat degradation (Klebenow 1981, Call and Maser 1985, Beck and Mitchell 2000), the intensity of grazing that is tolerable is not clear, but may be $\leq$ 25% utilization of the current year's growth of key forage species (Galt et al. 2000, Holechek et al. 2003). It is especially important that this level of grazing not be exceeded in areas where habitat restoration and maintenance is the objective (Galt et al. 2000), during drought years (Holechek et al. 2003), and/or following fires (Beck and Mitchell 2000). When habitat is degraded by over-grazing, recovery of the native plant community likely requires a dramatic reduction (if not a cessation) of grazing for a long period of time (Anderson and Inouye 2001). However, restoring severely altered habitat (e.g., area devoid of its native species and seed sources) often requires more than simply removing cattle to recover the native plant community (Bunting et al. 2002).

Chemical Treatments

Herbicides may be necessary to improve sage-grouse habitat where noxious weeds have replaced native vegetation (Washington Department of Fish and Wildlife 1995). Herbicide application should be followed with restoration efforts designed to enhance native vegetation or establish a desirable plant community. The herbicide 2,4-D should not be used for sagebrush control because its application results in a significant loss of native forbs (Call and Maser 1985). Tebuthiuron (e.g., Spike®) should not be used, except in small scale experiments, until it is demonstrated that it has no long-lasting impacts to sage-grouse habitat (Connelly et al. 2000).

Insecticides should not be applied to sage-grouse summer habitat, particularly organophosphorus and carbamate insecticides, which are highly toxic (Blus et al. 1989). Insects are the primary food source for young sage-grouse chicks, and insecticide use can be directly and indirectly detrimental to sage-grouse (Beck and Mitchell 2000).

Land managers should be encouraged to use integrated pest management that targets specific pests or noxious weeds, to use pest population thresholds to determine when to use pesticides or herbicides, and to use crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). For more information on alternatives such as integrated pest management, contact your county Washington State University Cooperative Extension Service or the USDA Natural Resource Conservation Service. Additional contacts are found in Appendix A.

Human Disturbance

Disturbances should be minimized from mid-February through early June within breeding and nesting areas (Hofmann 1991). Although nesting areas have been generally defined as locations within 3.2 km (2 mi) of leks, recent studies suggest that many nests are >3 km (2 mi) from leks (Wallestad and Pyrah 1974, Autenrieth 1981, Connelly et al. 1988, Eberhardt and Hofmann 1991, Wakkinen et al. 1992, Schroeder 1994).

Viewing and censusing sage-grouse leks should be conducted in a way that avoids disturbing the birds (Call and Maser 1985). Agencies should not provide lek locations to people who wish to view birds without supervision (Connelly et al. 2000). If public interest in viewing leks is high, agencies should consider constructing viewing blinds at specific locations for public use (Connelly et al. 2000). Camping on or near active leks should not be permitted (Connelly et al. 2000). On the Yakima Training Center, vehicle activity has been shown to disturb sage-grouse in critical areas (e.g., leks) (Hays et al. 1998). Therefore, activity on roads traversing sage-grouse leks should be restricted during hours when birds are active (sunset - 3 hours after sunrise) during the lekking season.

Fences, utility wires, and other structures can be hazardous to flying grouse. New and existing fences should be made more visible with flagging or by other means, within 1 km (0.6 mi) of sage-grouse habitat (Connelly et al. 2000). Woven wire fences negatively influence sage-grouse because they cannot quickly fly or travel through them (Braun 1998). Utility wires can also create hazards for sage-grouse (Borell 1939). Wind turbines should not be located in habitat known to be occupied by sage-grouse because this species avoids vertical structures and is sensitive to habitat fragmentation (U.S. Fish and Wildlife Service 2003). In grouse habitat, avoid placing turbines within 8 km (5 mi) of known leks (U.S. Fish and Wildlife Service 2003). The expansion of roads near shrub-steppe habitat used by grouse leads to habitat loss and fragmentation, direct mortality (Braun 1998), and the spread of invasive weeds. Consequently, limitations should be placed on the expansion of roads within grouse habitat.

Predation

The establishment of red fox and other non-native predators should be prevented in sage-grouse habitat (Connelly et al. 2000). Avoid building tall structures that provide raptor perch sites, such as utility structures, within 3 km (1.9 mi) of sage-grouse habitat. If structures are unavoidable or already exist, they should be modified to discourage raptors from perching on them (Connelly et al. 2000). Raptor-proofing techniques might include, but are not limited to placing power-lines underground, covering horizontal surfaces (e.g., ledges) and other structures with steeply angled slanting boards or sheets metal or placing low-voltage, electrically charged wires over perching structures. Fences with adjacent pathways (e.g., trails, roads) negatively impact sage-grouse because they provide travel corridors for potential predators (Braun 1998). Additionally, fences with wood posts provide perch sites for potential avian predators (Braun 1998).

Habitat alteration associated with grazing, drought, and wildfire may increase the rate of predation on juveniles, but this relationship is unclear and predation has not been identified as a major limiting factor for sage-grouse (Gregg et al. 1994, Connelly and Braun 1997, Schroeder and Baydack 2001). In general, management that retains or produces good quality grouse habitat should be used as the most cost-effective tool for minimizing the negative effects of predation (Schroeder and Baydack 2001).

Conservation and Restoration

Restoration of degraded shrub-steppe is a priority (Washington Department of Fish and Wildlife 1995). Efforts to restore depleted or converted habitat should concentrate on reestablishing locally adapted, native shrub-steppe vegetation (Connelly et al. 2000) and reducing grazing pressure when necessary (Beck and Mitchell 2000). Where introduced species are the only available alternative, use species that mimic the structural characteristics of the native species and that provide food (Connelly et al. 2000). Seeding of areas with highly competitive and structurally dissimilar species such as crested wheatgrass (*Agropyron cristatum* or *Agropyron desertorum*), intermediate wheatgrass (*Agropyron intermedium*), pubescent wheatgrass (*Agropyron trichophorum*), or smooth brome (*Bromus intermis*) should be discouraged (Beck and Mitchell 2000, Connelly et al. 2000, A. Sands, personal communication). Habitats that have been degraded should be managed to promote habitat recovery. Areas that possess an understory of native forbs and bunchgrasses prior to wildfire may not need re-seeding (M. Livingston, personal communication). However, sagebrush seeding might be necessary depending on fire size and intensity as well as the distance to seed sources.

Agricultural set-aside programs (such as the Conservation Reserve Program and the Wetlands Reserve Program) and other types of voluntary conservation incentive programs (e.g., Candidate Conservation Agreements, Partners for Fish and Wildlife) should be encouraged in sage-grouse management areas in Washington (Washington Department of Fish and Wildlife 1995). Set-aside conservation programs should be structured to encourage enrollees to plant a diverse range of perennial shrubs, grasses, and forbs and to retain annual residual cover (Hays et al 1998).

Local and regional government programs should be reviewed to ensure they address long-term conservation of sage-grouse populations and habitat. Specifically, critical areas protection that falls under Washington's Growth Management Act are intended to protect State-listed species and can be an effective conservation tool. Local development regulations could require mitigation standards and provide incentives to reduce impacts from projects that potentially affect sage-grouse habitat. Many resource agencies, including Washington Department of Fish and Wildlife, have staff that can provide assistance in critical areas planning.

REFERENCES

Anderson, J. E., and R. S. Inouye. 2001. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs 71:531-556.

Augustine, D. J., and S. J. McNaughton. 1998. Ungulate effects on the functional species composition of plant communities: Herbivore selectivity and plant tolerance. Journal of Wildlife Management 62:1165-1183.

Autenrieth, R. E. 1981. Sage grouse management in Idaho. Project W-125-R and W-160-R. Idaho Department of Fish and Game, Boise, Idaho, USA.

Barnett, J. K. and J. A. Crawford. 1994. Pre-laying nutrition of sage grouse hens in Oregon. Journal of Range Management 47:114-118.

Beck, J. L. and D. L. Mitchell. 2000. Influences of livestock grazing on sage grouse habitat. Wildlife Society Bulletin 28:993-1002.

Belnap, J., J. H. Kaltenenecker, R. Rosentreter, J. Williams, S. Leonard, D. Eldredge. 2001. Biological soil crusts: ecology and management. Technical Reference 1730-2, USDI Bureau of Land Management and U.S. Geological Survey.

Berry, J. D., and R. L. Eng. 1985. Interseasonal movements and fidelity to seasonal use areas by female sage grouse. Journal of Wildlife Management 49:237-240.

Blus, L. J., C. S. Staley, C. J. Henny, G. W. Pendleton, T. H. Craig, E. H. Craig, and D. K. Halford. 1989. Effects of organophosphorus insecticides on sage grouse in southeastern Idaho. Journal of Wildlife Management 53:1139-11-46.

Borell, A.E. 1939. Telephone wires fatal to Sage Grouse. Condor 41:85-86.

Braun, C. E. 1986. Changes in sage grouse lek counts with advent of surface coal mining. Issues and Technology in the Management of Impacted Western Wildlife 2:227-231.

____. 1998. Sage grouse declines in western North America: what are the problems. Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139-156.

Bunting, S. B., J. L. Kingery, M. A. Hemstrom, M. A. Schroeder, R. A. Gravenmier, and W. J. Hann. 2002. Altered rangeland ecosystems in the Interior Columbia Basin. USDA Forest Service General Technical Report PWN-553, Portland, Oregon, USA.

Call, M. W., and C. Maser. 1985. Wildlife habitats in managed rangelands-The Great Basin of southeastern Oregon-sage grouse. USDA Forest Service General Technical Report PNW-187, Portland, Oregon, USA.

Coggins, K. A. 1998. Sage grouse habitat use during the breeding season on Hart Mountain National Antelope Refuge. Thesis, Oregon State University, Corvallis, Oregon, USA.

Connelly, J. W., and C. E. Braun. 1997. Long-term changes in sage grouse *Centrocercus urophasianus* populations in western North America. Wildlife Biology 3/4:123-128.

____, Jr, H. W. Browers, and R. J. Gates. 1988. Seasonal movements of sage grouse in southeastern Idaho. Journal of Wildlife Management 52:116-122.

____, M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28:967-985.

____, W. L. Wakkinen, A. D. Apa, and K. P. Reese. 1991. Sage grouse use of nest sites in southeastern Idaho. Journal of Wildlife Management 55:521-524.

Crawford, J. A., and A. K. DeLong. 1993. Relationships between vegetative structure and predation rates of artificial sage grouse nests. Final Report. Oregon State University, Corvallis, Oregon, USA.

Dalke, P. D., D. B. Pyrah, D. L. Stanton, J. E. Crawford, and E. F. Schlatterer. 1963. Ecology, productivity, and management of sage grouse in Idaho. Journal of Wildlife Management 27:811-841.

Daubenmire, R. F. 1940. Plant succession due to overgrazing in the *Agropyron* bunchgrass prairie of southeastern Washington. Ecology 21:55-64.

Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Phase One Completion Report, Washington Department of Fish and Wildlife, Olympia, WA, USA.

Drut, M. S., W. H. Pyle, and J. A. Crawford. 1994. Technical note: Diets and food selection of sage grouse chicks in Oregon. Journal of Range Management 47:90-93.

Eberhardt, L. E., and L. A. Hofmann. 1991. Sage grouse on the Yakima Training Center: A summary of studies conducted during 1989 and 1990. U.S. Department of the Army, U.S. Department of Energy, and Pacific Northwest Laboratories, Yakima, Washington, USA.

Emmons, S. R., and C. E. Braun. 1984. Lek attendance of male sage grouse. Journal of Wildlife Management 48:1023-1028.

Eng, R. L., and P. Schladweiler. 1972. Sage grouse winter movements and habitat use in central Montana. Journal of Wildlife Management 36:141-146.

Fischer, R. A., A. D. Apa, W. L. Wakkinen, K. P. Reese, and J. W. Connelly. 1993. Nesting-area fidelity of sage grouse in southeastern Idaho. Condor 95:1038-1041.

____, K. P. Reese, J. W. Connelly. 1996. Influence of vegetal moisture content and nest fate on timing of female sage grouse migration. Condor 98:868-872.

Galt, D., F. Molinar, J. Navarro, J. Joseph, and J. Holechek. 2000. Grazing capacity and stocking rate. Rangelands 22(6):7-11.

Gibson, R. M. 1996. A re-evaluation of hotspot settlement in lekking sage grouse. Animal Behavior 52:993-1005.

Gray, G. M. 1967. An ecological study of sage grouse broods with reference to nesting, movements, food habits and sagebrush strip-spraying in the Medicine Lodge Drainage, Clark County, Idaho. Thesis, University of Idaho, Moscow, Idaho, USA.

Gregg, M. A. 1991. Use and selection of nesting habitat by sage grouse in Oregon. Thesis, Oregon State University, Corvallis, Oregon, USA.

____, J. A. Crawford, and M. S. Drut, and A. K. Delong. 1994. Vegetational cover and predation of sage grouse nests in Oregon. Journal of Wildlife Management 58:162-166.

Hays, D. W., M. J. Tirhi, and D. W. Stinson. 1998. Washington State status report for the sage grouse. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Hironaka, M., M. A. Fosberg, and A. H. Winward. 1983. Sagebrush-grass habitat types of southern Idaho. Idaho Forest, Wildlife and Range Experiment Station, Bulletin 35, Moscow, Idaho, USA.

Hofmann, L. A. 1991. The western sage grouse (*Centrocercus urophasianus*) on the Yakima Training Center in central Washington: a case study of a declining species and the military. Thesis, Central Washington University, Ellensburg, Washington, USA.

Holechek, J. L., H. Gomez, F. Molinar, and D. Galt. 1999. Grazing studies: what we've learned. Rangelands 21(2)12-16.

____, D. Galt, J. Joseph, J. Navarro, G. Kumalo, F. Molinar, and M. Thomas. 2003. Moderate and light cattle grazing effects on Chihuahuan desert rangelands. Journal of Range Management 56:133-139.

Jacobson, J. E., and M. C. Snyder. 2000. Shrubsteppe mapping of eastern Washington using Landsat Satellite Thematic Mapper data. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Johnson, G. D., and M. S. Boyce. 1990. Feeding trials with insects in the diet of sage grouse chicks. Journal of Wildlife Management 54:89-91.

____, and ____. 1991. Survival, growth, and reproduction of captive-reared sage grouse. Wildlife Society Bulletin 19:88-93.

Klebenow, D. A. 1969. Sage grouse nesting and brood habitat in Idaho. Journal of Wildlife Management 33:649-662.

____. 1972. The habitat requirements of sage grouse and the role of fire in management. Proceedings of the Annual Tall Timbers Fire Ecology Conference 12:305-315.

____. 1981. Livestock grazing interactions with sage grouse. Pages 113-123 *In* J. M. Peek and P. D. Dalke, editors. Wildlife-livestock relationships symposium: Proceedings 10. Forest Wildlife and Range Experiment Station, University of Idaho, Moscow, Idaho, USA.

____. 1985. Habitat management for sage grouse in Nevada. World Pheasant Association 10:34-46.

____, and G. M. Gray. 1968. Food habits of juvenile sage grouse. Journal of Range Management 21:80-83.

Klott, J. H,. and F. G. Lindzey. 1990. Brood habitat of sympatric sage grouse and Columbian sharp-tailed grouse in Wyoming. Journal of Wildlife Management 54:84-88.

Livingston, M. F.,and P. Nyland. 2002. Sage grouse breeding, distribution, and habitat use: Yakima Training Center 1999-2001. Yakima Training Center, Yakima, Washington, USA.

Lyman, R. L., and S. Wolverton. 2002. The late pre-historic-early historic game sink in the northwestern United States. Conservation Biology 16:73-85.

Mack, R. N., and J. N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. American Naturalist 119:757-773.

McArthur, E. D., A. C. Blauer, and S. C. Sanderson. 1988. Mule deer-induced mortality of mountain big sagebrush. Journal of Range Management 41:114-117.

Myers, O. B. 1992. Sage grouse habitat enhancement: effects of sagebrush fertilization. Thesis, Colorado State University, Fort Collins, Colorado, USA.

Oakleaf, R. J. 1971. The relationship of sage grouse to upland meadows in Nevada. Project W-48-2, Study R-VII, Job 7.1,2,3. Nevada Department of Wildlife, Reno, Nevada, USA.

Opperman, J. J., and A. M. Merenlender. 2000. Deer herbivory as an ecological constraint to restoration os degraded riparian corridors. Restoration Ecology 8:41-47.

Peterson, J. G. 1970. The food habits and summer distribution of juvenile sage grouse in central Montana. Journal of Wildlife Management 34:147-155.

Petersen, B. E. 1980. Breeding and nesting ecology of female sage grouse in North Park, Colorado. Thesis, Colorado State University, Fort Collins, Colorado, USA.

Pyle, W. H., and J. A. Crawford. 1996. Availability of foods of sage grouse chicks following prescribed burning in sagebrush-bitterbrush. Journal of Range Management 49:320-324.

Remington, T. E. 1983. Food selection, nutrition, and energy reserves of sage grouse during winter, North Park, Colorado. Thesis, Colorado State University, Fort Collins, Colorado, USA.

____, and C. E. Braun. 1985. Sage grouse food selection in winter, North Park, Colorado. Journal of Wildlife Management 49:1055-1061.

____, and ____. 1991. How surface coal mining affects sage grouse, North Park, Colorado. Issues and Technology in the Management of Impacted Western Wildlife 5:128-132.

Roberson, J. A. 1984. Sage grouse-sagebrush relationships: a review. Pages 157-167 *in* Biology of *Artemisia* and *Chrysothamnus*, Provo, Utah, USA.
Robertson, M. D. 1991. Winter ecology of migratory sage grouse and associated effects of prescribed fire in southeastern Idaho. Thesis, University of Idaho, Moscow, USA.
Schroeder, M. A. 1994. Movement and habitat use of sage grouse in north-central Washington. Progress Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
____. 1995. Productivity and Habitat Use of Sage Grouse in North-central Washington. Upland Bird Research, Job Progress Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
____, and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24-32.
____, D. W. Hays, M. F. Livingston, L. E. Stream, J. E. Jacobson, and D. J. Pierce. 2000. Changes in the distribution and abundance of sage grouse in Washington. Northwestern Naturalist 81:104-112.
____, J. R. Young, and C. E. Braun. 1999. Sage grouse (*Centrocercus urophasianus*). Number 425 *in* A. Poole and F. Gill, editors, The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.
Singer, F. J., and R. A. Renkin. 1995. Effects of browsing by native ungulates on the sagebrush communities in Yellowstone National Park. Great Basin Naturalist 55:201-212.
Stinson, E. R. and P. T. Bromley. 1991. Pesticides and wildlife: a guide to reducing impacts on animals and their habitat. Virginia Department of Game and Inland Fisheries, Richmond, Virginia, USA.
Sveum, C. M. 1995. Habitat selection by sage grouse hens during the breeding season in south-central Washington. Thesis, Oregon State University, Corvallis, Oregon, USA.
____, W. D. Edge, and J. A. Crawford. 1998a. Nesting habitat selection by sage grouse in south-central Washington. Journal of Range Management 51:265-269.
____, J. A. Crawford, and W. D. Edge. 1998b. Use and selection of brood-rearing habitat by sage grouse in south central Washington. Great Basin Naturalist 58:344-351.
Swenson, J. E., C. A. Simmons, and C. D. Eustace. 1987. Decrease of sage grouse *Centrocercus urophasianus* after ploughing of sagebrush steppe. Biological Conservation 41:125-132.
Tisdale, E. W., and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. Idaho Forest, Wildlife, and Range Experiment Station, Bulletin 33, Moscow, Idaho, USA.
U.S. Fish and Wildlife Service. 2003. Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines. [available at: http//www.fws.gov/r9dhcbfa/windenergy.htm], Washington, D.C. USA.
Vander Haegen, W. M., F. C. Dobler, and D. J. Pierce. 2000. Shrubsteppe bird response to habitat and landscape variables in eastern Washington, USA. Conservation Biology 14:1145-1160.
Wakkinen, W. L., K. P. Reese, and J. W. Connelly. 1992. Sage grouse nest locations in relation to leks. Journal of Wildlife Management 56:381-383.
Wallestad, R. O. 1975. Life history and habitat requirements of sage grouse in central Montana. Montana Department of Fish and Game, Helena, Montana, USA.
____, J. G. Peterson, and R. L. Eng. 1975. Foods of adult sage grouse in central Montana. Journal of Wildlife Management 39:628-630.
____, and D. Pyrah. 1974. Movement and nesting of sage grouse hens in central Montana. Journal of Wildlife Management 38:630-633.
____, and P. Schladweiler. 1974. Breeding season movements and habitat selection of male sage grouse. Journal of Wildlife Management 38:634-637.
Wambolt, C. L., A. J. Harp, B. L. Welch, N. Shaw, J. W. Connelly, K. P. Reese, C. E. Braun, D. A. Klebenow, E. D. McArthur, J. G. Thompson, L. A. Torell, J. A. Tanaka. 2002. Conservation of greater sage-grouse on publc lands in the western U.S.: implications of recovery and management policies. PACWPL-Policy Paper SG-02-02. Policy Analysis Center for Western Public Lands, Caldwell, Idaho, USA
Warren, C. 2001. Endangered and threatened wildlife and plants; 12-month finding for a petition to list the Washington population of western sage grouse *(Centrocercus urophasianus phaio*s). Federal Register 66:22984-22994.
Washington Department of Fish and Wildlife. 1995. Washington state management plan for sage grouse. Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Welch, B. L., J. C. Pederson, and R. L. Rodriquez. 1988. Selection of big sagebrush by sage grouse. Great Basin Naturalist 48:274-279.
____, F. J. Wagstaff, and J. A. Roberson. 1991. Preference of wintering sage grouse for big sagebrush. Journal of Range Management 44:462-465.

Yocom, C. N. 1956. The sage hen in Washington state. Auk 73:540-550.
Young, J. R., C. E. Braun, S. J. Oyler-McCance, J. W. Hupp, and T. W. Quinn. 2000. A new species of sage-grouse (Phasianedae: *Centrocercus*) from southwestern Colorado. Wilson Bulletin 112:445-453.
Young, J. A., and W. S. Longland. 1996. Impact of alien plants on Great Basin rangeland. Weed Technology 10:384-391.
Zwickel, F. C., and M. A. Schroeder. 2003. Grouse of the Lewis and Clark expedition. Northwestern Naturalist 84:1-19.

PERSONAL COMMUNICATIONS

Jayne Belnap, Soil Ecologist
United States Geological Survey
Biological Resources Division
Moab, Utah

Michael Livingston, Wildlife Biologist
Washington Department of Fish and Wildlife
Yakima, Washington

Alan Sands, Stewardship Ecologist
The Nature Conservancy - Idaho Field Office
Boise, Idaho

CONTACTS

Michael A. Schroeder
Washington Department of Fish and Wildlife
P.O. Box 1077
Bridgeport, Washington 98813
(509) 686-2692

Mick Cope
Washington Department of Fish and Wildlife
600 Capitol Way N.
Olympia, Washington 98501
(360) 586-2755

U. S. Fish and Wildlife Service
510 Desmond Drive SE, Suite 102
Lacey, Washington 98503
(360) 753-9440

WSU Cooperative Extension Service
Hulbert 411
Pullman, Washington 98502
(509) 335-2837

U.S. Agriculture Stabilization and Conservation Service
Evergreen Plaza Building, Room 502
711 Capitol Way
Olympia, Washington 98501-1278
(360) 753-9454

Foster Creek Conservation District
103 North Baker Street
P.O. Box 428
Waterville, Washington 98858
(509) 745-8362

KEY POINTS

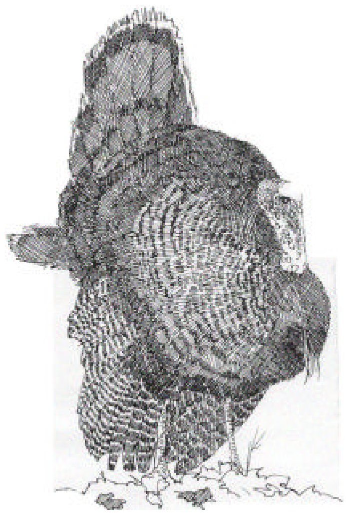
Habitat Requirements

- Sage-grouse depend on sagebrush for food and cover. Big sagebrush is a predominant species in sage-grouse habitat.
- During spring, males congregate on display sites (leks) to breed with females. Leks are typically located in open areas near relatively dense stands of sagebrush used for food and escape cover.
- Sage-grouse commonly nest in habitat containing sagebrush approximately 30-80 cm (12-31 in) in height, and relatively tall, dense herbaceous cover.

- Broods require an abundance of insects and forbs and often use wet meadows, irrigated farmland and areas at higher elevations.
- Sage-grouse winter in relatively dense sagebrush. Good wintering areas are found at a variety of elevations, and include windswept ridges and sagebrush flats.
- Adult sage-grouse feed almost entirely on sagebrush and forbs year-round. Forbs are consumed in spring, summer and early autumn. Insects and forbs are a critical food source to chicks.

Management Recommendations

- Conversion of shrub-steppe habitat is strongly discouraged.
- Removal or alteration of sagebrush is discouraged within sage-grouse management areas, particularly near leks and in nesting and wintering areas. Sagebrush should not be removed within 300 m (984 ft) of sage-grouse foraging areas along riparian areas, meadows, lake beds, and farmlands.
- Sagebrush removal should not occur where live sagebrush cover is <25% in nesting areas, and <30% in wintering areas, on slopes $20% and/or on slopes with shallow soils where big sagebrush is <30 cm (12 in) in height.
- Prescribed fires should be # 50 ha in size and cover less than 20% of an area used by sage-grouse during winter within any 20–30 year interval (depending on estimated recovery time for the sagebrush habitat). Because the availability of critical wintering habitat is likely the most significant limiting influence on sage-grouse, any burning conducted in wintering habitat should only be done with extreme caution as a means to restore habitat, and only very small portions of wintering habitat should be burned during any given season. Avoid using fire where increase of or invasion by cheatgrass is likely.
- Develop grazing management plans based on the vegetation characteristics of sage-grouse breeding, brood-rearing, and winter habitats (see Table 1).
- Grazing in sage-grouse breeding, brood-rearing, and winter habitats should be light enough to promote long-term sustainability of habitat and stocking rates should be reduced during drought.
- Dramatically reduce or cease all grazing for a long time period when site is degraded by over-grazing to allow recovery of the native plant community. The cessation of grazing alone will likely not restore sites that have been completely overtaken by annual species.
- Insecticides should not be applied to sage-grouse summer habitat. Organophosphorus and carbamate insecticides are especially toxic.
- Use integrated pest management techniques within sage-grouse management areas.
- Minimize human disturbances from mid-February through early June within breeding and nesting areas. Restrict activity on roads traversing sage-grouse leks during hours when birds are active during lek season.
- Avoid building powerlines, wind turbines and other tall structures within 3 km (1.9 mi) of grouse habitat or within 8 km (5 miles) of leks. Fences should be constructed or modified in a manner that will reduce associated mortality.
- Support agricultural set-aside programs (such as the Conservation Reserve Program and the Wetlands Reserve Program) in sage-grouse management areas. Set-aside conservation programs should be structured to encourage enrollees to plant a diverse range of perennial shrubs, grasses, and forbs and to retain annual residual cover.



Wild Turkey

Meleagris gallopavo

Last updated: 1999

Written by John T. Morgan, David A Ware, Michelle Tirhi, and Ruth L. Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Wild turkeys (*Meleagris gallopavo*) are native to North America. They have been successfully introduced into approximately 10 states outside of what is thought to be their ancestral range. They currently occur in 49 states, three Canadian provinces, and northern Mexico (Kennamer et al. 1992).

Three subspecies of wild turkey have been introduced in Washington. Merriam's turkeys occur in the northeastern and south-central part of the state, eastern wild turkeys occur west of the Cascades, and Rio Grande turkeys occur in the southeastern corner and scattered locations in the central part of the state (see Figure 1).

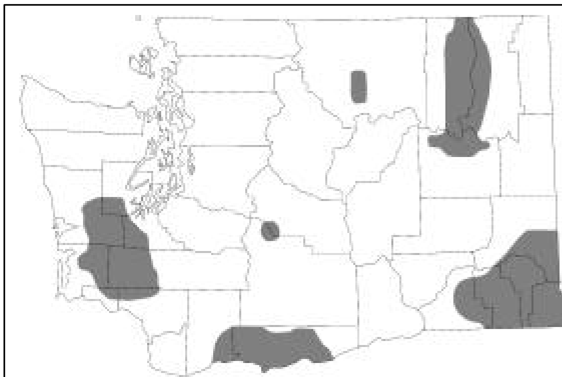


Figure 1. Primary management zone of the wild turkey, *Meleagris gallopavo*, in Washington. Map derived from Washington Department of Fish and Wildlife Game Division.

RATIONALE

Wild turkeys are a state game species and have high recreational value both for consumptive and nonconsumptive purposes. They are vulnerable to habitat loss or degradation.

HABITAT REQUIREMENTS

Wild turkeys are habitat generalists, adapting to a variety of conditions across their range (Dickson et al. 1978). However, the 2 habitat features wild turkeys depend on are trees and grasses. Trees provide food, escape cover, and roost sites, while grasses provide food for adults and an environment that allows poults (juvenile turkey) to efficiently forage for insects (Porter 1992).

Turkeys have been introduced to Washington and are established in a variety of habitats, though each population exists in habitat similar to that from which it came. Turkeys in western Washington are from the eastern subspecies, and occur in forests with open understories interspersed with agricultural areas and natural openings. Turkeys in northeast and southern Washington are native to the southwestern United States (Merriam's subspecies), and use hardwood draws and riparian areas associated with mature ponderosa pine. They are also associated with pine-oak habitats in south-central Washington. Turkeys in southeast and central Washington are from the Rio Grande subspecies, which originated in the south-central United States. They have become established in very open areas, such as open ponderosa pine, grasslands, and shrub-steppe interspersed with agricultural areas.

Nesting

Turkeys nest in a variety of habitats, though the key component appears to be lateral or horizontal cover (Porter 1992). Horizontal cover includes terrain and/or dense woody and herbaceous vegetation that helps conceal the nest (Beasom and Wildon 1992, Hurst and Dickson 1992, Lewis 1992, Shaw and Mollohan 1992, Wunz and Pack 1992). These conditions are found in timbered stands with a dense understory, fields, clearcuts, utility right-of-ways, young pine plantations, and some agricultural fields. In south-central Washington, Mackey (1982) noted that turkey nests were typically found at the base of a tree, partially covered by dead limbs or understory vegetation, in oak, oak/pine, or oak/fir forest types.

Shaw and Mollohan (1992) described Merriam's turkey nest sites as having complete protection on one side (either dense vegetation or terrain), dense cover on the remaining 3 sides between 0.0 m and 0.5 m (0-1.5 ft), and unrestricted visibility on 3 sides from 0.5 m to 0.9 m (1.5-3.0 ft). Also, nest sites had relatively solid cover 2.4-3.7 m (8-12 ft) above the nest and a forest canopy overhead. In south-central Washington, turkeys were found nesting in areas with understory height averaging 63 cm (25 in), understory canopy coverage of 36%, and forest canopy coverage of 70% (Mackey 1982). In parts of Washington without oak, turkeys nest in stands of other timber species with characteristics similar to that found by Mackey (1982) in south-central Washington.

Brood Range

Porter (1992) described three ingredients essential for brood habitat during the first 8 weeks after hatch. First, there must be an environment that produces insects and in which poults can efficiently forage. Additionally, good brood habitat must have features to permit frequent foraging throughout the day. Lastly, brood habitat must provide enough cover to hide poults while simultaneously allowing the adult female an unobstructed view to avoid predators. All of these must occur within a relatively small area because the weekly home range of a turkey brood has been reported as only 30 ha (75 ac) and a total summer home range of 100 ha (250 ac) (Speake et al. 1975, Porter 1980).

Brood habitat for wild turkeys consists of timbered areas adjacent to grassy openings. Grassy, herbaceous areas provide poults with insects for forage and cover from predators. Trees are also needed for thermal cover to protect poults from cold, wet conditions, particularly during the first 2 weeks after hatching, and as escape cover once poults can fly (10-12 days after hatching). Ideal brood habitat in Minnesota has been described as a 4:1 field-to-forest ratio (Porter 1980). Vegetation approximately 30-70 cm (12-28 in) in height allows poults to hide while allowing females to see predators (Porter 1980). Edge is important because broods usually remain near the field-forest ecotone during the first 2 weeks after hatching and later venture further into openings. Habitats meeting such conditions include forest stands interspersed with pastures and hayfields, utility right-of-ways, savannas, and cutover lands in early stages of succession.

In south-central Washington, broods were found to prefer oak and pine/oak habitats over open rangeland habitats during the first 2 weeks after hatching (Mackey 1982). This was probably because these forest types are very open (51-60% canopy coverage) and can provide an adequate insect prey base as well as cover. In parts of the state with denser forest canopy, interspersion of open areas will be much more important for brood habitat.

Roosting

Stands providing good roosting habitat are sheltered from prevailing winds and contain tall, large diameter trees with sizable horizontal branches, high canopy coverage and basal area (Hoffman 1968, Boeker and Scott 1969, Crockett 1973, Hauke 1975). Single large trees are apparently not used for roosting unless they are associated with a stand (Phillips 1980, Mackey 1984). In south-central Washington, Mackey (1982) found that only Douglas-fir stands met the criteria of good roosting habitat as listed above, though he did find smaller sized ponderosa pine and oak trees used as well. In Oregon, roosts are typically located in multi-layered, mature, mixed-conifer cover types, specifically ponderosa pine and Douglas-fir in the winter and ponderosa pine in the spring (Lutz and Crawford 1987a). In Montana, Jonas and Eng (1964) found that turkeys most often used mature ponderosa pine communities for roosting.

Fall and Winter

During fall and winter, turkeys switch to habitats that offer the best food resources, environmental conditions, and thermal cover for protection from colder temperatures and snow. Typically, this means greater use of stands of larger trees with greater canopy coverage and basal area; springs, seeps, and other riparian areas with denser vegetation; and areas with more abundant hard mast. It also means a decreased use of open areas (Beasom and Wilson 1992, Hurst and Dickson 1992, Shaw and Mollohan 1992, Wunz and Pack 1992). Turkeys may also exhibit an increase in flocking behavior during winter, particularly if available food is concentrated in specific areas (Thomas et al. 1966, 1973; Wunz and Pack 1992).

Food

Poults feed exclusively on high protein invertebrates in the first and second week after hatching, and by the third week they have switched to a diet dominated by plants (Jonas and Eng 1964, Rumble 1990, Hurst 1992, Rumble and Anderson 1996). The diet of both juvenile and adult turkeys is comprised of 75-85% plant matter and the remainder animal matter (Hurst 1992). Important year-round food items include fruits, grains, hard masts, insects, and the green leaves, flowers, and seeds of grasses, forbs, and sedges (Jonas and Eng 1964, Smith and Browning 1967, Burke 1982, Mackey 1982, Wise 1987, Rumble 1990, Hurst 1992, Rumble and Anderson 1996). During spring and summer, wild turkeys often prefer natural grassy meadows and agricultural fields due to the abundance of insects found within them (Burke 1982). Mast-producing tree and understory species are also an important food source (Wunz and Pack 1992). In fall and winter when green vegetation becomes scarce, turkeys switch to a diet composed more of grass seeds, fruits, ponderosa pine nuts, acorns, and other hard mast. Agricultural crops (wheat, barley, oats, legumes) also can serve as a valuable fall/winter food source. During the winter months, turkeys have been observed feeding on cow manure spread on croplands, corn stubble, and hay strips bordering fields of stubble corn (Vander Haegen et al. 1989).

Water

Turkeys can meet their needs for moisture through berries and other succulent vegetation when available. Whether or not turkeys drink water appears to depend on its availability and the ability of food items to provide moisture (Wunz and Pack 1992). When forage cannot meet their needs, turkeys obtain water from pools, ditches, streams, rivers, lakes, wetlands, snow, and dew. Turkeys in moist environments need less free water than those in more arid areas (Beasom and Wilson 1992, Hurst and Dickson 1992, Shaw and Mollohan 1992, Wunz and Pack 1992). Thus, turkeys in the eastern U.S. probably rely less on open water than those in the southwest or plains states. However, during times of drought or in drier eastern environments, open water may be important. Likewise, in more mesic western habitats, open water may be less important.

LIMITING FACTORS

Turkeys are limited by a number of natural and artificial factors. The northern natural range of turkeys in the east seems to be limited by the condition, depth, and duration of snowfall (Healy 1992). In the mid-west, central, and southwest United States, the range of the turkey is limited by the availability of trees. Nest and poult predation may significantly impact wild turkey populations when natural (predation, disease) and human-related (hunting, habitat change) mortality occur in conjunction (Miller and Leopold 1992). Because turkeys need an interspersion of forest and open areas, any management activities that disrupt this habitat diversity or degrade the habitat may impact local turkey populations. For instance, timber operations to open up areas for development or agricultural expansion may eliminate too much of the forest cover and food resource. On the other hand, forest thinning or creation of small openings may benefit turkey populations in some situations. Heavy grazing of grassy openings and understory vegetation may limit turkey populations by reducing food for adults and cover for nests and poults.

MANAGEMENT RECOMMENDATIONS

Regardless of subspecies or location in the state, the basic habitat requirement for wild turkeys is adequate quality, quantity, and distribution of forested and open areas. This can be achieved in mature, mast-producing forests with appropriate brood (open areas) and winter range (dense forest) areas. The actual density of forest cover, species composition, and proportion of forest and open areas will vary in different parts of the state. In areas with limited mast-producing trees, such as western Washington, agricultural fields and/or artificially constructed food plots may be needed to maintain turkey populations.

Mast Producing Vegetation - Wild turkey habitat should be managed so that 50-75% of the area is composed of mature, mast producing tree species. In Washington, this would mean maintaining species such as oak and ponderosa pine. Mackey (1982) found that the forest component of his study area in south-central Washington accounted for 74% of the landscape. Pine/oak habitat was the most preferred type for daytime use by turkeys during all seasons. In areas where food sources are scarce, mast-producing shrubs and small trees should be planted as orchards or as edges in clearings. When reseeding, sow a mixture of grasses and forbs that provide both food and cover for turkeys.

Forest Cover - Forest cover should be maintained in areas where wild turkeys exist. Forested areas are used extensively for nesting, roosting, escape and thermal cover, and even brood rearing in more open forest types. In stands lacking pine and oak, protection of mature timber is still important for cover and roosting habitat. Mackey (1982) noted that Douglas-fir stands were used extensively as roost sites. Sites used by roosting turkeys averaged greater canopy coverage (74%), greater canopy height [19 m (62 ft)], and greater basal area [34 m^2/ha (148 ft^2/ac)] than control plots (Mackey 1982). To maintain such characteristics in areas inhabited by turkeys, it is recommended that timber harvesting be done selectively and that clearcuts >12 ha (30 ac) should be avoided. Where logging is unavoidable, maintain a tree basal area 20 m^2/ha (87 ft^2/ac)(Mackey 1984). Turkeys frequently use access roads and trails. Therefore, roads created for timber harvest should be closed, gated, seeded, or tank-trapped following timber operations.

Brood Habitat - Brood-rearing habitat can be achieved through maintenance or creation of open timbered areas and/or natural and artificial openings in denser forest. Open areas can be created or maintained through selective timber harvest, prescribed burns, periodic mowing, and chemical treatments (Wunz and Pack 1992).

Livestock Grazing - Livestock grazing also may be used to maintain natural openings. Continuous light grazing seems to be compatible with wild turkey management (Beasom and Wilson 1992). Various types of grazing rotation systems have been described as providing for turkey food production but not as being good for nesting (Merrill 1975). To reduce the negative impacts of livestock grazing in turkey habitat, provide grazing exclosures within existing grazing systems. Blakey (1944 *in* Beasom and Wilson 1992) recommends that 40-200 ha (100-500 ac) be excluded from grazing within each 1,200-2,000 ha (3,000-5,000 ac) of rangeland for 24 months. As an alternative or in addition to constructing exclosures, roadside and railroad rights-of-ways or other fenced-out exclosures can be managed for turkeys. Where ungrazed areas are available, provide moderate grazing intensities on remaining areas to stimulate food plant growth (Beasom and Wilson 1992).

Land Management Activities - Turkeys are sensitive to disturbance at their nest sites (Lutz and Crawford 1987b); therefore, major land management activities in nesting habitat should be minimized during April, May, and early June. Construction of houses within turkey habitat should be restricted to nonforested areas that are larger than 2 ha (5 ac) in size (Mackey 1982).

Water - In more arid landscapes, a source of free water should be provided for turkeys. Suggestions from Beasom and Wilson (1992) include: providing water through ground-level ponds or catchments as opposed to standard livestock water troughs; fencing small, ground-level watering sites to exclude livestock; in rotational grazing systems, maintaining water in deferred pastures; in short-duration grazing sites, maintaining a fenced-out water site at least 0.4 km (0.25 mi) from the main livestock watering facility; and constructing gallinaceous guzzlers in more arid regions. Gallinaceous guzzlers collect rainfall on an impermeable apron and store the water in underground tanks that have access ramps for the birds.

REFERENCES

Beasom, S. L., and D. Wilson. 1992. Rio Grande turkey. Pages 306-330 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Boeker, E. L., and V. E. Scott. 1969. Roost tree characteristics for Merriam's turkey. Journal of Wildlife Management 33:121-124.

Burke, C. J. 1982. Wisconsin turkey hunter's guide. Wisconsin Department of Natural Resources, La Crosse, Wisconsin, USA.

Crockett, B. C. 1973. Quantitative evaluation of winter roost sites of the Rio Grande turkey in north-central Oklahoma. Pages 211-218 *in* G. C. Sanders and H. C. Schultz, editors. Wild turkey management: current problems and programs. University of Missouri Press, Columbia, Missouri, USA.

Dickson, J. G., C.D. Adams, and S. H. Hanley. 1978. Response of turkey populations to habitat variables in Louisiana. Wildlife Society Bulletin 6:163-166.

Hauke, H. H. 1975. Winter roost characteristics of the Rio Grande turkey in south Texas. Proceedings of the National Wild Turkey Symposium 3:164-169.

Healy, W. M. 1992. Population influences: environment. Pages 129-143 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Hoffman, D. M. 1968. Roosting sites and habitats of Merriam's turkeys in Colorado. Journal of Wildlife Management 32:859-866.

Hurst, G. A., and J. G. Dickson. 1992. Eastern turkey in southern pine-oak forests. Pages 265-285 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Jonas, R., and R. L. Eng. 1964. Population dynamics and ecology of Merriam's turkey in the Long Pines, southeastern Montana. Project W-91-R-6, Job II-B. Montana Department of Fish, Wildlife, and Parks, Helena, Montana, USA.

Kennamer, M. C., R. E. Brenneman, and J. E. Kennamer. 1992. Guide to the American wild turkey. Part 1: Status-numbers, distribution, seasons, harvests, and regulations. National Wild Turkey Federation, Incorporated, Edgefield, South Carolina, USA.

Lewis, J. B. 1992. Eastern turkey in midwestern oak-hickory forests. Pages 286-305 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Lutz, R. S., and J. A. Crawford. 1987a. Seasonal use of roost sites by Merriam's wild turkey hens and hen-poult flocks in Oregon. Northwest Science 61:174-178.

____, and J. A. Crawford. 1987b. Reproductive success and nesting habitat of Merriam's wild turkeys in Oregon. Journal of Wildlife Management 51:783-787.

Mackey, D. L. 1982. Ecology of Merriam's turkeys in south central Washington with special reference to habitat utilization. Thesis, Washington State University, Pullman, Washington, USA.

____. 1984. Roosting habitat of Merriam's turkeys in south-central Washington. Journal of Wildlife Management 48:1377-1381.

Merrill, L. B. 1975. Effect of grazing management practices on wild turkey habitat. Proceedings of the National Wild Turkey Symposium 3:108-112.

Miller, J. E., and B. D. Leopold. 1992. Population influences: predators. Pages 119-128 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.
Phillips, F. 1980. A basic guide to roost site management for Merriam's turkeys. Arizona Game and Fish Department. Wildlife Digest Abstract 12.
Porter, W. F. 1980. An evaluation of wild turkey brood habitat in southeastern Minnesota. Proceedings of the National Wild Turkey Symposium 4:201-212.
____. 1992. Habitat analysis and assessment. Pages 188-210 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Rumble, M. A. 1990. Ecology of Merriam's turkeys (*Meleagris gallopavo merriami*) in the Black Hills, South Dakota. Thesis, University of Wyoming, Laramie, Wyoming, USA.
____, and S. H. Anderson. 1996. Feeding ecology of Merriam's turkey (*Meleagris gallopavo merriami*) in the Black Hills, South Dakota. American Midland Naturalist 136:157-171.
Shaw, H. G., and C. Mollohan. 1992. Merriam's turkey. Pages 331-349 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.
Smith, W. A., and B. Browning. 1967. Wild turkey food habits in San Luis Obispo County, California. California Fish and Game 53:246-253.
Speake, D. W., T. E. Lynch, W. J. Fleming, G. A. Wright, and W. J. Hamrick. 1975. Habitat use and seasonal movements of wild turkeys in the southeast. Proceedings of the National Wild Turkey Symposium 3:122-130.
Thomas, J. W., C. V. Hoozer, and R. G. Marburger. 1966. Wintering concentrations and seasonal shifts in range of the Rio Grande turkey. Journal of Wildlife Management 30:34-49.
____, R. C. Marburger, and C. V. Hoozer. 1973. Rio Grande turkey migrations as related to harvest regulations in Texas. Pages 301-308 *in* G. C. Sanders and H. C. Schultz, editors. Wild turkey management: current problems and programs. University of Missouri Press, Columbia, Missouri, USA.
Vander Haegen, W. M., M. W. Sayre, and W. E. Dodge 1989. Winter use of agricultural habitats by wild turkeys in Massachusetts. Journal of Wildlife Management 53:30-33.
Wise, S. 1987. The wild turkey. PUBL-WM-133 87 8645. Bulletin, Wildlife Management, Wisconsin Department of Natural Resources, La Crosse, Wisconsin, USA.
Wunz, G. A., and J. C. Pack. 1992. Eastern turkey in eastern oak-hickory and northern hardwood forests. Pages 232-264 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

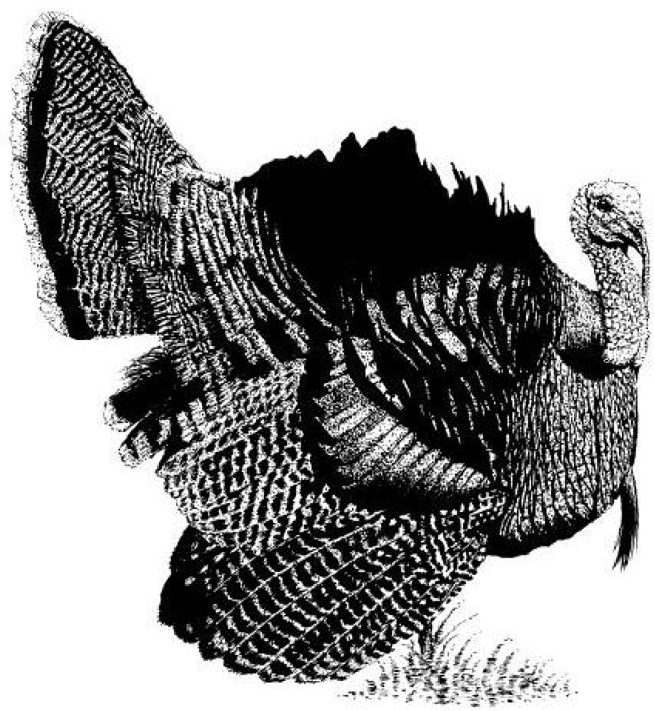
KEY POINTS

Habitat Requirements

- Trees and grass are prominent features of wild turkey habitat.
- Wild turkeys use a combination of forested and open habitats, including conifers, hardwoods, mixed woodlands, riparian areas, open grasslands, and edges of agricultural fields.
- Wild turkeys nest in timber stands with dense understories, weedy fields, clearcuts, utility rights-of-ways, young pine plantations, and agricultural fields. Typical vegetation provides dense cover up to 0.5 m (1.5 ft), unrestricted visibility from 0.5-1.0 m (1.5-3.0 ft), and a canopy of understory and forest trees above the nest.
- Brood range includes open forested areas and natural and artificial openings within close proximity to timbered areas. Ground vegetation should be 30-70 cm (12-28 in) in height to protect poults.
- Good roosting habitat includes stands of timber that are sheltered from prevailing winds and that contain trees that are larger in height, canopy cover, diameter at breast height, and basal area than trees in other stands.
- In climates with more severe winter conditions, turkeys will decrease their use of open areas and will increase their use of stands of larger trees with greater canopy coverage and basal area. Springs, seeps, and other riparian areas, as well as areas with more abundant hard mast, are also used during the winter.
- Poults feed exclusively on high protein invertebrates in the first and second weeks after hatching.
- The diet of juveniles and adults is comprised of 15-25% animal matter and 75-85% plant matter, including green vegetation, grasses, forbs, sedges, fruits, grains, and mast.
- Good turkey range has an adequate supply of water.

Management Recommendations

- Wild turkey habitat should be managed so that 50-75% of the area is composed of mature, mast-producing timber species.
- Timber should be managed through selective cuts in pine and oak habitats, and through selective cuts or small clearcuts [<12 ha (30 ac)] in Douglas-fir habitats. Avoid logging within known roost sites.
- Natural openings should be maintained and created where lacking. Unused logging roads should be closed and reseeded with grasses and legumes, and planted with shrubs and small trees.
- In areas inhabited by turkeys, grazing should be managed through light, continuous use, or with a deferred-rotation system. Provide grazing exclosures within any grazing system.
- Livestock and other disturbances to nesting habitat should be restricted from April to early June.
- Housing development should be restricted to non-forested areas larger than 2 ha (5 ac) in size.
- Sources of free water should be provided in more arid landscapes.



Sandhill Crane

Grus canadensis

Last updated: 2000

Written by Kelly A. Bettinger and Ruth Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

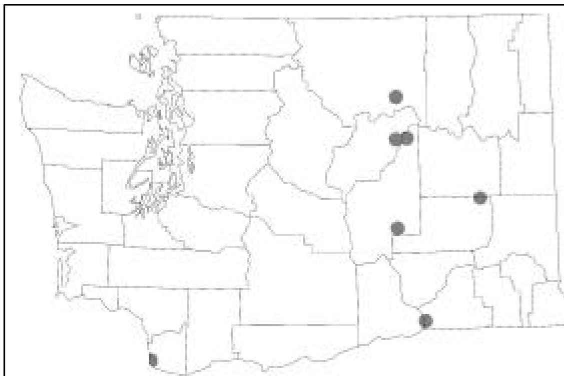


Figure 1. Known migratory stopovers and nesting areas for the sandhill crane, *Grus Canadensis*, in Washington.

The breeding range of the sandhill crane (*Grus canadensis*) includes Siberia, Alaska and Northern Canada, the Great Lakes, and portions of Idaho, Washington, Oregon, Nevada, and California. It also includes the southeastern United States, Cuba, and the Isle of Pines (Tacha et al. 1992). Six migratory populations with distinct wintering areas are recognized. These are the Lower Colorado River, Central Valley, Rocky Mountain, Pacific Flyway, Mid-continent, and Eastern populations. Three additional populations breeding in the southeastern United States and Cuba are nonmigratory (Tacha et al. 1994). Cranes breeding in Washington belong to the Central Valley population and winter in the Central Valley of California (Kramer et al. 1983, Pogson and Lindstedt 1991). This was most recently confirmed when 2 colts banded at Conboy Lake National Wildlife Refuge (NWR) in June 1996 were sighted again near Glenn, California, in January of 1997 (J. D. Engler, personal communication). Migrants moving through Washington belong to both the Central Valley and Pacific Flyway populations.

Of the 6 recognized subspecies of sandhill cranes, only the greater sandhill crane (*Grus canadensis tabida*) breeds in Washington. According to Jewett et al. (1953), the breeding range was formerly more widespread in Washington and occurred both east and west of the Cascade crest. Historic eastern Washington locales included Okanogan, Collville, Spokane, Prescott, Rockland, Cashmere, Fort Simcoe, and Camas Prairie. Fewer historic western Washington breeding sites are known. Cooper and Suckley (1860) reported sandhill cranes breeding on interior prairies of western Washington, though their most specific location description was "on prairies near Steilacoom." They also reported that sandhill cranes were very abundant on the south Puget Sound prairies during autumn migration.

Between 1975 and 1987, a single pair of sandhill cranes nested at Conboy Lake NWR in Klickitat County (see Figure 1). Since 1988, 2 to 6 pairs/year are known to have nested on the refuge, and in 1996 there were 9 confirmed breeding pairs (Anderson et al. 1996). Nesting cranes were discovered recently at a second site in Washington on the Yakama Indian Reservation in Yakima County, where 1 pair nested in 1994 and 1995, and 2 pairs nested in 1996 (Leach 1995; R. Leach, personal communication).

Migrants of 2 other subspecies, the lesser sandhill crane (*G. c. canadensis*) and the Canadian sandhill crane (*G. c. rowani*), occur in Washington during spring and fall. The largest concentrations are found in the central Columbia Basin. In the spring, lesser sandhills migrating to northwest Canada and Alaska enter Washington east of the Cascades south of Pasco. They regularly stop near Moses Lake and Ephrata in Grant County, and near Mansfield in Douglas County before continuing north through the Okanogan Valley (see Figure 1; Littlefield and Thompson 1981, Kramer et al. 1983). Lesser sandhill cranes migrating west of the Cascades enter the state near Sauvie Island in the Columbia River, and either move north through the Puget Sound region or follow the coast, passing over Cape Flattery toward Vancouver, British Columbia. The same routes are used in the fall (Littlefield and Thompson 1981). Migrating greater sandhill cranes that breed in British Columbia and Canada probably use similar routes.

Breeding sandhill cranes arrive at Conboy Lake NWR in early March. Most nesting occurs from April to June, though a newly hatched colt has been observed as late as early July (H. Cole, personal communication). Breeding cranes and their surviving young leave the state between late September and mid-October.

RATIONALE

The sandhill crane is a State Endangered species. Sandhill cranes are in jeopardy of extinction in Washington because of their limited distribution, low numbers, poor breeding success and colt survival, and loss of shallow marshes or wet meadows for feeding and nesting (Safina 1993). In addition, a large percentage of their wintering habitat is privately owned and subject to potential alteration (Lewis 1980, Pogson and Lindstedt 1991).

HABITAT REQUIREMENTS

Sandhill cranes use large and small tracts of open habitat where visibility is good from all vantage points. Wet meadows, marshes, shallow ponds, hayfields, and grainfields are all favored for nesting, feeding, and roosting. Emergent wetland vegetation is a key component of nesting territories, and nests are typically placed on piles of emergent vegetation, grass, and mud (Safina 1993, Baker et al. 1995). At Conboy Lake NWR, nesting usually takes place in shallow-water marshes with dense emergent plant cover, including reed canarygrass (*Phalaris arundinacea*) and rushes (*Juncus* spp). Bulrushes (*Scirpus* spp.) are often used for nesting in southeastern Oregon (Littlefield and Ryder 1968), but such vegetation is not common at Conboy Lake NWR. Pairs return to the same territory and even the same approximate nest location every year (Littlefield and Ryder 1968, Walkinshaw 1989).

Sandhill cranes are omnivorous, feeding on grains, plant material, invertebrates, amphibians, and small mammals (Reinecke and Krapu 1986, Tacha et al. 1992, Davis and Vohs 1993). Wet meadows or grasslands are used as feeding grounds and are sometimes used for nesting (U.S. Fish and Wildlife Service 1978, Littlefield 1995a). Grainfields and pastures are also important feeding areas (Littlefield and Ryder 1968). Wet meadow or marsh habitats used by sandhill cranes in Washington occur in forested areas (predominantly lodgepole pine [*Pinus contorta*], Douglas-fir [*Pseudotsuga menziesii*], ponderosa pine [*Pinus ponderosa*], and/or grand fir [*Abies grandis*]), and in more open conditions where they are surrounded by grasslands, shrublands, and/or agricultural lands (Tacha et al. 1992).

LIMITING FACTORS

Sandhill cranes are limited by the availability of large tracts of undisturbed marshes or meadows for feeding and nesting, and by adequate water levels during the nesting period (Safina 1993). Low nesting success and colt survival, with subsequent low annual recruitment of new birds into the population can result in a decline of breeding pairs over time (Stern et al. 1985, Stevens 1991, Littlefield 1995b,c).

Sandhill cranes are extremely wary, requiring isolated sites with good nesting cover. Repeated disturbance often results in nest desertion and increases the likelihood of predation on unattended nests (Safina 1993). Pedestrian and vehicle traffic, construction, timber harvest, and low-flying aircraft can potentially disturb breeding and roosting cranes (Kramer et al. 1983, Norling et al. 1992, Joe Engler, personal communication). Additionally, structures such as power lines and wire fences can pose hazards to cranes that may collide with or become entangled in the wires (U.S. Fish and Wildlife Service 1978, Kramer et al. 1983, Walkinshaw 1989, Morkill and Anderson 1991, Brown and Drewien 1995).

Predator populations near sandhill crane nesting areas can seriously hamper nesting success (Stern et al. 1985). Losses of eggs and chicks to predators have greatly impacted crane numbers on the Malheur National Wildlife Refuge in Oregon (Littlefield 1995b,c). Coyotes (*Canis latrans*) are the most serious predator, followed by ravens (*Corvus corax*), raccoons (*Procyon lotor*), and mink (*Mustela vison*). A combination of habitat improvement (increasing non-woody vegetative cover) and predator control has been highly successful in increasing the breeding crane population on the Malheur National Wildlife Refuge (Littlefield 1995b,c).

Livestock can also cause problems for nesting sandhill cranes. Grazing reduces vegetative cover for nests which can result in increased nest depredation (Braun et al. 1975, Littlefield and Paullin 1990, Littlefield 1995b). Eggs and young are also at risk of being trampled by cattle where spring and summer grazing is allowed (Schlorff et al.1983). Cattle trails into emergent wetlands provide easy access for mammalian predators, and habitat deterioration from mowing or grazing reduces the small mammal populations that are the favored prey of predators. This leaves predators more likely to feed on alternative prey such as crane eggs and chicks. In addition, cattle crush emergent vegetation while using it for bedding in winter, resulting in decreased cover for crane nests in April and May (Littlefield and Paullin 1990).

Nesting areas must have water shallow enough to support emergent vegetation. Cranes prefer to roost in water less than about 20 cm (8 in) deep (Lovvorn and Kirkpatrick 1981, Norling et al. 1992). Increasing water depth can flood and destroy nests, while lowering water levels can improve predator access to nests. Decreased water levels in June and July can cause a shortage of moist soil and aquatic invertebrates required by young cranes during their first 6 weeks of life, resulting in their starvation (Schlorff et al. 1983).

MANAGEMENT RECOMMENDATIONS

In order for sandhill cranes to survive in Washington, their breeding, migration, and wintering habitats need to be protected and enhanced. It is crucial that further losses of Washington's remaining wetlands are prevented. In some instances, the creation of additional habitat should be considered (Safina 1993, Tacha et al. 1994).

Disturbing cranes during the breeding season (March to September) should be avoided. Road and foot travel should be avoided within 400 m (1,312 ft) of nests, and logging operations within 800 m (2,625 ft) of crane nests should be curtailed during the breeding season (Schlorff et al. 1983). Avoid aircraft activity or keep to high altitudes over areas used by cranes (Kramer et al. 1983). In addition, construction and development within 1.2 km (0.75 mi) of nest sites should be avoided (Joe Engler, personal communication).

New power line corridors should be located away from crane migration and breeding sites, or buried underground. Line markers or other devices should be installed on existing transmission lines that pose hazards to cranes (Kramer et al. 1983, Morkill and Anderson 1991, Brown and Drewien 1995).

All fences that are not essential to controlled grazing and that are near areas used by sandhill cranes, should be removed to prevent cranes from becoming entangled in fence wires (U.S. Fish and Wildlife Service 1978, Walkinshaw 1989).

Predator populations may need to be controlled around nesting areas. A combination of habitat improvement (increasing non-woody vegetative cover) and predator control has been shown to be effective (Littlefield 1995b,c).

Livestock grazing at sandhill crane breeding sites should be limited or eliminated. Grazing and cattle trails reduce vegetative cover for crane nests, increase predator access, and increase the risk of crane eggs and young being trampled by livestock (Braun et al. 1975, Schlorff et al. 1983, Littlefield and Paullin 1990, Littlefield 1995b).

Changes in water levels should be avoided while sandhill cranes are nesting. New water projects such as dams or irrigation ditches that would alter water levels and cause negative changes to vegetation should be avoided in important crane breeding or migration areas (Schlorff et al. 1983).

Meadows should be mowed and hayed no earlier than mid-August to prevent mortality of flightless young cranes hiding in the tall vegetation (Schlorff 1983). Detailed knowledge of a given year's nesting chronology, or of when particular foraging sites are used, could allow for timing flexibility.

Mowing and hay removal conducted after 15 August may benefit cranes by providing feeding areas. All hay should be removed and residual hay cleaned up immediately after mowing to prevent mold development. "Moldy" hay provides favorable conditions for aspergillosis, which is known to infect young cranes (U.S. Fish and Wildlife Service 1978).

Fall plowing of crane feeding habitat should be avoided. Waste grain is more useful if knocked over rather than left standing (Johnson and Stewart 1972). Wheat is the preferred grain to attract cranes to a feeding site, though barley and corn are favored as well (Littlefield 1986, Sugden et al. 1988).

U.S. Fish and Wildlife Service guidelines for managing greater sandhill cranes of the Central Valley population suggest maintaining ponds and wetlands within 3.2 km (2 mi) of grain sites to provide roost sites for cranes (U.S. Fish and Wildlife Service 1978). In Saskatchewan, Canada, 90% of sandhill cranes foraged in fields within 8.0 km (5.0 mi) of their night roost sites, and observations of cranes decreased with distance from roost centers (Sugden et al. 1988). On the Malheur National Wildlife Refuge in southeast Oregon, all grainfields are within 7.6 km (4.7 mi) of night roosts (Littlefield 1986).

New construction or traffic increases within 800 m (2,625 ft) of feeding areas should be avoided. Additionally, low flying aircraft should be avoided over areas used by cranes (Kramer et al. 1983).

The construction of roads and buildings within 500 m (1,640 ft) of known night roost locations should be avoided. Preferred night roost sites used during migration are usually located away from paved or gravel roads, single dwellings, and bridges (Norling et al. 1992).

Hunting activity should be avoided near established roosts, or restricted to 4 hours after sunrise until 2 hours before sunset. Hunting should also be avoided near major feeding areas (Lovvorn and Kirkpatrick 1981, Littlefield 1986).

REFERENCES

Anderson, E., J. Engler, and H. Cole. 1996. Breeding greater sandhill cranes at Conboy Lake National Wildlife Refuge. Unpublished Report, U.S. Fish and Wildlife Service, Ridgefield, Washington, USA.

Baker, B. W., B. S. Cade, W. L. Mangus, and J. L. McMillen. 1995. Spatial analysis of sandhill crane nesting habitat. Journal of Wildlife Management 59:752-758.

Braun, C. E., R. C. Drewien, C. D. Littlefield, and L. H. Walkinshaw. 1975. Conservation committee report on the status of sandhill cranes. Wilson Bulletin 87:297-302.

Brown, W. M., and R. C. Drewien. 1995. Evaluation of two power line markers to reduce crane and waterfowl collision mortality. Wildlife Society Bulletin 23:217-227.

Cooper, J. G., and G. Suckley. 1860. The natural history of Oregon and Washington. Bailliere Brothers, New York, New York, USA.

Davis, C. A., and P. A. Vohs. 1993. Role of macroinvertebrates in spring diet and habitat use of sandhill cranes. Transactions of the Nebraska Academy of Science 20:81-86.

Jewett, S. G., W. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. Pages 232-235 *in* Birds of Washington State. University of Washington Press, Seattle, Washington, USA.

Johnson, D. H., and R. E. Stewart. 1972. The sandhill cranes, with emphasis on aspects related to North Dakota. Prairie Naturalist 4:65-76.

Kramer, G. W., B. Conant, G. Kaiser, C. D. Littlefield, R. W. Schlorff, and D. E. Timm. 1983. Pacific Flyway management plan for the Pacific Flyway population of lesser sandhill cranes. Pacific Flyway Council, U.S. Fish and Wildlife Service, Migratory Bird Management Office, Portland, Oregon, USA.

Leach, R. H. 1995. Confirmed sandhill crane nesting in Yakima County, Washington. Northwestern Naturalist 76:148.

Lewis, J. C. 1980. Sandhill crane. Pages 4-43 *in* G. Sanderson, editor. Management of migratory shore and upland game birds in North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Littlefield, C. D. 1986. Autumn sandhill crane use in southeast Oregon. Wilson Bulletin 98:131-137.

____. 1995a. Greater sandhill crane nesting and production in northeastern California, 1988. Western Birds 26:34-38.

____. 1995b. Sandhill crane nesting habitat, egg predators, and predator history on Malheur National Wildlife Refuge, Oregon. Northwestern Naturalist 76:137-143.

____. 1995c. Demographics of a declining flock of greater sandhill cranes in Oregon. Wilson Bulletin 107:667-674.

____, and D. G. Paullin. 1990. Effects of land management on nesting success of sandhill cranes in Oregon. Wildlife Society Bulletin 18:63-65.

____, and R. A. Ryder. 1968. Breeding biology of the greater sandhill crane on Malheur National Wildlife Refuge, Oregon. Transactions of the North American Wildlife and Natural Resources Conference 33:444-454

____, and S. P. Thompson. 1981. The Pacific Coast population of lesser sandhill cranes in the contiguous United States. Pages 288-294 *in* Proceedings of the 1981 Crane Workshop. National Audubon Society, Tavernier, Florida, USA.

Lovvorn, J. R., and C. M. Kirkpatrick. 1981. Roosting behavior and habitat of migrant greater sandhill cranes. Journal of Wildlife Management 45:842-856.

Morkill, A. E., and S. H. Anderson. 1991. Aviation marker balls deter sandhill cranes from collisions with a transmission line on the Platte River, Nebraska, USA. Prairie Naturalist 23:177-178.

Norling, B. S., S. H. Anderson, and W. A. Hubert. 1992. Roost sites used by sandhill crane staging along the Platte River, Nebraska. Great Basin Naturalist 52:253-261.

Pogson, T. H., and S. M. Lindstedt. 1991. Distribution and abundance of large sandhill cranes, *Grus canadensis*, wintering in California's Central Valley. Condor 93:266-278.

Reinecke, K. J., and G. L. Krapu. 1986. Feeding ecology of sandhill cranes during spring migration in Nebraska. Journal of Wildlife Management 50:71-79.

Safina, C. 1993. Population trends, habitat utilization, and outlook for the future of the sandhill crane in North America: a review and synthesis. Bird Populations 1:1-27.

Schlorff, R. W., G. Herron, G. Kaiser, C. Kebbe, G. Kramer, and C. D. Littlefield. 1983. Pacific flyway management plan for the Central Valley population of greater sandhill cranes. Pacific Flyway Council, U.S. Fish and Wildlife Service, Migratory Bird Management Office, Portland, Oregon, USA.

Stevens, L. 1991. Sandhill crane (*Grus canadensis*) recovery plan. Colorado Field Ornithologists Journal 25:49-51.

Stern, M. A., G. J. Pampush,, and R. E. Del Carlo. 1985. Nesting ecology and productivity of greater sandhill cranes at Sycan Marsh, Oregon. Proceedings of the 1985 Crane Workshop: 249-256. WR206.

Sugden, L. G., R. G. Clark, E. J. Woodsworth, and H. Greenwood. 1988. Use of cereal fields by foraging sandhill cranes in Saskatchewan. Journal of Applied Ecology 25:111-124.

Tacha, T. C., S. A. Nesbitt, and P. A. Vohs. 1994. Sandhill crane. Pages 77-96 *in* T. C. Tacha and C. E. Braun, editors. Migratory Shore and Upland Game Bird Management in North America. International Association of Fish and Wildlife Agencies, Washington D.C., USA.

____, S. A. Nesbitt, and P. A. Vohs. 1992. Sandhill crane. No. 31 *in* A. Poole, P. Stettenheim, and F. Gill, editors. The Birds of North America. Academy of Natural Sciences and the American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

United States Fish and Wildlife Service. 1978. Guidelines for management of the Central Valley population of greater sandhill cranes. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

Walkinshaw, L. H. 1989. The greater sandhill crane in Michigan: an update of nest data, with observations on site fidelity. Jack-Pine Warbler 67:3-17.

PERSONAL COMMUNICATIONS

Harold Cole, Wildlife Biologist
U.S. Fish and Wildlife Service, Conboy Lake National Wildlife Refuge
Glenwood, Washington

Joseph D. Engler, Wildlife Biologist
U.S. Fish and Wildlife Service, Ridgefield National Wildlife Refuge
Ridgefield, Washington

Rosemary Leach, Wildlife Biologist
Yakama Indian Nation
Toppenish, Washington

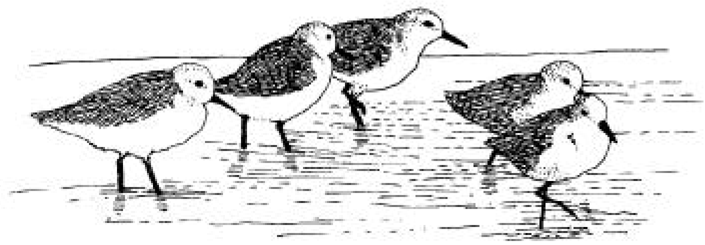
KEY POINTS

Habitat Requirements

- Sandhill cranes use large and small tracts of open habitat where visibility is good from all vantage points.
- Wet meadows, marshes, shallow ponds, pastures, hayfields, and grainfields are all used for nesting, feeding, and/or roosting.
- Dense, emergent wetland vegetation is a key component of nesting territories. Nests are typically placed on piles of emergent vegetation, grass, and mud.
- Ideal nesting locations have good visibility, are near feeding areas, and are free from human disturbance.
- Migrating sandhill cranes use roost sites with shallow water (<20.0 cm [8.0 in]) deep) that are close to feeding sites and are free from human disturbance
- Sandhill cranes are highly omnivorous, feeding on grains, plant material, invertebrates, amphibians, and small mammals.

Management Recommendations

- Sandhill cranes should not be disturbed during their breeding season (March - September).
- Vehicle and foot traffic should be avoided within 400 m (1,312 ft) of nesting areas during the breeding period (March - September).
- Logging should be avoided within 800 m (2,625 ft) of nests during the breeding period.
- Aviation balls or other markers should be used to make existing transmission lines visible to flying cranes.
- Avoid building new power lines in areas used by cranes, or place lines underground.
- All unnecessary wire fences should be removed from areas used by cranes.
- Cattle should be excluded from crane nesting marshes.
- Predator control may be necessary in some situations.
- Water levels should not be altered in wetlands used by cranes. New water projects that might alter water levels or change vegetation should be avoided in nesting or migration areas.
- Meadows should be mowed after 15 August, and all hay should be removed soon after mowing to prevent mold.
- Grainfields should not be fall-plowed; waste grain should be knocked down.
- Wetlands should be maintained within 3 km (2 mi) of upland feeding areas.
- Construction and road building should be avoided within 800 m (2,625 ft) of feeding areas.
- The construction of new roads or buildings should be avoided within 500 m (1,640 ft) of night roosts.
- Hunting near roosts should be avoided, or restricted from 4 hours after sunrise until 2 hours before sunset.



Shorebirds: Plovers, Oystercatchers, Avocets and Stilts, Sandpipers, Snipes, and Phalaropes

Last updated: 2000

Written by Joseph B. Buchanan

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Shorebirds are represented in Washington by many families, including plovers, oystercatchers, avocets and stilts, sandpipers, snipes, and phalaropes (Paulson 1993). In Washington, shorebirds occur as year-round residents, breeding or summer residents, spring and/or fall migrants, and migrants that winter in the region (Table 1). Some species, such as the killdeer and spotted sandpiper, have resident and migrant sub-populations.

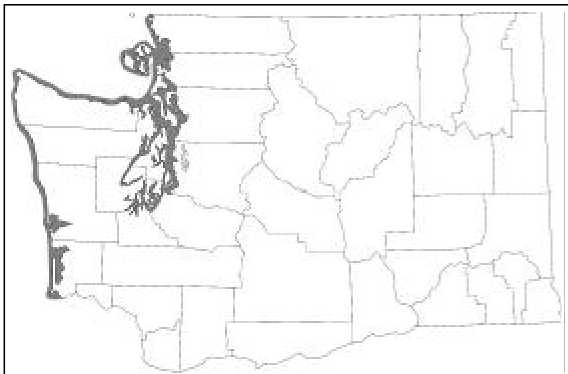


Figure 1: Primary wintering and migratory ranges of shorebirds associated with estuaries and/or shoreline habitats in Washington. Various shorebird species are also associated with freshwater or other upland habitats that are difficult to generalize and identify on a map of this scale (see text). Map derived from the literature.

The vast majority of wintering and migratory shorebirds in Washington occur at coastal estuaries (Figure 1). These areas include the Columbia River estuary, Willapa Bay, Grays Harbor, coastal Washington beaches, the Strait of Juan de Fuca, Hood Canal, the San Juan Islands, and the Greater Puget Sound region (Figure 1). The highest counts of wintering birds are from Willapa Bay (38,000-90,000 shorebirds; Buchanan and Evenson 1997), Grays Harbor (approximately 20,000 shorebirds annually during 1979-1988; Paulson 1993, Brennan et al. 1985), and the northern estuaries of Puget Sound (>10,000 shorebirds at several estuaries and >50,000 shorebirds in the region; Evenson and Buchanan 1995, 1997).

The most significant areas during migration include Grays Harbor (>one million shorebirds during spring; Herman and Bulger 1981), Willapa Bay (>100,000 shorebirds during spring; Buchanan and Evenson 1997), and the many estuaries of Puget Sound (>50,000 shorebirds during spring; Evenson and Buchanan 1997). Species such as the red-necked phalarope may occur in large numbers offshore during migration (Jehl 1986). Other significant wintering and migratory staging areas in the region include Boundary Bay and the Fraser River delta in southern coastal British Columbia, Canada (Butler and Campbell 1987, Butler 1994, Vermeer et al. 1994).

Other habitats in western Washington are also important for shorebirds. Flocks of black-bellied plovers and dunlins occasionally occur at non-estuarine sites in western Washington (e.g., flooded fields in the Wynoochee and Chehalis River valleys) during migration or winter periods (J. Buchanan, unpublished data). Some of these birds may have been temporarily displaced by flooding (Strauch 1966) or other conditions that reduced prey availability at coastal estuaries (Townshend 1981). Large numbers of shorebirds forage and roost on ocean beaches during winter (Buchanan 1992) and migration (Myers 1988-89, Myers et al. 1986). Other important habitats include rocky shorelines and the pelagic zones (Paulson 1993).

Compared to the coastal region, shorebirds are far less abundant at wintering and migratory stop-over areas in the eastern part of the state where they occur at widely scattered ponds, "potholes" and lakes, marshes, flooded fields, and riverine systems (Paulson 1993). As is true in other interior regions in North America, the seasonal distribution and abundance of shorebirds in this part of the state is somewhat unpredictable in that the suitability of shorebird habitats in many areas is dependent on changing water levels that are sensitive to varying water use practices, drought, and other environmental conditions (Fredrickson and Reid 1990, Skagen 1997). The highest counts of migratory shorebirds (most counts are <1,000 birds) in the interior region of Washington are from Lake Lenore (i.e., red-necked phalarope), Soap Lake, Turnbull National Wildlife Refuge, Yakima River delta, and water bodies near Reardan (Paulson 1993). It is likely that other areas of concentrated use by shorebirds have not been documented. In Washington, the primary breeding ranges of the American avocet, black-necked stilt, and Wilson's phalarope occur within the Columbia Plateau region in the eastern part of the state.

Breeding and Wintering Ranges

The breeding distribution of migrant shorebirds includes species that nest locally, such as the spotted sandpiper and American avocet (Jewett et al. 1953), and also species that nest in the arctic and subarctic, such as the dunlin and western sandpiper. The wintering range of nearctic shorebirds is vast, extending from southeastern Alaska to southern South America (Morrison 1984) and generally falls within 3 categories: 1) wintering areas primarily within North America, 2) wintering areas extending throughout much of the western hemisphere, and 3) wintering areas primarily within South America.

Distribution of Age and Sex Classes

The age and sex compositions of some shorebird populations vary spatially and temporally across their ranges. Examples of local or regional spatial segregation can be found, although the population structure of most species is poorly known. For example, adult male and juvenile western sandpipers winter primarily in western North America whereas most females of this species winter in South America (Page et al. 1972). Additionally, populations of wintering dunlins exhibit pronounced local and regional segregation by age class (Kus et al. 1984, van der Have and Nieboer 1984, Buchanan et al. 1986).

Temporal segregation of age and sex classes occurs during migration in many species (Morrison 1984, Butler et al. 1987). In Washington, this segregation involves 2 of the most abundant species in western North America, the western sandpiper and dunlin (Page and Gill 1994). An understanding of spatial and temporal segregation can be important for population and habitat management, because habitat loss or degradation at certain wintering or migratory staging areas may significantly impact specific age or sex classes of these or other species at the local, regional, or population level.

RATIONALE

Over 40 species of shorebirds occur in Washington throughout their breeding and nonbreeding seasons (Paulson 1993, Gill et al. 1994). Two of these, the snowy plover (*Charadrius alexandrinus*) and the upland sandpiper (*Bartramia longicauda*), are listed as State Endangered species (the upland sandpiper may be approaching extirpation in Washington). During the nonbreeding period, most shorebird species in Washington aggregate in large single- or multi-species flocks at estuaries, beaches, wetlands, or other foraging and/or roosting locations. Because of the limited distribution of these habitats, and the propensity of shorebirds to form large aggregations, shorebirds are vulnerable to habitat loss; chemical, metal or oil pollution; various disturbance factors; and other potentially significant impacts.

Many shorebird species are long-distance migrants that travel thousands of miles between wintering and breeding areas. The availability of wintering sites and migratory staging areas has decreased throughout North America due to the destruction of biologically rich but economically important areas used by these birds (Page and Gill 1994, Skagen 1997). The number and quality of these sites likely constrains shorebird populations during the nonbreeding season (Myers 1983, Senner and Howe 1984, Myers et al. 1987b), although habitat loss can adversely impact shorebird populations at any season (Evans and Pienkowski 1984, Goss-Custard and Durell 1990, Sutherland and Goss-Custard 1991).

Nearly all of Washington's shorebird species are represented by individual birds en route to wintering grounds in Central or South America or breeding grounds in Alaska, Canada or the Russian Far East. A number of sites in Washington support substantial shorebird populations (Herman and Bulger 1981, Evenson and Buchanan 1995, Buchanan and Evenson 1997) and qualify as important regional or hemispheric sites in the Western Hemisphere Shorebird Reserve Network (Myers et al. 1987a). Moreover, the region as a whole supports huge numbers of birds during winter and migration. Consequently, during one season or another, this region supports substantial segments of shorebird populations that are truly international in their distribution (Gratto-Trevor and Dickson 1994). For this reason, shorebird populations and the habitats they use in Washington are integral components of a greater hemispherical population of birds and must be managed from this international perspective (Gill et al. 1994).

Large-scale censuses of shorebirds conducted in Britain (Prater 1981, Moser 1987), the Canadian Arctic (Gratto-Trevor et al. 1998), and eastern North America (Howe et al. 1989, Morrison et al. 1994a) indicate that populations of many species are declining. Long-term research from migratory staging areas in eastern North America indicates that several species of shorebirds, including some that also migrate through Washington, have experienced significant population declines along the east coast (scientific names are presented in Table 1): black-bellied plover, semipalmated plover, whimbrel, ruddy turnstone, red knot, sanderling, semipalmated sandpiper, least sandpiper, and short-billed dowitcher (Howe et al. 1989, Morrison et al. 1994a). Populations of American golden-plover, lesser yellowlegs, red-necked phalarope, and red phalarope are also thought to have declined in Canadian breeding areas (Haig et al. 1997, Sauer et al. 1997, Gratto-Trevor et al. 1998).

Other species have experienced population declines as well. For example, the size of the wintering population of rock sandpipers along the Pacific coast of Oregon, Washington, and British Columbia declined suddenly and dramatically (and appears to have shifted north to Alaska) in association with the 1982-83 El Nino event (Buchanan in review). Black turnstone numbers have also declined along the Pacific Northwest coast (Paulson 1993). Species such as the snowy plover and upland sandpiper have also clearly declined in response to habitat destruction (Washington Department of Fish and Wildlife 1995a, 1995b). Analyses of data collected from Breeding Bird Survey routes throughout Washington indicate the occurrence of significant population declines at one or more spatial or temporal scales for the following four species of locally-nesting shorebirds: spotted sandpiper in the Columbia Basin, (-9.1% between 1966 and 1996), killdeer statewide (-2.3% between 1966 and 1996 and -4.1% between 1980 and 1996), common snipe in the Columbia Basin (-3.2% between 1966 and 1996) and statewide (-5.5% between 1980 and 1996), and Wilson's phalarope in the Columbia Basin (-10.9% between 1980 and 1996) (Sauer et al. 1997).

Table 1. Seasonal abundance and habitat use of shorebirds in Washington. Habitats are described in Paulson (1992, 1993). Bold text refers to primary habitat or area where the species is locally or seasonally common; standard text refers to secondary habitats. Abundance codes are from (Paulson 1993). Seasonal abundance codes may differ from Paulson (1993) based on other available information. Codes with an asterisk (*) represent unique local populations. Abundance codes in parentheses refer to interior Washington.

Species	Abundance by season[a]				Habitat
	Winter	Spring	Summer	Fall	
Black-bellied plover (Pluvialis squatarola)	VA	VA (VU)	FC	VA (U)	**coastal and estuarine sand beaches and mud flats**, exposed shorelines of ponds and lakes, farmland, wet lowland meadow
American golden-plover (Pluvialis dominica)		R		C (U)	**coastal and estuarine mud flats and saltmarsh**, exposed shorelines of ponds and lakes, farmland, alpine/subalpine meadow, wet lowland meadow
Pacific golden-plover (Pluvialis fulva)	VR	R		C	**coastal and estuarine mud flats and saltmarsh**, exposed shorelines of ponds and lakes, farmland, alpine/subalpine meadow, wet lowland meadow
Snowy plover (Charadrius alexandrinus)	U	FC*	FC*	FC*	**coastal sand beaches**
Semipalmated plover (Charadrius semipalmatus)	FC	A (VU)	U	A (U)	**coastal and estuarine sand beaches and mud flats, exposed shorelines of ponds and lakes**
Killdeer (Charadrius vociferus)	C (U)	C (C)	C (C)	C (C)	estuarine mud flats and **saltmarsh; exposed shores of ponds, lakes**, and large rivers; **fresh marsh, wet lowland meadow, grassy areas and farmland**
Black Oystercatcher (Haematopus bachmani)	FC	FC	FC	FC	**coastal rocky shore**
Black-necked Stilt (Himantopus Mexicanus)		VU (U)	(FC)		**shallow marshy ponds and lakes**

Species	Abundance by season[a]				Habitat
	Winter	Spring	Summer	Fall	
American avocet (Recurvirostra americana)		R (FC)	(C)	R (A)	**shallow marshy ponds and lakes**
Greater yellowlegs (Tringa melanoleuca)	VC (VU)	VC (FC)	R	VC (FC)	**estuarine mud flats, shorelines of shallow ponds, lakes and large rivers**, flooded fields
Lesser yellowlegs (Tringa flavipes)		VU (U)		FC (FC)	estuarine mud flats, **shorelines of shallow ponds and lakes**, flooded fields,
Solitary sandpiper (Tringa solitaria)		U (VU)	(R)	VU (U)	**shorelines of shallow ponds and lakes, including those found in wooded settings; flooded fields and other ephemeral freshwater areas**
Willet (Catoptrophorus semipalmatus)	U*	VU (VU)	(U)	VU (VU)	shorelines of shallow ponds and lakes, **estuarine mud flats**
Wandering tattler (Heteroscelus incanus)		FC		FC	**coastal rocky shores**
Spotted sandpiper (Actitis macularia)	U*	U (U)	U (R)	U (VU)	**shorelines of streams, rivers, shallow ponds and lakes, marshes**; rocky shore, estuarine mud flats
Upland sandpiper (Bartramia longicauda)			(VU)		**wet meadow/ grassland**
Whimbrel (Numenius phaeopus)	VU*	VC	FC	VC	**coastal and estuarine sand beaches and mud flats, saltmarsh**
Long-billed curlew (Numenius americanus)	U*	VU (FC)	(FC)	VU (FC)	**dry grassland, farmland; estuarine mud flats**, saltmarsh

Species	Abundance by season[a] Winter	Spring	Summer	Fall	Habitat
Bar-tailed godwit (Limosa lapponica)				R	**coastal and estuarine sand beaches and mud flats**
Marbled godwit (Limosa fedoa)	C*	FC (FC)	R	FC (FC)	**coastal and estuarine sand beaches and mud flats**, exposed shorelines of interior ponds and lakes
Ruddy turnstone (Arenaria interpres)	VU	C		FC	**coastal rocky shore, sand beaches, mud flats**
Black turnstone (Arenaria melanocephala)	C	C		C	**coastal rocky shore**
Surfbird (Aphriza virgata)	C	C		C	**coastal rocky shore**
Red knot (Calidris canutus)	VU	VC	R	U (R)	**estuarine sand and mud flats**, coastal sand beaches
Sanderling (Calidris alba)	VA	VA (R)	VU	VA (U)	**coastal sand beaches**, estuarine sand and mud flats, coastal rocky shore
Semipalmated sandpiper (Calidris pusilla)		VU (U)		U (U)	**Exposed shoreline of shallow ponds**, mud flats
Western sandpiper (Calidris mauri)	VC*	VA (U)	U	VA (C)	**coastal and estuarine sand beaches, mud flats**, and salt marsh; **exposed shoreline of shallow ponds and lakes**; freshwater low marsh
Least sandpiper (Calidris minutilla)	FC	VC (C)		VC (C)	**estuarine mud flats, salt marsh; exposed shoreline of shallow ponds and lakes; freshwater low marsh**
Baird's sandpiper (Calidris bairdii)		VU (U)		FC (FC)	**coastal sand beaches**, mud flats, **exposed shoreline of shallow ponds and lakes, grassy areas, alpine/ subalpine meadow**

Species	Abundance by season[a] Winter	Spring	Summer	Fall	Habitat
Pectoral sandpiper (Calidris melanotos)		VU		C (FC)	**estuarine and freshwater marsh**, mud flats
Sharp-tailed sandpiper (Calidris acuminata)				U	**estuarine salt marsh**, mud flat edges
Rock sandpiper (Calidris ptilocnemis)	FC	FC		FC	**coastal rocky shore**
Dunlin (*Calidris alpina*)	VA	VA (U)	U	VA (VU)	**coastal and estuarine sand beaches and mud flats, flooded fields**, rocky shores
Curlew sandpiper (*Calidris ferruginea*)				R	estuarine marsh, sand beaches, mudflats; freshwater low marsh
Stilt sandpiper (*Calidris himantopus*)				VU (VU)	**fresh and brackish marsh; sewage lagoons,** flooded fields
Buff-breasted sandpiper (*Tryngites subruficollis*)				VU	**grassy areas, coastal sand beaches**
Ruff (*Philomachus pugnax*)				VU	**estuarine mud flats, salt marsh; flooded fields, shallow ponds**
Short-billed dowitcher (*Limnodromus griseus*)		VA (R)	FC	VA (VU)	**estuarine mud flats,** coastal sand beaches, flooded fields, freshwater areas
Long-billed dowitcher (*Limnodromus scolopaceus*)	FC	C (VC)		VC (VC)	**exposed shoreline of shallow ponds and lakes; estuarine mud flats (winter), freshwater marsh**

Species	Abundance by season[a] Winter	Spring	Summer	Fall	Habitat
Common snipe (*Gallinago gallinago*)	FC (U)	U (FC)	U (FC)	FC (FC)	**estuarine and freshwater marsh; flooded grassy fields, farmland**
Wilson's phalarope (*Phalaropus tricolor*)		U (FC)	VU (FC)	VU (FC)	**ponds and lakes, freshwater marsh, sedge meadows**
Red-necked phalarope (*Phalaropus lobatus*)		A (FC)		A (FC)	**marine waters; ponds and lakes**
Red phalarope (*Phalaropus fulicaria*)	U	FC		VC	**off-shore marine waters**

VA = Very Abundant (over 1,000 individuals observed per day), **A** = Abundant (200-1,000 individuals per day), **VC** = Very Common (50-200 individuals per day), **C** = Common (20-50 individuals per day), **FC** = Fairly Common (7-20 individuals per day), **U** = Uncommon (1-6 individuals per day), **VU** = Very Uncommon (more than 6 individuals per season in the region, but not seen every day), **R** = Rare (1-6 individuals per year in the entire region). The list does not include very rare (over 6 total records), casual (2-6 records), or accidental (1 record) species in the region.

[a] Winter refers to the period of local residency following autumn migration. The winter period for most species is November through March. Spring migration for most species is generally April through mid-May although some species begin migrating in Washington during March and others extend into June. Fall migration extends from late June to late October; some fall migrants occasionally remain in Washington until mid-November.

Other species, for which adequate information is lacking, are likely at risk of population-level impacts due to the vulnerability of their primary habitats (species to which Page and Gill [1994] assigned high vulnerability scores [a score $\geq$ 10 is used here to define 'high'] include American avocet, black-necked stilt, common snipe, killdeer, marbled godwit, snowy plover, upland sandpiper, willet, and Wilson's phalarope) and may be declining (Paulson 1992, Morrison et al. 1994b), although population monitoring data are generally lacking (see exceptions above). Finally, a number of species, including red knot, and various species of plovers, curlews, godwits, and dowitchers suffered substantial, if not catastrophic, population declines between 1870 and 1927 in response to unregulated hunting (Page and Gill 1994; see Cooke 1910, Forbush 1912, Grinnell et al. 1918). Populations of some of these species have not recovered and the likelihood of recovery appears low due to the negative effects of additional or more recent impacts, such as habitat loss (Paulson 1993, Page and Gill 1994).

HABITAT REQUIREMENTS

Most shorebird species exhibit unique migratory strategies that include preferences for specific habitat components (Davidson and Stroud 1996). Research on habitat selection by birds indicates that a range of habitats may be used although certain habitats are preferred and selected when possible (Fretwell and Lucas 1970). Although research on habitat selection by shorebirds has not been conducted in Washington, the habitat preferences of most species are obvious, assuming the predominant patterns of distribution and abundance reflect habitat preference (Ruggiero et al. 1988; Table 1). Some secondary habitats are used on occasion, however, and may be locally important, particularly during periods of adverse weather or depletion of food sources (Warnock et al. 1995, Davidson and Stroud 1996).

Coastal Environments

Most shorebirds in Washington occur as migrants or winter residents (Table 1). During the nonbreeding period, most can be found concentrated at beach or estuarine sites where fat and protein reserves required for overwintering or continued migration are replenished (Evans et al. 1991). The primary habitat requirements of these birds relate to the availability of adequate foraging and roosting areas. The foraging requirements of many shorebirds in western Washington are met primarily in estuarine ecosystems associated with silt or silt/sand intertidal areas and adjacent beaches or salt marshes, where tidal mud flats provide foraging substrates for many species. Black-bellied plover, dunlin, western sandpiper, and dowitchers forage on mud flats with high levels of silt, whereas semipalmated plovers and sanderlings forage in sandy or silt/sand areas (Paulson 1993). Other species, such as rock sandpiper, surfbird, and wandering tattler are found almost exclusively along rocky intertidal shores (Paulson 1993). Many species in eastern Washington use wet meadows, flooded fields and other areas of shallow water. The habitat associations of shorebirds in Washington are summarized in Table 1.

As a group, shorebirds are behaviorally and morphologically adapted to forage in a rather narrow range of microhabitat conditions (Burton 1974, Gerritsen and van Heezik 1985), including exposed tide flats or beaches, shallow water, salt marshes, and even open water. Consequently, the selection of invertebrate prey by shorebirds during the nonbreeding season is related to shorebird morphology and environmental factors that influence prey availability. These factors include tidal range, tidal exposure, wave action and tidal current, substrate slope, sediment mobility, organic pollution, local or regional climate, microhabitat conditions, and invertebrate behavior (Bryant 1979, Pienkowski 1981, Quammen 1982, Ferns 1983, Grant 1984, Hicklin and Smith 1984, Gerritsen and van Heezik 1985, Reise 1985, Esselink et al. 1989, Hockey et al. 1992, Beukema et al. 1993, Nehls and Tiedemann 1993, Wanink and Zwarts 1993, Zwarts and Wanink 1993).

Shorebirds use a variety of habitats for roosting. They often roost in salt marshes adjacent to intertidal feeding areas, even when these areas are extremely limited in size (Brennan et al. 1985, Buchanan 1988). Shorebirds at Grays Harbor and Willapa Bay often roost in large flocks on Pacific beaches, occasionally concentrating near the mouths of small creeks where they bathe and preen (Buchanan 1992). In some areas, shorebirds roost on natural and dredge spoil islands and on higher elevation sand beaches (Herman and Bulger 1981, Brennan et al. 1985). Some species also roost in fields or other grassy areas near intertidal foraging sites (Brennan et al. 1985, Butler 1994); shorebirds may forage at these or other roost sites if suitable prey are present. Shorebirds occasionally roost on pilings, log rafts, floating docks, and other floating structures when natural roost sites are limited (Buchanan 1988; Wahl 1995; J. Buchanan, unpublished data).

Shorebirds will fly considerable distances between foraging and roosting locations where roost sites are limited (Page et al. 1979). Distances >16 km (10 mi) have been documented (Symonds et al. 1984, Buchanan et al. 1986). On rare occasions, some species (i.e., dunlins) will engage in continuous flight during the high tide period, even though suitable roosting habitat is available (Prater 1981, Brennan et al. 1985). The reason for this behavior is not understood. In addition, shorebirds will also fly for extended periods when disturbed at a roost site. The energetic costs associated with extensive flights at or among roosting and foraging locations are not well understood.

Other habitats used by shorebirds in this region include pasture and agricultural land. Thousands of shorebirds roost (and occasionally forage) in pastures near Raymond and Bay Center on Willapa Bay during winter and spring migration (Buchanan and Evenson 1997). Large concentrations of roosting birds have been observed on fallow fields at Nisqually delta, Skagit Bay, Samish Bay, Lummi Bay, and adjacent to other large estuaries in northern Puget Sound and the Fraser River Valley (Brennan et al. 1985, Butler 1994, Wahl 1995, Evenson and Buchanan 1997). This type of habitat use has been documented in other areas (Townshend 1981; Colwell and Dodd 1995, 1997; Rottenborn 1996).

Use of artificial wetlands by shorebirds has not been documented in Washington. However, many species of shorebirds, including at least 12 species that occur in western Washington, used managed coastal wetlands in South Carolina (Weber and Haig 1996) indicating that such habitats, if suitable, would likely be used in this state. Salt marsh created at the Jay Dow Sr. wetlands in northeastern California provides important habitat for shorebirds migrating through and breeding in that region (Robinson and Warnock 1996). Similarly, salt evaporation ponds are an important habitat used by over-wintering and spring migrant western sandpipers in San Francisco Bay (Warnock and Takekawa 1995) and by shorebirds in other parts of the world (Davidson and Evans 1986, Martin and Randall

1987, Sampath and Krishnamurthy 1988, Velasquez and Hockey 1992). Shorebirds also forage, usually in comparatively small numbers, in sewage lagoons associated with waste treatment facilities.

Shorebirds are generally site-faithful to specific wintering areas (Townshend 1985, Myers et al. 1986) although some individuals may move considerable distances among sites (Warnock et al. 1995, Warnock 1996). This fidelity to particular sites has important ramifications for conservation management and mitigation. For example, because shorebirds do not settle in their winter quarters in a random manner, but rather return to areas used in previous years, mitigation efforts must recognize that habitat loss will most likely result in density dependent competition (e.g., greater competition for the same level of resources due to a greater density of birds at a given site) at other sites in the region (see the "Habitat Loss" section below).

Freshwater Environments

Most shorebirds that forage in freshwater areas require ponds and pools that have exposed shorelines or that are shallow enough to allow foraging by wading birds. As with estuarine sites, the availability of appropriate prey (e.g. various invertebrates) and roost sites are important habitat requirements.

Locally nesting species have specific nest site requirements. Killdeer and spotted sandpiper both nest on gravel/cobble substrates, however they often occupy vastly different environments (Paulson 1993). Killdeers nest in habitats including dry lake beds, short-grass fields, and unpaved margins of roadways. In contrast, spotted sandpipers typically nest where there is herbaceous cover in sandy or rocky substrates along creeks, rivers and lakes in both forested and arid environments (Oring et al. 1997). American avocets, black-necked stilts, common snipes, and Wilson's phalaropes also nest in Washington, primarily in the eastern part of the state. Avocets and stilts nest in rather open areas in or near marshes or other bodies of water, while phalaropes and snipes nest in wet meadows and marshes (Paulson 1993). Other habitats used by shorebirds include marshes, pastures, flooded fields, reservoirs, impoundment drawdowns, sewage treatment ponds, stormwater wetlands, and other artificial wetlands (Rundle and Fredrickson 1981, Perkins and Lawrence 1985, Duffield 1986, Paulson 1993). Habitat associations of interior species are summarized in Table 1.

LIMITING FACTORS

Habitat Loss

Effects of Habitat Loss or Degradation During the Nonbreeding Season - During the past century the amount of coastal estuarine wetlands in North America has been severely reduced (Dahl 1990). In Washington, approximately 66% of the coastal wetlands were destroyed over this period (Boule et al. 1983). Most of Washington's wintering and migrant shorebird species are dependent on these estuarine areas for essential foraging and roosting requirements. The most typical form of habitat loss occurs when wetlands or intertidal areas, including roost sites (Burton et al. 1996), are filled for development purposes (Page and Gill 1994).

Activities that degrade rather than destroy habitat also have the potential to impact shorebirds. Temporary or permanent reductions of habitat quality may reduce foraging efficiency and increase shorebird energetic requirements and/or mortality rates. Mineral extraction activities such as removal of sand from coastal beaches (Phipps 1990) or gravel from river beds, may degrade or destroy foraging, roosting and nesting habitat used by shorebirds.

For some shorebird populations, the loss of nonbreeding habitats, including roosting sites (Burton et al. 1996), results in increased density-dependent mortality (Sutherland and Goss-Custard 1991). This increased mortality occurs when shorebirds are forced to leave degraded or destroyed sites and settle elsewhere. Such movement to other sites increases the density of birds at remaining sites and results in greater competition for limited resources (Goss-Custard 1977, Evans et al. 1979, Goss-Custard 1979, Schneider and Harrington 1981, Goss- Custard 1985, Moser 1988, Lambeck et al. 1989) because of higher rates of prey depletion and increased rates of competitive interference (Goss-Custard and Durell 1990, Sutherland and Goss-Custard 1991, Evans 1991). It is likely that these movements force some birds to occupy lower-quality sites where competition for marginal resources is more intense

(Evans 1976, Sutherland and Goss-Custard 1991). These movements may have a greater impact on juvenile shorebirds (Goss-Custard and Durell 1987) and may therefore considerably influence population structure; this may have occurred in a wintering population of dunlins in Europe (Sutherland and Goss-Custard 1991).

For shorebird species that forage on invertebrates associated with kelp windthrow, the health of offshore kelp forests may be important for maintaining stable populations in this region. In coastal California, linear densities of spotted sandpiper, wandering tattler, whimbrel, black turnstone, and ruddy turnstone were higher on the Palos Verdes Peninsula in 1985-86, after offshore kelp forests had been restored, than in 1969-73 when kelp was absent (Bradley and Bradley 1993). Although these relationships were highly significant, the authors cautioned against generalizing their results to other regions because other factors may have partially contributed to the observed population changes.

Effects of Habitat Loss or Degradation on Reproductive Capability - The loss or degradation of habitat at migratory stop-over sites may influence survival rates and annual productivity of shorebirds on their Subarctic/Arctic breeding grounds. The timing of arrival at the breeding grounds sometimes occurs during periods of adverse weather or depleted prey availability. Survival at this time is more likely if the birds have accumulated sufficient fat and protein reserves at temperate staging sites (Morrison and Davidson 1989). Some shorebirds carry more fat than is needed to make flights between staging areas and the breeding range (Davidson and Evans 1989, Evans and Davidson 1990) and it is thought that these reserves provide insurance in the event of adverse conditions during migration or upon arrival at the breeding grounds. When shorebirds are delayed at staging areas or are otherwise unable to adequately accumulate these body reserves before or during migration, they are more likely to experience nest failure due to late arrival or poor physiological condition at the breeding grounds (Davidson and Evans 1989, Evans and Davidson 1990). Consequently, marginal environmental conditions at wintering or migratory staging areas in Washington may influence shorebird productivity at breeding areas thousands of miles away.

Bivalve Management - A number of economically important bivalve species are produced and harvested in Washington's sheltered marine waters, but there have been no studies on the relationship between their presence or harvest and shorebird behavior or abundance. The geoduck clam (*Panopea abrupta*) is generally harvested in waters ≥6 m deep at mean low low-water or ≥200 m from shore and its management therefore does not appear to have a direct bearing on shorebirds. Other bivalve species, however, are managed in intertidal areas that are also used by shorebirds. These areas are either privately owned or leased from the Washington Department of Natural Resources.

Bivalve management, when conducted on silt or silt-sand tide flats, clearly alters substrate conditions (Simenstad et al. 1991). These substrate alterations influence the quality of sites and in some cases may render a site less suitable or unsuitable for shorebird species associated with fine-silt substrates. The only study to address shorebird response to aquiculture activities, conducted in Tomales Bay, California, found far lower densities of dunlins and western sandpipers in aquiculture plots than in adjacent control plots (Kelly et al. 1996). The significance of substrate alteration and the resulting changes in suitability of foraging habitat to local shorebird populations is unknown. It should be noted that some shorebirds may benefit from bivalve management. The density of willets, an uncommon species in Washington, was greater in aquiculture plots than in control plots at Tomales Bay, California (Kelly et al. 1996). Shorebirds in Washington, particularly greater yellowlegs, occasionally forage in tidal pools associated with aquiculture operations (J. Buchanan, unpublished data). The significance of this potential association is also unknown.

Water Diversion - Habitat loss in interior regions of Washington occurs primarily when wetland areas are drained and used for agricultural or development purposes. It is possible that changes in the water table resulting from irrigation demands on local drainages has reduced or eliminated some areas of wetland or moist habitats (Hallock and Hallock 1993, Neel and Henry 1996). Such habitat losses may increase density-dependent effects on shorebirds in the manner described above.

Water Salinization - Changes in water chemistry, manifested through salinization, may adversely effect shorebirds or their habitats in the Columbia Basin. Although a natural phenomenon in the intermountain west (defined as the portion of western North America that lies between the Cascade and Rocky Mountain ranges), water salinization increases as greater demands are placed on limited water resources (American Society of Civil Engineers 1990). Water salinization occurs when water is diverted for other uses. Diversion of water typically results in less water delivered to wetlands and other water bodies. As a result, wetlands and ponds become shallower and more saline through evaporative concentration (Rubega and Robinson 1996). The extent to which water salinization has occurred in interior Washington is unknown. In addition, it is not clear how to best manage saline wetlands for shorebirds or other wildlife (Rubega and Robinson 1996).

Salinization may directly effect shorebirds in a number of ways. First, salinization interferes with their ability to regulate water balance through excretion of excess salt (Rubega and Robinson 1996). Although some birds have well developed salt glands that enable them to excrete excess salt (Schmidt-Nielson 1960), it is not clear that all shorebirds have this capability (Rubega and Robinson 1996). An inability to maintain water balance results in dehydration and death (Rubega and Robinson 1996).

Second, water salinization may influence shorebird behavior. Shorebirds in highly saline areas often concentrate near freshwater sources such as springs (Rubega and Robinson 1996; J. Buchanan, personal observation). If these freshwater sources are scarce it is likely that energetic costs will be increased for birds that travel to these sites. Like all birds, shorebirds bathe regularly. It is thought that salinization may increase feather wetting, which in turn may increase thermoregulatory demands (Rubega and Robinson 1996). Water balance and thermoregulatory considerations may be particularly significant to fledglings (Rubega and Robinson 1996).
Water salinization may also result in changes in emergent vegetation as well as in the composition of the invertebrate community (Wolheim and Lovvorn 1995). These changes may influence the composition of shorebirds using particular sites by reducing the species richness of potential prey species (Rubega and Robinson 1996). Research is clearly needed to investigate the relationship between increasing water salinization and the health and behavior of shorebirds that migrate through or nest in the Columbia Basin.

Effects of Livestock Grazing - A number of research projects indicate that livestock grazing has a variety of positive and negative effects on shorebirds and their habitats in the interior portion of western North America (Powers and Glimp 1996). The direct effects, including trampling and disturbance, are negative, whereas the indirect effects are either positive or negative and include habitat changes and factors related to foraging and predation (Powers and Glimp 1996). The potential significance of these effects are thought to be related to the species of grazer and the timing and distribution of grazing (Powers and Glimp 1996).

The effects of trampling by livestock include destruction of eggs or nests (Rohwer et al. 1979, Guldemond et al. 1993), abandonment of disturbed nests (Delehanty and Oring 1993), and increased time adult birds spend away from their nests (Graul 1975), which likely results in increased exposure of eggs. Although each of these effects has been noted in shorebirds (Powers and Glimp 1996), research on these topics is lacking from the intermountain west.

Livestock may also impact shorebird habitats by altering attributes of the environment. For example, livestock grazing can alter vegetation composition, compact soil, and increase erosion (Kadlec and Smith 1989, Powers and Glimp 1996). These changes have been demonstrated to result in reduced populations of invertebrates (Mono Basin Ecosystem Study Committee 1987), reduced use of habitats by shorebirds (Bowen and Kruse 1993), and increased egg depredation and predation upon chicks and adults (Redmond and Jenni 1986, Bowen and Kruse 1993).

Conversely, livestock grazing has certain demonstrated or potential benefits to shorebird habitats, depending on the timing and intensity of grazing. Grazing was thought to control the growth of vegetation that would otherwise have been too tall or dense to allow use by shorebirds (Crouch 1982, Kohler and Rauer 1991, Nilsson 1997). In addition, several studies in non-arid regions indicate that grazed lands supported greater populations of invertebrate prey species and that shorebird foraging and body condition was enhanced at those sites (Galbraith 1987, Granval et al. 1993). It is unknown whether these potential benefits of livestock grazing would occur in the intermountain west.

Effects of Exotic Plants - Three exotic species of cordgrass (*Spartina* spp.) have invaded the intertidal areas of Washington (Frenkel and Kunze 1984). Although *Spartina alterniflora* was introduced to Willapa Bay in 1894, and was recognized as a potential problem in 1942, its spread has increased dramatically in the past decade (Mumford et al. 1991). Cordgrass grows in dense stands that effectively trap sediments; this process leads to changes in substrate elevation that may substantially degrade the original salt marsh environment (Sayce 1988, Landin 1991). Research in Europe indicates that tideflat areas with *Spartina* growth have lower densities of the invertebrate prey of shorebirds (Millard and Evans 1984, Atkinson 1992). Moreover, an association between the spread of *Spartina* and a decline in shorebird abundance was reported in Great Britain (Goss-Custard and Moser 1988). Observations near the mouth of the Willapa River in Willapa Bay in spring 1998 indicate that extensive areas used by red knots and western sandpipers in the early 1980s are now covered by cordgrass and no longer appear to be used by these shorebirds (Chris Chappell, personal communication). Consequently, although the information for North America is rather limited, it appears that the colonization and alteration of tideflats by cordgrass has the potential to influence the availability of shorebird foraging and roosting habitats in Washington.

Another exotic species, purple loosestrife (*Lythrum salicaria*), has invaded the Columbia Basin (Engilis and Reid 1996). Loosestrife is a dense, woody plant that can grow to over two meters in height along the margins of ponds, lakes and wetlands. This fast-growing plant can render invaded shoreline areas unsuitable for shorebirds. Additional exotic species that may cause habitat degradation, although likely at a lesser scale, include *phragmites* which grows along salt marsh margins, and reed canarygrass (*Phalaris arundinacea*), which grows along margins of freshwater wetlands and flooded fields that might be used by shorebirds.

Effects of Exotic Vertebrates and Invertebrates - Numerous exotic vertebrate and invertebrate species have been introduced to coastal and interior wetlands (Carlton and Geller 1993). The common carp (*Cyprinus carpio*) was introduced to many wetland areas in the intermountain west and appears to be degrading wetland habitats (Engilis and Reid 1996). The foraging behavior of this exotic species disturbs aquatic plant beds which increases turbidity and reduces photosynthetic activity by submerged plants (Robel 1961). The likely consequence is a change in wetland vegetation composition and a reduction in invertebrate populations.

A number of exotic marine invertebrates, transported and introduced via ballast water introduction (Cordell 1998), have the potential to impact shorebird prey populations in Washington's estuaries. The Asian clam (*Potamocorbula amurensis*) has recently become established in San Francisco Bay, California (Carlton et al. 1990). The invasion of this clam was very rapid and in some areas of San Francisco Bay it now dominates the macrobenthic fauna (Nichols et al. 1990). We have no evidence to suggest that this species has colonized estuarine sites in Washington. The European green crab (*Carcinus maenas*) was documented in coastal estuaries of Washington in 1998. It too has the capability to dramatically alter the macrofaunal community of marine estuaries. Such changes would be potentially deleterious to shorebird and other wildlife populations associated with marine estuaries.

Similarly, various Asian copepods have recently been introduced via ballast waters to coastal estuaries in the Pacific Northwest (Cordell 1998, Cordell and Morrison 1996). Although the outcome of these invasions is not clear, potentially significant deleterious effects similar to those associated with other invasions of this type are likely to occur (Carlton et al. 1990, Nichols et al. 1990, Cordell 1998).

Utility Lines - Collisions with utility lines have been documented for a wide variety of bird species including shorebirds (Kitchin 1949, Bevanger 1994, Brown and Drewien 1995, Janss and Ferrer 1998). Placement of utility lines adjacent to intertidal areas may degrade habitat quality by increasing the likelihood of in-flight collisions (Scott et al. 1972, Lee 1978). Fatal injuries to shorebirds following collisions with utility lines have occurred where utility lines were situated adjacent to intertidal foraging areas in western Washington and at the Fraser River estuary in British Columbia (Kitchin 1949; J. Buchanan, unpublished data; R. Butler, personal communication; S. Richardson, personal communication).

Wind Turbines - Mortality of shorebirds has been documented at wind turbine sites in the Netherlands (Musters et al. 1995, 1996) and in the United States (Erickson et al. 2001), although the rate of documented mortality was generally low. It is likely, however, that mortality would be greater at complexes of turbines situated along flight corridors used by large concentrations of shorebirds. Wind turbine sites in southeastern Washington occur near areas used by a relatively small flyway of migrating shorebirds, but the potential impact of the turbines on those shorebirds is currently unknown. There are relatively few wind turbine sites in Washington at present, but it is expected that many such sites will be established in the near future as the technology for managing this efficient source of energy is refined. The significance of wind turbines as a source of mortality will likely depend on the number and location of these complexes built in the coming years.

Other Potentially Hazardous Structures - One million or more birds are killed annually across North America in collisions with structures such as skyscrapers and communication towers (see www.towerkill.com [1998]). Because of their great height, these structures are a hazard to low-flying migrant birds. Even the illumination from safety lights is thought to confuse birds, causing circling behavior around the structure that increases the likelihood of collisions with support cables or the structure itself (Avery et al. 1976). As of November 1998, there were 241 towers exceeding 61 m (200 ft) in Washington, including 19 towers of at least 152 m (500 ft). Many of these towers are located in the Puget Trough; the presence of these towers may be a mortality factor for shorebirds that overwinter and/or migrate through this region. The potential magnitude of this factor has not been addressed (see www.towerkill.com [1998]). Shorebirds have also been documented colliding with coastal lighthouses; multiple incidents involving red-necked phalaropes occurred at the Destruction Island lighthouse in 1916 (Bowles 1918). Such occurrences are poorly documented, but this is likely related to limited access and search efforts at such sites.

Pollution

Chemicals and Heavy Metals - Research from other temperate coastal regions indicates that rather high levels of organochlorine contaminants (White et al. 1980, White et al. 1983) and heavy metals (Goede 1985, Goede and de Voogt 1985, Blomqvist et al. 1987, Ferns and Anderson 1994) occur in shorebird tissues. Although the effects of these contaminants on shorebirds are not known, physiological and behavioral abnormalities associated with high contaminant levels have been reported for other temperate marine bird species (Gilbertson et al. 1976, Gilbertson and Fox 1977, Sileo et al. 1977, Fox et al. 1978).

Contaminant levels have been reported in black-bellied plovers, dunlins, and western sandpipers wintering in western Washington (Schick et al. 1987, Custer and Myers 1990). Both studies found levels of organochlorine contaminants below those known to affect the survival or reproduction of shorebirds. However, some spring migrants from Grays Harbor carried very high DDE residues (Schick et al. 1987). Black-bellied plovers from two Puget Sound sites carried low levels of mercury and elevated levels of selenium (Custer and Myers 1990). In addition, dunlins occasionally ingest lead shot (Kaiser et al. 1980, J. Buchanan, unpublished data), but residue levels of lead in shorebirds are unreported for this area. Given the lack of current data on concentrations of organochlorine and heavy metal contaminants in shorebirds in this area (Schick et al. 1987, Custer and Myers 1990), it is difficult to assess the potential current effects related to these contaminants. Other contaminants, such as organophosphorus insecticides, also occur in the environment; there is no information on the presence or effects of these contaminants on shorebirds in this region (Morrison 1991).

Contaminants known or suspected to have originated from upland agricultural areas have been documented in shorebirds (White et al. 1980, Zinkl et al. 1981, DeWeese et al. 1983, White et al. 1983, Schick et al. 1987, Custer and Mitchell 1991). The discovery of contaminants (i.e., selenium) in waterfowl and wading birds that use freshwater marshes (Ohlendorf et al. 1986, Saiki and Lowe 1987, DuBowy 1989, Williams et al. 1989) suggests that common snipe, American avocet, black-necked stilt, and Wilson's phalarope may be vulnerable to exposure to a similar variety of contaminants. Two incidents of dunlins killed after exposure to agricultural chemicals have been reported from northern Puget Sound (Lora Leshner, personal communication). In California, killdeers and dunlins died after ingesting grain poisoned by strychnine (Warnock and Schwarzbach 1995); the likelihood of such an event occurring in Washington is unknown.

Heavy metals and other contaminants are present in naturally-occurring and dredged sediments in estuaries, and accumulate in fish, birds, mammals, and invertebrates (Goerke et al. 1979, Seelye et al. 1982, Duinker et al. 1984). Contaminants can also be released from sediments by bait digging in the intertidal zone (Howell 1985). Intake of these contaminants occurs when shorebirds forage in intertidal areas. Other sources of pollutants include waste discharge, which has been associated with the disappearance of invertebrate prey species of shorebirds in the Netherlands (Esselink et al. 1989, van Impe 1985). The significance of waste discharge on shorebird abundance or physical condition in this region is unknown.

Oil Pollution - In a summary report on the potential effects of oil spill contamination in northern Puget Sound and the Strait of Juan de Fuca, 10 shoreline habitat types were identified in the order of their sensitivity to oil contamination (Kopenski and Long 1981). Three of the four most sensitive habitat types - sheltered marshes, sheltered tidal shores, and exposed tidal flats - are primary foraging and roosting habitats for numerous shorebird species. The most abundant wintering shorebird species to use these habitats, the dunlin, is considered highly sensitive to oil spill pollution (Vermeer and Vermeer 1975). Other species, such as the sanderling, are likely sensitive as well (Chapman 1984). Certain species that use rocky shoreline habitats may be less vulnerable to some impacts from oil spills (Smith and Bleakney 1969), since oil would have a shorter "residence time" on rocky shorelines exposed to high wind and wave energy. This reduces the time period during which birds would be exposed to oil, although short-term impacts to these species can still be substantial (Andres 1997).

Spill-related avian impacts can be manifested in at least 5 ways. First, direct mortality occurs due to a number of factors related to plumage fouling or toxicity (Leighton 1990). Second, reduced invertebrate food supplies caused by oil pollution (Bellamy et al. 1967, Grassle et al. 1980, Maccarone and Brzorad 1995) may result in reduced survival rates if birds are forced to relocate to densely-occupied or less productive areas (Sutherland and Goss-Custard 1991). This is especially true during winter, when foraging efficiency may be constrained by adverse weather, particularly if body-fat reserves are too low to fuel significant emigrations. Third, the activity associated with the actual cleanup of the spill may disturb shorebirds to such an extent that foraging and roosting patterns are disrupted (Burger 1997). Fourth, research indicates that oiled shorebirds spend more time preening and less time foraging after a spill (Burger 1997). Burger (1997) concluded that this was a potentially negative influence on the condition of the birds upon their departure for migration (and also on their arrival at the breeding grounds; see above), and added that the detrimental effects were magnified by the presence of people (see section on human disturbance). Finally, oiled birds may be more vulnerable to predation, particularly if 1) plumage fouling or thermal stress make them less efficient at avoiding predators, or 2) their marked plumage or altered behavior make them more conspicuous to predators (Curio 1976).

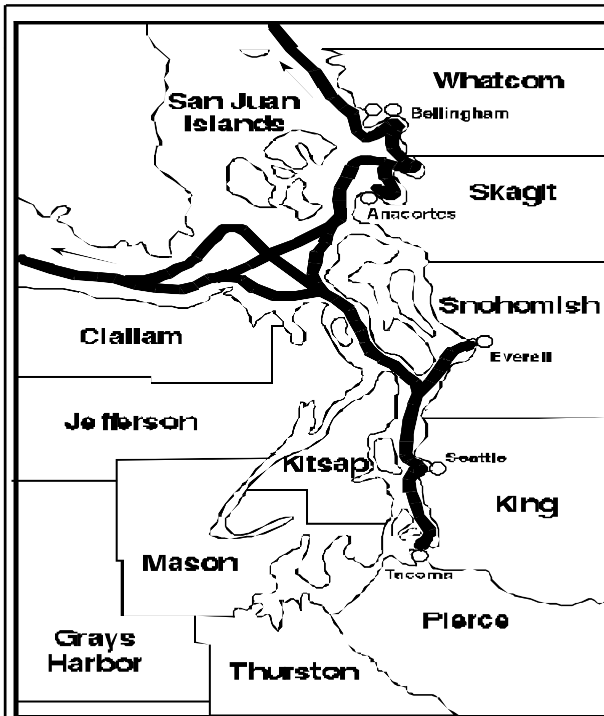


Figure 2: Major shipping lanes in the Puget Sound and the Strait of Juan De Fuca. These lanes extend northwards through the Strait of Georgia, and along Washington's outer coast into the Columbia River.

Recent experience indicates that oil pollution is a significant potential threat to shorebirds in this region. Larsen and Richardson (1990) found that 3,574 of 11,708 shorebirds (mostly dunlins) were still oiled 5 days following the *Nestucca* oil spill off Grays Harbor in December, 1988. This proportion of oiled birds declined over the next 3 weeks, and it was unclear whether the decline was related to self-cleaning, emigration, or mortality. The beaches fouled by this spill support very high overwintering concentrations of sanderlings and roosting dunlins (Buchanan 1992). It is noteworthy that the largest Puget Sound populations of shorebirds in winter, spring, and fall occur at estuaries in close proximity to major shipping lanes and/or oil refineries (Evenson and Buchanan 1995, 1997; Figure 2).

Other Sources of Pollution - Plastic-particle pollution has been documented in most marine waters (Coe and Rogers 1997) and occurs when plastic debris (e.g., packaging material) enters the marine environment from land (Liffmann and Boogaerts 1997, Redford et al. 1997) or at-sea sources (Coe and Rogers 1997). The variety of plastic waste present in the marine environment is quite high and differs from one site to the next (Ribic et al. 1997). Debris surveys conducted at the ports of Seattle and Tacoma and on the beach at Olympic National Park reported high amounts of plastic debris; the park survey in 1992 found an average quarterly accumulation of 1729 pieces of plastic debris/km (Ribic et al. 1997). Plastics digestible by wildlife comprised between 44-74% of the debris found in surveys along the west coast of North America (Ribic et al. 1997).

Plastic pollution in marine environments is potentially detrimental to shorebirds and other wildlife after it is intentionally or accidentally ingested. Small particles are ingested by surface feeding marine birds (Baltz and Morejohn 1976, Day et al. 1985) and have been associated with reduced fat deposits (Connors and Smith 1982, Ryan 1988) and perhaps intestinal blockage and ulcerations in other species (Day et al. 1985). Among shorebirds, the red phalarope appears most vulnerable to this type of contamination in Washington (Bond 1971, Connors and Smith 1982, Day et al. 1985), although other shorebird species have been known to ingest plastic particles (i.e., bar-tailed godwit [*Limosa lapponica*] and red-necked phalarope; Robards et al. 1997).

Human Disturbance

Human disturbance has the potential to influence shorebirds in at least 3 ways (Fox and Madsen 1997). First, substantial disturbances force birds to alter their normal activity patterns resulting in an increase in energetic costs. Second, shorebirds forced to leave an area due to human disturbance may settle in lower-quality alternate habitats. Third, increased energetic costs and use of lower-quality habitats may expose shorebirds to greater risks of predation. The occurrence and potential significance of these patterns is only now beginning to be investigated and understood in North America.

Many human disturbances are related to recreation. Sources of disturbances include beachwalkers, wandering dogs, birdwatchers, hunters, windsurfers, horseback riders, cyclists, vehicles, boats, kayaks, personal water craft (e.g., jet skis), helicopters, and airplanes (Kirby et al. 1993, Goss-Custard and Verboven 1993, Koolhaas et al. 1993, Smit and Visser 1993). In Washington, these types of activities are responsible for both inadvertent and intentional disruption of foraging and roosting behavior (J. Buchanan, unpublished data). Most disturbances from recreational sources are temporary (e.g., birds relocate to a new site following a disturbance). However, cumulative effects of repeated disturbances, particularly during periods of peak human activity (Kirby et al. 1993), or during periods of peak shorebird abundance (e.g., migration; Burger 1986) may be significant (Klein et al. 1995), although this has not been well assessed (Goss-Custard and Verboven 1993). Human disturbance may be most significant in areas where roost sites are limited (Warnock et al. 1995) because the birds do not have alternate sites they can use when disturbed.

Pedestrian and Vehicular Recreational Activities - Perhaps the most common type of human disturbance is recreational walking or other travel on beaches. Pedestrian or vehicle traffic on beaches or other areas used by shorebirds negatively affects shorebird distribution, abundance, foraging efficiency, and behavior (Burger and Gochfeld 1991, Pfister et al. 1992, Goss-Custard and Verboven 1993, Kirby et al. 1993). In fact, local population declines of sanderling, semipalmated sandpiper, short-billed dowitcher, and red knot along the Atlantic coast of North America may be related to site disturbance from moderate levels of vehicle traffic (Pfister et al. 1992). Klein et al. (1995) found that several shorebird species were more common in areas further from roads and trails (or dikes) on a wildlife refuge than in similar habitats near roads and trails. Some species (i.e., black-bellied plover, willet) were particularly sensitive to higher levels of vehicle traffic and responded by moving further from roads (Klein et al. 1995). Limited information suggests that black oystercatchers will abandon areas with regular human activity (Ainley and Lewis 1974, Nysewander 1977, Andres 1998); this may be particularly critical in nesting areas.

Human disturbance occasionally escalates to a point where shorebirds are killed. At North Beach, Washington, a beach open to vehicle traffic, roosting flocks of western sandpipers, dunlins, sanderlings, and dowitchers have been intentionally targeted by speeding motorists; at least 480 birds were killed in 2 separate incidents on this beach (R. Schuver, personal communication; M. Cenci, personal communication). Harassment by motorists of roosting shorebirds is not uncommon on Washington beaches (J. Buchanan, personal observation).

Water-related Recreational Activities - Shorebirds are also disturbed by recreational activities on water (Weston 1997). Smit and Visser (1993) reported that kayakers represent a potentially important source of disturbance to roosting birds because the small daft of a kayak allows close approach to roost sites in intertidal areas. Disturbance by personal motorized water craft (e.g., jet skis) has been documented at a large roost site in Grays Harbor (L. Vicencio, personal communication). These types of disturbances may occur throughout marine areas of Washington.

Waterfowl Hunting - A common human disturbance activity is waterfowl hunting. The noise associated with shotgun blasts disturbs foraging and roosting black-bellied plovers, greater yellowlegs, dunlins, and western sandpipers in Washington and can cause birds to temporarily leave an area (J. Buchanan, unpublished data). In a review of the effects of hunting disturbance on waterbirds (including shorebirds), Madsen and Fox (1995) reported that hunting disturbances can result in temporary disruption of daily activities (foraging, roosting, preening) and displace birds from preferred foraging areas. These responses to hunting disturbance result in greater energetic costs due to under-exploitation of preferred foraging areas. Given that populations of many species may be limited during the winter period the potential significance of the disturbance is clear, though it is unknown whether the level of disturbance from hunting reduces the physical condition or survival of shorebirds in Washington.

Although many shorebird species were hunted formerly (Bent 1927, Page and Gill 1994), the common snipe is the only shorebird game species in Washington. Other species, including dunlin, long-billed dowitcher, and greater yellowlegs, are occasionally shot by hunters who mistake them for snipes (Hainline 1974, J. Buchanan, unpublished data; R. Butler, personal communication; J. Hidy, personal communication). In a small sample of snipe wings submitted anonymously by hunters, 18% of the wings were actually from long-billed dowitchers (Buchanan and Kraege 1998). It is currently unclear whether this source of mortality is as substantive as these preliminary data suggest.

Intentional killing of non-game shorebirds by waterfowl hunters has also been documented at several sites in western Washington, including Samish Bay, Totten Inlet, and Willapa Bay (J. Hidy, personal communication; R. Woods, personal communication, J. Buchanan, unpublished data). The Willapa National Wildlife Refuge is closed to snipe hunting to reduce the likelihood that nontarget species will be shot (J. Hidy, personal communication).

Aircraft - Aircraft traffic and military activities can also disturb shorebirds (Smit et al. 1987, Koolhaas et al. 1993, Smit and Visser 1993). In a review of shorebird disturbance factors in Europe, Smit and Visser (1993) found that the distance at which shorebirds flushed varied among sites, suggesting that shorebirds were less habituated to aircraft disturbances at certain sites. Nonetheless, they reported that shorebirds were usually disturbed (e.g., they flushed from foraging or roosting sites) by aircraft flying at <300 m (990 ft). Similarly, shorebirds were more restless on days with jet activity than on days without (Koolhaas et al. 1993). Helicopters disturbed shorebirds at greater distances than other aircraft, although one study showed no disturbance from helicopters flying at 100-300 m (330-990 ft) 2-3 times per hour, suggesting, perhaps, that habituation had occurred to the regular flights (Smit and Visser 1993). Small and slow flying aircraft were one of the most disturbing phenomena in the Wadden Sea area (Smit and Visser 1993). Additionally, ultralight aircraft may cause impacts because of low flights and associated noise, although there are no data on shorebird responses to this potential source of disturbance (Smit and Visser 1993).

Environmental Conditions, Predation, and Disease

The effects of adverse weather, predation, and disease on the physical condition of shorebirds is important from a management perspective. Although these factors (i.e., general storm patterns, predation) typically operate at a level beyond human influence, their significance may be far greater if coupled with the effects of subsequent human activities (e.g. habitat loss, pollution, disturbance). Consequently, a general understanding of these factors is necessary for effective management.

Adverse Weather Conditions - Reduced body mass, emigration, depleted invertebrate food sources, reduced availability of adequate nesting and foraging areas, and outright mortality are known to occur during winter storms or prolonged periods of flooding or drought. The impact of winter storms may be more severe in regions with normally mild weather conditions because shorebirds maintain fat levels and muscle mass (i.e., protein reserves) adequate for survival under the prevailing environmental regime (Davidson 1981, Davidson and Evans 1982, Davidson et al. 1986a, b; Dugan et al. 1981). Unusual storm events therefore have the potential to catch the birds “off guard”.

Flood and drought conditions are known to influence habitat use by shorebirds. Drought in interior areas may result in reduced availability of foraging or nesting habitats, particularly for species that use wetlands (Alberico 1993). Significant flooding in estuarine or interior habitats may inundate foraging, roosting or nesting locations for extended periods, and in estuarine areas may deplete invertebrate populations through erosion or scouring of fine intertidal sediments (Ferns 1983). These conditions are unsuitable for certain species and can result in reduced body condition or site abandonment (Strauch 1966, Rundle and Fredrickson 1981, Hands et al. 1991, Warnock et al. 1995). Extensive winter movements (up to 160 km [100 mi]) in response to adverse weather have been documented in California (Warnock et al. 1995) and appear to occur in Washington (Evenson and Buchanan 1995, 1997).

On the other hand, changes in water levels, particularly at interior sites, may create more suitable conditions for certain shorebird species (Rundle and Fredrickson 1981, Hands et al. 1991, Smith et al. 1991, Taylor et al. 1993). Sites that generally lack adequate foraging areas due to extremely high or low water levels will be used by shorebirds when foraging opportunities are created by changing water levels.

Global Warming - There is currently considerable debate regarding the ecological significance of global warming. A change in global temperature would likely have both predictable and unforeseen impacts on shorebirds. Changes in sea level will likely alter the distribution and extent of estuarine areas, and may reduce the area of intertidal and saltmarsh habitats available to shorebirds (Lester and Myers 1989-90). Other potential responses to global warming include changes in migration timing, migration routes, extent and quality of breeding habitats, and the availability of prey.

Other changes related to climatic conditions are occurring along the Pacific coast of North America. Recent research indicates that significant warming has occurred in waters of the California Current. This warming has been linked to declines in zooplankton and seabird populations (Roemmich and McGowan 1995, Veit et al. 1996). Changing conditions in offshore waters may influence the distribution and abundance of phalaropes migrating through the region. In addition, rock sandpiper numbers have declined substantially in the southern portion of their wintering range during this period of oceanic warming (Buchanan 1999).

Predation - Predation is a potentially significant limiting factor because it is a substantial source of mortality among shorebirds. The overall mortality rate of most shorebird species is very high (Martin-Löf 1961, Boyd 1962, Soikkeli 1967, Gromadzka 1983; see Warnock et al. 1997). The presence of predators in an area typically results in heightened levels of vigilance by shorebirds (Metcalfe 1984). This enhanced vigilance, in combination with other sources of disturbance, can have a potentially significant effect on shorebird activity schedules and physical condition (Burger 1997). Perhaps the most significant predators of shorebirds in Washington are the peregrine falcon (*Falco peregrinus*) and merlin (*F. columbarius*), both recognized as priority species in Washington. An estimated 21% of a wintering population of dunlins in California were taken by falcons (Page and Whitacre 1975). In some situations predation by raptors may influence the latitudinal distribution of wintering shorebirds (Whitfield et al. 1988) as well as population structure (Townshend 1984). Some studies show that juvenile shorebirds are preferentially selected by raptors, or that they are more vulnerable to predation because they roost in atypical habitats (Kus et al. 1984, Townshend 1984). Shorebirds also respond to the presence of mammalian predators such as rats; this may be most significant at nocturnal roosts (Burton et al. 1996).

Disease - The significance of disease for most shorebird species is unknown. However, outbreaks of avian cholera and botulism Type C are capable of killing thousands of birds, including shorebirds (Kadlec and Smith 1989).

Political and Management Constraints

Shorebirds as a group are characterized by annual, round-trip flights of enormous distances between wintering and breeding areas. This life history attribute alone makes it difficult for management agencies to identify species of concern and facilitate meaningful protection strategies. Factors that influence the health of shorebird populations may operate on the breeding grounds, the wintering grounds and/or along flyways. Consequently, managing shorebirds, particularly the highly migratory species, requires that these factors be addressed wherever they occur.

Current methods of identifying and protecting species of concern across broad geographical areas are somewhat limited in their utility (unless the species is listed by federal governments). For example, a species listed as threatened or endangered at the state or province level generally has no special standing elsewhere (except for basic protections under the Migratory Bird Treaty Act). This creates potential difficulties for management of a state-listed species if a limiting factor exerts significant influence during migration through a state or province where the species (does not breed and) is not listed. States tend to list only those species that have breeding populations within state boundaries and generally focus on determining a species' status within the state. In short, it is currently difficult, if not impossible, for states (and likely provinces) to effectively enact legal protection for species for which there is local or regional, but not federal, concern.

MANAGEMENT RECOMMENDATIONS

These management recommendations are based on a combination of locally and regionally important conservation issues. The following sections contain a spectrum of management recommendations that land owners, resource managers, and others can use to reduce impacts to shorebirds or to improve shorebird habitats. These recommendations address regional or large scale conservation issues, as well as site-specific actions that may be meaningful to local sub-populations. Some of these recommendations can be implemented by landowners and local governments, while others are more policy oriented, and need to be addressed by state and federal agencies, and conservation organizations. Because of the broad range of shorebird distributions and their dynamic life history characteristics, it is important to understand these management issues at various spatial and temporal scales.

Habitat Identification and Preservation

Identify important local and regional sites - One of the first tasks required to protect shorebird habitat is to identify important local and regional sites. British workers have developed a system to evaluate site populations by comparing them to national, international and flyway populations (Prater 1981). Field work to identify locally and regionally important sites is ongoing in much of western North America (Page and Gill 1994; G. Page, personal communication), and many important sites in western Washington have been identified (Buchanan and Evenson 1997, Evenson and Buchanan 1997). Additional work is needed for the migration periods in eastern Washington, the fall migration period in western Washington, and for the group of rocky shoreline species along the Washington coast.

Wetland habitats of all sizes support shorebird populations in Washington. In North America, standards set forth by the Western Hemisphere Shorebird Reserve Network specify that sites which support at least 20,000 shorebirds or at least 5% of the flyway population are of regional importance (Myers et al. 1987a; Harrington and Perry 1995; I. Davidson, personal communication). This strategy appears to effectively identify several of the major estuarine sites in Washington. However, recent research in Puget Sound indicates that numerous sites support populations of <5,000 shorebirds, and that cumulatively these sites may account for as much as 20-50% of the Puget Sound shorebird population (Evenson and Buchanan 1995, 1997), indicating a need to recognize the importance of assemblages of smaller sites. This may also be particularly important for some shorebirds that migrate through the Columbia Basin (Robinson and Warnock 1996, Skagen 1997).

Preserve remaining wetland habitat - Preservation of remaining wetland habitat should be a priority for shorebird conservation programs. Locally and regionally important sites should be purchased to reduce the loss or degradation of habitat important for shorebirds and other wildlife. Following an assessment of water needs and a determination of salinization significance, efforts should be made to insure the availability of high-quality water for important wetlands and wetland complexes in the Columbia Basin. In a review of coastal wetland conservation strategies, Bildstein et al. (1991) recommended the development of new protective and regulatory legislation, and more effective enforcement of existing laws concerning wetland use.

Land Use Assessment

Assess livestock grazing in habitats used by shorebirds for potential impacts - Research indicates a number of direct and indirect impacts on shorebirds or their habitats due to grazing livestock (Powers and Glimp 1996). Negative impacts described elsewhere include the destruction of eggs or nests (Rohwer et al. 1979, Guldemond et al. 1993), abandonment of disturbed nests (Delehanty and Oring 1993), and adult birds spending an increased time away from their nests (Graul 1975), which likely results in increased exposure of eggs.

Assess commercial sand and gravel extraction from beach and riverine areas for potential impacts to shorebirds - Certain beach and riverine areas are important foraging, roosting, or nesting areas for shorebirds (Buchanan 1992, Paulson 1993). The development of a review process for these activities would help ensure that shorebirds are considered as part of the permitting process.

Utility Lines and Wind Turbines

Assess impacts associated with placement of new utility towers and lines - New towers and utility lines should not be placed in known or suspected flight corridors or near wetland areas used by shorebirds. New lines should be placed below ground if possible. In areas where placement of towers and lines have been proposed, an effort should be made to determine whether flight corridors or wetlands occur nearby so that more appropriate alternate strategies may be developed and implemented.

Mark existing utility lines to make them more visible - Where possible, existing utility lines should be marked or treated to make them more detectable by birds in areas where collisions involving shorebirds have occurred or are likely to occur. Techniques include: coating or painting wires, marking wires with mobile (i.e., non-stationary) spirals or strips of fiberglass or plastic, warning lights, and placement of predator silhouettes or acoustical devices to scare birds (Bevanger 1994). Recent research indicates that static wire-marking may effectively reduce the number of collisions birds have with power lines (Janss and Ferrer 1998); the wire markings used in that study included white spirals (30 cm diameter x 100 cm length) looped around the static wire and black crossed bands (two 35 cm bands attached side-by-side at their mid point) on conductors. Similarly, collision mortality (of cranes and waterfowl) was reduced in sections of transmission and distribution lines marked with dampers (112-125 cm [1.27 cm diameter] polyvinyl chloride plastic lengths twisted around the transmission lines and placed at 3.3 m intervals on the uppermost static wire) or plates (30.5 x 30.5 cm yellow fibreglass squares with a contrasting black diagonal stripe 5 cm in width and placed at 23-32 m intervals on static wires or center conductors) (Brown and Drewien 1995). Also, yellow marking devices may be more visible to birds and should be used in areas characterized by dark or cloudy conditions, whereas a combination of colors (red markers may be best in bright sunlight) would suffice for variable conditions (Raevel and Tombal 1991, Brown and Drewien 1995).

Some strategies may be more effective for certain species groups than others due to species differences in sound or color perception. Research should be conducted to evaluate the effectiveness of these and other techniques designed to reduce collisions (Bevanger 1994, English 1996). Evaluations of potential techniques should consider the type of behavior that places birds at risk. For example, the first 3 approaches listed above may be less effective in areas where shorebirds make significant nocturnal flights between foraging and roosting locations.

Other strategies to reduce the incidence of bird collisions with utility lines involve line configuration. Grouping multiple lines might make them more visible to birds, and the lines will occupy a smaller area of flight space, thus reducing the likelihood of collisions Bevanger (1994). In addition, the lines should be arranged side by side rather than in a vertical stacked formation (Bevanger 1994).

Assess impacts associated with placement of wind turbines - Wind turbines should not be placed in known or suspected flight corridors, near known concentrations of birds, or near wetland areas used by shorebirds. In areas where wind turbine placement has been proposed, an effort should be made to determine whether flight corridors, important wetlands, or other habitats occur nearby so that alternate strategies may be used.

Oil Spills

In the event of an oil spill, limit public access to beach or estuarine spill sites - Oiled birds typically spend a considerable amount of time attempting to clean their plumage and spend less time foraging (Burger 1997). This results in an increase in energetic costs. Consequently, the impacts of an oil spill can be exacerbated by disturbances caused by human recreation (e.g., beach walking), except in some circumstances where intentional disturbance is used to exclude shorebirds and other wildlife from oiled beaches. For this reason, public access to the vicinity of spill sites or areas where oiled birds occur should be limited as much as necessary or possible until shorebird roosting, foraging, and preening behavior returns to a baseline level.

Assess and enhance navigational assistance procedures for commercial marine vessels - An assessment of the causes of oil spills should be conducted to determine how navigational aids might reduce the incidence of these events. Although determining the specific enhancements is beyond the scope of this document, they might include better navigational charts or training, and increased tug boat availability to assist larger vessels that enter Strait of Juan de Fuca and Puget Sound waters.

Continue the development and refinement of oil trajectory models - A number of oil trajectory models have been developed for spill response management. These models typically incorporate factors such as characteristics of the oil; wave action and other physical processes; and oceanographic and meteorological factors such as tidal cycle, currents and weather (ASCE Task Committee 1996, Galt 1994, Galt et al. 1996). These models are used to respond to actual spills and to identify high risk sites (Begg et al. 1997). Because of the complex functioning of currents and tides within the Puget Sound region, however, researchers are attempting to develop new models to improve site protection and spill response. These important efforts should be continued and supported (Begg et al. 1997).

Develop baseline information needed to assess impacts of oil spills - Baseline information on shorebird abundance and habitat use is lacking for a number of species and should be updated periodically for all potentially vulnerable species. This information will be important for efforts to: 1) assess impacts of oil spills (Parsons 1996), 2) develop appropriate remediation for spill damages (Parsons 1996), and 3) improve protection and response strategies (Begg et al. 1997).

Plastics in the Marine Environment

Develop procedures for controlling spills of plastics into the marine environment - Small plastic particles injure surface feeding marine birds that intentionally or inadvertently ingest them. A strategy to control the amount of plastic that enters the marine environment will be complex because plastic waste originates from land and at-sea sources, it is virtually impossible to identify the origin of most debris (Ribic et al. 1997), and compliance is difficult to enforce (offenders are rarely caught; Laska 1997, Sutinen 1997). Local waste management programs are generally ineffective because the mobility of plastic makes this form of pollution a global management issue (Ninaber 1997).

Much of the land-based plastic pollution appears to enter the marine environment from storm water runoff. Moreover, plastic pellets are transported to marine waters from locations at any sector of the plastics industry (Redford et al. 1997), indicating that better containment is needed in all phases of pellet manufacture, packaging, transport, and use. Strategies to limit land-based sources of marine debris should involve development and implementation of regulatory and administrative measures, use of education to identify problems and solutions, creation of solid waste management infrastructure, use of new technologies, political commitment, and assessment and monitoring programs (Redford et al. 1997).

Support changes to marine pollution regulations that result in global control of marine plastic pollution. Annex V of the International Convention for the Protection of Pollution from Ships, known as MARPOL (73/78), was enacted in 1988 to reduce at-sea marine pollution. MARPOL is a product of the International Maritime Organization. Some authorities believe the provisions of MARPOL must be enhanced to be truly effective (Ninaber 1997). Improvements to MARPOL and other marine pollution regulations are needed and should consist of the following elements at the very least: 1) technological innovations that reduce the amount of plastic materials used on ships or that allow for at-sea processing, 2) organizational and operational changes within the shipping and marine recreation industries to facilitate policy development that addresses waste management, 3) educational communication that is designed to promote an environmental ethic and which targets specific marine 'user' groups, 4) government and private regulation and enforcement efforts that require development of waste management plans for ocean-going vessels and that extend authority to state or municipal authorities to levy fines for illegal dumping, and 5) creation of economic incentives by promoting development and use of recyclable products and development of on-board waste-processing equipment (Laska 1997). Finally, because waste management in the marine environment is a global issue, a standardized approach that facilitates participation by vessels and ports world-wide is needed. Incompatible vessel and port waste management programs (e.g. removal and handling of recyclable waste) will result in failure to control marine plastic pollution. For additional recommendations regarding plastic particle pollution, see Koss (1997), Laska (1997), Liffmann et al. (1997), Ninaber (1997), Sutinen (1997), and Wallace (1997).

Pesticides and Other Chemicals

Use extreme caution when applying chemicals near habitats used by shorebirds - Some pesticides (including insecticides, fungicides, rodenticides, herbicides) and fertilizers (including animal waste) can directly kill fish and wildlife and indirectly affect habitat quality when used inappropriately. Because information on the toxicity and effects of specific chemical treatments to fish and wildlife is scarce or lacking for many chemical compounds, a conservative approach to chemical treatments is recommended and alternatives to chemical use are encouraged (Odum 1987). Appendix A (of this volume) lists contacts useful in assessing pesticides, herbicides, and their alternatives.

Use current information to establish buffer zones when applying chemicals - Buffer zones should be implemented around shorebird and waterfowl nesting habitat in agricultural landscapes to minimize the impacts of spray drift (e.g., Payne et al. 1988), particularly when the effects of drift are negative or unknown. These buffer zones should be specific to the types of chemicals used and their methods of application. Creation of adequate buffer zones requires up-to-date information about the potentially adverse effects of various compounds on estuarine and wetland ecosystems and the wildlife that use these habitats.

Promote public education about chemical use and wetland functions through natural-resource agencies, local governments, conservation groups, and others - There is a need for a general understanding by the public that actions near or within wetlands affect the proper functioning of the ecosystem (Grue et al. 1986). Efforts to provide important information to the public will likely require elements of research, monitoring, and education. Implementation of an integrated training and certification program for landowners and commercial pesticide applicators has been recommended as a means to provide pesticide users with important biological information and training (Grue et al. 1989).

Human Disturbance

Control public access and human activities in areas important to shorebirds - This may consist of directing foot traffic away from roosting or foraging sites that should not be disturbed by human visitors. Similar efforts to control areas open to the public at Grays Harbor during spring migration appear to have been successful although an ecological assessment of human disturbance on shorebirds there has not been done. Similarly, Pfister et al. (1992) recommended identifying important beach areas and establishing vehicle restriction zones during critical roosting periods to reduce disturbance to shorebirds.

Develop site-specific strategies to manage human disturbance - Important wintering and migratory staging sites should be identified so that site-specific strategies can be developed, as necessary, to manage human disturbance. Potential strategies include developing informational signs that identify or describe important foraging or roosting areas. Groups of volunteers ("beach patrols") at the Dee estuary in Europe have successfully educated the public about shorebird ecology by distributing leaflets and leading organized birdwatching trips to roost sites (Kirby et al. 1993). It may be possible to coordinate similar groups of volunteers in Washington if future site disturbance warrants such action.

Post informational signs to reduce human disturbance - Informing the public about the sensitivity of large concentrations of roosting or foraging birds may reduce disturbance at such sites. One means to accomplish this would be to post informational signs at beach access points, public boat launches, or other marine access points.

Address the effects of disturbance in refuge management plans - Management plans for existing or proposed refuge or wildlife management areas should address the potential impacts of hunting and other human disturbances. Fox and Madsen (1997) assert that many refuge/wildlife management areas are linear in shape and as a consequence have few disturbance-free areas. They propose that refuges should be designed to provide disturbance-free areas and adequate buffer zones, and that refuge design must take into account the ecology of the species expected to use the area. For shorebirds, this means identifying important foraging and roosting areas and accounting for typical spatial and temporal patterns of use. For example, it would be important to determine whether shorebirds exhibited differential use of diurnal and nocturnal roost sites, and whether there was age-, sex- or species-related segregation in habitat use (Meltofte et al. 1994). In addition, it has been recommended that complexes of disturbance-free roosting sites should be situated such that the distance among roosts is equal to normal intra-roost flight distances of the species that typically move the shortest distances within a single estuary (Rehfisch et al. 1996). Obviously, a substantial amount of information is need to examine the issue of disturbance and to develop scientifically-based management guidelines as needed (Hill et al. 1997).

Assess the level of unintentional shorebird mortality due to hunting - The level of unintentional mortality of shorebirds due to hunting is likely very low. An evaluation of this source of mortality would provide an indication as to whether a new identification/information guide for shorebirds should be developed for inclusion in a waterfowl hunting pamphlet. Such an assessment may allow for more effective refuge design or area access considerations.

Implement educational programs that inform the public about the ecology and behavior of shorebirds through natural-resource agencies, local governments, conservation groups, and others - This may reduce harassment of shorebirds in areas of high use by humans (Kirby et al. 1993). In addition, public education programs should emphasize the international scope of shorebird conservation (Bucher 1995, Finney 1995); such an effort should greatly improve conservation efforts throughout the western hemisphere (Castro 1993). Finally, resource management agencies and wildlife interest groups must work together to improve regional involvement in international conservation efforts. Such efforts require improved information on the basic ecology of flyway species, identification of significant threats or potential impacts, and development of real conservation measures (Davidson et al. 1995).

Control of Exotic Species

Continue efforts to control the establishment and growth of cordgrass, purple loosestrife, and other noxious weeds- A substantial effort is underway to implement an integrated weed management program in Puget Sound and Willapa Bay following guidelines set forth in an environmental impact statement on noxious emergent plant control (Washington Department of Agriculture et al. 1993). Potential methods to eradicate noxious weeds include biological control, repeated mowing, hand pulling of seedlings, and chemical treatment (Washington Department of Agriculture et al. 1993). Some of these methods are currently being used (Kilbride et al. 1995, Washington Department of Fish and Wildlife 1995c). A monitoring and assessment strategy is essential to determine the efficacy of the methods and to safeguard against unanticipated impacts (e.g., those resulting from chemical application). Appendix A lists useful contacts for assessing pesticides, herbicides, and their alternatives.

Develop guidelines or regulations to control the transport of exotic invertebrates in marine waters - A large number of exotic invertebrate species are transported in ship ballast and discharged in estuarine or portside waters around the world (Carlton 1985). Ballast occasionally is discharged in ‘technically restricted places” if it is felt that petroleum products are not contained in the ballast (Carlton 1985), making current controls on ballast uptake and discharge limited or ineffective. Due to the potentially deleterious effects of exotic marine invertebrates on native marine assemblages and the apparent lack of meaningful controls on ballast management, policy makers and resource management agencies should work with marine transport organizations to develop meaningful procedures for uptake and discharge of ballast.

Restoration/Creation of Habitat

The restoration or creation of tidal and nontidal areas for overwintering shorebirds is a possible means to mitigate environmental impacts. There is potential risk associated with this approach, however, because shorebirds do not settle in their winter quarters in a random manner, but rather return to areas used in previous years. Little information is available to assess the potential effectiveness of such restoration efforts (Wilcox 1986, Rehfisch 1994), and it is stressed that restoration is not an adequate substitute for safeguarding existing wetlands. Mitigation efforts at wintering grounds must recognize that habitat loss will most likely result in density-dependent competition at other sites in the region (see below).

Restoration of habitats used during breeding and migration seasons is also an important consideration. Substantial efforts are currently underway in the intermountain west to manage and restore wetland habitats (Inter-mountain West Joint Venture; Ratti and Kadlec 1992). These efforts should be supported.

There are many risks, often unforeseen, associated with restoration/creation projects. For example, restoration projects that reduce shore width typically result in the covering of adjacent high-level sandy tide flats with fine silt (Hill and Randerson 1986); the resulting change in substrate may not support species that formerly used the site (Burton et al. 1996).

Develop site-specific strategies for restoration projects - Information on local water, soil, and vegetation conditions and requirements (freshwater environments; Hammer 1997) or tidal, wind pattern, sea swell, and substrate conditions (marine environments; see below) needs to be incorporated.

Create new sites at least five years prior to modification of natural habitat - Artificially created sites should provide for all displaced birds and should address this need at least 5 years prior to the modification of natural habitat to allow an assessment of its success (Davidson and Evans 1987). Specifically, this 5-year period is needed to: 1) identify suitable sites; 2) acquire, design, and construct the mitigation features at sites; 3) allow settlement and stabilization of suitable sediments; and 4) allow colonization of sufficient densities of invertebrate prey species (Davidson and Evans 1987).

Address population dynamics at long-term and regional scales through mitigation - Mitigation studies should model population dynamics in a variety of local habitats over wide spatial (e.g. coastal, Puget Sound, and interior) and temporal (e.g., at least 5 years) scales. This is important because 1) shorebirds may use a variety of habitats (e.g., intertidal mudflats, beach, salt marsh) in an area (Burger et al. 1997); 2) changes in shorebird populations at a site during the nonbreeding season may also reflect responses to factors at other sites within the estuary, at other estuaries, or even at breeding areas (Goss-Custard and Durell 1990, Goss-Custard and Yates 1992); and 3) impacts to a site may influence shorebird populations at other sites.

Evaluate shorebird use of artificial impoundments - Artificially created sites may be very important to shorebirds, particularly in the Columbia Basin. Artificial drawdown sites may provide more nesting opportunities for certain species depending on the type of shoreline or the availability of nesting substrate (Paton and Bachman 1996). Care must be taken, however, to determine whether the spatial extent of the shoreline area created by the drawdown concentrates predator search effort and leads to high predation rates (Rönkä and Koivula 1997). In addition, efforts to modify such sites should be evaluated in the same manner as undisturbed sites (Warnock and Takekawa 1995).

Create adequate roost sites - Roost sites are an important habitat resource used by shorebirds during the nonbreeding season. Although most shorebirds appear to prefer salt marshes and beaches as roost sites, they also use dredge-spoil islands and other human-created areas. Shorebirds will likely use artificial sites if they are properly designed. A primary consideration in creating a roost site is that it must be designed to address the needs of the species that will use the site. Island roosts should provide shelter from strong winds or sea swell if these are significant environmental conditions in the particular area (Burton et al. 1996). In addition, Burton et al. (1996) recommended that island roosts should be open, with flat tops and gently sloping sides so that the birds can effectively scan for predators (Metcalfe 1984).

Manage artificial (freshwater) sites for breeding season use - Shorebirds will nest in artificial wetlands and impoundment drawdowns when certain conditions are met (Green 1988, Paton and Bachman 1996). The first consideration required when managing habitats for breeding birds is to determine the focal species that will use the site. Nesting requirements are quite different for species like the killdeer and American avocet. Other considerations include the depth of water in impoundments and the availability of invertebrate prey (see sections below).

Manage artificial (freshwater) sites during fall migration - During fall migration, shorebirds are attracted to drawdowns in reservoirs and other artificial impoundments, flooded agricultural lands, and artificial fish ponds (Rundle and Fredrickson 1981, Hands et al. 1991, Smith et al. 1991). Gradual draw-downs in impoundments are recommended because this more effectively facilitates the extended-use period of shorebirds during fall migration and assures availability of resource alternatives as local conditions change (Rundle and Fredrickson 1981, Skagen and Knopf 1994). Rundle and Fredrickson (1981) further recommended that shallow [0-5 cm (0-2 in) deep] flood pools be interspersed with exposed saturated soils to enhance shorebird use; shorebirds also used areas disked prior to flooding. It is important to maintain drawdown and flooded lands habitat for the duration of fall migration to provide habitat conditions favorable for late-season movements of juveniles (Morrison 1984, Hands et al. 1991). Shorebirds are attracted to these artificially created areas during spring migration, but seem to use them less than during fall (Rundle and Fredrickson 1981, Hands et al. 1991), although data from sites in the Pacific Northwest are lacking.

Maximize invertebrate production at artificial (freshwater) sites - Artificial impoundments will be most effective if the site contains features that maximize invertebrate production and foraging efficiency by shorebirds (Rehfisch 1994). The enhancement or creation of artificial sites will require local knowledge of the potential for a specific site to support desired populations of invertebrates. Some recommendations for the management of artificial impoundments are provided in Table 2.

Table 2. Features of pastures, fields, and artificial impoundments that maximize benefits for nesting or migrating shorebirds.

Site feature	Recommended condition or action	References
Water depth	• Less than 5 cm (2 in) for sandpipers. • Less than 10-15 cm (4-6 in) for larger species (e.g., yellowlegs, avocets). Areas of slightly deeper water may be suitable for phalaropes. • Particularly at sites with a permanent or long-term management emphasis, areas of deeper water [>30 cm (12 in)] should be maintained in the center of impoundments to minimize winter mortality of invertebrates. Also, the deeper area(s) should not be allowed to dry out and would thus act as a source from which invertebrates might colonize areas flooded during migration periods.	Hands et al. (1991), and Rundle and Fredrickson (1981) Rehfisch (1994)
Seasonal availability	• Impoundments and managed drawdowns may be most important during autumn migration. Where possible, maintain a number of units (e.g., 6) during peak periods of anticipated use to ensure the availability of suitable conditions; the most important period in eastern Washington is probably August-September. • Gradual drawdowns create suitable conditions over a longer time period.	Hands et al. (1991), Rundle and Fredrickson (1981)
Vegetation	• In impoundments generated by spring precipitation or runoff, greater water depths may be needed to inhibit growth of undesirable aquatic vegetation. Short drying periods may also be required to control invasive plant species. • Dense shoreline vegetation may impede use by shorebirds. • Use of pastures by small and medium-sized shorebirds increases when vegetation is <20 cm (8 in) tall; shorebirds appear to prefer sites with vegetation <10 cm (4 in) tall.	Rundle and Fredrickson (1981) and Rehfisch (1994) Rundle and Fredrickson (1981) Colwell and Dodd (1997)
Special methods of site prep-aration	• Disking prior to flooding may improve site conditions.	Rundle and Fredrickson (1981)
Arrangement of units	• Where possible, maintain a number of sites (e.g., 6) during peak periods of anticipated use to ensure the availability of suitable conditions. • Create mosaic of shallow water areas interspersed with areas of exposed, saturated soil.	Hands et al. (1991) and Reid et al. (1983) Rundle and Fredrickson (1981)

Maintain agricultural areas and pasturelands near sites used by shorebirds - Colwell and Dodd (1995, 1997) recommended that a mosaic of pasture lands with various vegetation heights and flooding conditions be maintained in coastal areas near estuaries. They felt that it might be possible to manage for appropriate vegetation height through cattle grazing. They added, however, that the information needed to make specific recommendations about grazing intensity and timing was not currently available. Similarly, Rottenborn (1996) stated that the greatest use by shorebirds of agricultural lands in Virginia was in areas of flooded, bare (plowed) earth. He believed that the potential value of staging areas might be enhanced by managing adjacent pasture and agricultural lands for the open conditions most often used by shorebirds. Prescribed fire may be a potential method to create or enhance shorebird habitat in certain upland areas (Stone 1994).

Effectively manage artificial sites - There are several additional practical issues that should be addressed by those interested in creating or maintaining artificial habitats (Engilis and Reid 1996). First, in areas where flooding or erosion are important issues, it will be necessary to design and use spillways properly to prevent damage. Second, exotic species such as carp and purple loosestrife must be controlled and their potential reinvasion routes managed to prevent the reestablishment of these species. Third, in areas with a controlled water source it is important to maintain water flow, provide adequate draining, and use adequate spacing between inflow and outflow points to minimize stagnant water and reduce the likelihood of outbreaks of avian cholera and botulism Type C (Kadlec and Smith 1989). Fourth, an assessment of soil conditions is necessary to determine whether the site will effectively hold water (e.g., prevention of drainage to the water table, or seepage through dikes). The capacity of a site to contain water may be accomplished with as little as 10% clay content although 30% clay content is more desirable

(Engilis and Reid 1996). Finally, artificially constructed islands designed as shorebird nest sites must have a gently sloping shoreline (a minimum 5:1 ratio to a height 30-60 cm above water level is recommended; Engilis and Reid 1996) and be large enough to enable shorebirds to effectively use predator avoidance behavior to protect eggs or fledglings. Resource managers should consult Engilis and Reid (1996) and Hammer (1997) for more details about wetland habitats and restoration.

Consider other recommendations - Evans (1991) made a number of additional recommendations that should be considered in any restoration or mitigation project. These recommendations are based on shorebird ecological studies and do not reflect results of actual mitigation assessments, which are largely lacking. First, many wintering shorebirds forage in protected areas during periods of strong winds. In areas where strong winds are known to occur, it may be important to provide sheltered, yet open feeding areas. This might be accomplished by excavating channels through mitigation tideflats. Second, it may be possible to increase the availability of invertebrate prey at wintering sites by discharging clean cooling water from industrial processes. Evans (1991) suggests that increases in prey availability may occur if such discharges increase water and mud temperatures. However, it is recommended that such action be done experimentally and evaluated for its potential impacts to plankton and invertebrate communities prior to more widespread use. Finally, creation of adjacent wetlands may be beneficial in some situations where reclamation eliminates habitat and effectively reduces the amount of time that shorebirds can spend foraging at a site. This may be particularly important for smaller shorebirds that face a competitive disadvantage to larger species for spatially or temporally limited resources (Davidson and Evans 1986). [Shorbird conservation planning documents were prepared after this PHS document was completed; see Brown et al. (2000) and Drut and Buchanan (2000)].

Conservation Planning

Develop a comprehensive planning process within state and federal natural resource agencies - Managing for shorebird populations in Washington requires development of comprehensive conservation objectives for the various shorebird species and the habitats they use. This must be done in the context of a landscape scale that incorporates the full range of species occurrences and community interactions in the habitats involved (Skagen 1997). Accomplishing this will likely facilitate more effective implementation of the recommendations described above and will likely provide greater opportunities to address the conservation needs of other species associated with the habitats used by shorebirds (Dickson and McKeating 1993, Laubhan and Fredrickson 1993, Streeter et al. 1993, Fredrickson and Laubhan 1994) [Shorbird conservation planning documents were prepared after this PHS document was completed; see Brown et al. (2000) and Drut and Buchanan (2000)].

Broaden the geopolitical scale of conservation planning - Due to the migratory status of most shorebirds and the potential difficulties associated with their management as described above, there is a need for comprehensive conservation planning at the flyway level. Strong partnerships and governmental commitments developed at this geopolitical scale may result in:

1) better understanding of limiting factors and population health of various species, 2) more effective management of refuges and other important areas used by shorebirds, and 3) opportunities to efficiently protect shorebirds and a large number of other species through the development of regional or flyway-level plans that emphasize specific needs and solutions. The current effort to develop a National Shorebird Conservation Plan may address these issues and should be supported. In addition, as part of a comprehensive planning and coordination process, cooperative agreements should be established whereby listing a species as threatened or endangered in a flyway state or province would prompt other flyway states or provinces to evaluate that species' status. The evaluation would determine 1) whether factors in the other states or provinces may have influenced the initial listing or are significant for recovery planning, and 2) whether the species should be listed in other states or on a flyway basis. This second concept requires that regional or flyway standards for listing be developed.

RESEARCH NEEDS

Many authors have commented on the importance of research for conserving wildlife resources (Bildstein et al. 1991, Morrison 1991). Essential research should investigate shorebird distribution, population trends, and annual survival or mortality estimates, as well as energetic and eco-physiological relationships. In addition, shorebird ecology and habitat relationships in Washington need to be studied, including threats to shorebird habitats and their

Table 3. Summary of research and information gaps relating to shorebird species in Washington that are addressed in this document. An asterisks (*) represents areas of information developed from Washington, pound sign (#) represents areas of information from elsewhere within the species range that is pertinent to Washington.

Species	Important sites identified[a]	Population trends monitor[d]	Food habits[b]	Physiolog/ mortality factors	Recent contaminant studies[c]	Effects of disturbance[d]	Effects of habitat degradation	References[e]
Black-bellied plover	*				*	#	#	7,8,9, 15,16
American golden-plover	*							14
Pacific golden-plover	*							14
Semipalmated plover	*					#		14
Killdeer	*					#		9,14
Black oyster-catcher	*		*			#		11,13, 17
Black-necked stilt	*					#		14
American avocet	*							14
Greater yellowlegs	*					#		3,7,9
Lesser yellowlegs						#		
Solitary sandpiper								
Wandering tattler							#	1
Spotted sandpiper							#	1
Whimbrel							#	1
Marbled godwit	*							14
Ruddy turnstone							#	1
Black turnstone							#	1
Surfbird								
Red knot	*					#		14
Sanderling	*				*	#		4,15
Western sandpiper	*				*	#		7,9, 15
Least sandpiper						#		
Baird's sandpiper								
Pectoral sandpiper	*							5
Rock sandpiper		*						6,14
Dunlin	*		*		*	#		2,4, 9,15
Short-billed dowitcher	*					#		7,10, 14
Long-billed dowitcher	*							7,10,14

Species	Important sites identified[a]	Population trends monitor[d]	Food habits[b]	Physiolog/ mortality factors	Recent contaminant studies[c]	Effects of disturbance[d]	Effects of habitat degradation	References [e]
Common snipe	*							14
Wilson's phalarope	*							14
Red-necked phalarope	*		*					12,14
Red phalarope	*							14

[a]Various species that migrate through eastern Washington use habitats whose availability is seasonally or annually unpredictable due to changes in water levels; important habitats for many species (for example, lesser yellowlegs, solitary sandpiper, spotted sandpiper, and least sandpiper) can likely be predicted seasonally or annually based on availability of suitable conditions; [b]Only the food habits studies conducted in Washington, Oregon, or southern British Columbia are included because of substantial regional differences in energetic demands, prey availability, and prey use; [c]Includes chemical, industrial, heavy metal, plastic, and oil pollution; [d]See table 4 for details and references; [e]References are as follows: 1 = Bradley and Bradley 1993, 2 = Brennan et al. 1990, 3 = Buchanan 1988, 4 = Buchanan 1992, 5 = Buchanan (in prep - a), 6 = Buchanan (in prep - b), 7 = Buchanan and Evenson 1997, 8 = Custer and Myers 1990, 9 = Evenson and Buchanan 1995, 10 = Evenson and Buchanan 1997, 11 = Frank 1982, 12 = Jehl 1986, 13 = Nysewander 1977, 14 = Paulson 1993, 15 = Schick et al. 1987, 16 = Sutherland and Goss-Custard 1991, 17 = Vermeer et al. 1989.

use of artificial wetlands. Research on environmental contaminants and shorebird toxicology is needed in Washington (Morrison 1991). Additional research needs are presented below. Many of these and other research topics have not been addressed for shorebird species in Washington **(**Table 3**)**.

Evaluate the potential impacts of commercial shellfish management may have on shorebird populations - There is currently a dearth of information on the response of shorebirds to management of bivalves in intertidal areas in the Pacific Northwest. Due to this lack of information, research should be conducted to evaluate whether various aspects of commercial bivalve production influence site quality for shorebirds.

Determine the relationship between livestock grazing and shorebird habitat quality - Information on the effects livestock trampling may have on shorebirds is needed for the intermountain west. Negative effects noted elsewhere include eggs or nest destruction (Rohwer et al. 1979, Guldemond et al. 1993), nest abandonment (Delehanty and Oring 1993), and adult birds spending an increased time away from their nests (Graul 1975), which likely results in increased exposure of eggs. Vegetation control is one potential positive effect. An effort is needed to identify these relationships, particularly in the Columbia Basin, and determine the conditions under which grazing activities and shorebird habitat management might be compatible.

Develop a better understanding of the ecology and population status of the common snipe - The common snipe is a state game species. The effects of hunting mortality on common snipe populations need to be investigated to ensure appropriate management.

Evaluate the effects of various types of human disturbance on shorebirds - Studies have shown that many types of human activities disturb shorebirds. Research on disturbance effects should focus on 1) vehicle and pedestrian traffic on beaches, 2) watercraft disturbance on lakes and bays, and 3) tourist/birdwatcher disturbance at migratory stopover sites.

Determine the effects of water salinization on shorebirds and other wildlife - The relationship between increasing water salinization within the Columbia Basin and the shorebirds that migrate through or nest in that region needs to be investigated. Understanding this relationship will be required to better control the potentially harmful effects of increasing salinization on shorebirds and other wildlife, and for effective management of vegetation.

Use new technology to improve our understanding of shorebird ecology - Satellite imagery has been used to assess habitat suitability and availability (Yates et al. 1993a,b), as well as to predict presence or abundance of birds (Lavers and Haines-Young 1997). Development of this and other tools, including Geographic Information Systems, should greatly increase our ability to address management issues of concern.

Table 4. Summary of responses by shorebirds to human disturbances.

Species	Response behavior and type of disturbance	Reference
Killdeer	• Moved to areas beyond 60 m (197 ft) from trail[1] when visitation level exceeded 301-450 visitors/4 hr time period. Did not appear to be as sensitive to vehicle traffic.	Klein et al. (1995)
Black-bellied plover	• Generally found far [81-100 m (266-328 ft)] from roads, and moved to areas beyond 100 m (328 ft) when traffic level exceeded 601-750 vehicles/4 hr time period. • In northern Europe, mean flush distance in response to people walking on tidal flats was 124 m (407 ft).	Klein et al. (1995), Smit and Visser (1993)
Semipalmated plover	• Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period. • In northern Europe, the mean flush distance in response to people walking on tide flats by the closely related ringed plover (*Charadrius semipalmatus*) was 121 m (397 ft).	Klein et al. (1995), Smit and Visser (1993)
Willet	• Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period. Moved to areas beyond 40 m (131 ft) from trail when visitation level exceeded 151-300 visitors/4 hr time period.	Klein et al. (1995)
Sanderling	• Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period. Moved to areas beyond 60 m (197 ft) from trail when visitation level exceeded 301-451 visitors/4 hr time period. • Median flush response distance on a New England beach was 12 m (39 ft). • More sensitive to disturbance (humans, dogs, etc.) on beaches at dusk [flush response distance = 8.3 m (27.2 ft)] than during day [flush response distance = 5.0 m (16.4)]. • Concentrated on sections of beach with fewer people. • At high disturbance levels (vehicle count >100/day), used back beach much more than front beach, compared to periods of lower disturbance (vehicle count <20/day).	Klein et al. (1995), Roberts and Evans (1993) Burger and Gochfeld (1991) Pfister et al. (1992)
Dunlin	• Generally found far [81-100 m (266-328 ft)] from roads, and moved to areas beyond 100 m (328 ft) when traffic level exceeded 301-450 vehicles/4 hr time period. • In northern Europe, mean flush distance in response to people walking on tidal flats was 71-163 m (233-535 ft).	Klein et al. (1995), Smit and Visser (1993)
Western/least sandpiper	• Generally found far [61-80 m (200-262 ft)] from roads, and moved to areas beyond 80 m (262 ft) when traffic level exceeded 451-600 vehicles/4 hr time period.	Klein et al. (1995)

Species	Response behavior and type of disturbance	Reference
Greater yellowlegs	• Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Most greater yellowlegs used areas >20 m (66 ft) from the road.	Klein et al. (1995)
Lesser yellowlegs	• Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Most lesser yellowlegs used areas >20 m (66 ft) from the road.	Klein et al. (1995)
Red Knot	• Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Most red knots used areas >90 m (295 ft) from the road. • In northern Europe, mean flight distance in response to person in kayak was about 250 m (820 ft) • Mean flight distance in response to wind surfer was about 200 m (656 ft). • In northern Europe, birds less approachable on days with aircraft activity. Incidence of restlessness greater on days with aircraft activity.	Klein et al. (1995) Smit and Visser (1993), Koolhaas et al. (1993)
Short-billed dowitcher	• Did not respond to differing levels of road traffic, but foraging areas were located further from road than expected based on distribution of habitat. Dowitchers were more common at >90 m (295 ft) than at any distances closer to road. • Abundance on front beach declined sharply when level of disturbance exceeded 10-40 vehicles/day.	Klein et al. (1995) Pfister et al. (1992)
Black-necked stilt	• Avoided habitats within 20 m (66 ft) of road.	Klein et al. (1995)
Eurasian oystercatcher (*Haematopus ostralegus*)	• In northern Europe, took to flight when walking person within 250 m (820 ft) 57% of time. In northern Africa, flocks were flushed by a walking person at 400-500 m (1,312-1,640 ft). Mean flight distance in response to walking person ranged from 85-138 m (279-453 ft). • Mean flight distance in response to person in kayak was about 40 m (131 ft). • Mean flight distance in response to wind surfer was about 125 m (410 ft).	Smit and Visser (1993)
Redshank *Tringa totanus*	• Mean flight distance in response to person in kayak was about 195 m (640 ft). • Mean flight distance in response to wind surfer was about 285 m (935 ft).	Smit and Visser (1993)

Species	Response behavior and type of disturbance	Reference
Bar-tailed godwit	• Mean flight distance in response to person in kayak was about 200 m (656 ft). • Mean flight distance in response to wind surfer was about 240 m (787 ft). • Mean flight distance in response to walking person ranged from 101-219 m (331-718 ft). • At least 20% of birds in flock flushed when jet flew within 400-500 m (1,312-1,640 ft). • At least 55% of birds in flock flushed when helicopter flew within 900-1,000 m (2,953-3,281 ft).	Smit and Visser (1993)
Eurasian Curlew *Numenius arquata*	• Mean flight distance in response to person in kayak was about 230 m (755 ft). • Mean flight distance in response to wind surfer was about 400 m (1,312 ft). • Mean flight distance in response to walking person ranged from 101-339 m (331-1,112 ft).	Smit and Visser (1993)
Black turnstone	• In northern Europe, mean flush distance in response to people walking on tidal flats was 47 m (154 ft).	Smit and Visser (1993)
Primarily 8 species, including: semipalmated sandpiper, ruddy turnstone, sanderling, both dowitchers, red knot, dunlin, and greater yellowlegs	• In two New Jersey bays, factors influencing whether shorebirds flew but returned as a result of disturbances included duration of disturbance (short disturbances causes more flights), number of disturbances, distance between birds and source of disturbance, number of children at the site, number of people walking, and number of dogs. Factors influencing whether shorebirds flew away and did not return included duration of disturbance, the number of boats, and the number of children at the site.	Burger (1986)

[1]Trail or road traffic in various studies refers to responses of shorebirds to pedestrian or vehicular activity on trails or roads adjacent to intertidal areas within a refuge, unless otherwise noted.

ACKNOWLEDGMENTS

This document was improved by constructive comments provided by Dr. Robert W. Butler, Dr. Robert E. Gill, Jr., and Dr. Susan K. Skagen. Comments were provided by the following WDFW staff: Brett Dumbauld, Doug Kuehn, Greg Lippert, Hal Michael, Ruth Milner, Greg Schirato, and Mark Schuller. Dr. Nils Warnock provided advice and important reference materials.

REFERENCES

Ainley, D. G. and T. J. Lewis. 1974. The history of Farallon Island marine bird populations, 1854-1972. Condor 76:432-446.

Alberico, J. A. R. 1993. Drought and predation cause avocet and stilt breeding failure in Nevada. Western Birds 24:43-51.

American Society of Civil Engineers. 1990. Agricultural salinity assessment and management. K. K. Tanji, editor. ASCE manuals and reports on engineering practice, Number 71.

Andres, B. A. 1997. The *Exxon Valdez* oil spill disrupted the breeding of black oystercatchers. Journal of Wildlife Management 61:1322-1328.

_____. 1998. Shoreline habitat use of black oystercatchers breeding in Prince William Sound, Alaska. Journal of Field Ornithology 69:626-634.

Atkinson, J. 1992. A preliminary investigation of benthic invertebrates associated with intertidal mud-flats and intertidal mudflats infested with *Spartina* at one location in Willapa Bay, Washington. Report to Willapa Bay National Wildlife Refuge.

ASCE Task Committee on Modeling of Oil Spills of the Water Resources Engineering Division. 1996. State-of-the-art review of modeling transport and fate of oil spills. Journal of Hydrological Engineering 122:594-609.

Avery, M., P.F. Springer, and J. F. Cassell. 1976. The effects of a tall tower on nocturnal bird migration: a portable ceilometer study. Auk 93:281-291.

Baltz, D. M., and G. V. Morejohn. 1976. Evidence from seabirds of plastic particle pollution off central California. Western Birds 7:111-112.

Begg, G. S., J. B. Reid, M. L. Tasker, and A. Webb. 1997. Assessing the vulnerability of seabirds to oil pollution: sensitivity to spatial scale. Colonial Waterbirds 20:339-352.

Bellamy, D. F., P. H. Clarke, D. M. John, D. Jones, A. Whitick, and T. Darke. 1967. Effects of pollution from the Torrey Canyon on littoral and sublittoral ecosystems. Nature 216:1170-1173.

Bent, A. C. 1927. Life histories of North American shorebirds. Part 1. U.S. National Museum Bulletin, Washington, D.C., USA.

Beukema, J. J., K. Essink, H. Michaelis, and L. Zwarts. 1993. Year-to-year variability in the biomass of macrobenthic animals on tidal flats of the Wadden Sea: how predictable is this food source for birds? Netherlands Journal of Sea Research 31:319-330.

Bevanger, K. 1994. Bird interactions with utility structures: collision and electrocution, causes and mitigating measures. Ibis 136:412-425.

Bildstein, K. L., G. T. Bancroft, P. J. Dugan, D. H. Gordon, R. M. Erwin, E. Nol, L. X. Payne, and S. E. Senner. 1991. Approaches to the conservation of coastal wetlands in the western hemisphere. Wilson Bulletin 103:218-254.

Blomqvist, S., A. Frank, and L. R. Petersson. 1987. Metals in liver and kidney tissues of autumn- migrating dunlin (*Calidris alpina*) and curlew sandpiper (*Calidris ferruginea*) staging at the Baltic Sea. Marine Ecology Program Service 35:1-13.

Bond, S. I. 1971. Red phalarope mortality in southern California. California Birds 2:97.

Boule, M., N. Olmsted, and T. Miller. 1983. Inventory of wetland resources and an evaluation of wetland management in western Washington. Washington Department of Ecology, Olympia, Washington, USA.

Bowen, B. S., and A. D. Kruse. 1993. Effects of grazing on nesting by upland sandpipers in south central North Dakota. Journal of Wildlife Management 57: 291-301.

Bowles, J. H. 1918. The Limicolae of the state of Washington. Auk 35:326-333.

Boyd, H. 1962. Mortality and fertility of European Charadrii. Ibis 104:368 -387.

Bradley, R. A., and D. W. Bradley. 1993. Wintering shorebirds increase after kelp (*Macrocystis*) recovery. Condor 95:372-376.

Brennan, L. A., J. B. Buchanan, S. G. Herman, and T. M. Johnson. 1985. Interhabitat movements of wintering dunlins in western Washington. Murrelet 66: 11-16.

_____, M. A. Finger, J. B. Buchanan, C. T. Schick, and S. G. Herman. 1990. Stomach contents of some dunlins collected in western Washington. Northwestern Naturalist 71:99-102.

Brown, S., C. Hickey and B. Harrington. 2000. United States shorebird conservation plan. Manomet Center for Conservation Sciences, Manomet, Massachusetts.

Brown, W. M., and R. C. Drewien. 1995. Evaluation of two power line markers to reduce crane and waterfowl collision and mortality. Wildlife Society Bulletin 23:217-227.

Bryant, D. M. 1979. Effects of prey density and site character on estuary usage by overwintering waders (Charadrii). Estuarine, Coastal and Marine Science 9:369-384.
Buchanan, J. B. 1988. Migration and winter populations of greater yellowlegs, *Tringa melanoleuca*, in western Washington. Canadian Field-Naturalist 102:611-616.
_____. 1992. Winter abundance of shorebirds at coastal Washington beaches. Washington Birds 2:12-19.
_____. In prep. Pectoral sandpiper. In T. R. Wahl and W. M. Tweit, editors. Birds of Washington.
_____. 1999. Recent changes in the winter distribution and abundance of rock sandpipers in North America. Western Birds 30:193-199.
_____, L. A. Brennan, C. T. Schick, S. G. Herman, and T. M. Johnson. 1986. Age and sex composition of wintering dunlin populations in western Washington. Wader Study Group Bulletin 46:31-41.
_____, and J. R. Evenson. 1997. Abundance of shorebirds at Willapa Bay, Washington. Western Birds 28:158-168.
_____, and D. Kraege. 1998. Results of a hunter survey for common snipes harvested in the winter of 1997-1998. Unpublished Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Bucher, E. H. 1995. Western Hemisphere Shorebird reserve network: looking to the future. Wader Study Group Bulletin 77:64-66.
Burger, J. 1997. Effects of oiling on feeding behavior of sanderlings and semipalmated plovers in New Jersey. Condor 99:290-298.
_____, and M. Gochfeld. 1991. Human activity influence and diurnal and nocturnal foraging of Sanderlings (*Calidris alba*). Condor 93:259-265.
_____, L. Niles, and K. E. Clark. 1997. Importance of beach, mudflat, and marsh habitats to migrant shorebirds on Delaware Bay. Biological Conservation 79:283-292.
Burton, N. H. K., P. R. Evans, and M. A. Robinson. 1996. Effects on shorebird numbers of disturbance, the loss of a roost site and its replacement by an artificial island at Hartlepool, Cleveland. Biological Conservation 77:193-201.
Burton, P. J. K. 1974. Feeding and the feeding apparatus in waders. British Museum of Natural History, London, England.
Butler, R. W. 1994. Distribution and abundance of western sandpipers, dunlins, and black-bellied plovers in the Fraser River estuary. Pages 18-23 *in* R. W. Butler and K. Vermeer, editors. The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia. Canadian Wildlife Service Occasional Paper Number 83.
_____, and R. W. Campbell. 1987. The birds of the Fraser River delta: populations, ecology and international significance. Canadian Wildlife Service Occasional Paper Number 65.
_____, G. W. Kaiser, and G. E. J. Smith. 1987. Migratory chronology, length of stay, sex ratio and weight of western sandpipers (*Calidris mauri*) on the south coast of British Columbia. Journal of Field Ornithology 58:103-111.
Carlton, J. T. 1985. Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. Oceanography and Marine Biology, Annual Review 23:313-371.
_____, and J. B. Geller. 1993. Ecological roulette: the global transport of nonindigenous marine organisms. Science 261:78-82.
_____, J. K. Thompson, L. E. Schemel, and F. H. Nichols. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. I. Introduction and dispersal. Marine Ecology Program Service 66:81-94.
Castro, G. 1993. Conserving migratory waterbirds - a challenge for international cooperation. Pages 120-123 *in* M. Moser, R. C. Prentice, and J. van Vessem, editors. Waterfowl and wetland conservation in the 1990s: a global perspective. International Waterfowl and Wetlands Research Bulletin, Special Publication Number 26. United Kingdom.
Chapman, B. R. 1984. Seasonal abundance and habitat-use patterns of coastal bird populations on Padre and Mustang Island barrier beaches (following the Ixtoc oil spill). U.S. Fish and Wildlife Service, FWS/OBS-83/31.
Coe, J. M. and D. B. Rogers, editors. 1997. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.
Colwell, M. A., and S. L. Dodd. 1995. Waterbird communities and habitat relationships in coastal pastures of northern California. Conservation Biology 9:827-834.
_____, and _____. 1997. Environmental and habitat correlates of pasture use by nonbreeding shorebirds. Condor 99:337-344.

Connors, P. G., and K. G. Smith. 1982. Oceanic plastic particle pollution: suspected effect on fat deposition in red phalaropes. Marine Pollution Bulletin 13:18-20.
Cooke, W. W. 1910. Distribution and migration of North American shorebirds. United States Biological Survey Bulletin No. 35.
Cordell, J. R. 1998. Asian copepods in Pacific Northwest estuaries. Puget Sound Notes 41:1-5.
_____, and S. M. Morrison. 1996. The invasive Asian copepod *Pseudodiaptomus inopinus* in Oregon, Washington, and British Columbia estuaries. Estuaries 16:629-638.
Crouch, G. L. 1982. Wildlife on ungrazed and grazed bottomlands on the south Platte River, northeastern Colorado. Pages 186-197 *in* J. M. Peek and P.D. Dalke, editors. Wildlife-livestock relationships symposium. University of Idaho, Moscow, Idaho, USA.
Curio, E. 1976. The ethology of predation. Springer Verlag, New York, USA.
Custer, T. W., and C. A. Mitchell. 1991. Contaminant exposure of willets feeding in agricultural drainages of the Lower Rio Grande Valley of south Texas. Environmental Monitoring and Assessment 16: 189-200.
_____, and J. P. Myers. 1990. Organochlorines, mercury, and selenium in wintering shorebirds from Washington and California. California Fish and Game 76:118-125.
Dahl, T. E. 1990. Wetlands of the United States 1780's to 1980's. Unpublished Report, U. S. Fish and Wildlife Service, Washington, D.C., USA.
Davidson, N. C. 1981. Survival of shorebirds (Charadrii) during severe weather: the role of nutritional reserves. Pages 231 -249 *in* N. V. Jones and W. J. Wolfe, editors. Feeding and the survival strategies of estuarine organisms. Plenum Press, New York, New York, USA.
_____, and P. R. Evans. 1982. Mortality of redshanks and oystercatchers from starvation during severe weather. Bird Study 29:183-188.
_____, and _____. 1986. The role and potential of man-made and man-modified wetlands in the enhancement of the survival of overwintering shorebirds. Colonial Waterbirds 9:176-188.
_____, and _____. 1987. Habitat restoration and creation: its role and potential in the conservation of waders. Wader Study Group Bulletin 49 (Supplemental): 139-145.
_____, and _____. 1989. Prebreeding accumulation of fat and muscle protein by arctic-breeding shorebirds. Proceedings of the International Ornithological Congress 19:342-352.
_____, _____, and J. D. Uttley. 1986a. Geographical variation of protein reserves in birds: the pectoral muscle mass of dunlins *Calidris alpina* in winter. Journal of Zoology, London (A) 208:125-133.
_____, P. I. Rothwell, and M. W. Pienkowski. 1995. Towards a flyway conservation strategy for waders. Wader Study Group Bulletin 77:70-81.
_____, and D. A. Stroud. 1996. Conserving international coastal habitat networks on migratory waterfowl flyways. Journal of Coastal Conservation 2:41-54.
_____, J. D. Uttley, and P. R. Evans. 1986b. Geographic variation in the lean mass of dunlins wintering in Britain. Ardea 74:191-198.
Day, R. H., D. H. S. Wehle, and F. C. Coleman. 1985. Ingestion of plastic pollutants by marine birds. Pages 344-386 *in* R. S. Shomura and H. O. Yoshida, editors. Proceedings of the workshop on the fate and impact of marine debris. U.S. Department Committee, NOAA Technical Memo, NMFS, NOAA-TM-NMFS-SWFC-54.
Delehanty, D. A., and L. W. Oring. 1993. Effect of clutch size on incubation persistence in male Wilson's phalaropes (*Phalaropus tricolor*). Auk 110: 293-300.
DeWeese, L. R., L. C. McEwen, L. A. Settimi, and R. D. Deblinger. 1983. Effects on birds of fenthion aerial application for mosquito control. Journal of Economic Entomology 76:906-911.
Dickson, H. L., and G. McKeating. 1993. Wetland management for shorebirds and other species - experiences on the Canadian prairies. Transactions of the North American Wildlife and Natural Resources Conference 58:370-378.
Drut, M. S., and J. B. Buchanan. 2000. U.S. National shorebird conservation plan: Northern Pacific coast working group regional management plan. U.S. Fish and Wildlife Service, Portland, Oregon.
DuBowy, P. J. 1989. Effects of diet on selenium bio-accumulation in marsh birds. Journal of Wildlife Management 53:776-781.
Duffield, J. M. 1986. Waterbird use of a urban stormwater wetland system in central California, USA. Colonial Waterbirds 9:227-235.
Dugan, P. J., P. R. Evans, L. R. Goodyer, and N. C. Davidson. 1981. Winter fat reserves in shorebirds: disturbance of regulated levels by severe weather conditions. Ibis 123:359-363.

Duinker, J. C., J. P. Boon, and M. T. J. Hillebrand. 1984. Organochlorines in benthic invertebrates and sediments from the Dutch Wadden Sea: identification of individual PCB components. Netherlands Journal of Sea Research 17:19-38.

Engilis, A., Jr., and F.A. Reid. 1996. Challenges in wetland restoration of the western Great Basin. International Wader Studies 9:71-79.

English, I. 1996. Power cable casualties within the Clyde Valley. Scottish Bird News 41:10.

Erickson, W. P., G. D. Johnson, M. D. Strickland, D. P. Young Jr., K. J. Sernka, and R. E. Good. 2001. Avian collisions with wind turbines: A summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinationg Committee (NWCC), Washington D.C.

Esselink, P., J. van Belkum, and K. Essink. 1989. The effect of organic pollution on local distribution of *Nereis diversicolor* and *Corophium volutator*. Netherlands Journal of Sea Research 23:323-332.

Evans, P. R. 1976. Energy balance and optimal foraging strategies in shorebirds: some implications for their distributions and movements in the non-breeding season. Ardea 64:117-139.

_____. 1991. Seasonal and annual patterns of mortality in migratory shorebirds: some conservation implications. Pages 346-359 *in* C. M. Perrins, J. D. Lebreton, and G. J. M. Hirons, editors. Bird population studies: relevance to conservation and management. Oxford University Press, Oxford, United Kingdom.

_____, and N. C. Davidson. 1990. Migration strategies of waders breeding in arctic and north temperate latitudes. Pages 387-398 *in* E. Gwinner, editor. Bird migration - physiology and ecophysiology. Springer-Verlag, Berlin, Germany.

_____, _____, T. Piersma, and M. W. Pienkowski. 1991. Implications of habitat loss at migration staging posts for shorebird populations. Proceedings of the International Ornithological Congress 20:2228- 2235.

_____, D. M. Herdson, P. J. Knight, and M. W. Pienkowski. 1979. Short term effects of reclamation of part of Seal Sands, Teesmouth, on wintering waders and Shelduck. I. Shorebird diets, invertebrate densities, and the impact of predation on the invertebrates. Oecologia 41:183-206.

_____, and M. W. Pienkowski. 1984. Population dynamics of shorebirds. Pages 83-123 *in* J. Burger and B. L. Olla, editors. Shorebirds: breeding behavior and populations. Plenum Press, New York, New York, USA.

Evenson, J. R., and J. B. Buchanan. 1995. Winter shorebird abundance at Greater Puget Sound estuaries: recent census results and identification of potential monitoring sites. Pages 647-654 *in* E. Robichaud, editor. Puget Sound Research '95. Puget Sound Water Quality Authority, Olympia, Washington, USA.

_____, and _____. 1997. Seasonal abundance of shorebirds at Puget Sound estuaries. Washington Birds 6:34-62.

Ferns, P. N. 1983. Sediment mobility in the Severn estuary and its influence upon the distribution of shorebirds. Canadian Journal of Fisheries and Aquatic Sciences 40 (Supplemental 1):331-340.

_____, and J. I. Anderson. 1994. Cadmium in the diet and body tissues of dunlins *Calidris alpina*, from the Bristol Channel, United Kingdom. Environmental Pollution 86:225-231.

Finney, G. 1995. Western Hemisphere Shorebird Network: looking to the future. Wader Study Group Bulletin 77:66-68.

Forbush, E. H. 1912. A history of the game birds, wildfowl, and shore birds of Massachusetts and adjacent states. Massachusetts Board of Agriculture.

Fox, A. D., and J. Madsen. 1997. Behavioral and distributional effects of hunting disturbance on waterbirds in Europe: implications for refuge design. Journal of Applied Ecology 34:1-13.

Fox, G. A., A. P. Gilman, D. B. Peakall, and F. W. Anderka. 1978. Behavioral abnormalities of nesting Lake Ontario herring gulls. Journal of Wildlife Management 42:477-483.

Frank, P. W. 1982. Effects of winter feeding on limpets by black oystercatchers, *Haematopus bachmani*. Ecology 63:1352-1362.

Fredrickson, L. H., and M. K. Laubhan. 1994. Intensive wetland management: a key to biodiversity. Transactions of North American Wildlife and Natural Resources Conference 59:555-565.

_____, and F. A. Reid. 1990. Impacts of hydrologic alteration on management of freshwater wetlands. Pages 71-90 *in* J. M. Sweeney, editor. Management of dynamic ecosystems. North Central Section, The Wildlife Society, West Lafayette, Indiana, USA.

Frenkel, R. E., and L. M. Kunze. 1984. Introduction and spread of three *Spartina* species in the Pacific Northwest. Association of American Geographers 4:22-25.

Fretwell, S. D., and H. L. Lucas. 1970. On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development. Acta Biotheoretica. 19:16-36.

Galbraith, H. 1987. Threats to breeding waders: the impact of changing agricultural land-use on the breeding ecology of lapwings. Wader Study Group Bulletin 49(Suppl.):102-104.

Galt, J. A. 1994. Trajectory analysis for oil spills. Journal of Advanced Marine Technical Conference 11:91-126.

_____, D. L. Payton, H. Norris, and C. Friel. 1996. Digital distribution standard for NOAA trajectory analysis information. HAZMAT Report 96-4. National Oceanographic and Atmospheric Administration, Seattle, Washington, USA.

Gerritsen, A. F. C., and Y. M. van Heezik. 1985. Substrate preference and substrate related foraging behaviour in three *Calidris* species. Netherlands Journal of Zoology 35:671-692.

Gilbertson, M., and G. A. Fox. 1977. Pollutant-associated embryonic mortality of Great Lakes herring gulls. Environmental Pollution 12:211-216.

_____, R. D. Morris, and R. A. Hunter. 1976. Abnormal chicks and PCB levels in eggs of colonial birds on the lower Great Lakes (1971-73). Auk 93:434-442.

Gill, R. E., Jr., R. W. Butler, P. S. Tomkovich, T. Mundkur, and C. M. Handel. 1994. Conservation of North Pacific shorebirds. Transactions of North American Wildlife and Natural Resources Conference 59:63-78.

Goede, A. A. 1985. Mercury, selenium, arsenic and zinc in waders from the Dutch Wadden Sea. Environmental Pollution (series A) 37:287-309.

_____, and P. de Voogt. 1985. Lead and cadmium in waders from the Dutch Wadden Sea. Environmental Pollution (series A) 37:311-322.

Goerke, H., G. Elder, K. Weber, and W. Ernst. 1979. Patterns of organochlorine residues in animals of different trophic levels from the Waser estuary. Marine Pollution Bulletin 10:127-133.

Goss-Custard, J. D. 1977. The ecology of the Wash. III. Density-related behavior and the possible effects of a loss of feeding grounds on wading birds (Charadrii). Journal of Applied Ecology 14:721- 739.

_____. 1979. Effects of habitat loss on the numbers of overwintering shorebirds. Studies in Avian Biology 2:167-178.

_____. 1985. Foraging behavior of wading birds and the carrying capacity of estuaries. Pages 169-188 *in* R. M. Sibley and R. H. Smith, editors. Behavioral ecology: ecological consequences of adaptive behaviour. Blackwell, Oxford, United Kingdom.

_____, and S. E. A. le V. dit Durell. 1987. Age-related effects in oystercatchers, *Haemotopus ostralegus* feeding on mussels, *Mytilus edulis*. II. Aggression. Journal of Animal Ecology 56:537-548.

_____, and N. Verboven. 1990. Bird behaviour and environmental planning: approaches in the study of wader Populations. Ibis 132:273-289.

_____, and M. E. Moser. 1988. Rates of change in the numbers of dunlin *Calidris alpina*, wintering in British estuaries in relation to the spread of *Spartina anglica*. Journal of Applied Ecology 25:95-109.

_____, and N. Verboven. 1993. Disturbance and feeding shorebirds on the Exe estuary. Wader Study Group Bulletin 68 (special issue):59-66.

_____, and M. G. Yates. 1992. Towards predicting the effect of saltmarsh reclamation on feeding bird numbers on the Wash. Journal of Applied Ecology 29:330-340.

Grant, J. 1984. Sediment microtopography and shorebird foraging. Marine Ecology - Program Series 19: 293-296.

Granval, P., R. Aliaga, and P. Soto. 1993. The impact of agricultural management on earthworms (*Lumbicidae*), common snipe (*Gallinago gallinago*) and the environmental value of grasslands in the Dives marshes Calvados. Gibier faune sauvage 10:59-73.

Grassle, J. F., R. Elmoren, and J. P. Grassle. 1980. Response of benthic communities in MERL experimental ecosystems to low level, chronic additions of Number 2 fuel oil. Marine Environmental Research 4:279-297.

Graul, W. D. 1975. Breeding biology of the mountain plover. Wilson Bulletin 87:6-31.

Green, R. E. 1988. Effects of environmental factors on the timing and success of breeding common snipe *Gallinago gallinago*. Journal of Applied Ecology 25:79-93.

Grinnell, J., H.C. Bryant, and T. I. Scorer. 1918. The game birds of California. University of California Press, Berkeley.

Gromadzka, J. 1983. Results of bird-ringing in Poland: migrations of dunlin *Calidris alpina*. Acta Ornithologica Warsaw 19:113-136.

Gratto-Trevor, C. L. and H. L. Dickson. 1994. Confirmation of elliptical migration in a population of semipalmated sandpipers. Wilson Bulletin 106:78-90.

_____, V. H. Johnson, and S. T. Pepper. 1998. Changes in shorebird and eider abundance in the Rasmussen Lowlands, NWT. Wilson Bulletin 110:316-325.

Grue, C. E., L. R. DeWeese, P. Mineau, G. A. Swanson, J. R. Foster, P. M. Amold, J. N. Huckins, P. J. Sheehan, W. K. Marshall, and A. P. Ludden. 1986. Potential impacts of agricultural chemicals on waterfowl and other wildlife inhabiting prairie wetlands: an evaluation of research needs and approaches. Transactions of North American Wildlife and Natural Resources Conference 51: 357-383.

_____, M. W. Tome, T. A. Messmer, D. B. Henry, G. A. Swanson, L. R. DeWeese. 1989. Agricultural chemicals and prairie pothole wetlands: meeting the needs of the resource and the farmer-U.S. perspective. Transactions of North American Wildlife and Natural Resources Conference 54:43-57.

Guldemond, J. A., F. Parmentier, and F. Visbeen. 1993. Meadow birds, field management and nest protection in a Dutch peat soil area. Wader Study Group Bulletin 70:42-48.

Haig, S. M., C. L. Gratto-Trevor, T. D. Mullins, and M. A. Colwell. 1997. Population identification of western hemisphere shorebirds throughout the annual cycle. Molecular Ecology 6:413-427.

Hainline, J. L. 1974. The distribution, migration, and breeding of shorebirds in western Nevada. Thesis, University of Nevada, Reno, Nevada, USA.

Hallock, R. J. and L. L. Hallock. 1993. Detailed study of irrigation drainage in and near wildlife management areas, west-central Nevada, 1987-90. Part B. Effect on biota in Stillwater and Fernley Wildlife Management Areas and other nearby wetlands. U.S. Geologic Survey, Water Resources Investigations, Report Number 92-4024B.

Hammer, D. A. 1997. Creating freshwater wetlands. Second edition. CRC Press/Lewis Publishing Company, Boca Raton, Florida, USA.

Hands, H. M., M. R. Bran, and J. W. Smith. 1991. Migrant shorebird use of marsh, moist soil, and flooded agricultural habitats. Wildlife Society Bulletin 19:457-464.

Harrington, B. and E. Perry. 1995. Important shorebird staging sites meeting Western Hemisphere Shorebird Reserve Network criteria in the United States. Western Hemisphere Shorebird Reserve Network.

Helmers, D. L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts, USA.

Herman, S. G., and J. B. Bulger. 1981. The distribution and abundance of shorebirds during the 1981 spring migration at Grays Harbor, Washington. U.S. Army Corps of Engineers, Contract report DACW67-81-M-0936. Seattle, Washington, USA.

Hicklin, P. W. and P. C. Smith. 1984. Selection of foraging sites and invertebrate prey by migrant semipalmated sandpipers, *Calidris pusilla* (Pallas), in Minas Basin, Bay of Fundy. Canadian Journal of Zoology 62:2201-2210.

Hill, D., D. Hockin, D. Price, G. Tucker, R. Morris, and J. Treweek. 1997. Bird disturbance: improving the quality and utility of disturbance research. Journal of Applied Ecology 34:275-288.

Hill, M. I., and P. F. Randerson. 1986. Saltmarsh vegetation communities of the Wash and their recent development. Pages 111-122 *in* P. Doody and B. Barnett, editors. The Wash and its environment. Nature Conservancy Council, Peterborough, United Kingdom.

Hockey, P. A. R., R. A. Navarro, B. Kalejta, and C. R. Velasquez. 1992. The riddle of the sands: why are shorebird densities so high in southern estuaries? American Naturalist 140:961-979.

Howe, M. A., P. H. Geissler, and B. A. Harrington. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biological Conservation 49:185-199.

Howell, R. 1985. The effect of bait-digging on the bioavailability of heavy metals from surficial intertidal marine sediments. Marine Pollution Bulletin 16:292-295.

Janss, G. F. E., and M. Ferrer. 1998. Rate of bird collision with power lines: effects of conductor-marking and static wire-marking. Journal of Field Ornithology 69:8-17.

Jehl, J. R., Jr. 1986. Biology of red-necked phalaropes (*Phalaropus lobatus*) at the western edge of the Great Basin in fall migration. Great Basin Naturalist 46:185-197.

Jewett, S. G., W. P. Taylor, W. T. Shaw, and J. W. Aldridge. 1953. Birds of Washington state. University of Washington Press, Seattle, Washington, USA.

Kadlec, J. A., and L. M. Smith. 1989. The Great Basin marshes. Pages 451-474 in L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.

Kaiser, G. W., K. Fry, and J. G. Ireland. 1980. Ingestion of lead shot by dunlin. Murrelet 61:31.

Kelly, J. P., J. G. Evens, R. W. Stallcup, and D. Wimpfheimer. 1996. Effects of aquaculture on habitat use by wintering shorebirds in Tomales Bay, California. California Fish and Game 82:160-174.

Kilbride, K. M., F. L. Paveglio, and C. E. Grue. 1995. Control of smooth cordgrass with Rodeo in a southwestern Washington estuary. Wildlife Society Bulletin 23:520-524.

Kirby, J. S., C. Clee, and V. Seager. 1993. Impact and extent of recreational disturbance to wader roosts on the Dee estuary: some preliminary results. Wader Study Group Bulletin 68 (special issue):53-58.

Kitchin, E. A. 1949. Birds of the Olympic Peninsula. Olympic Stationers, Port Angeles, Washington, USA.

Klein, M. L., S. R. Humphrey, and H. F. Percival. 1995. Effects of ecotourism on distribution of waterbirds in a wildlife refuge. Conservation Biology 9:1454-1465.

Kohler, B., and G. Rauer. 1991. Grazing to improve wader habitat on alkaline meadows in eastern Austria. Wader Study Group Bulletin 61 (Supplemental):82-85.

Koolhaas, A., A. Dekinga, and T. Piersma. 1993. Disturbance of foraging knots by aircraft in the Dutch Wadden Sea in August-October 1992. Wader Study Group Bulletin 68 (special issue):20-22.

Kopenski, R. P. and E. R. Long. 1981. An environmental assessment of North Puget Sound and the Strait of Juan de Fuca: a summary. National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Seattle, Washington, USA.

Koss, L. J. 1997. Dealing with ship-generated plastic waste on U.S. Navy surface ships. Pages 263-270 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Kus, B. E., P. Ashman, G. W. Page, and L. E. Stenzel. 1984. Age-related mortality in a wintering population of dunlin. Auk 101:69-73.

Lambeck, R. H. D., A. J. J. Sandee, and L. de Wolf. 1989. Long-term patterns in the wader usage of an intertidal flat in the Oosterschelde (SW Netherlands) and the impact of the closure of an adjacent estuary. Journal of Applied Ecology 26:419-431.

Landin, M. C. 1991. Growth habits and other considerations of smooth cordgrass, *Spartina alterniflora* Loisel. Pages 15-20 *in* T. F. Mumford Jr., P. Peyton, J. R. Sayce, and S. Harbell, editors. Spartina workshop record. Washington Sea Grant Program, University of Washington, Seattle, Washington, USA.

Larsen, E. M., and S. A. Richardson. 1990. Some effects of a major oil spill on wintering shorebirds at Grays Harbor, Washington. Northwestern Naturalist 71:88-92.

Laska, S. 1997. A comprehensive waste management model for marine debris. Pages 203-211 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Laubhan, M. K., and L. H. Fredrickson. 1993. Integrated wetland management: concepts and opportunities. Transactions of North American Wildlife and Natural Resources Conference 58:323-334.

Lavers, C., and R. Haines-Young. 1997. The use of satellite imagery to estimate dunlin *Calidris alpina* abundance in Caithness and Sutherland and in the Shetland Islands. Bird Study 44:220-226.

Lee, J. M. 1978. Effects of transmission lines on bird flights: studies of Bonneville Power Administration lines. Pages 93-116 *in* M. L. Avery, editor. Impacts of transmission lines on birds in flight: proceedings of a workshop. U.S. Fish and Wildlife Service, FWS/OBS 78-48. Washington, D.C.

Leighton, F. A. 1990. The toxicity of petroleum oil to birds: an overview. Pages 43-57 *in* J. White, L. Frank, T. Williams, and R. Davis, editors. The effects of oil on wildlife. The Sheridan Press, Hanover, Pennsylvania, USA.

Lester, R. T., and J. P. Myers. 1989-90. Global warming, climate disruption, and biological diversity. Pages 177-221 *in* W. J. Chandler, editor. Audubon Wildlife Report, Academic Press, San Diego, California, USA.

Liffmann, M. and L. Boogaerts. 1997. Linkages between land-based sources of pollution and marine debris. Pages 359-366 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Liffmann, M., B. Howard, K. O'Hara, and J. M. Coe. 1997. Strategies to reduce, control, and minimize land-source marine debris. Pages 381-390 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Maccarone, A. D. and J. N. Brzorad. 1995. Effects of an oil spill on the prey populations and foraging behavior of breeding wading birds. Wetlands 15:397-407.

Madsen, J. and A. D. Fox. 1995. Impacts of hunting disturbance on waterbirds - a review. Wildlife Biology 1:193-207.

Martin, A. P. And R. M. Randall. 1987. Number of waterbirds at a commercial saltpan, and suggestions for management. South African Journal of Wildlife Research 17:73-81.

Martin-Löf, P. 1961. Mortality rate calculations on ringed birds with special reference to the dunlin (*Calidris alpina*). Arkiv För Zoologi 13:483-491.

Meltofte, H., J. Blew, J. Frikke, H. U. Rösner, and C. Smit. 1994. Numbers and distribution of waterbirds in the Wadden Sea. IWRB special publication 34, IWRB, Slimbridge, United Kingdom.

Metcalfe, N. B. 1984. The effects of habitat on the vigilance of shorebirds: is visibility important? Animal Behaviour 32:981-985.

Millard, A. V., and P. R. Evans. 1984. Colonization of mudflats by *Spartina anglica*: some effects on invertebrate and shorebird populations at Lindisfame. Pages 41-48 *in* P. Doody, editor. Spartina anglica in Great Britain. Nature Conservancy Council, Peterborough, United Kingdom.

Mono Basin Ecosystem Study Committee. 1987. The Mono Basin ecosystem: effects of changing lake level. National Academic Press, Washington, D.C., USA.
Morrison, R. I. G. 1984. Migration systems of some New World shorebirds. Pages 125-202 *in* J. Burger and B. L. Olla, editors. Behavior of marine mammals, Volume 5. Shorebirds: breeding behavior and populations. Plenum Press, New York, New York, USA.
_____. 1991. Research requirements for shorebird conservation. Transactions of the North American Wildlife and Natural Resources Conference 56:473-480.
_____, A. Bourget, R. Butler, H. L. Dickson, C. Gratto-Trevor, P. Hicklin, C. Hyslop, and R. K. Ross. 1994b. A preliminary assessment of the status of shorebird populations in Canada. Canadian Wildlife Service Program Notes, Number 208.
_____, and N. C. Davidson. 1989. Migration, body condition and behaviour of shorebirds at Alert, Ellesmere Island, NWT. Syllogeus (National Museum Natural History), Ottawa, Ontario, Canada.
_____, C. Downes, and B. Collins. 1994a. Population trends of shorebirds on fall migration in eastern Canada. Wilson Bulletin 106:431-447.
Moser, M. E. 1987. A revision of population estimates for waders (Charadrii) wintering on the coastline of Britain. Biological Conservation 39:153-164.
_____. 1988. Limits to the numbers of grey plovers *Pluvialis squatarola* wintering on British estuaries: an analysis of long-term population trends. Journal of Applied Ecology 25:473-485.
Mumford, T. F., Jr., P. Peyton, J. R. Sayce, and S. Harbell, editors. 1991. *Spartina* workshop record. Washington Sea Grant Program, University of Washington, Seattle, Washington, USA.
Musters, C. J. M., M. A. W. Noordervliet, and W. J. ter Keurs. 1995. Bird casualties and wind turbines near the Kreekrak sluices of Zeeland. Milieu-biologie R.U. Leiden, Leiden, Netherlands.
_____, _____, _____. 1996. Bird casualties caused by a wind energy project in an estuary. Bird Study 43: 124-126.
Myers, J. P. 1983. Conservation of migrating shorebirds: staging areas, geographic bottlenecks, and regional movements. American Birds 37:23-25.
_____. 1988-89. The Sanderling. Pages 651-666 *in* W. J. Chandler, editor. Audubon wildlife report 1988/1989. Academic Press, San Diego, California, USA.
_____, C. T. Schick, and G. Castro. 1986. Structure in sanderling (*Calidris alba*) populations: the magnitude of intra- and interyear dispersal during the non-breeding season. Proceedings of the International Ornithological Congress 19:604-614.
_____, P. D. McLain, R. I. G. Morrison, P. Z. Antas, P. Canevari, B. A. Harrington, T. E. Lovejoy, V. Pulido, M. Sallaberry, and S. E. Senner. 1987a. The Western Hemisphere Shorebird Reserve Network. Wader Study Group Bulletin 49 (Supplemental): 122-124.
_____, R. I. G. Morrison, P. Z. Antas, B. A. Harrington, T. E. Lovejoy, M. Sallaberry, S. E. Senner, and A. Tarak. 1987b. Conservation strategy for migratory species. American Scientist 75:19-26.
Neel, L. A. and W. G. Henry. 1996. Shorebirds of the Lahontan Valley, Nevada, USA: a case history of western Great Basin Shorebirds. International Wader Studies 9:15-19.
Nehls, G., and R. Tiedemann. 1993. What determines the densities of feeding birds on tidal flats? A case study on dunlin, *Calidris alpina*, in the Wadden Sea. Netherlands Journal of Sea Research 31:375-384.
Nichols, F. H., J. K. Thompson, and L. E. Schemel. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamo-corbula amurensis*. II. Displacement of a former community. Marine Ecology Progress Series 66:95-101.
Nilsson, L. 1997. Restoring inland shore-meadows for breeding birds. Wader Study Group Bulletin 84:39-44.
Ninaber, E. 1997. MARPOL Annex V, commercial ships, and port reception facilities: making it work. Pages 239-243 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.
Nysewander, D. R. 1977. Reproductive success of the black oystercatcher in Washington state. Thesis, University of Washington, Seattle, Washington, USA.
Odum, E. P. 1987. Reduced-input agriculture reduces nonpoint pollution. Journal of Soil and Water Conservation 42:412-413.
Ohlendorf, H. M., D. J. Hoffman, M. K. Saiki, and T. W. Aldrich. 1986. Embryonic mortality and abnormalities of aquatic birds: apparent impacts of selenium from irrigation drainwater. Science of the Total Environment 52:49-63.

Oring, L. W., E. M. Gray, and J. M. Reed. 1997. Spotted sandpiper (*Actitus macularia*). Pages 1-32 *in* A. Poole, and F. Gill, editors. The birds of North America, Number 289. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., USA.

Page, G., B. Pearls, and R. M. Jurek. 1972. Age and sex composition of western sandpipers on Bolinas Lagoon. Western Birds 3:79-86.

Page, G. W., L. E. Stenzel, and C. M. Wolfe. 1979. Aspects of the occurrence of shorebirds on a central California estuary. Studies in Avian Biology 2: 15-32.

_____, and R. E. Gill, Jr. 1994. Shorebirds in western North America: late 1800s to late 1900s. Studies in Avian Biology 15:147-160.

_____, and D. F. Whitacre. 1975. Raptor predation on wintering shorebirds. Condor 77:73-83.

Parsons, K. C. 1996. Recovering from oil spills: the role of proactive science in mitigating adverse effects. Colonial Waterbirds 19:149-153.

Paton, P. W. C., and V. C. Bachman. 1996. Impoundment drawdown and artificial nest structures as management strategies for snowy plovers. International Wader Studies 9:64-70.

Paulson, D. R. 1992. Northwest bird diversity: from extravagant past and changing present to precarious future. Northwest Environmental Journal 8:71-118.

_____. 1993. Shorebirds of the Pacific Northwest. University of Washington Press, Seattle, Washington, USA.

Payne, N. J., B. V. Helson, K-M. S. Sundaram, and R. A. Fleming. 1988. Estimating buffer zone widths for pesticide applications. Pesticide Science 24:147-161.

Perkins, G. A. and J. S. Lawrence. 1985. Bird use of wetlands created by surface mining. Transactions of the Illinois State Academy of Science 78:87-96.

Pfister, C., B. A. Harrington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biological Conservation 60:115-126.

Phipps, J. B. 1990. Coastal accretion and erosion in southwest Washington: 1977-1987. Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, Washington, USA.

Pienkowski, M. W. 1981. How foraging plovers cope with environmental effects on invertebrate behavior and availability. Pages 179-192 *in* N. V. Jones and W. J. Wolff, editors. Feeding and survival strategies of estuarine organisms. Plenum Press, New York, New York, USA.

Powers, L. C. and H. A. Glimp. 1996. Impacts of livestock on shorebirds: a review and application to shorebirds of the western Great Basin. International Wader Studies 9:55-63.

Prater, A. J. 1981. Estuary birds of Britain and Ireland. Poyser, Calton, United Kingdom.

Quammen, M. L. 1982. Influence of subtle substrate differences on feeding by shorebirds on intertidal mudflats. Marine Biology 71:339-343.

Ratti, J. T., and J. A. Kadlec. 1992. Concept plan for the preservation of wetland habitat of the Intermountain West. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

Raevel, P., and J. C. Tombal. 1991. Impact des lignes hautetension sur l'avi faune. Vol. 2. Les Cahiers de L'A.M.B.E. et Environnement.

Redmond, R. L. and D. A. Jenni. 1986. Population ecology of the long-billed curlew (*Numenius americanus*) in western Idaho. Auk 103:755-767.

Rehfisch, M. M. 1994. Man-made lagoons and how their attractiveness to waders might be increased by manipulating the biomass of an insect benthos. Journal of Applied Ecology 31:383-401.

_____, N. A. Clark, R. H. W. Langston, and J. J. D. Greenwood. 1996. A guide to the provision of refuges for waders: an analysis of 30 years of ringing data from the Wash, England. Journal of Applied Ecology 33:673-687.

Reid, F. A., W. D. Rundle, M. W. Sayre, and P. R. Covington. 1983. Shorebird migration chronology at two Mississippi River Valley wetlands of Missouri. Transactions of the Missouri Academy of Science 17:103-115.

Reise, K. 1985. Tidal flat ecology. Springer-Verlag, Berlin, Germany.

Redford, D. P., H. K. Trulli, and W. R. Trulli. 1997. Sources of plastic pellets in the aquatic environment. Pages 335-343 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Ribic, C. A., S. W. Johnson, and C. A. Cole. 1997. Distribution, type, accumulation, and source of marine debris in the United States, 1989-1993. Pages 35-47 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Robards, M. D., P. J. Gould, and J. F. Piatt. 1997. The highest global concentrations and increased abundance of oceanic plastic debris in the North Pacific: evidence from seabirds. Pages 71-80 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Robel, R. J. 1961. The effects of carp populations on the production of waterfowl food plants on a western waterfowl marsh. Transactions of the North American Wildlife and Natural Resources Conference 26:147-159.
Roberts, G., and P.R. Evans. 1993. Responses of foraging sanderlings to human approaches. Behaviour 126:29-43.
Robinson, J. A., and S. E. Warnock. 1996. The staging paradigm and wetland conservation in arid environments: shorebirds and wetlands of the North American Great Basin. International Wader Studies 9:37-44.
Roemmich, D., and J. A. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267:1324-1326.
Rohwer, S., D. F. Martin, and G. G. Benson. 1979. Breeding of the black-necked stilt in Washington. Murrelet 60:67-71.
Rönkä, A., and K. Koivula. 1997. Effect of shore width on the predation rate of artificial wader nests. Ibis 139:405-407.
Rottenborn, S. C. 1996. The use of coastal agricultural fields in Virginia as foraging habitat by shorebirds. Wilson Bulletin 108:783-796.
Rubega, M. A. and J. A. Robinson. 1996. Water salinization and shorebirds: emerging issues. International Wader Studies 9:45-54.
Ruggiero, L. F., K. B. Aubry, R. S. Holthausen, J. W. Thomas, B. G. Marcot, and E. C. Meslow. 1988. Ecological dependency: the concept and its implications for research and management. Transactions of the North American Wildlife and Natural Resources Conference 53:115-126.
Rundle, W. D. and L. H. Fredrickson. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildlife Society Bulletin 9:80-87.
Ryan, P. G. 1988. Effects of ingested plastic on seabird feeding: evidence from chickens. Marine Pollution Bulletin 19:125-128.
Saiki, M. K. and T. P. Lowe. 1987. Selenium in aquatic organisms from subsurface agricultural drainage water, San Joaquin Valley, California. Archives of Environmental Contamination and Toxicology 16: 657-670.
Sampath, K., and K. Krishnamurthy. 1988. Shorebirds of the salt ponds at the Great Vedaranyam salt swamp-Tamil Nedu, India. Stilt 15:20-23.
Sauer, J. R., J. E. Lines, G. Gogh, I. Thomas, and B.G. Peterjohn. 1997. The North American Breeding Bird Survey: results and analysis. Version 96.3. Patuxent Wildlife Research Center, Laurel, MD. [data from <www.patuxent> web site]
Sayce, K. 1988. Introduced cordgrass, *Spartina alterniflora* Loisel, in salt marshes and tidelands of Willapa Bay, Washington. U.S. Fish and Wildlife Service.
Schick, C. T., L. A. Brennan, J. B. Buchanan, M. A. Finger, T. M. Johnson, and S. G. Herman. 1987. Organochlorine contamination in shorebirds from Washington state and the significance for their falcon predators. Environmental Monitoring and Assessment 8:1-17.
Schmidt-Nielsen, K. 1960. The salt-secreting gland of marine birds. Circulation 21:955-967.
Schneider, D. C. and B. A. Harrington. 1981. Timing of shorebird migration in relation to prey depletion. Auk 98:801-811.
Scott, R. E., L. J. Roberts, and C. J. Cadbury. 1972. Bird deaths from powerlines at Dungeness. British Birds 65:273-286.
Seelye, J. G., R. J. Hesselberg, and M. J. Mac. 1982. Accumulation by fish of contaminants released from dredged sediments. Environmental Science and Technology 16:459-464.
Senner, S. and M. A. Howe. 1984. Conservation of nearctic shorebirds. Pages 379-421 *in* J. Burger and B. L. Olla, editors. Behavior of marine mammals, Volume 5. Shorebirds: breeding behavior and populations. Plenum Press, New York, New York, USA.
Sileo, L., L. Karstad, R. Frank, M. V. H. Holdrinet, E. Addison, and H. E. Braun. 1977. Organochlorine poisoning of ring-billed gulls in southern Ontario. Journal of Wildlife Diseases 13:313-322.
Simenstad, C. A., J. R. Cordell, and L. A. Weitkamp. 1991. Effects of substrate modification on littoral flat meiofauna: assemblage structure changes associated with adding gravel. Contract report FRI-UW-9111 to Washington Department of Fisheries, Brinnon, Washington, USA.
Skagen, S. K. 1997. Stopover ecology of transitory populations: the case of migrant shorebirds. Ecological Studies 125:244-269.
_____. and F. L. Knopf. 1994. Migrating shorebirds and habitat dynamics at a prairie wetland complex. Wilson Bulletin 106:91-105.
Smit, C. J., R. H. D. Lambeck, and W. J. Wolff. 1987. Threats to coastal wintering and staging areas of waders. Wader Study Group Bulletin 49 (Supplemental):105-113.

_____, and G. J. M. Visser. 1993. Effects of disturbance on shorebirds: a summary of existing knowledge from the Dutch Wadden Sea and Delta area. Wader Study Group Bulletin 68 (special issue):6-19.

Smith, K. G., J. C. Neal, and M. A. Mlodinow. 1991. Shorebird migration at artificial fish ponds in the prairie-forest ecotone of northwestern Arkansas. Southwestern Naturalist 36:107-113.

Smith, P. C. and J. S. Bleakney. 1969. Observations on oil pollution and wintering purple sandpipers, *Erolia maritima* (Brunnich), in Nova Scotia. Canadian Field-Naturalist 83:19-22.

Soikkeli, M. 1967. Breeding cycle and population dynamics in the dunlin (*Calidris alpina*). Annales Zoologici Fennici 4:158-198.

Strauch, J. G., Jr. 1966. Spring migration of dunlin in interior western Oregon. Condor 68:210-212.

Stone, K. L. 1994. Shorebird habitat use and responses to burned marshes during spring migration in south-central Kansas. Thesis, Oklahoma State University, Stillwater, Oklahoma, USA.

Streeter, R. G., M. W. Tome, and D. K. Weaver. 1993. North American waterfowl management plan: shorebird benefits? Transactions of the North American Wildlife and Natural Resources Conference 58:363-369.

Sutherland, W. J. and J. D. Goss-Custard. 1991. Predicting the consequence of habitat loss on shorebird populations. Proceedings of the International Ornithological Congress 20:2199-2207.

Sutinen, J. G. 1997. A socioeconomic theory for controlling marine debris: is moral suasion a reliable policy tool? Pages 161-170 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Symonds, F. L., D. R. Langslow, and M. W. Pienkowski. 1984. Movements of wintering shorebirds within the Firth of Forth: species differences in usage of an intertidal complex. Biological Conservation 28:187-215.

Taylor, D. M., C. H. Trost, and B. Jamison. 1993. Migrant shorebird habitat use and the influence of water level at American Falls Reservoir, Idaho. Northwestern Naturalist 74:33-40.

Townshend, D. J. 1981. The importance of field feeding to the survival of wintering male and female curlews *Numenius arquata* on the Tees estuary. Pages 261-273 in N. V. Jones and W. J. Wolff, editors. Feeding and survival strategies of estuarine organisms. Plenum Press, New York, New York, USA.

_____. 1984. The effects of predators upon shorebird populations in the nonbreeding season. Wader Study Group Bulletin 40:51-54.

_____. 1985. Decisions for a lifetime: establishment of spatial defense and movement patterns by juvenile grey plovers (*Pluvialis squatarola*). Journal of Animal Ecology 54:267-274.

van der Have, T. and E. Nieboer. 1984. Age-related distribution of dunlin in the Dutch Wadden Sea. Pages 160-176 *in* Evans, P. R., J. D. Goss-Custard, and W. G. Hale, editors. Coastal waders and wildfowl in winter. Cambridge University Press, Cambridge, Massachusetts, USA.

van Impe, J. 1985. Estuarine pollution as a probable cause of increase of estuarine birds. Marine Pollution Bulletin 16:271-276.

Veit, R. R., P. Pyle, and J. A. McGowan. 1996. Ocean warming and long-term change in pelagic bird abundance within the California current system. Marine Ecology Progress Series 139:11-18.

Velasquez, C. R. and P. A. R. Hockey. 1992. The importance of supratidal foraging habitats for waders at a south temperate estuary. Ardea 80:243-253.

Vermeer, K., R. W. Butler, and K. H. Morgan. 1994. Comparison of seasonal shorebird and waterfowl densities within Fraser River delta intertidal regions. Pages 6-17 *in* R. W. Butler and K. Vermeer, editors. The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia. Canadian Wildlife Service Occasional Paper, Number 83.

_____, K. H. Morgan, and G. E. J. Smith. 1989. Population and nesting habitat of American black oystercatcher in the Strait of Georgia. Pages 118-122 *in* K. Vermeer and R. W. Butler, editors. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia. Special Publication, Canadian Wildlife Service.

_____, and R. Verneer. 1975. Oil threat to birds on the Canadian west coast. Canadian Field-Naturalist 89: 278-298.

Wahl, T. R. 1995. Birds of Whatcom County: status and distribution. Independently published. Bellingham, Washington, USA.

Wallace, B. 1997. A strategy to reduce, control, and minimize vessel-source marine debris. Pages 277-286 *in* Coe, J. M. and D. B. Rogers, editors. Marine debris: sources, impacts, and solutions. Springer-Verlag, New York.

Wanink, J. H. and L. Zwarts. 1993. Environmental effects on the growth rate of intertidal invertebrates and some implications for foraging waders. Netherlands Journal of Sea Research 31:407-418.

Warnock, N. 1996. Local and regional differences in habitat utilization by dunlins *Calidris alpina* as revealed by radio-telemetry: conservation implications. International Wader Studies 8:35-38.

_____, G. W. Page, and B. K. Sandercock. 1997. Local survival of dunlin wintering in California. Condor 99:906-915.
_____, _____, _____, and L. E. Stenzel. 1995. Non-migratory movements of dunlins on their California wintering grounds. Wilson Bulletin 107:131-139.
_____, and S. E. Schwarzbach. 1995. Incidental kill of dunlin and killdeer by strychnine. Journal of Wildlife Diseases 31:566-569.
Warnock, S. E., and J. Y. Takekawa. 1995. Habitat preferences of wintering shorebirds in a temporally changing environment: western sandpipers in the San Francisco Bay estuary. Auk 112:920-930.
Washington Department of Agriculture, Washington Department of Ecology, Washington Department of Natural Resources, Washington Department of Fisheries, Washington Department of Wildlife, and Noxious Weed Control Board. 1993. Noxious emergent plant management. Final environmental impact statement, Olympia, Washington, USA.
Washington Department of Fish and Wildlife. 1995a. Washington state recovery plan for the snowy plover. Washington Department of Fish and Wildlife, Olympia, Washington, USA.
_____. 1995b. Washington state recovery plan for the upland sandpiper. Washington Department of Fish and Wildlife, Olympia Washington, USA.
_____. 1995c. Integrated weed management plan for *Spartina* control on Washington Department of Fish and Wildlife lands in Willapa Bay. Washington Department of Fish and Wildlife, Olympia Washington, USA.
Weber, L. M. and S. M. Haig. 1996. Shorebird use of South Carolina managed and natural coastal wetlands. Journal of Wildlife Management 60:73-82.
Weston, M. A. 1997. Disturbance of common sandpipers *Actitus hypoleucos* by motorboats. Stilt 30:50-51.
White, D. H., K. A. King, and R. M. Prado. 1980. Significance of organochlorine and heavy metal residues in wintering shorebirds at Corpus Christi, Texas, 1976-77. Pesticides Monitoring Journal 14: 58-63.
White, D. H., C. A. Mitchell, and T. E. Kaiser. 1983. Temporal accumulation of organochlorine pesticides in shorebirds wintering on the south Texas coast. Archives of Environmental Contamination and Toxicology 12:241-245.
Whitfield, D. P., A. D. Evans, and P. A. Whitfield. 1988. The impact of raptor predation on wintering waders. Proceedings of International Ornithological Congress 19:674-687.
Wilcox, C. G. 1986. Shorebird and waterfowl use on restored and natural intertidal wetlands at Upper Newport Bay, California. Colonial Waterbirds 9: 218-226.
Williams, M. L., R. L. Hothem, and H. M. Ohlendorf. 1989. Recruitment failure in American avocets and black-necked stilts nesting at Kesterson Reservoir, California, 1984-1985. Condor 91:797-802.
Wolheim, W. M., and J. R. Lovvorn. 1995. Salinity effects on macroinvertebrate assemblages and waterbird food webs in shallow lakes of the Wyoming High Plains. Hydrobiologia 310:207-223.
Yates, M. G., A. R. Jones, J. D. Goss-Custard, and S. McGrorty. 1993a. Satellite imagery to monitor ecological change in estuarine systems: example of the Wash, England. Pages 56-60 *in* M. Moser, R. C. Prentice, and J. van Vessem, editors. Waterfowl and wetland conservation in the 1990s: a global perspective. International Waterfowl and Wetlands Research Bureau, Special Publication Number 26. United Kingdom.
_____, _____, S. McGrorty, and J. D. Goss-Custard. 1993b. The use of satellite imagery to determine the distribution of intertidal surface sediments of the Wash, England. Estuarine, Coastal and Shelf Science 36:333-344.
Zinkl, J. G., D. A. Jessup, A. I. Bischoff, T. E. Lew, and E. B. Wheeldon. 1981. Fenthion poisoning of wading birds. Journal of Wildlife Diseases 17:117-119.
Zwarts, L. and J. H. Wanink. 1993. How the food supply harvestable by waders in the Wadden Sea depends on the variation in energy density, body weight, biomass, burying depth and behavior of tidal-flat invertebrates. Netherlands Journal of Sea Research 31:441-476.

PERSONAL COMMUNICATIONS AND UNPUBLISHED DATA

Joseph B. Buchanan, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

Robert W. Butler, Biologist
Canadian Wildlife Service
Delta, British Columbia, Canada

Michael Cenci, Enforcement Official
Washington Department of Fish and Wildlife
Olympia, Washington

Chris Chappell, Biologist
Washington Department of Natural Resources
Olympia, Washington

Ian Davidson, Director
Western Hemisphere Shorebird Reserve Network
Ottawa, Ontario, Canada

Lora Leshner, Biologist
Washington Department of Fish and Wildlife
Mill Creek, Washington

Gary Page, Research Biologist
Point Reyes Bird Observatory
Stinson Beach, California

Dennis R. Paulson, Professor
University of Puget Sound
Tacoma, Washington

Scott A. Richardson, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

R. Schuver, Volunteer
Willapa National Wildlife Refuge
Longbeach, Washington

William Tweit, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

Louise Vicencio, Biologist
U.S. Fish and Wildlife Service
Olympia, Washington

Terry Wahl, Biologist
Bellingham, Washington

Ralph Woods, Enforcement Official
Washington Department of Fish and Wildlife
Bellingham, Washington

KEY POINTS

Habitat Requirements

Coastal Environments

- The primary habitat requirements of migrant or winter resident shorebirds relate to the availability of adequate foraging and roosting areas.
- Most species in western Washington are associated with silt or silt/sand intertidal areas and adjacent beaches or salt marshes. Pastures and agricultural land are also used by roosting and foraging shorebirds in western Washington.
- Shorebirds are adapted to forage in a narrow range of microhabitat conditions, from exposed tide flats or beaches to shallow water, salt marshes, and even open water.
- The foraging requirements of many shorebirds are met primarily in estuarine ecosystems, where tidal mud flats provide foraging substrates. Black-bellied plover, dunlin, western sandpiper, and dowitchers forage on mud flats with high levels of silt, whereas semipalmated plovers and sanderlings forage in sandy or silt/sand areas. Other species, such as rock sandpiper, surfbird, and wandering tattler are found almost exclusively along rocky intertidal shores.
- Shorebirds often roost in salt marshes adjacent to intertidal feeding areas, but will use a variety of habitats. Shorebirds at Grays Harbor and Willapa Bay often roost in large flocks on Pacific beaches, occasionally concentrating near the mouths of small creeks. In some areas, shorebirds roost on naturally-occurring and dredge-spoil islands and on higher elevation sand beaches. Some species may also roost in fields near intertidal foraging areas; foraging occurs at these or other roost sites if suitable prey are present. Shorebirds occasionally roost on log rafts, floating docks, and other floating structures when natural roost sites are limited.

- Use of artificial wetlands by shorebirds has not been documented in Washington. However, many species of shorebirds, including at least 12 species that occur in western Washington, use artificial or managed coastal wetlands in other parts of the United States and the world. Artificial wetlands could potentially provide important shorebird habitat in Washington.
- Shorebirds are generally site-faithful to specific wintering areas. This fidelity to particular sites has important ramifications for conservation management and mitigation.

Freshwater Environments

- Many species in eastern Washington use wet meadows, flooded fields and other areas of shallow water.
- Most shorebirds that forage in freshwater areas require ponds and pools that have exposed shorelines or that are shallow enough to allow foraging by wading birds. As with estuarine sites, the availability of appropriate invertebrate prey and roost sites are important habitat requirements.
- Habitats used by shorebirds in nonestuarine regions include marshes, pastures, flooded fields, reservoirs, impoundment drawdowns, stormwater wetlands, and other artificial wetlands.

Management Recommendations

Habitat Protection

- Identify and preserve wetland habitats important to shorebirds. Assemblages of smaller sites, as well as major estuaries provide critical habitat to shorebirds in Washington.
- Where livestock grazing occurs in pastures used by shorebirds, assess for potential trampling or disturbance of nesting birds.
- Assess commercial sand and gravel extraction from beach and riverine areas for potential impacts to shorebirds. The development of a review process for these activities would help ensure that shorebirds are considered as part of the permitting process.
- Avoid placement of new utility towers and lines in flight corridors or near wetland areas used by shorebirds. New lines should be placed below ground if possible.
- Where possible, treat existing utility lines to make them more detectable by birds in areas where collisions with shorebirds have occurred or are likely to occur. Techniques include coating or painting wires, marking of wires with mobile spirals or strips of fiberglass or plastic, placement of predator silhouettes, warning lights, and acoustical devices to scare birds. Static wire-marking may effectively reduce the number of collisions with power lines. Grouping multiple lines may make them more visible to birds and will occupy a smaller area of flight space. In addition, it is suggested that the lines be arranged side by side rather than in a vertical stacked formation.
- Address shorebirds and their flight corridors in wind turbine and cellular tower proposals.
- In the event of an oil spill, limit public access to beach or estuarine spill sites. The impacts of an oil spill can be exacerbated by disturbances caused by human recreation (e.g., beach walking).
- Control the entry of plastic litter into the marine environment. Small plastic particles injure surface feeding marine birds that inadvertently ingest them.
- Continue efforts to control the establishment and growth of cordgrass, purple loosestrife, and other noxious weeds. Potential methods to eradicate noxious weeds include biological control, repeated mowing, hand pulling of seedlings, and chemical treatment.
- Use extreme caution when applying chemicals near habitats used by shorebirds. Encourage alternatives to chemical use. Appendix A (of this volume) lists contacts useful in assessing pesticides, herbicides, and their alternatives.
- Use current information to establish buffer zones when applying chemicals. Implement buffer zones around shorebird and waterfowl nesting habitat in agricultural landscapes to minimize the impacts of spray drift.
- Assess whether or not public access and human activities should be controlled at areas important to shorebirds. If needed, potential solutions may include erecting cordons to restrict foot traffic from roosting or foraging sites, and establishing vehicle restriction zones during critical roosting periods.

Restoration/Creation of Habitat

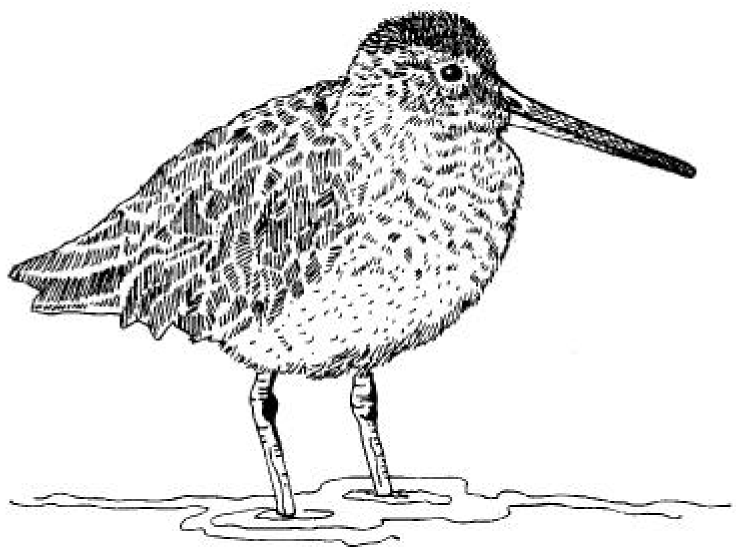
- Develop a site-specific strategy for any restoration project affecting shorebirds. Information on local water, soil, and vegetation conditions and requirements (freshwater environments) or tidal, wind pattern, sea swell, and substrate conditions (marine environments) needs to be incorporated.
- Create new sites at least five years prior to modification of natural habitat. Artificially created sites should provide for all displaced birds and should address this need at least 5 years prior to the modification of natural habitat to allow an assessment of its success. This 5-year period is needed to 1) identify suitable sites; 2) acquire, design, and construct the mitigation features at sites; 3) allow settlement and stabilization of suitable sediments; and 4) allow colonization of sufficient densities of invertebrate prey species.
- When conducting mitigation studies, model population dynamics in a variety of local habitats over wide spatial (e.g. coastal, Puget Sound, and interior) and temporal (e.g., at least 5 years) scales.
- Evaluate shorebird use of artificial impoundments. Artificially-created sites may be very important to shorebirds, particularly in the Columbia Basin. Artificial drawdown sites may provide more nesting opportunities for certain species depending on the type of shoreline or the availability of nesting substrate. In addition, efforts to modify such sites should be evaluated in the same manner as undisturbed sites.
- Create adequate roost sites. A primary consideration in creating a roost site is that it must be designed to address the needs of the species that will use the site. Island roosts should provide shelter from strong winds or sea swell if these are significant environmental conditions in the particular area. Island roosts should also be open, with flat tops and gently sloping sides so that the birds can effectively scan for predators.
- Manage artificial (freshwater) sites for breeding season use as well as fall migration.
- Maximize invertebrate production at artificial (freshwater) sites.
- Maintain agricultural areas and pasturelands near sites used by shorebirds.
- Practical considerations regarding management of artificial sites include:

  - proper design and use of spillways in areas prone to flooding and erosion,
  - control of exotic species such as carp and purple loosestrife,
  - water flow maintenance that minimizes stagnant water and reduces the likelihood of outbreaks of avian cholera and botulism Type C,
  - an assessment of soil conditions to determine whether a site will effectively hold water (e.g., prevention of drainage to the water table, or seepage through dikes).

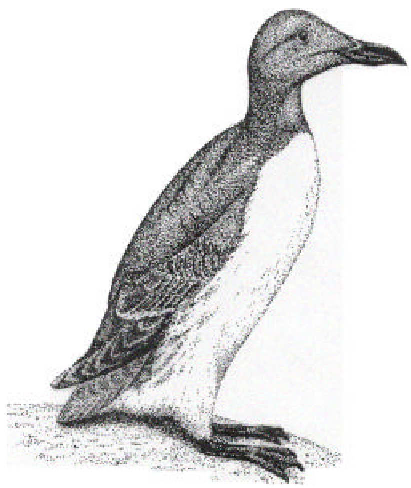
Policy needs and considerations for government agencies and conservation organizations

- Initiate and design conservation planning efforts to address the following:
  - comprehensive, multi-species, landscape-level or ecosystem plans that address many species, habitats, as well as factors such as community dynamics.
  - flyway-level biological and policy coordination among states and provinces to improve regional management and enhance opportunities to protect shorebird populations.
- Identify important local and regional sites.
- Preserve remaining wetland habitat. Locally or regionally important sites should be purchased to reduce the risk of loss or degradation of habitat important for shorebirds and other wildlife. New protective and regulatory legislation needs development, and existing laws concerning wetland use need more effective enforcement.
- Promote public education about chemical use and wetland functions. Implementation of an integrated training and certification program for landowners and commercial pesticide applicators has been recommended as a means to provide pesticide users with important biological information and training.
- Continue the development and refinement of oil trajectory models.
- Develop site-specific strategies to manage human disturbance. Potential strategies include developing informational signs that identify or describe important foraging or roosting areas and organizing groups of volunteers ("beach patrols") to educate the public about shorebird ecology.
- Post informational signs at boat docks, moorage areas, and beach access points to explain the impacts of disturbances caused by boats, personal watercraft, unleashed dogs, and other human activities.

- Address the effects of human disturbance in refuge management plans. Refuges should be designed to provide disturbance-free areas and should take into account the ecology of the species expected to use the area.
- Assess the level of unintentional mortality due to hunting. An evaluation of this source of mortality would provide an indication as to whether a new identification/information guide for shorebirds should be developed for inclusion in a waterfowl hunting pamphlet.
- Implement educational programs to inform the public about the ecology and behavior of shorebirds. Public education programs should emphasize the regional and international scope of shorebird conservation. Such efforts require improved information on the basic ecology of flyway species, identification of significant threats or potential impacts, and development of real conservation measures.
- Undertake comprehensive efforts to control the spread of exotic invertebrates in marine waters.



Common Murre removed from Priority Habitat and Species list in 2018



Common Murre

Uria aalge

Last updated: 2003

Written by Kenneth I. Warheit and Christopher Thompson

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The common murre is a gregarious, colonially nesting, and circumpolar seabird with a boreal, low Arctic, and northern temperate distribution (American Ornithologists' Union 1983, Nettleship and Evans 1985, Gaston and Jones 1998, Ainley et al. 2002). Based mostly on morphological differences, there have been up to eight subspecies or races described for the common murre (Storer 1952, Tuck 1961, Bédard 1985, Gaston and Jones 1998, Ainley et al. 2002), with three to six occurring in the Atlantic Ocean and two in the Pacific Ocean (*Uria aalge inornata*, *U. a. californica*).

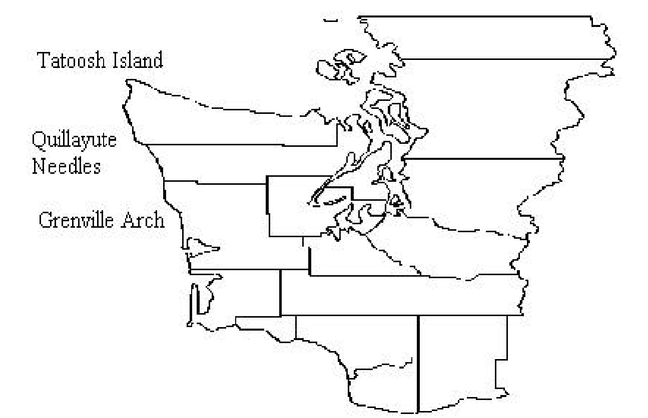


Figure 1. The breeding distribution of common murres, *Uria aalge,* in Washington is restricted to locations between Tatoosh Island and Greenville Arch (Speich and Wahl 1989, Carter et al. 2001).

In the Atlantic Ocean there are roughly 2,000,000 (Nettleship and Evans 1985) to as many as 9,000,000 (Gaston and Jones 1998) adult common murres breeding from the Labrador and Newfoundland coast in Canada, north to southern Greenland, Iceland, northern Norway and Spitsbergen, and south to Great Britain and the coast of Europe to Portugal (Harrison 1983, Gaston and Jones 1998, Ainley et al. 2002). In the Pacific and Arctic Oceans, common murres range from Cape Lisburne, Chukchi Sea, Siberian and Alaskan coasts of the Bering Sea, and south along the eastern and western north Pacific to Hokkaido, Japan, and Hurricane Point, central California, respectively (Sowls et al. 1978, American Ornithologists' Union 1983, Harrison 1983, Gaston and Jones 1998, Ainley et al. 2002). In the northern parts of the Pacific Ocean and throughout the Arctic Ocean, the common murre and the closely related thick-billed murre (*Uria lomvia*) may nest together in mixed colonies, making it difficult to estimate the total population of either species (Gaston and Jones 1998). Based on the work of Carter et al. (2001), U.S. Fish and Wildlife Service [USFWS] (2001), and others (e.g., Takekawa et al. 1990, Lowe and Pitkin 1996), Ainley et al. (2002) recorded nearly 5,000,000 common murres and 4,500,000 unidentified murres from California through Alaska, and Gaston and Jones (1998) added an additional 2,700,000 common murres from the Siberian Bering Sea and Kuril Island in the western Pacific Ocean.

Although common murres move away from breeding colonies after the breeding season, their winter range is essentially the same as their breeding range, but extends further south where murres are regularly found in southern California in the Pacific and Maine in the Atlantic (American Ornithologists' Union 1983). Some populations of common murres may remain resident near breeding colonies throughout the year (e.g., common murres nesting in central California; Boekelheide et al. 1990, Sydeman 1993).

Washington Colony Distribution, Attendance, and Trends

Distribution: The breeding distribution for common murres in Washington State is restricted to the outer coast from Grenville Arch (47° 18′ N, 124° 17′ W) to Tatoosh Island (48° 24′ N, 124° 44′ W) and include at least five groups of colonies or "complexes": Point Grenville, Split-Willoughby, Quillayute Needles, Carroll-Jagged, and Tatoosh (see Figure 1; Speich and Wahl 1989, Carter et al. 2001). All colonies, except that on Tatoosh Island, are part of the USFWS National Wildlife Refuge (NWR) system (North to South: Flattery Rocks, Quillayute Needles, and Copalis NWRs) and have been aerially surveyed each year since 1979 (Wilson 1991, Carter et al. 2001). Tatoosh Island is owned by the Makah Tribe and regular ground and boat surveys of breeding common murres on the island began in 1990 (Parrish 1995), although some data on murre status were collected on the island in the 1980s (Paine et al. 1990).

Attendance[1]: Data on the attendance of common murres in Washington have been recorded continuously by USFWS since 1979, when more than 31,000 birds were recorded from 12 localities (Speich and Wahl 1989, Carter et al. 2001). USFWS surveys did not include Tatoosh Island until 1994 (Carter et al. 2001), although work by University of Washington researchers estimated attendance at Tatoosh Island in 1979 to be less than 500-1000 birds (Paine et al. 1990, Parrish et al. 2001). In 2002 there were between 5,785 and 5,925 common murres in attendance at 15 NWR colonies (Wilson 2003), plus an additional 4,466 murres at Tatoosh Island (Thompson et al. 2003), for a total of over 10,000 birds. The largest colony in the state is Tatoosh Island, followed by Cake Island (Wilson 2003), both of which are in the northern part of Washington's common murre range.

Trends: In order to better understand the population dynamics of murres in Washington through 2002, we added to the analyses of Wilson (1991) and Carter et al. (2001), and included additional data for the refuge islands (Wilson 1996, 1999, 2002, and 2003) and for Tatoosh Island (Paine et al. 1990, Thompson et al. 2003). This new dataset provides nearly continuous data for common murres in Washington from 1979 through 2002, with the following exceptions: (1) refuge colony-specific data for 1999 and 2000 were not available, although total counts were obtained from Figure 1 in Wilson (2003); and (2) continuous attendance data from Tatoosh Island were only available from 1991 through 2002 (Thompson et al. 2003), although Paine et al. (1990) plotted murre attendance for 1978, 1979, 1986, and 1988). In order to fill in the gaps, we used the plotted attendance figures for these years and extrapolated from these figures using linear regression to obtain attendance estimates at Tatoosh Island for 1987 and 1989-1990 (Figures 2, 3). Our analysis is similar to that of Wilson (2003), except we include data for Tatoosh Island, and we do not focus attention on a time period dictated by the *Tenyo Maru* oil spill. When multiple aerial surveys were conducted in a given year, we chose the median values in our analysis. Our results indicate that the common murre population in Washington appears stable over the past decade.

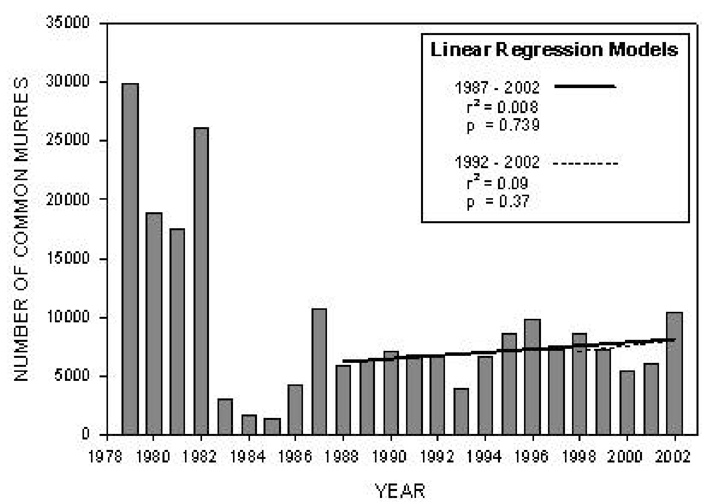


Figure 2 The number of common murres attending all Washington colonies from 1979-2002. Data from Paine et al. (1990), Wilson (1996, 1999, 2002, and 2003), Carter et al. (2001), Thompson et al. (2003).

[1] Attendance is the number of individuals counted during a colony census, and represents breeding and non-breeding birds. At the time of these censuses, the breeding population at the colony was composed of breeding birds (i.e., adults) that were at the colony and were therefore counted. Adult birds (generally the mates of the birds present at the colony) that were at-sea were not counted. The total population was composed of all juvenile, subadult, and adult birds that would or potentially would breed at the colony.

Figure 2 shows the total attendance at murre colonies from 1979 through 2002. The dramatic decline in murre attendance in 1983, as initially documented by Wilson (1991), is clearly evident. Murre numbers stayed low from 1983-1985 and began to increase through 1987. After 1987, murre numbers remained stable through 2002. If murres in Washington are at "carrying capacity[2]" (Wilson 2003:2), this capacity is remarkably lower than that in the late 1970s and early 1980s (see below, and Parrish and Zador 2003 for discussion of common murre carrying capacity in Washington).

Carter et al. (2001) divided the murre colonies into a southern (Gray's Harbor County, including Point Grenville and Split-Willoughby Complexes) and a northern component (Jefferson and Clallam Counties, including the Quillayute Needles, Carroll-Jagged, and Tatoosh Complexes). From 1979 through 1982, common murres attending Washington colonies in the southern areas averaged 92% of the total Washington population (Figure 3). In 1988, the dominance of the southern areas ended and by the mid 1990s the Washington murre population had shifted to the northern colonies (Figure 3). In 2002, 81% of common murres in Washington were nesting in the northern areas, with 44% at Tatoosh Island and 35% at the Quillayute Needles Complex.

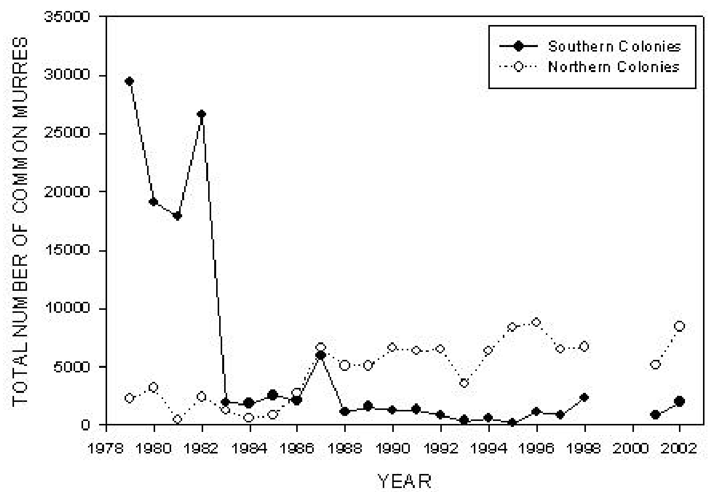


Figure 3. Numbers of common murres attending all Washington colonies, divided into south and north components, from 1979-2002.

Although murre attendance summed across all colonies (as presented in Figure 2) has been relatively stable for 15 years, attendance at individual rocks has varied (Carter et al. 2001). This is especially true at the Quillayute Needles and Carroll-Jagged Complexes, in particular Cake Rock and Carroll, Huntington, and Petrel Islands (Figure 4; see also Carter et al.
2001:Figure 2.11). In the early 1980s, Petrel Island was the predominant murre colony in the area, followed by Huntington Island from the mid 1980s through the early 1990s. The murre population at Carroll Island increased dramatically following the 1994 breeding season, but has been replaced by Cake Rock (Figure 4) as the main murre colony in the area.

Understanding trends in common murre colony attendance in Washington over the past two decades is confounded by at least two basic issues. First, as discussed above, there does not appear to be a uniform trend in colony attendance among colonies from the Quillayute Needles and Carroll-Jagged Complexes. The fact that all Washington murre colonies are within a range of 127 km (79 mi) makes these data even more perplexing. Second, counts at particular colonies generally have not been replicated in any given year, and census methods used by different researchers may differ and may not be directly comparable. Counts at common murre refuge colonies have been conducted only once per year from 1979 through 1993 (Carter et al. 2001), and single yearly counts can result in poor estimates of breeding attendance (Hatch and Hatch 1989). Censuses by other researchers often resulted in different population estimates. For example, Wilson (in Carter et al. 2001:Appendix F) estimated that only 50 common murres were in attendance on Grenville Arch during an aerial survey on June 26, 1985. However, Speich et al. (1987) provided a maximum count of 8,000 common murres on Grenville Arch for the week that included June 26, 1985, based on a combination of shore- and boat-based counts. Land, boat, and aerial surveys have the potential of sampling different parts of a colony, and therefore they may produce different results. In addition, there may be inherent hourly or daily variability in attendance at Washington colonies (Parrish 1996a, b), and censuses taken on two different days (or at two different times during the same day) may differ as a result of this variability.

[2] The number of individuals that the resources of a habitat can support.

Common Murre removed from Priority Habitat and Species list in 2018

At-sea Distribution

Although common murre breeding in Washington is restricted to cliffs, rocks, and islands on the outer coast, murres are found throughout the year in all marine waters of the state, including Puget Sound (Wahl et al. 1981, Briggs et al. 1992, Thompson 1997, 1999, Nysewander et al. 2001, Thompson et al. 2002, 2003). In Puget Sound, murre densities are positively correlated with distance from the shore and water depth (D. Nysewander, personal communication; Wahl et al. 1981); however, this relationship does not exist along the outer coast and in the western portions of the Strait of Juan de Fuca (Thompson 1997, 1999). The temporal and spatial patterns for the abundance and distribution of common murres in Puget Sound are highly variable (Thompson 1997, 1999, Nysewander et al. 2001). For example, population indices for common murres in the Puget Sound in July were 48,423; 9,915; 5,271; and 30,660 for 1993 through 1996, respectively (D. Nysewander, personal communication). The reason for this variability is unclear, although the timing of post-breeding dispersal of adult murres from coastal colonies is most likely an important variable. The at-sea density of common murres is highest in the fall (i.e., post-breeding, beginning late July/early August) on the outer coast (Briggs et al. 1992, Thompson 1997, 1999, unpublished data) and in Puget Sound (D. Nysewander, personal communication). The increase of murres in Washington waters following the breeding season is, in part, a result of post-breeding dispersal from colonies in Oregon (Warheit 1996, Thompson 1997, 1999), possibly California, and to a lesser extent, British Columbia and Alaska. Although murre distribution and abundance also varies substantially in time and location on the outer coast, total at-sea population estimates of murres on the outer coast were consistent in 2001 and 2002 ([mean, 95% CI] 2001: 72,840; 48,816–91,124; 2002: 74,011; 35,803 – 103,048; Thompson, unpublished data).

RATIONALE

The common murre is a State Candidate species. Carter et al. (2001) concluded that the common murre population dropped dramatically from approximately 26,000 in 1982 to 3,000 in 1983, coinciding with a severe El Niño-Southern Oscillation (ENSO) (Wilson 1991). This decline was mirrored at common murre colonies in California (Boekelheide et al. 1990) and Oregon (Hodder and Graybill 1985). However, unlike colonies in California and Oregon total attendance at Washington refuge colonies has not recovered to pre-1983 ENSO levels and has not exceeded 11,000 since that event. Wilson (1991) and Carter et al. (2001) suggested that the lack of recovery to pre-1983 numbers and low attendance within the NWRs may be the result of a combination of ENSOs, oil spills, gillnet mortality, and Naval disturbances at breeding colonies.

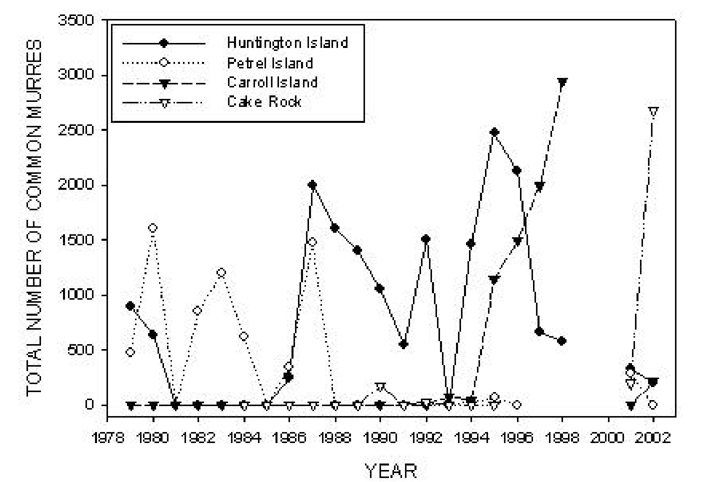


Figure 4. Numbers of common murres attending four colonies from the Quillayute Needles and Carroll-Jagged Complexes. Data from Wilson (1996, 1999, 2002, and 2003), Carter et al. (2001).

HABITAT REQUIREMENTS

Common murres require coastal cliff ledges or elevated marine terraces on islands or rocky headlands for breeding (Ainley et al. 2002). The habitat must be above the splash zone, inaccessible to terrestrial predators or pests (such as cats, rats, foxes, or raccoons), sufficiently windswept or elevated to permit takeoff and landing (Tuck 1961), and in "full ocean view" (Ainley et al. 2002:5). Common murres do not build nests, and each pair lays a single egg directly on the substrate, usually on bare rock, although on Tatoosh Island a subcolony of murres nested on soil near vegetation (salmonberry [*Rubus spectabilis*]; Parrish 1995, Parrish and Paine 1996). Common murres also require marine habitats with relatively abundant prey. Prey include Pacific herring (*Clupea harengus*), Pacific sandlance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), rockfish (*Sebastes* spp.), salmon (*Oncorhynchus* spp.), squid, and euphasids (Vermeer et al. 1987, Boekelheide et al. 1990, Ainley et al. 2002). Common murres require that breeding habitat be sufficiently close to productive foraging areas (e.g., oceanographic fronts, tidal sheers, upwelling plumes, shelf-break fronts, and runoff plumes; Ainley et al. 2002) so that repeated trips between the colony and prey sources can be made within a single day (foraging radius for common murres is approximately 60 km [37 mi]; see Ainley et al. 1991). Following the breeding season, common murres require only suitable marine habitat for foraging and resting, although murres may return to colony rocks prior to the breeding season. During this time murres are frequently seen close to shore (Ainley et al. 2002).

Diet

There have been only two detailed studies of the diet of common murres in Washington. The first study is based on the contents of the gastrointestinal tracts of common murres collected from salmon drift gill nets in the late summer and fall from 1993 through 1996 (Wilson 1998, Wilson and Thompson 1998, Lance and Thompson, in press). In this geographically limited study, common murres fed on Pacific herring (74.2 % frequency of occurrence), Pacific sandlance (45.8%), and salmonid species (21.9%). The proportion of these prey species in the diet of murres did not differ significantly between murre age classes (adult vs. subadult), gender, or among years. The mean lengths of Pacific herring and Pacific sandlance were not significantly different in the murre diet. Diet diversity within individual murres was low with most gastrointestinal tracts containing only one or two prey species. Based on the time of day in which Pacific herring and Pacific sandlance were present in murre esophagi and/or proventriculi, Wilson and Thompson (1998) and Lance and Thompson (in press) determined that murres fed most frequently on these two species at dusk (2100-2259 PST).

The second study included only the diet of chicks fed by adults at nest sites on Tatoosh Island (Parrish 1996 a, b, Parrish and Zador 2003, Thompson et al. 2003). The primary prey items fed to chicks were surf smelt (*Hypomesus pretiosus*), Pacific herring, Pacific sandlance, and eulachon (*Thaleichthys pacificus*) (Parrish and Zador 2003, Thompson et al. 2003).

LIMITING FACTORS

A variety of natural and human-induced factors can affect common murre populations. Colony attendance and reproductive success for murre populations along the west coast of North America have been affected by ENSO events (Hodder and Graybill 1985, Ainley and Boekelheide 1990, Wilson 1991). Additional natural factors that may affect murre abundance, distribution, and reproductive success include food availability, predation pressure, and the distribution of specific marine habitats (Briggs et al. 1987, 1992; Speich et al. 1987; Ainley and Boekelheide 1990; Allen 1994; Ainley et al. 1995; Parrish 1996a; Parrish and Paine 1996; Thompson 1997). Disturbance caused by aerial predators such as the bald eagle (*Haliaeetus leucocephalus*) can also negatively affect the reproductive success of breeding murres (Speich et al. 1987, Parrish 1995, 1996a, b; Parrish et al. 2001, Thompson et al. 2003; R. Lowe, personal communications).

Common murres are also vulnerable to drowning in fish-nets or becoming oiled during spills because they are gregarious on land and at sea (Burger and Fry 1993, DeGange et al. 1993, Warheit et al. 1997). In the last 10-20 years, there have been several oil spills in California, Oregon, and Washington, with two major spills in Washington resulting in substantial mortality to common murres. Murres were the most numerous seabirds affected in the *Tenyo Maru* and *Nestucca* oil spills off the coast of Washington (Ford et al. 1991, Momot 1995, *Tenyo Maru* Oil Spill Natural Resources Trustees 2000). Seabird mortality associated with gillnets in Washington and central California have shown a bias toward common murres (Takekawa et al. 1990, Erstad et al. 1994, Pierce et al. 1994, Thompson et al. 1998). Overall, in Washington, it is estimated that thousands of common murres have been killed in salmon gillnets and by oil spills (Ford et al. 1991, Momot 1995; Melvin and Conquest 1996; Warheit 1996; Melvin et al. 1997). Recreational fishing does not appear to be a threat to common murres in Washington (C. MacDonald and W. Beeghley, unpublished data); however, more research is necessary before any conclusions can be reached. The degree to which these factors affect the long-term stability of the population(s) of common murres in Washington is unknown.

Population Regulation

Population responses of a common murre colony to natural or human-induced environmental changes may depend on how that colony is reproductively linked to other colonies and how the overall population is geographically structured. There have been three studies particularly relevant to the geographic structure of common murres occurring from British Columbia south to California. First, Warheit (1996) estimated that 55–58% of common murres killed during the *Tenyo Maru* oil spill were from Washington (the remaining birds were from Oregon). These results indicate that at certain times of the year the Washington "population" of common murres is simply an association of birds from different geographic areas, and not necessarily an integrated breeding nexus. Second, Warheit (1999) stated that based on preliminary genetic analysis, there is little to no geographic structure to common murre populations from British Columbia to California, although there is a slight north-south gradient in allelic frequencies. These tentative conclusions also indicate that there is no evidence for a distinct Washington "population." Finally, Drovetski et al. (submitted) found a lack of geographic structure to mitochondrial DNA variation among common murres from Japan, Russia, Alaska, and California, and that the history of common murres in the Pacific is highlighted by local population declines and recovery through high migration and gene flow.

The results from the two genetic analyses suggest that common murres in Washington are part of a large and integrated metapopulation that includes, at a minimum, birds from Oregon and British Columbia. However, because both studies limited the Washington samples from one locality (near Tatoosh Island), neither contributes to our understanding of the geographic structure and demographics of common murres within Washington.

There are few data available to help determine what factors (natural or human-induced) are actually "regulating" common murre populations in Washington. Common murre abundance and distribution may be determined by factors such as migration from outside Washington (as the genetic data suggests), food distribution, or bald eagle predation or disturbance. Wilson (2003) has suggested that common murres in Washington are at their carrying capacity and that growth of this population is being limited by food. Parrish and Zador (2003) looked for correlations between a series of mechanisms and several measures of murre demographics and foraging behaviors. They concluded that although a central Oregon colony of murres (Yaquina Head) may be near carrying capacity, Washington colonies "probably exist well below carrying capacity," and at Tatoosh Island eagle predatory pressure is affecting several demographic parameters (Parrish and Zador 2003:1054). Without additional data on potential regulating factors, it is impossible to predict how a particular colony or population will be affected by events such as gillnet or oil spill mortality. In addition, without more inclusive data on common murre demographic parameters throughout Washington (such as survival, reproductive success, or dispersal from colonies in addition to Tatoosh Island) or information about common murre food habits and potential effects of climate change on prey distribution and abundance, it is difficult to design a comprehensive management or restoration plan for common murres in Washington.

MANAGEMENT RECOMMENDATIONS

To successfully manage the population(s) of common murres in Washington, additional baseline data are needed. Therefore, the following management recommendations consist of two parts. First, we will outline the priority research recommendations. Second, we list direct management activities that should be or have been implemented for the conservation of the breeding and at-sea populations of common murres in Washington.

Research and Monitoring Recommendations

1) *Breeding distribution and phenology, and reproductive success*: Tatoosh Island, and to a lesser extent Point Grenville (Thompson et al. 2003) are the only areas in Washington where definitive data have been collected on the basic reproductive parameters of common murres. Therefore, there are no extensive data on breeding phenology, reproductive success, or factors affecting reproductive success (e.g., food availability) available from murre colonies south of Tatoosh Island. This information is important to understanding the demographics of common murres in Washington and for implementing effective management programs.

2) *Geographic structure of population*: There are at least two aspects of the geographic structure of common murre populations in Washington that are important in designing management plans.
   a) Dispersal: The connectivity among colonies is based on the degree to which birds hatched in an area disperse to another area. If the dispersal rate among several areas is high, these areas function as one population, and natural recovery following a disturbance may be relatively quick due to the influx of immigrants. In these cases, management activities need to be directed at the population, rather than an individual colony. However, if a colony or area is isolated and few or no birds disperse to or from the colony, management activities need to be directed at the colony or area because recovery following disturbance must be through local recruitment and natal philopatry (i.e., birds that hatch at a colony and return to that colony to breed). Data on dispersal can be collected directly through the observation of banded birds and indirectly through genetic analyses of individuals from colonies throughout a particular geographic range. At this time our entire knowledge of the genetic structure of common murres from British Columbia to California is based on only four colonies.
   b) Identification of origin of birds: If common murres are geographically structured either within Washington or between Washington and other regions along the west coast, particular morphological or genetic markers may exist that can identify a bird from a specific colony or region. If such markers exist, it may be possible to identify the areas of origin (e.g., Washington versus Oregon) for common murres killed in oil spills or fishing nets in Washington marine waters (e.g., Warheit 1996, Edwards et al. 2001).

3) *Survival rates*: Adult and juvenile survival are important parameters in understanding the demographics of common murre populations (Nur et al. 1994). Although there are data on the survival rates for common murres from both the Atlantic and Pacific oceans (Hudson 1985, Harris and Wanless 1988, 1995; Sydeman 1993), no data are currently available from any Washington colony. Obtaining data on survival rates requires banding individual birds.

4) *Sources of mortality:* Researchers (Parrish 1996a, b; Parrish and Paine 1996; Parrish et al. 2001) studied the effects of eagle disturbance on survival and reproductive success of common murres on Tatoosh Island. This type of study should be conducted at other murre colonies in Washington, as was attempted at Point Grenville (Thompson et al. 2003). To better understand the effects of fishing bycatch mortality and oil spills on common murres in Washington, more data are needed on the number of individuals killed each year in all types of fishing gear (including recreational fishing) and in oil spills (including small-scale but chronic spills). Systematic and wide-ranging beach bird surveys are essential to document baseline mortality rates for marine birds in Washington. The Coastal Observation and Seabird Survey Team initiated such a comprehensive coastwide program in 1999 (Hass and Parrish 2000).

5) *Fisheries bycatch mortality*: More research is required to further reduce the number of birds killed in all kinds of fishing gear.
   a) Pingers: Melvin et al. (1997) conducted experiments on the use of audio devices (i.e., pingers) attached to gillnets as a method to reduce the rate by which seabirds become entangled. We recommend that new experiments be conducted on the use of pingers on 20 mesh nets.
   b) Recreational fishery activities: Based on one year of data, it appears that bycatch of common murres in recreational fishing lines are minimal (C. MacDonald and W.Beeghley, personal communications). Nevertheless, a more comprehensive, multi-year, and systematic study needs to be implemented to effectively evaluate this potential problem.
   c) Monitoring: Comprehensive monitoring of the at-sea distribution of common murres in Puget Sound, Strait of Juan de Fuca, the outer coast, and along the Oregon coast needs to be implemented and maintained; monitoring and surveying have been or are currently being conducted on Tatoosh Island (Paine et al. 1990, Parrish 1995) and on all colonies managed by USFWS (Speich et al. 1987, Wilson 1991, Briggs et al. 1992, Carter et al. 2001). These data should be used to determine seasonal murre abundance that might influence the regulation of a particular gillnet fishery. This information will also help determine potential injury from oil spills occurring in particular places at specific times of the year.

6) *Food habits*: Short- and long-term changes in food resources for common murres can result from factors such as ENSO events, Pacific Decadal Oscillation (Mantua et al. 1997, Minobe 1999), overfishing, and global climate change. Food shortages resulting from ENSO events have been documented to be associated with large die-offs of common murres in Washington (Good et al. 1999). Management plans must be designed that

incorporate this information. Detailed analysis of food habits for common murres in Washington is limited for most sites. Comprehensive studies of common murre food habits and foraging ecology are needed and should combine information gathered both at sea and at breeding colonies. These studies need to be long-term, multiyear endeavors, and should include analyses on diet, adult foraging rates, chick diet at nest sites, and information about the marine food web (in particular, the abundance, distribution, and life history of the primary prey species, and how these prey species might be affected by climate change). This type of comprehensive analysis was initiated in 2001 (Thompson et al. 2003), but the *Tenyo Maru* Oil Spill Trustee Committee terminated funding for this project after two years.

7) *Spatial factors affecting murre distribution*: As described in the Trends Section above, common murres have shifted their Washington distribution to the north (Figure 3), and have experienced irregular attendance at the Quillayute Needles and Carroll-Jagged Complexes (Figure 4). These spatial patterns are unmistakable and may relate to differences in local terrestrial and marine environments. Differences in factors such as food availability, human and eagle disturbance, and rates of predation need to be examined.

Direct Management Actions and Recommendations

1) *Reduce bycatch of common murres in Washington drift gillnets*: A considerable amount of research has been conducted in Washington to determine the degree to which seabirds, in particular common murres, are caught in non-treaty salmon drift gillnets (Erstad et al. 1994, 1996; Pierce et al. 1994; Thompson et al. 1998). In addition, researchers (Melvin and Conquest 1996, Melvin et al. 1997) have developed procedures to reduce seabird bycatch in drift gillnets. Because thousands of murres are potentially killed by gillnets each year (Thompson et al. 1998), specific management activities to reduce this mortality are warranted. The Washington Fish and Wildlife Commission adopted procedures and commercial fishing regulations designed to reduce the bycatch of seabirds, particularly common murres and rhinoceros auklets, in gillnets (Washington Department of Fish and Wildlife 1997). These regulations set the following gillnet design standards and timing restrictions to reduce mortality associated with gillnets:
   a) Net design: The monofilament line in the first 20 meshes below the corkline of nets must be replaced with #12 white twine which is more visible to diving birds. Melvin et al. (1997) showed that the 20 mesh nets (but with thicker #18 white twine) significantly reduced seabird bycatch without significantly reducing fishing efficiency.
   b) Length of season: The Department of Fish and Wildlife was authorized to end the 1997 sockeye and pink salmon gillnet fisheries in northern Puget Sound (Areas 7/7a) when the number of seabirds in the fishing area became abundant in order to eliminate common murre bycatch. This authority should be extended to future years.
   c) Fishing hours: The Commission eliminated early morning (change-of-light period) and most night fishing to reduce the time in which fishers would be unable to see and thereby avoid flocks of birds; the designated open fishery was from 1.5 hours after sunrise to midnight.
   d) Educational programs: Although the Commission's new regulations did not require the implementation of educational programs, the Commission's goals may be best met through programs designed to instruct the commercial fishing fleet in Washington on how best to avoid encountering seabirds.

2) *Reduce effects from oil spills*: Oil spills are usually accidents and as such are difficult to plan and manage. Nevertheless, activities can be employed to reduce the probability and negative effects of an oil spill. The Washington Departments of Ecology and Fish and Wildlife are addressing the following:
   a) Spill prevention through vessel and facility inspections
   b) Coordinated spill response and injury assessment
   c) Restoration planning and implementation
   d) Oiled wildlife rescue capabilities
   e) Industry and coast guard drills and geographic response plans to enhance spill response activities

3) *Reduce human disturbance at breeding colonies*: Human disturbance through activities such as kayaking, boating, or aircraft overflights can disturb nesting common murres and affect local recruitment and productivity (Speich et al. 1987, Parrish 1996b,Warheit et al. 1997). As provided in the *Nestucca* oil spill restoration plan (Momot 1995), the USFWS will inform citizens about the sensitivities of seabird breeding colonies at NWR sites in Washington through brochures and signs/posters displayed prominently at commercial, private, and

public boat launches and marinas, and in refuges and parks. These brochures and signs will also inform the public that it is illegal to harass seabirds and to enter onto a NWR island without proper authorization. The *Tenyo Maru* Oil Spill Trustee Committee has implemented a similar program in Oregon and the Cape Flattery – Tatoosh Island area in Washington (*Tenyo Maru* Oil Spill Natural Resources Trustees 2000). Finally, although the use of brochures and signs promises to reduce disturbance at specific colonies, other factors such as aircraft ceiling violations over specific common murre colonies (e.g., Tatoosh Island; Parrish 1996b) need to be addressed through a combination of educational programs and enforcement of existing laws and regulations.

REFERENCES

Ainley, D. G., and R. J. Boekelheide, editors. 1990. Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling-system community. Stanford University Press, Palo Alto, California, USA.

_____, D. N. Nettleship, H. R. Carter, and A. E. Storey. 2002. Common murre (*Uria aalge*). Number 666 *In* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

_____, W. J. Sydeman, and R. H. Parrish. 1991. Upwelling, offshore transport, and the availability of rockfish in central California. Pages 131-136 *in* J. L. Betancourt and V. L. Tharp, editors. Proceedings of the Seventh Annual Pacific Climate (PACLIM) Workshop. California Department of Water Resources Interagency Ecological Studies Program Technical Report 26.

_____, _____, and J. Norton. 1995. Upper trophic level predators indicate interannual negative and positive anomalies in the California current food web. Marine Ecology Progress Series 118:69-79.

Allen, S. G. 1994. The distribution and abundance of marine birds and mammals in the Gulf of the Farallones and adjacent waters, 1985-1992. Dissertation, University of California, Berkeley, California, USA.

American Ornithologists' Union. 1983. Checklist of North American birds. Sixth edition. American Ornithologists' Union, Baltimore, Maryland, USA.

Bédard, J. 1985. Evolution and characteristics of the Atlantic Alcidae. Pages 1-51 *in* D. N. Nettleship and T. R. Birkhead, editors. The Atlantic Alcidae. Academic Press, London, United Kingdom.

Boekelheide, R. J., D. G. Ainley, S. H. Morrell, H. R. Huber, and T. J. Lewis. 1990. Common Murre. Pages 245-275 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling-system community. Stanford University Press, Palo Alto, California, USA.

Briggs, K. T., W. T. Tyler, D. B. Lewis, and D. R. Carlson. 1987. Bird communities at sea off California: 1975 to 1983. Studies in Avian Biology 11.

_____, D. H. Varoujean, W. W. Williams, R. G. Ford, M. L. Bonnell, and J. L. Casey. 1992. Seabirds of the Oregon and Washington outer continental shelf, 1989-1990. Chapter 3 *in* J.J. Brueggeman, editor. Oregon and Washington marine mammal and seabird surveys. Final Report, USDI Minerals Management Service, Los Angeles, California, USA.

Burger, A. E., and D. M. Fry. 1993. Effects of oil pollution on seabirds in the northeast Pacific. Pages 254-263 *in* K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey, editors. The status, ecology and conservation of marine birds of the North Pacific. Canadian Wildlife Service, Ottawa, Ontario, Canada.

Carter, H. R., U. W. Wilson, R. W. Lowe, M. S. Rodway, D. A. Manuwal, J. E. Takekawa, and J. L. Yee. 2001. Population trends of the common murre (*Uria aalge californica*). Pages 33-132 *in* D. A. Manuwal, H. R. Carter, T. S. Zimmerman, and D. L. Orthmeyer, editors. Biology and conservation of the common murre in California, Oregon, Washington, and British Columbia. Volume 1: Natural history and population trends. U.S. Geological Survey, Information and Technology Report USGS/BRD/ITR-2000-0012, Washington D.C., USA.

DeGange, A. R., R. H. Day, J. E. Takekawa, and V. M. Mendenhall. 1993. Losses of seabirds in gill nets in the north Pacific. Pages 204-211 *in* K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey, editors. The status, ecology and conservation of marine birds of the North Pacific. Canadian Wildlife Service, Ottawa, Ontario, Canada.

Drovetski, S. V., A. S. Kitaysky, R. M. Zink, M. T. Sultz, J. F. Piatt, K. I. Warheit, W. E. Davies, and S. Rohwer. Submitted. Effect of complex demographic history on mitochondrial DNA variation in Pacific Common Murres (*Uria aalge*). Submitted to Molecular Ecology.

Edwards, S. V., M. C. Silva, T. Burg, V. Friesen, and K. I. Warheit. 2001. Molecular genetic markers in the analysis of seabird bycatch populations. Pages 115-140 *in* E. F. Melvin, and J. K. Parrish, editors.

Proceedings - seabird bycatch: trends, roadblocks, and solutions. University of Alaska Sea Grant AK-SG-01-01.
Erstad, P., S. J. Jeffries, and D. J. Pierce. 1994. 1994 preliminary report for areas 7 & 7A Puget Sound Fishery Observer Program. Non-Treaty Sockeye Gill Net Fishery. Washington Department of Fish and Wildlife, Olympia, Washington, USA.
_____, _____, and _____. 1996. 1994 report for the Puget Sound Fishery Observer Program in management areas 10/11 and 12/12b. Non-treaty Chum Gill Net Fishery. Final Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Ford, R. G., D. H. Varoujean, D. R. Warrick, W. A. Williams, D. B. Lewis, C. L. Hewitt, and J. L. Casey. 1991. Seabird mortality resulting from the *Nestucca* oil spill incident, winter 1988-89. Final Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Gaston, A. J., and I. L. Jones. 1998. The Auks *Alicidae*. Oxford University Press. Oxford, United Kingdom.
Good, T. P., C. W. Thompson, and M. L. Wilson. 1999. Common Murre (*Uria aalge*) mortality along Washington outer coast beaches: patterns and implications for breeding populations. Pacific Seabirds 26:36.
Harris, M. P., and S. Wanless. 1988. The breeding biology of guillemots *Uria aalge* on the Isle of May over a six-year period. Ibis 130:172-192.
_____, and S. Wanless. 1995. Survival and non-breeding of adult common guillemots *Uria aalge*. Ibis 137:192-197.
Harrison, P. 1983. Seabirds: an identification guide. Houghton Mifflin, Boston, Massachusetts, USA.
Hass, T., and J. K. Parrish. 2000. Beach birds. A COASST field guide. Wavefall Press, Seattle, Washington, USA.
Hatch, S. A., and M. A. Hatch. 1989. Attendance patterns of murres at breeding sites: implications for monitoring. Journal of Wildlife Management 53:483-493.
Hodder, J., and M. R. Graybill. 1985. Reproduction and survival of seabirds in Oregon during the 1982-83 El Niño. Condor 87:535-541.
Hudson, P. J. 1985. Population parameters for the Atlantic Alcidae. Pages 233-261 *in* D. N. Nettleship and T. R. Birkhead, editors. The Atlantic Alcidae. Academic Press, London, United Kingdom.
Lance, M. M., and C. W. Thompson. In press. Diet of Common Murres and Rhinoceros Auklets in Puget Sound, Washington in late summer and fall. Auk.
Lowe, R. W., and D. S. Pitkin. 1996. Replicate aerial photographic censuses of Oregon common murre colonies 1995. Final report submitted to the *Tenyo Maru* Trustee Committee. U.S. Fish and Wildlife Service, Newport, Oregon, USA.
Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific decadal climate oscillation with impacts on salmon. Bulletin of the American Meteorological Society 78:1069-1079.
Melvin, E. F., and L. Conquest. 1996. Reduction of seabird bycatch in salmon drift gillnet fisheries: 1995 sockeye/pink salmon fishery final report. Project number A/FP-2(a).
_____, _____, and J. K. Parrish. 1997. Seabird bycatch reduction: new tools for Puget Sound drift gillnet salmon fisheries: 1996 sockeye and 1995 chum non-treaty salmon test fishery final report. Washington Sea Grant Program. Project number A/FP-7.
Minobe, S. 1999. Resonance in bidecadal and pentadecadal climate oscillations over the North Pacific: role in climatic regime shifts. Geophysical Research Letters 26:855-858.
Momot, J. J. 1995. *Nestucca* oil spill restoration plan. U.S. Fish and Wildlife Service, Olympia, Washington, USA.
Nettleship, D. N., and P. G. H. Evans. 1985. Distribution and status of the Atlantic Alcidae. Pages 53-154 *in* D. N. Nettleship and T. R. Birkhead, editors. The Atlantic Alcidae. Academic Press, London, United Kingdom.
Nysewander, D. R., J. R. Evenson, B. L. Murphie, and T. A. Cyra. 2001. Report of marine bird and marine mammal component, Puget Sound Ambient Monitoring Program, for July 1992 to December 1999 period. Draft Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Nur, N., R. G. Ford, and D. G. Ainley. 1994. Computer models of Farallon seabird populations. Final Report to Gulf of the Farallones National Marine Sanctuary. U.S. National Oceanic and Atmospheric Administration, San Francisco, California, USA.
Paine, R., J. T. Wooton, and P. D. Boersma. 1990. Direct and indirect effects of peregrine falcon predation on seabird abundance. Auk 107:1-9.
Parrish, J. K. 1995. The influence of group size and habitat type on reproductive success in common murres (*Uria aalge*). Auk 112:390-401.
_____. 1996a. Continued monitoring of common murres on Tatoosh Island. Final Report (1995) submitted to the *Tenyo Maru* Trustee Committee, University of Washington, Seattle, Washington, USA.

_____. 1996b. Attendance and reproductive success of Tatoosh Island common murres. Final Report (1996) submitted to the *Tenyo Maru* Trustee Committee, University of Washington, Seattle, Washington, USA.
_____., M. Marvier, and R. T. Paine. 2001. Direct and indirect effects: interactions between bald eagles and common murres. Ecological Applications 11:1858-1869.
_____, and R. T. Paine. 1996. Ecological interactions and habitat modification in nesting common murres, *Uria aalge*. Bird Conservation International 6:261-269.
_____, and S. G. Zador. 2003. Seabirds as indicators: An exploratory analysis of physical forcing in the Pacific northwest coastal environment. Estuaries 26:1044-1057.
Pierce, D. J., W. P. Ritchie, and R. Kreuiger. 1994. Preliminary findings of seabird interactions with the non-treaty salmon gill net fishery: Puget Sound and Hood Canal Washington. Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Sowls, A. L., S. A. Hatch, and C. J. Lensink. 1978. Catalog of Alaskan seabird colonies. U.S. Fish and Wildlife Service. FWS/OBS-78/78.
Speich, S. M., and T. R. Wahl. 1989. Catalog of Washington seabird colonies. U.S. Fish and Wildlife Service. Biological Report 88(6).
_____, B. L. Troutman, A. C. Geiger, P. J. Meehan-Martin, and S. J. Jeffries. 1987. Evaluation of military flight operations on wildlife of the Copalis National Wildlife Refuge, 1984-1985. Final Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Storer, R. W. 1952. A comparison of variation, behavior, and evolution in the seabird genera *Uria* and *Cepphus*. University of California Publications in Zoology 52:121-222.
Sydeman, W. J. 1993. Survivorship of common murres on southeast Farallon Island, California. Ornis Scandinavica 24:135-141.
Takekawa, J. E., H. R. Carter, and T. E. Harvey. 1990. Decline of the common murre in central California, 1980-1986. Studies in Avian Biology 14:149-163.
Tenyo Maru Oil Spill Natural Resources Trustees. 2000. Final Restoration Plan and Environmental Assessment for the *Tenyo Maru* Oil Spill. Contact agency: U.S. Fish and Wildlife Service, Lacy, Washington, USA.
Thompson, C. W. 1997. Distribution and abundance of marbled murrelets and common murres on the outer coast of Washington. 1997 Completion Report, *Tenyo Maru* Trustee Committee.
_____. 1999. Distribution and abundance of Marbled Murrelets and Common Murres on the outer coast of Washington - Summer 1997 through winter 1998-1999. Unpublished Report, Washington Department of Fish and Wildlife, Mill Creek, Washington, USA.
_____, J. K Parrish, S. Zador, and K, Ryan. 2002. Restoration of Common Murre Colonies in the Copalis National Wildlife Refuge, Washington - Phase I. Summary Report for 2001 Field Season. Annual report to the *Tenyo Maru* Trustee Committee, Lacey, Washington, USA.
_____, K. Ryan, J. K. Parrish, S. Zador, and K. Warheit. 2003. Restoration of Common Murre Colonies in the Copalis National Wildlife Refuge, Washington Phase I. Draft Final Report to the *Tenyo Maru* Trustee Committee, Lacey, Washington, USA.
_____, M. L. Wilson, D. J. Pierce, and D. DeGhetto. 1998. Population characteristics of Common Murres and Rhinoceros Auklets entangled in gillnet fisheries in Puget Sound, Washington, 1993-1994. Northwestern Naturalist 79:77-91.
Tuck, L. M. 1961. The murres. Canadian Wildlife Service Monograph Number 1.
U.S. Fish and Wildlife Service. 2001. Beringian Seabird Colony Catalog, 26 March 2001. Division of Migratory Bird Management, Anchorage, Alaska, USA.
Vermeer, K., S. G. Sealy, and G. A. Sanger. 1987. Feeding ecology of the Alcidae in the eastern north Pacific Ocean. Pages 189-227 *in* J. P. Croxall, editor. Seabirds: feeding ecology and role in marine ecosystems. Cambridge University Press, Cambridge, United Kingdom.
Wahl, T. R., S. M. Speich, D. A. Manuwal, K. V. Hirsch, and C. Miller. 1981. Marine bird populations of the Strait of Juan de Fuca, Strait of Georgia, and adjacent waters in 1978 and 1979. U.S. Environmental Protection Agency, DOC/EPA Interagency Energy/Environment R&D Program Report EPA/600/f-81-156.
Warheit, K. I. 1996. Assessment of the origin of and the demographic impact to common murres (*Uria aalge*) killed during the 1991 Tenyo Maru oil spill. Final Report, U.S. Fish and Wildlife Service Document Control Number 98210-93-376.
_____. 1999. Genetic analyses of Common Murre (*Uria aalge*) populations from British Columbia to California, with emphasis on restoration planning in Washington. Final Report submitted to the *Tenyo Maru* Trustee Committee. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

_____, C. S. Harrison, G. J. Divoky, editors. 1997. *Exxon Valdez* oil spill seabird restoration workshop. Pacific Seabird Group. Exxon Valdez Oil Spill Restoration Project Final Report, Project 95038. Technical Publication Number 1.

Washington Department of Fish and Wildlife. 1997. Washington Department of Fish and Wildlife News release: new commercial fishing regulations to protect sea birds in northern Puget Sound. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Wilson, M. L. 1998. Diet of Common Murres (Uria aalge) and Rhinoceros Auklets (Cerorhinca monocerata) in Puget Sound, Washington in Late Summer and Fall, 1993-1996. Thesis, The Evergreen State College, Olympia, Washington, USA.

_____, and C. W. Thompson. 1998. Dietary preferences of Common Murres and Rhinoceros Auklets in Puget Sound, Washington, in late summer and fall, 1993-1996. Pacific Seabirds 25:48-49.

Wilson, U. W. 1991. Responses of three seabird species to El Niño events and other warm episodes on the Washington coast, 1979-1990. Condor 93:853-858.

_____. 1996. Washington common murre colony surveys 1996. Final Report submitted to the *Tenyo Maru* Trustee Committee, U.S. Fish and Wildlife Service, Sequim, Washington, USA.

_____. 1999. Common murre colony surveys, Washington Islands National Refuge, 1997-1998. Final Report submitted to the *Tenyo Maru* Trustee Committee, U.S. Fish and Wildlife Service, Sequim, Washington, USA.

_____. 2002. Common murre colony surveys, Washington Islands National Refuge, 2001. Final Report submitted to the *Tenyo Maru* Trustee Committee, U.S. Fish and Wildlife Service, Sequim, Washington, USA.

_____. 2003. 2002 common murre colony surveys with management recommendations for Point Grenville. Final Report submitted to the *Tenyo Maru* Trustee Committee, U.S. Fish and Wildlife Service, Sequim, Washington, USA.

PERSONAL COMMUNICATIONS

Wendy Beeghley, Wildlife Biologist
Washington Department of Fish and Wildlife
Montesano, Washington

Roy Lowe, Wildlife Biologist.
U.S. Fish and Wildlife Service
Oregon Coastal Refuges
Newport, Oregon

Colleen MacDonald, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

David Nysewander, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

Common Murre removed from Priority Habitat and Species list in 2018

KEY POINTS

Habitat Requirements

- Requires for breeding coastal cliff ledges or elevated marine terraces on islands or rocky headlands that are inaccessible to terrestrial predators.
- Lays a single egg directly on the substrate, usually on bare rock.
- Requires breeding habitat to be sufficiently close to productive foraging areas.
- In the eastern Pacific, preys upon Pacific herring, Pacific sandlance, northern anchovy, rockfish, salmon, squid, and euphasids.
- In Washington, chicks are fed surf smelt, Pacific herring, Pacific sandlance, and eulachon by adults at the nest site.
- Dietary diversity of individual murres tends to be low.
- Requires only suitable marine habitat for foraging and resting following the breeding season. However, murres may return to colony rocks prior to the breeding season.

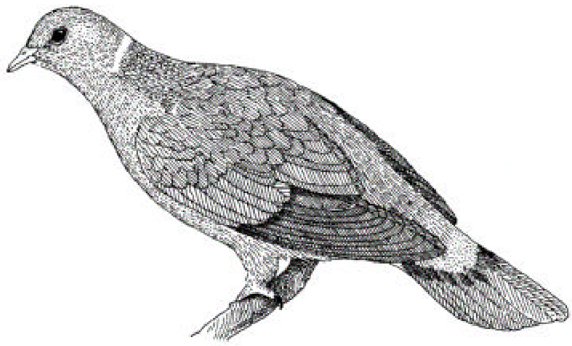
Management Recommendations

Research and Monitoring Recommendations

- Collect data on breeding phenology, reproductive success, and factors affecting reproductive success in Washington to support the implementation of more effective management programs.
- Gather comprehensive data to determine the rate of dispersal among colonies to better focus management efforts. Identification of genetic markers to track the origin of individual murres is also important.
- Collect survival data to more accurately understand murre demographics in Washington.
- Conduct comprehensive surveys to better understand the effects of various sources of mortality (e.g., natural mortality, bycatch, oil spills).
- Carry out additional research and monitoring efforts that will help identify ways to further reduce the number of birds killed in fishing gear.
- Develop and conduct comprehensive studies of murre food habits and foraging ecology. These studies should combine information gathered both at-sea and at breeding colonies.
- Examine spatial factors affecting murre distribution. Differences in factors such as food availability, human and eagle disturbance, and rates of predation need to be examined.

Direct Management Actions and Recommendations

- Replace the monofilament line in the first 20 meshes below the corkline of nets with #12 white twine which is more visible to diving birds. 20 mesh nets (but with thicker #18 white twine) significantly reduced seabird bycatch without significantly reducing fishing efficiency.
- Extend the Fish and Wildlife Commission's authority to end certain fishing seasons when the number of seabirds in a fishing area becomes abundant.
- Design programs to instruct commercial fishing fleets on how to best avoid seabird bycatch.
- Resource agencies should continuously improve their capabilities to reduce the effect of oil spills through various means (e.g., vessel and facility inspections, coordinated spill response and injury assessments, restoration, wildlife rescue).
- Reduce human disturbance at breeding colonies caused by activates such as kayaking, boating, or aircraft overflights.



Band-tailed Pigeon

Columba fasciata

Last updated: 2003

Written by Jeffrey C. Lewis, Michelle Tirhi, and Don Kraege

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Band-tailed pigeons are primarily restricted to coniferous forest zones in mountainous areas of western North America (Jarvis and Passmore 1992). Braun (1994) recognized two races of band-tailed pigeons in North America. The interior race (*Columba fasciata fasciata*) breeds primarily in the Rocky Mountains south of Wyoming, whereas the Pacific Coast race (*Columba fasciata monilis*) breeds west of the Cascade and Sierra Nevada crests [up to 4,200 m (13,800 ft) elevation; Pacific Flyway Council 1983] from British Columbia and southeastern Alaska south to Baja California, Mexico.

Figure 1. General range of the band-tailed pigeon, *Columba fasciata*, in Washington (Smith et al. 1997).

The bulk of Pacific Coast population of band-tailed pigeons winters from south of Redding, California through Mexico (Schroeder and Braun 1993); however, year-round residents occur in the Pacific Northwest (Jarvis and Passmore 1992). Schroeder and Braun (1993) found that some interchange occurs between the Pacific coast and interior races.

Band-tailed pigeons reside mainly in western Washington (see Figure 1) and are typically located around mineral springs and seeps (Keppie and Braun 2000). The highest densities occur on the Olympic Peninsula and on Washington=s southern coast (Grays Harbor, Pacific, and Wahkiakum counties). During the breeding season (April - September), most of the population is found below 305 m (1,000 ft) elevation (Jeffrey 1989). In late summer, band-tailed pigeons may move to higher elevations. By late September, most band-tailed pigeons leave Washington and migrate to their wintering grounds. However, year-round residents are known to occur in the Puget Sound as far north as Seattle (B. Tweit, personal communication).

RATIONALE

Band-tailed pigeons are listed as a State and Federal Game species. The hunting season in Washington underwent an emergency closure in 1991 due to a rapid decline in the population as determined from pigeon surveys (Braun 1994). Breeding Bird Survey data indicated the population of band-tailed pigeons in Washington declined significantly from 1968 to 1993 (Braun 1994, Keppie and Braun 2000). However, more recent data showed increases in population that allowed the reinstatement of a limited hunting season in 2002, after a 10-year restriction on hunting (Washington Department of Fish and Wildlife 2001, 2002).

Band-tailed pigeons require mineral springs close to a food source during the breeding and brood-rearing season (Jarvis and Passmore 1992). A scarcity of mineral sites combined with the alteration of available nesting habitat jeopardizes band-tailed pigeon populations (Braun 1994). Intensive hunting pressure in the past has also been held responsible for declines in the population (Jarvis and Passmore 1992).

HABITAT REQUIREMENTS

In Washington, band-tailed pigeons are associated with Douglas-fir (*Pseudotsuga menziesii*), red alder (*Alnus rubra*), western hemlock (*Tsuga heterophylla*), red cedar (*Thuja plicata*), bigleaf maple (*Acer macrophyllum*), sitka spruce (*Picea sitchensis*), willow (*Salix* spp.), pine (*Pinus* spp.), cottonwood (*Populus* spp.), and Garry oak (*Quercus garryana*) (Jeffrey 1989, Braun 1994). Berry- and nut-producing trees and shrubs are also common in their range (Keppie and Braun 2000).

Breeding Season

During the breeding season (April - September), band-tailed pigeons are found in mixed conifer and hardwood forests interspersed with younger wooded areas or small fields (Jeffrey 1977, 1989). Abundant food and mineral sources are necessary during this time (Jarvis and Passmore 1992). Nesting habitat in western Oregon is dominated by closed-canopy, conifer forests (mostly Douglas-fir) in sapling-pole forest development stages (Leonard 1998). Nests are placed in conifers or broad-leafed trees, typically 4.5-12.0 m (15-40 ft) above the ground. Nests may be distributed in small groups or well-dispersed (Jeffrey 1977, Curtis and Braun 1983). In Oregon, average home range size during the nesting season was 11,121 ha. (Leonard, 1998).

Band-tailed pigeons seek sources of mineral salts (especially calcium) necessary for egg production and the production of "crop milk" for feeding young (March and Sadleir 1975, Jarvis and Passmore 1992, Braun 1994). Mineral salts are found in mineral springs and marine shorelines, and occasionally livestock salt blocks are used (Jeffrey 1977). Pigeons have been documented returning to mineral springs in subsequent years (Jarvis and Passmore 1977, 1992).

Food

During spring migration, this herbivorous bird feeds on acorns, buds, blossoms, young leaves and needles, fruits, and berries (Jeffrey 1977). Primary food sources include Cascara buckthorn (*Rhamnus purshiana*), elderberry (*Sambucus* spp.), wild cherry (*Prunus* spp.), huckleberry (*Gaylussacia* spp.), madrone (*Arbutus menziesii*), dogwood (*Cornus* spp.), and oak (*Quercus* spp.) in late spring and summer (Jeffrey 1977). Pacific red elderberry (*Sambucus callicarpa*), blue elderberry (*Sambucus cerulea*), and cascara buckthorn were determined to be important food items in the Northwest because of their high caloric, calcium and protein content (Jarvis and Passmore 1992, Keppie and Braun 2000, Sanders 2000). During the spring and summer, newly planted fields or stubble containing grains from the fall harvest are also preferred food sources (Jarvis and Passmore 1992, Braun 1994, Keppie and Braun 2000).

During fall and winter, band-tailed pigeons feed on acorns, nuts, berries, grains and fruits (Fry and Vaughn 1977, Jeffrey 1989). Pigeons often move to high elevation meadows in the fall prior to migration (Jeffrey 1989). In the Oregon coastal range, primary feeding sites for radio-marked band-tailed pigeons were located in riparian or moist bottomlands (Leonard 1998). Nestlings feed on "crop milk" which is later supplemented by other regurgitated crop contents from either parent (Keppie and Braun 2000).

LIMITING FACTORS

Land development and forest practices that degrade or destroy mineral springs and nesting habitat limit band-tailed pigeon populations (Pacific Flyway Council 1983). Although undocumented mineral sites likely occur, only a limited number of mineral sites actively used by pigeons are known to exist in western Washington (Gillum 1993). A lack of berry/mast- producing plants may also limit use of areas by band-tailed pigeons (D. Kraege, personal communication).

Band-tailed pigeons lay a single egg 1 to 3 times per year (Leonard 1998); thus, their productivity is considered low. Intensive hunting of band-tailed pigeons can be detrimental (Neff 1947; D. Kraege, personal communication), especially at mineral sites where breeding adults are more abundant than juveniles during the hunting season (Jarvis and Passmore 1992).

Outbreaks of the protozoan disease Trichomoniasis are suspected in periodic large-scale mortalities of band-tailed pigeons (Keppie and Braun 2000). Trichomoniasis is transmitted through contaminated feed at urban bird feeders and possibly through contaminated mineral springs (D. Kraege, personal communication).

MANAGEMENT RECOMMENDATIONS

To adequately conserve nesting habitat, mineral springs and other mineral sources used by band-tailed pigeons should be protected (Braun 1994). Trees surrounding mineral sites are important for perching (Pacific Flyway Council 2001), and their removal should be avoided. Mineral sources may be enhanced by removing dense vegetation that could limit bird access. Because mineral sites are uncommon, they should be a high priority for conservation-oriented acquisitions.

Large clearcuts should be discouraged in band-tailed pigeon habitat (Jeffrey 1977). Clearcuts should be replanted with a variety of species rather than a single tree species. Berry/mast- producing shrubs and trees are important food sources and should be maintained and enhanced, particularly those close to mineral sources and higher elevation areas used during migration (Braun 1994).

The use of herbicides that eliminate food producing shrubs and trees should be discouraged, particularly in stands containing the important food sources described by Jeffrey (1977). Modern silvicultural practices, including the use of herbicides to control deciduous shrubs and trees, have potentially reduced food-producing plants throughout the range of the band-tailed pigeon (Braun 1994). Landowners are encouraged to use integrated pest management strategies that target specific pests or weeds, use pest population thresholds to determine when to use pesticides or herbicides, and to use crop rotation/diversity and beneficial insects to control pests (Stinson and Bromley 1991). If pesticide or herbicide application is planned for areas used by band-tailed pigeons, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

People maintaining bird feeders should regularly clean feeders and report all sick and dying band-tailed pigeons to the nearest Washington Department of Fish and Wildlife regional office, the U.S. Fish and Wildlife Service regional headquarters, or to the USGS Wildlife Health Research Center at (608) 271-4640 (D. Kraege, personal communication).

REFERENCES

Braun, C. E. 1994. Band-tailed pigeon. Pages 60-74 *in* T.C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Curtis, P. D., and C. E. Braun. 1983. Radio telemetry location of nesting band-tailed pigeons (*Columba fasciata*) in Colorado, USA. Wilson Bulletin 95:464-466.

Fry, M. E., and C. E. Vaughn. 1977. Acorn selection by band-tailed pigeons. California Department of Fish and Game 61:59-60.

Gillum, J. M. 1993. Band-tailed pigeon survey for 1993 conducted at mineral sites in Washington State. Washington Department of Wildlife, Olympia, Washington, USA.

Jarvis, R. L., and M. F. Passmore. 1977. Band-tailed pigeon investigations in Oregon, an overview. Upland Game Bird Commission, Oregon State University, Corvallis, Oregon, USA.

____, and ____. 1992. Ecology of band-tailed pigeons in Oregon. Biological Report, 6, U.S. Fish and Wildlife Service, Washington, D.C.

Jeffrey, R. G. 1977. Band-tailed pigeon (*Columba fasciata*). Pages 210-245 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C.

____. 1989. The band-tailed pigeon: distribution, effects of harvest regulations, mortality rates, and habits 1968-79. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.

Keppie, D. M., and C.E. Braun. 2000. Band-tailed pigeon (*Columba fasciata*). Number 530 *in* A Poole and F. Gill, editors. Birds of North America, Incorporated, Philadelphia, Pennsylvania, USA.

Leonard, J.P. 1998. Nesting and foraging ecology of the band-tailed pigeon in western Oregon. Ph.D. Dissertation, Oregon

State University, Corvallis, Oregon, USA.
March, G. L., and R. M. F. S. Sadleir. 1975. Studies on the band-tailed pigeon (*Columba fasciata*) in British Columbia: seasonal changes in body weight and calcium distribution. Physiological Zoology 48:49-56.
Neff, J. A. 1947. Habits, food, and economic status of the band-tailed pigeon. North American Fauna 58:1-76
Pacific Flyway Council. 1983. Pacific Coast band-tailed pigeon management plan. U.S. Fish and Wildlife Service, Portland, Oregon, USA.
____. 2001. Pacific and Central Flyways management plan for the Four Corners population of band-tailed pigeons. Pacific Flyway Council, U.S. Fish and Wildlife Service, Portland, Oregon, USA.
Sanders, T. A. 2000. Habitat availability, dietary mineral supplement, and measuring abundance of band-tailed pigeons in western Oregon. Ph.D. Dissertation, Oregon State University, Corvallis, Oregon, USA.
Schroeder, M. A., and C. E. Braun. 1993. Movement and philopatry of band-tailed pigeons captured in Colorado. Journal of Wildlife Management 57:103-112.
Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington GAP Analysis - Final Report Seattle Audubon Society Publication in Zoology Number 1, Seattle, Washington, USA.
Stinson, E. R., and P. T. Bromley. 1991. Pesticides and wildlife: a guide to reducing impacts on animals and their habitat. Virginia Department of Game and Inland Fisheries, Richmond, Virginia, USA.
Washington Department of Fish and Wildlife. 2001. 2001 Game status and trend report. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, Washington, USA.
Washington Department of Fish and Wildlife. 2002. News release, June 10, 2002. Olympia, Washington, USA.

PERSONAL COMMUNICATIONS

Don Kraege, Waterfowl Section Manager
Washington Department of Fish and Wildlife
Olympia, Washington
Bill Tweit, Biologist

Bill Tweit, Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

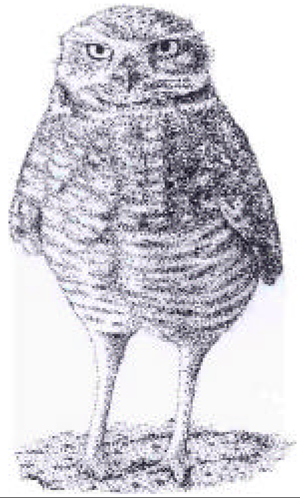
KEY POINTS

Habitat Requirements

- $ Band-tailed pigeons are associated with Sitka spruce, red cedar, western hemlock, red alder, bigleaf maple, Douglas-fir, willow, pine, cottonwood, Garry oak, and other berry- and nut-producing trees and shrubs.
- $ Mixed conifers and hardwoods with a good interspersion of different forest development stages and openings, abundant food resources, and mineral springs are necessary during the breeding and brood-rearing seasons.
- $ Band-tailed pigeons feed on grains, acorns, nuts, buds, blossoms, young leaves, needles, and the fruits and berries of several trees and shrubs.

Management Recommendations

- $ Protected and/or enhance mineral springs and other mineral sources used by band-tailed pigeons. These areas should be a high priority for conservation-oriented acquisition.
- $ Avoid removal of trees surrounding mineral sites.
- $ Avoid large clearcuts in band-tailed pigeon habitat.
- $ Replant clearcuts with multiple tree species. Maintain and enhance berry-, fruit-, and nut-producing shrubs and trees in band-tailed pigeon habitat.
- $ Avoid using herbicides that eliminate local food producing trees and shrubs and use integrated pest management within band-tailed pigeon habitats when possible. If pesticide or herbicide use is being considered for areas used by band-tailed pigeons, refer to Appendix A for a list of contacts to consult to assess pesticides, herbicides and their alternatives.
- $ Report sick and dying band-tailed pigeons (indicating Trichomoniasis disease) to the nearest Washington Department of Fish and Wildlife regional office, the U.S. Fish and Wildlife Service regional headquarters, or to the USGS Wildlife Health Research Center at (608) 271-4640.
- $ Avoid maintaining bird feeders in urban areas where Trichomoniasis outbreaks have been documented and regularly clean feeders.



Burrowing Owl

Athene cunicularia

Last updated: 2003

Written by Noelle Nordstrom

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The breeding range of the burrowing owl includes southern Canada from southern British Columbia eastward to south-central Manitoba, and extends as far south as Mexico (Haug et al. 1993). This species was extirpated from British Columbia but was reintroduced into the province in 1983. In Washington, burrowing owls typically occupy shrub-steppe habitat of the eastern part of the state during the breeding season (see Figure 1; Bryant 1990).

Figure 1. General range of the burrowing owl, *Athene cunicularia*, in Washington. Map derived from Washington Department of Fish and Wildlife data files and GAP Analysis of Washington.

Burrowing owls winter mainly in the southern United States, central Mexico and Central America (Zarn 1974). Little information is available on the migration routes and times or wintering areas used by burrowing owls (Haug et al. 1993). Recent banding data have shown that some owls overwinter in eastern Washington (Conway et al. 2002). Additionally, a resident owl was recently found with eggs that were produced in late February (C. Conway, personal communication). Most burrowing owls from Canada and the northern United States are believed to migrate south in September and October. The northern migration to the breeding grounds is thought to occur from March through the first week of May (James and Ethier 1989, James 1992, Haug et al.1993).

RATIONALE

The burrowing owl is a State Candidate species and a Federal Species of Concern that was once widespread throughout steppe and prairie communities of North America. Currently, the burrowing owl is declining throughout much of its range in the western United States and Canada (Bent 1961, Holroyd and Wellicome 1997, Sheffield 1997). Breeding Bird Survey data for the Columbia Plateau indicate increasing populations, although this estimate is considered imprecise (Sauer et al. 2001).

HABITAT REQUIREMENTS

Burrowing owls inhabit open, dry areas in well-drained grasslands, shrub-steppe, prairies and deserts (Martin 1973). They also nest on agricultural lands and suburban areas (Haug et al. 1993). They use burrows for nesting, shelter, protection from predators and to reduce exposure to extreme temperatures (Zarn 1974, Winchell 1994). Although they are capable of digging, burrowing owls usually depend on abandoned burrows excavated by burrowing rodents such as prairie dogs (*Cynomys* spp.) and ground squirrels (*Citellus* spp.), or by larger mammals such as badgers (*Taxidea taxus*), foxes (*Vulpes* spp.) or coyotes (*Canis latrans*) (Mutafov 1992). In the Pacific Northwest, nesting burrowing owls often use unoccupied badger dens (Green and Anthony 1989).

The primary habitat characteristics preferred by burrowing owls include a complex of available burrows, short and/or sparse vegetation that provides good visibility, and adequate populations of prey species (Haug et al. 1993). Soil type affects the life and reusability of nesting burrows (Green and Anthony 1989, Holmes et al., in press). Specifically, the friable nature of sandy soils results in relatively high rates of burrow failure due to erosion and trampling by livestock. Silt-loam soils are more structurally stable and less likely to fail than are soils with a sand component.

Although badgers provide nesting sites for burrowing owls in Washington, they also are one of the owl's main predators (Haug et al. 1993). Burrowing owls line their nests with shredded livestock or ungulate dung, which may reduce nest predation by masking the owl's scent (Martin 1973, Zarn 1974, Green and Anthony 1989). However, several research teams have recently examined the use of dung by owls and found that this conclusion may not be true (C. Conway, personal communication).

Burrowing owls appear at breeding sites in February, and hatchlings emerge in May (C. Conway, personal communication). Recent observations suggest that resident owls initiate nesting earlier than migratory owls (C. Conway, personal communication). Incubation lasts approximately 28 days, and owlets emerge from the burrow about 2 weeks after hatching. At 2 to 3 weeks, the young begin to use other burrows near their nest burrow (C. Conway, personal observation). Paired owls will use up to 10 auxiliary burrows that are within 90 m (300 ft) of their primary nesting burrow (Climpson 1977). These auxiliary burrows are used to provide escape cover from predators, as secondary burrows for fledgling owlets and as alternates if the primary nest becomes heavily infested with parasites (Winchell 1994). Nests may also be located in natural cavities in small rock outcrops (Rich 1986). Nest burrows are often reused in successive years (Haug et al. 1993, Lutz and Plumpton 1999). There are no known records for a second brood during the breeding season in Washington (Haug et al. 1993).

The number of available burrows is not the only factor owls use to select a breeding site. They also look for areas that are open, with short and/or sparse vegetation and good horizontal visibility to see predators and locate prey (Green and Anthony 1989). In areas containing shrubs, they choose nesting burrows located near perches (Martin 1973, Green and Anthony 1989). Burrowing owls hunt by chasing prey items on foot or by catching them in the air (Haug et al. 1993). Their diet changes throughout the day, with insects most often caught during daylight and mammals preyed upon after dark (Martin 1973, Plumpton and Lutz 1993a).

Food availability and quality is likely to affect nesting densities of these owls for a given location (Desmond and Savidge 1996). Burrowing owls are opportunistic feeders, but they consume mostly insects and mammals (Green and Anthony 1989). Other prey species include birds, amphibians and reptiles (Zarn 1974, Gleason and Craig 1979, Mutafov 1992, Haug et al. 1993). Green and Anthony (1989) found a seasonal variation in diets, with rodents making up most of the owl's diet in the spring, and then shifting their diet almost exclusively to insects during the summer.

LIMITING FACTORS

Human activities that eliminate nesting and foraging habitat are likely the primary cause of this species decline (Haug et al. 1993, Sheffield 1997, Belthoff and King 2002). Intensive cultivation of shrub-steppe, grasslands and native prairies has long been recognized as a primary cause of the declining burrowing owl population (Haug et al. 1993). Agriculture and other development also expose owls to pesticides and increase their vulnerability to predation (Haug et al. 1993, Sheffield 1997). Although some burrowing owls take advantage of crop fields to exploit abundant food sources during the winter, intensive cultivation of native grasslands is a suggested cause of declines in populations of breeding owls (Haug et al. 1993). The burrowing owl is also limited by the availability of mammal burrows. Additional mortality has been attributed to collisions with automobiles and shooting (Butts 1973, Haug et al. 1993).

Habitat Alteration

Although not all nesting burrowing owls use multiple burrows, some nests are associated with multiple burrows in close proximity to one another (Holmes et al., in press). The availability of burrows is reduced directly by destroying them (e.g., trampling of burrows by livestock and diking/tilling) and indirectly by eliminating or reducing the numbers of the animals that excavate the burrows (Haug et al. 1993). Burrow destruction by humans and dogs also occur. Thomsen (1971) estimated that 65% of the damaged burrows at her study site were caused by humans and 20% by domestic dogs. Large-scale efforts to control burrowing mammal populations can harm burrowing owls in areas where they rely on rodent burrows (Butts 1973, Holroyd et al. 2001).

Pesticides

Pesticides (specifically insecticides and rodenticides) can harm burrowing owls by causing direct mortality or sublethal effects such as decreased body weight and low reproductive success (Haug et al. 1993, Sheffield 1997, Holroyd et al. 2001). Indirect problems such as a decrease in available prey also occurs (James and Fox 1987). Burrowing owls are susceptible to secondary poisoning from insecticides and rodenticides because they feed on carcasses of poisoned prey species (Haug et al. 1993).

Direct exposure to carbofuran, a carbamate insecticide used to control grasshoppers, can significantly impact the survival and reproductive success of burrowing owls (James and Fox 1987, Mutafov 1992). When carbofuran (Furadan 480F) was applied over nest burrows, the number of young was reduced by 83% and nesting success was reduced by 82% (Mutafov 1992). In some instances, sprayed areas were less frequently occupied the following year by burrowing owls.

James et al. (1990) studied the control of ground squirrels with strychnine and its impacts on burrowing owls in southern Saskatchewan. They found, at least in the short term, no direct lethal effects on breeding burrowing owls. Adult survival, breeding success and chick weights were virtually the same in both treated and untreated areas. However, adult owls weighed significantly less in the treated versus the control sites, suggesting a sublethal effect on the species. Winchell (1994) states that nuisance rodent species can be baited or fumigated safely if care is taken not to treat burrows used by owls. However, even if burrowing owls escape inadvertent poisoning, their numbers will likely decrease because fewer burrowing mammals are creating new excavations for owl nesting and because of reduced available prey (C. Conway, personal communication).

Other Human Disturbances

Burrowing owls seem tolerant of human presence. However, Millsap and Bear (1988) found that reproductive success of burrowing owls in Florida was less at sites where home construction was taking place than at sites adjacent to construction, or where construction was absent.

Burrowing owls can also apparently become accustomed to vehicular traffic. However, nesting near roads may increase burrowing owl road kills. Plumpton and Lutz (1993b) found that vehicular traffic on roads near nesting sites did not create disturbance significant enough to influence the behavior of nesting owls. Unfortunately, owls frequently sit and hunt on roads at night, and collisions with vehicles occur frequently (Mutafov 1992).

Competition

Green and Anthony (1989) conducted a two-year study of 76 burrowing owl nests in the north-central Oregon and found nesting success to be only 57% the first year and 50% the second. Desertion was the primary reason for nest failure, which may have been related to the proximity of other nesting owls. Nestling mortality was greatest when pairs nested closer than 110 m (360 ft) apart. Green and Anthony (1989) suggested that in the Columbia Basin, nest sites were both clumped and scarce, forcing owls to nest too closely. If food sources are scarce, competition may then be strong enough to force some pairs to abandon their nests. Bryant (1990) found that competition might also limit the nesting success and return rates of burrowing owls reintroduced to areas they historically occupied. Owls returning to their breeding grounds selected burrows as far away from neighboring owls as possible.

MANAGEMENT RECOMMENDATIONS

Protect Existing Habitat

Important ecological characteristics of areas used by burrowing owls should be maintained (Sheffield 1997). This includes preserving areas of native vegetation (e.g., shrub-steppe) and protecting burrowing mammal species (e.g., ground squirrels, badgers that create nesting habitat) for burrowing owls (Holroyd et al. 2001, Holmes et al., in press). Colonies of burrowing mammals should be preserved in areas where burrowing owls occur.

Nesting and satellite burrows should be protected from disturbance (Winchell 1994). Problems such as agricultural equipment collapsing burrow entrances and the inadvertent application of pesticides to occupied burrows can be reduced by placing markers near the burrows (Zarn 1974). Rangelands with sandy soils are especially prone to destruction of burrows by livestock (Holmes et al., in press). Where damage to burrows is likely or occurring, changes should be made in stocking rates, duration and/or season of grazing.

Activities such as oil and gas exploration and development, or other sources of human disturbance, should be restricted within 0.8 km (0.5 mi) of burrowing owl nests between 15 February and 25 September (T. Lloyd, personal communication; C. Conway personal communication). Direct destruction of burrows through chaining (dragging a heavy chain over an area to remove shrubs), cultivation, and urban, industrial, or agricultural development should be entirely avoided. Irrigation troughs should be regularly maintained because burrows often flood as a result of leaking irrigations systems (C. Conway, personal communication).

Local and regional government programs should be reviewed to ensure they address long-term conservation of burrowing owl habitat (Holroyd et al. 2001). Specifically, critical areas protection that fall under Washington's Growth Management Act could be a useful tool to conserve species, such as the burrowing owl, that are limited by loss of native habitat. Local development regulations could be designed to require mitigation and provide incentives to reduce potential impacts to this species resulting from proposed projects in owl habitat. Many resource agencies, including WDFW, have staff that can provide recommendations to assist in critical areas planning.

Pesticides

Insecticides and rodenticides are likely to harm burrowing owls directly through poisoning as well as indirectly by reducing populations of burrowing mammals (Holroyd et al. 2001). Therefore, it is recommended that alternatives should be researched thoroughly before resorting to their use. If pesticide use is planned for areas where burrowing owls occur, refer to Appendix A for contacts that can help evaluate pesticides and their alternatives.

Insecticides used in grasshopper control programs, especially carbofuran, have been shown to reduce reproductive productivity in burrowing owls. Carbofuran should not be applied within 250 m (820 ft) of active burrowing owl nests (Haug et al. 1993). Active burrowing owl nests should not be directly sprayed with any pesticide (James and Fox 1987, Lynch 1987).

Fumigation, treated bait or other means of poisoning nuisance animals should not be used in areas where burrowing owls occur. Burrowing owls are likely to scavenge the carcasses of poisoned rodents, making the owls potentially vulnerable to indirect poisoning (Sheffield 1997).

In cases where there are no alternatives to controlling burrowing mammals with poisoned bait or fumigation, thoroughly survey the area for burrowing owls during the nesting season (March through September) (Zarn 1974). Identify and mark nesting and satellite burrows by observing sentry owls, owl droppings and tracks, pellets, and dry, shredded animal dung. The use of treated grain to poison mammals should be restricted to the months of January and February (Butts 1973, Zarn 1974).

Mitigation

Artificial nest burrows are useful for expanding the capacity of existing nesting sites, and in transplant operations where burrowing owls are reintroduced into parts of their former range (Thomson 1988). Artificial burrows can also give researchers opportunities to study burrowing owl nesting ecology without destroying existing burrows (Bryant 1990, Olenick 1990, Haug et al. 1993). Dring (2000) and Green and Anthony (1997) have published papers that touch upon the design and use of artificial nesting burrows. State or federal wildlife agencies should be consulted for additional guidance prior to using artificial nesting burrows.

Artificial perches such as fence posts or stakes can be used in areas where vegetation is greater than 5 cm (2 in) tall (Green and Anthony 1989). Several perches scattered throughout the nesting area should benefit this species. Additionally, these and other mitigation measures could be incorporated into local critical areas ordinances where this species exists.

REFERENCES

Belthoff, J.R., and R. A. King. 2002. Nest-site characteristics of burrowing owls in the Snake River Birds of Prey National Conservation Area, Idaho, and applications to artificial burrow installation. Western North American Naturalist 62:112-119.

Bent, A. C. 1961. Life histories of American birds of prey. Volume 2. Dover Publishing, New York, New York, USA.

Bryant, A. A. 1990. Burrowing owls (*Athene cunicularia*) in the Columbia Basin, Washington: results of the 1990 inventory. Okanogan Region Wildlife Heritage Fund Society, Kelowna, British Columbia, Canada.

Butts, K. O. 1973. Life history and habitat requirements of burrowing owls in western Oklahoma. Thesis, Oklahoma State University, Stillwater, Oklahoma, USA.

Climpson, J. T. 1977. Feeding ecology and selected other aspects of the behavior and ecology of the burrowing owl (*Speotyto cunicularia*). Thesis, Washington State University, Pullman, Washington, USA.

Conway, C. J., L. Ellis, V. Garcia, and M. Smith. 2002. Population ecology and habitat use of burrowing owls in eastern Washington. Annual Report, USGS, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, Arizona, USA.

Desmond, M. J., and J. A. Savidge. 1996. Factors influencing burrowing owl (*Speotyto cunicularia*) nest densities and numbers in western Nebraska. American Midland Naturalist 136:143-148.

Dring, T. P. 2000. Technical notes: burrowing owl nest box specifications and habitat management. USDA Natural Resource Conservation Service, Spokane, Washington, USA.

Gleason, R. L., and T. H. Craig. 1979. Food habits of burrowing owls in southeastern Idaho. Great Basin Naturalist 39:274-276.

Green, G. A., and R. G. Anthony. 1989. Nesting success and habitat relationships of burrowing owls in the Columbia Basin, Oregon. Condor 91:347-354.

____, ____. 1997. Ecological considerations for management of breeding burrowing owls in the Columbia Basin. Journal of Raptor Research 9:117-121.

Haug, E. A., B. A. Millsap, and M. S. Martell. 1993. Burrowing owl (*Speotyto cunicularia*). No. 61 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Holmes, A. L., G. A. Green, R. L. Morgan and K. B. Livezey. In Press. Burrowing owl nest success and burrow longevity in north-central Oregon. Western North American Naturalist.

Holroyd, G. L., and T. I. Wellicome. 1997. Report on the western burrowing owl (*Speotyto cunicularia*) conservation workshop. Pages 612-615 *in* J. R. Duncan, D. H. Johnson and T. H. Niccolls, editors. Biology and conservation of owls in the northern hemisphere. USDA Forest Service Publication NC-190, St. Paul, Minnesota, USA.

____, R. Rodriguez-Estrella, and S. R. Sheffield. 2001. Conservation of the burrowing owl in western North America: issues, challenges, and recommendations. Journal of Raptor Research 35:399-407.

James, P. C. 1992. Where do Canadian burrowing owls spend the winter? Blue Jay 50:93-95.

____, and T. J. Ethier. 1989. Trends in the winter distribution and abundance of burrowing owls in North America. American Birds 43:1224-1225.

____, and G. A. Fox. 1987. Effects of some insecticides on productivity of burrowing owls. Blue Jay 44:65-68.

____, and ____, and T. J. Ethier. 1990. Is the operational use of strychnine to control ground squirrels detrimental to

burrowing owls? Journal of Raptor Research 24:120-123.
Lutz, R. S., and D. L. Plumpton 1999. Philopatry and nest-site reuse by burrowing owls: implications for productivity. Journal of Raptor Research 33:149-153.
Lynch, W. 1987. Effects of some insecticides on productivity of burrowing owls. Blue Jay 45:65-71.
Martin, D. J. 1973. Selected aspects of burrowing owl ecology and behavior. Condor 75:446-456.
Millsap, B. A., and C. Bear. 1988. Cape Coral burrowing owl population monitoring. Annual Performance Report, Florida Game and Freshwater Fish Commission, Tallahassee, Florida, USA.
Mutafov, D. T. 1992. Does the labeling restriction on carbofuran containers help protect burrowing owls? Blue Jay 50:201-203.
Olenick, B. E. 1990. Breeding biology of burrowing owls using artificial nest burrows in southeastern Idaho. Thesis, Idaho State University, Pocatello, Idaho, USA.
Plumpton, D. L., and R. S. Lutz. 1993a. Prey selection and food habits of burrowing owls in Colorado. Great Basin Naturalist. 53:299-304.
____, and ____. 1993b. Influence of vehicular traffic on time budgets of nesting burrowing owls. Journal of Wildlife Management 57:612-616.
Rich, T. 1986. Habitat and nest-site selection by burrowing owls in the sagebrush steppe of Idaho. Journal of Wildlife Management 50:548-555.
Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American breeding bird survey, results and analysis 1966-2000. Version 2001.2. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.
Sheffield, S. R. 1997. Current status, distribution, and conservation of the burrowing owl (*Speotyto cunicularia*) in Midwestern and western North America. Pages 399-407 *In* USDA Forest Service General Technical Report NC-190, St. Paul, Minnesota, USA.
Thomsen, L. 1971. Behavior and ecology of burrowing owls on the Oakland municipal airport. Condor 73:177-192.
Thomson, K. A. 1988. Management of burrowing owls in Manitoba: population distribution and plan for recovery. Thesis, University of Manitoba, Winnipeg, Manitoba, Canada.
Winchell, C. S. 1994. Natural history and protection of burrowing owls. Pages 83-86 *in* W. S. Halverson and A. C. Crabb, editors. Proceedings of the 16th Vertebrate Pest Conference. University of California, Davis, California, USA.
Zarn, M. 1974. Habitat management series for unique or endangered species: Report Number 11, Burrowing Owl (*Speotyto cunicularia hypugaea*). US Bureau of Land Management, Denver, Colorado, USA.

PERSONAL COMMUNICATIONS

Courtney Conway, Assistant Unit Leader-Wildlife
Arizona Cooperative Fish and Wildlife Research Unit
Tuscan, Arizona

Tracy Lloyd, Regional Habitat Program Manager
Washington Department of Fish and Wildlife
Ephrata, Washington

KEY POINTS

Habitat Requirements

- Burrowing owls inhabit open, dry areas in well-drained grasslands, shrub-steppe, prairies and deserts. They also nest on agricultural lands and suburban areas.
- Preferred characteristics of burrowing owl habitat include a complex of available burrows, short and/or sparse vegetation that provides good visibility, and an adequate availability of prey.

Management Recommendations

- Preserve areas of native vegetation (e.g., shrub-steppe) used by the burrowing owl.
- Protect populations of badgers and other burrowing mammals that provide nesting habitat for burrowing owls.
- Direct local and regional government programs and policies (e.g., critical areas regulations) to ensure the survival of species, such as the burrowing owl, that are limited by loss of native habitat.
- Refer to Appendix A for contacts that should be used when evaluating pesticides and their alternatives. Insecticides and rodenticides have the potential to harm burrowing owls, and it is recommended that alternatives should be carefully considered before resorting to their use.
- Carbofuran should not be applied within 250 m (820 ft) of active burrowing owl nests. Active burrowing owl nests should not be directly sprayed with any pesticide.
- Fumigation, treated bait or other means of poisoning nuisance animals should not be used in areas where burrowing owls occur. Burrowing owls are likely to scavenge the carcasses of poisoned rodents and are potentially vulnerable to secondary poisoning.
- If there are no alternatives to controlling burrowing mammals with poisoned bait or fumigation, survey for burrowing owls during the nesting season (March through September). Identify and mark burrows used by owls by observing sentry owls, owl droppings and tracks, pellets, prey remains and burrows lined with dried animal feces.
- If all alternatives have been exhausted, poisoning of burrowing mammal colonies with treated grain should be restricted to January and February to minimize harmful effects to burrowing owls.
- Protect both nesting and auxiliary burrows from disturbance. Markers placed at burrows can direct earth moving and other heavy equipment away from burrowing areas and help prevent the collapse of underground passages. In addition, markers can help direct pesticide applications away from occupied burrows.
- Where damage to burrows from livestock trampling is likely or is occurring already, changes should be made in stocking rates, duration and/or season of grazing.
- Restrict activities such as oil and gas exploration and development or other sources of human disturbance within 0.8 km (0.5 mi) of burrowing owl nests between 15 February and 25 September. Direct destruction of burrows by urban, industrial or agricultural development should be avoided entirely.
- Artificial nest burrows can be used to expand the capacity of existing nesting sites and can aid in the reintroduction of owls into parts of their former range.
- Artificial perches, such as fence posts or stakes can be used in areas where vegetation is greater than 5 cm (2 in) tall. Several perches scattered throughout the nesting area might be required to benefit this species.

Flammulated Owl

Otus flammeolus

Last updated: 2003

Written by David W. Hays and Elizabeth A. Rodrick

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Flammulated owls are found in mountainous areas of western North America from Guatemala to Canada (American Ornithologists' Union 1983).

In Washington, they are breeding residents along the eastern slope of the Cascades, Okanogan Highlands and Blue Mountains. (see Figure 1; Smith et al. 1997).

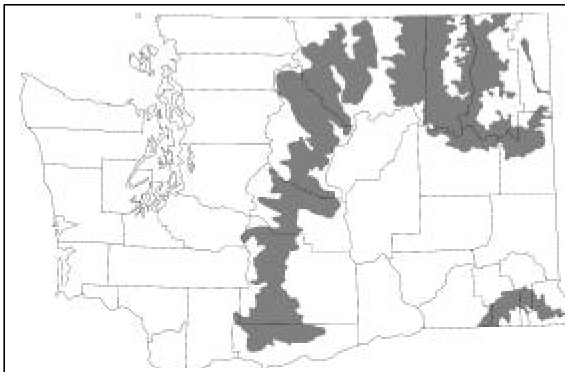


Figure 1. General range of the flammulated owl, *Otus flammeolus*, in Washington. Map derived from GAP Analisys of Washington (Smith et al. 1997).

RATIONALE

The flammulated owl is a State Candidate species. Limited research on the flammulated owl indicates that its demography and life history, coupled with narrow habitat requirements, make it vulnerable to habitat changes. The mature and older forest stands that are used as breeding habitat by the flammulated owl have changed during the past century due to fire management and timber harvest.

HABITAT REQUIREMENTS

Flammulated owls are typically found in mid-elevation coniferous forests containing mature to old, open canopy yellow pine (ponderosa pine [*Pinus ponderosa*] and Jeffrey pine [*Pinus jeffreyi*]), Douglas fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*) (Bull and Anderson 1978, Goggans 1986, Howie and Ritchie 1987, Reynolds and Linkhart 1992, Powers et al. 1996). In central Colorado, Linkhart and Reynolds (1997) reported that 60% of the habitat within the area defended by territorial males consisted of old (200-400 year) ponderosa pine/Douglas-fir forest. Territories most consistently occupied by breeding pairs (>12 years) contained the greatest (>75%) amount of old ponderosa pine/Douglas-fir forest. Marcot and Hill (1980) reported that California black oak (*Quercus kellogii*) and ponderosa pine occurred in 67% and 50%, respectively, of the flammulated owl nesting territories they studied in northern California. In northeastern Oregon, Bull and Anderson (1978) noted that ponderosa pine was an overstory species in 73% of flammulated owl nest sites. Powers et al. (1996) reported that ponderosa pine was absent from their flammulated owl study site in Idaho and that Douglas-fir and quaking aspen (*Populus tremuloides*) accounted for all nest trees.

The owls nest primarily in cavities excavated by flickers (*Colates* spp.), hairy woodpeckers (*Picoides villosus*), pileated woodpeckers (*Dryocopus pileatus*), and sapsuckers (*Sphyrapicus* spp.) (Bull et al. 1990, Goggans 1986, McCallum 1994). Bull et al. (1990) found that flammulated owls used pileated woodpecker cavities with a greater frequency than would be expected based upon available woodpecker cavities. There are only a few reports of this owl using nest boxes (Bloom 1983). Reynolds and Linkhart (1987) reported occupancy in 2 of 17 nest boxes put out for flammulated owls.

In studies from northeastern Oregon and south central Idaho, nest sites were located 5-16 m (16-52 ft) high in dead wood of live trees, or in snags with an average diameter at breast height (dbh) of >50 cm (20 in) (Goggans 1986, Bull et al. 1990, Powers et al. 1996). Most nests were located in snags. Bull et al. (1990) found that stands containing trees greater than 50 cm (20 in) dbh were used more often than randomly selected stands. Reynolds and Linkhart (1987) suggested that stands with trees >50 cm (20 in) were preferred because they provided better habitat for foraging due to the open nature of the stands, allowing the birds access to the ground and tree crowns. Some stands containing larger trees also allow more light to the ground that produces ground vegetation, serving as food for insects preyed upon by owls (Bull et al. 1990).

Both slope position and slope aspect have been found to be important indicators of flammulated owl nest sites (Goggans 1986, Bull et al. 1990). In general, ridges and the upper third of slopes were used more than lower slopes and draws (Bull et al. 1990). It has been speculated that ridges and upper slopes may be preferred because they provide gentle slopes, minimizing energy expenditure for carrying prey to nests. Prey may also be more abundant or at least more active on higher slopes because these areas are warmer than lower ones (Bull et al. 1990).

Breeding occurs in mature to old coniferous forests from late April through early October. Nests typically are not found until June (Bull et al. 1990). The peak nesting period is from mid-June to mid-July (Bent 1961). Mean hatching and fledging dates in Idaho were 26 June and 18 July, respectively (Powers et al. 1996).

In Oregon, individual home ranges averaged about 10 ha (25 ac) (Goggans 1986). Territories are typically found in core areas of mature timber with two canopy layers present (Marcot and Hill 1980). The uppermost canopy layer is formed by trees at least 200 years old. Core areas are near, or adjacent to clearings of 10-80% brush cover (Bull and Anderson 1978, Marcot and Hill 1980). Linkhart and Reynolds (1997) found that flammulated owls occupying stands of dense forest were less successful that owls whose territories contain open, old pine/fir forests.

Day roosts are located in mature mixed conifer stands with dense, multi-layered canopies (Bull and Anderson 1978, Goggans 1986). Dense stands presumably provide cover from weather and predators, and they may form core areas of the owls' territories.

Flammulated owls are presumed to be migratory in the northern part of their range (Balda et al. 1975), and winter migrants may extend to neotropical areas in central America. In Oregon, they arrive at the breeding sites in early May and begin nesting in early June; young fledge in July and August (Goggans 1986; E. Bull, personal communication). In Colorado, owlets dispersed in late August and the adults in early October (Reynolds and Linkhart 1987).

Flammulated owls are entirely insectivores; nocturnal moths are especially important during spring and early summer (Reynolds and Linkhart 1987). As summer progresses and other prey become available, lepidopteran larvae, grasshoppers, spiders, crickets, and beetles are added to the diet (Johnson 1963, Goggans 1986). In Colorado, foraging occurred primarily in old ponderosa pine and Douglas-fir with an average tree age of approximately 200 years (Reynolds and Linkhart 1992). Old growth ponderosa pine were selected for foraging, and young Douglas-firs were avoided. Flammulated owls principally forage for prey on the needles and bark of large trees. They also forage in the air, on the ground, and along the edges of clearings (Goggans 1986; E. Bull, personal communication; R. Reynolds, personal communication). Grasslands in and adjacent to forest stands are thought to be important foraging sites (Goggans 1986). However, Reynolds (personal communication) suggests that ground foraging is only important from the middle to late part of the breeding season, and its importance may vary annually depending upon the abundance of ground prey. Ponderosa pine and Douglas-fir were the only trees selected for territorial singing in male defended territories in Colorado (Reynolds and Linkhart 1992).

LIMITING FACTORS

Availability of suitable nest cavities and/or arthropod prey in ponderosa pine or mixed conifer forests are likely limiting. Reasons for the apparent narrow elevation range exhibited by flammulated owls are not known, but reasons are likely related to food and ecological tolerances (R. Reynolds, personal communication).

MANAGEMENT RECOMMENDATIONS

Creation of large areas of even-aged timber is likely detrimental to flammulated owls. Uneven stands of open mature and old timber located near brushy clearings provide good habitat for flammulated owls. The selection for mature to old-growth ponderosa pine/Douglas-fir forests in areas where owls have been studied throughout the west indicates that this habitat may also be important in Washington. Marcot and Hill (1980) noted the potential importance of old black oak trees to flammulated owls in California because of their numerous natural cavities. Washington's white oak/conifer forests should be surveyed for these owls.

All conifers and hardwoods having natural or excavated cavities in and adjacent to flammulated owl territories should be left undisturbed (Marcot and Hill 1980). Bull et al. (1990) suggests leaving large snags and trees (>50 cm [20 in] dbh and 6 m [20 ft] tall) along ridge-tops, and south and east facing slopes in ponderosa pine/Douglas-fir or grand fir forest types. Reynolds (personal communication) recommends leaving at least 5 snags/ha (2/ac) in ponderosa pine habitat.

Future nest snags should be recruited by continually retaining large, mature trees in or adjacent to suitable flammulated owl habitat (Marcot and Hill 1980). Where snags are lacking, large trees can be topped to promote woodpecker use and cavity formation. Fuelwood collection should be limited where flammulated owls occur because this practice eliminates nest snags.

Areas with brushy understory vegetation may provide insect prey and feeding cover when flammulated owls forage near the ground. Therefore, forest practices (e.g., application of herbicide) that remove brush from clearings adjacent to flammulated owl territories should be avoided. Application of insecticides that affect the owl's prey species should not occur within close proximity to flammulated owl home range areas, approximately 305 m (1,000 ft) from the nest. If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A for contacts to assist in assessing the use of chemicals and their alternatives.

REFERENCES

American Ornithologists' Union. 1983. Checklist of North American birds. Sixth edition. American Ornithologists' Union, Baltimore, Maryland, USA.

Balda, R. P., B. C. McKnight, and C. D. Johnson. 1975. Flammulated owl migration in the southwestern United States. Wilson Bulletin 87:520-530.

Bent, A. C. 1961. Life histories of North American birds of prey. Dover Publishing, Incorporated, New York, New York, USA.

Bloom, P. H. 1983. Notes on the distribution and biology of the flammulated owl in California. Western Birds 14:49-52.

Bull, E. L., and R. G. Anderson. 1978. Notes on flammulated owls in northeastern Oregon. Murrelet 59:26-28.

____, Wright, A. L., and M.G. Henjum. 1990. Nesting habitat of flammulated owls in Oregon. Journal of Raptor Research 24:52-55.

Goggans, R. 1986. Habitat use by flammulated owls in northeastern Oregon. Thesis, Oregon State University, Corvallis, Oregon, USA.

Howie, R. R., and R. Ritcey. 1987. Distribution, habitat selection, and densities of flammulated owls in British Columbia. Pages 249-254 *in* R. W. Nero, R. J. Clark, R. J. Knapton, and R. H. Hamre, editors. Biology and conservation of northern forest owls. USDA Forest Service General Technical Report RM-142.

Johnson, N. K. 1963. The supposed migratory status of the flammulated owl. Wilson Bulletin 75:174-178.

Linkhart, B. D., and R. T. Reynolds. 1997. Territories of flammulated owls: is occupancy a measure of habitat quality? Pages 250-254 *in* J. R. Duncan, D. H. Johnson, and T. H. Nicholls, editors. Biology and conservation of owls of the northern hemisphere: second international symposium. USDA Forest Service General Technical Report NC-190.

Marcot B. G., and R. Hill. 1980. Flammulated owls in northwestern California. Western Birds 11:141-149.

McCallum, D. A. 1994. Review of technical knowledge: flammulated owls. Pages 14-46 *in* G. D. Hayward and J. Verner, technical editors. Flammulated, boreal, and great gray owls in the United States: A technical conservation assessment. USDA Forest Service General Technical Report RM-253.

Powers, L. R., A. Dale, P. A. Gaede, C. Rodes, L. Nelson, J. J. Dean, and J. D. May. 1996. Nesting and food habits of the flammulated owl (*Otus flammeolus*) in southcentral Idaho. Journal of Raptor Research 30:15-20.

Reynolds, R. T., and B. D. Linkhart. 1987. The nesting biology of flammulated owls in Colorado. Pages 239-248 *in* R. W. Nero, R. J. Clark, R. J. Knapton, and R. H. Hamre, editors. Biology and conservation of northern forest owls. USDA Forest Service General Technical Report RM-142.

____, and ____. 1992. Flammulated owl in ponderosa pine: evidence of preference for old growth. Pages 166-169 *in* M.R. Kaufman, W.H. Moir, and R.L. Bassett, technical coordinators. Proceedings of the workshop on old-growth in the Southwest and Rocky Mountain Region. Portal, Arizona, USA.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington GAP Analysis - Final Report Seattle Audubon Society Publication in Zoology Number 1, Seattle, Washington, USA.

PERSONAL COMMUNICATIONS

Evelyn L. Bull, Biologist
USDA Forest Service
Forestry and Range Science Lab
La Grande, Oregon

Richards T. Reynolds, Research Wildlife Biologist
USDA Forest Service
Rocky Mountain Forest and Range Experiment Station
Fort Collins, Colorado

KEY POINTS

Habitat Requirements

- Associated with mid-elevation coniferous forest.
- Nest and roost in mature and old, multi-storied stands.
- Nest in cavities.
- Insectivorous, forage in open areas.

Management Recommendations

- Maintain stands of open, mature timber near brushy clearings.
- Retain all trees with cavities in or adjacent to flammulated owl territories.
- Maintain at least 5 snags/ha (2/ac) >50 cm (20 in) dbh and >6 m (20 ft) tall in ponderosa pine forests.
- Ensure snag recruitment by retaining large, mature trees in or adjacent to flammulated owl habitat.
- Where snags are lacking, top large trees to promote woodpecker use and cavity formation.
- Limit fuelwood collection where flammulated owls occur.
- Leave brush in clearings near owl territories.
- Do not apply insecticides or herbicides in areas used by owls.

Vaux's Swift

Chaetura vauxi

Last updated: 2002

Written by Jeffrey C. Lewis, Morie Whalen, and Ruth L. Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Vaux's swifts breed from southeastern Alaska, northwestern and southern British Columbia, western Montana, and northern Idaho south to central California and west to the Pacific Coast. They winter from northern Mexico south to Central America and Venezuela (Bull and Collins 1993, DeGraaf and Rappole 1995, Sibley 2000).

Vaux's swifts are summer residents throughout wooded areas of Washington (see Figure 1; Hoffman 1927, Jewett et al. 1953, Manuwal and Huff 1987, Lundquist and Mariani 1991). They usually arrive in Washington around early May and remain until September (Hoffman 1927). Breeding populations may occur in forested habitats throughout the state (Kitchin 1949, Jewett et al. 1953, Thomas et al. 1979, Brown 1985).

Figure 1. Range of the Vaux's swift, *Chaetura* vauxi, in Washington. Map derived from Washington Department of Fish and Wildlife data files and GAP Analysis of Washington.

RATIONALE

The Vaux's swift is a State Candidate species associated with old-growth and mature forests in the Cascade Range (Manuwal and Huff 1987, Lundquist and Mariani 1991), Olympic Peninsula (Kitchin 1949), and Blue Mountains (Jewett et al. 1953). Throughout their breeding range they are highly dependent on large hollow trees and snags for nesting and roosting (Baldwin and Zaczkowski 1963, Bull 1991, Bull and Cooper 1991). Loss of old-growth and mature forested habitat in Washington (Harris 1984, Thomas et al. 1990) threaten Vaux's swift populations (Bull 1991, Bull and Hohmann 1993).

HABITAT REQUIREMENTS

Vaux's swifts are strongly associated with old-growth forests (Manuwal and Huff 1987, Gilbert and Allwine 1991, Huff and Raley 1991, Lundquist and Mariani 1991, Manuwal 1991, Bull and Hohmann 1993), nesting primarily in old-growth coniferous forests (Baldwin and Zaczkowski 1963, Bull and Cooper 1991, Bull and Hohmann 1993). However, the characteristics of the stand as a whole (i.e., age, canopy layering, stem density) may not be as critical as the availability of suitable nesting or roosting structures (Bull and Hohmann 1993). The availability of suitable nesting or roosting structures is suspected to be the limiting factor for this species (Bull and Hohmann 1993). They require hollow chambers in large snags or live trees with broken tops for nesting and night roosting. The height where swifts nest in hollow trees or snags may vary, ranging from near base level (Baldwin and Zaczkowski 1963) to an average of 12 m (39 ft) (Bull and Cooper 1991). Bull and Cooper (1991) found that nest trees averaged 25 m (82 ft) in height and 68 cm (27 in) in diameter at breast height (dbh). Many Vaux's swifts nest in hollow trees used by roosting pileated woodpeckers (*Dryocopus pileatus*). Swifts enter these trees through holes excavated by pileated woodpeckers. Without the aid of pileated woodpecker excavation, swifts would have no access to many hollow tree chambers (Bull and Collins 1993). Sterling and Paton (1996) suggested that Vaux's swifts may rely on pileated woodpeckers to create nesting habitat, potentially explaining the similar ranges of these two species in California.

Vaux's swifts have been frequently observed nesting or roosting in chimneys (Jewett et al. 1953, Huey 1960, Griffee 1961, Baldwin and Hunter 1963, Thompson 1977, Sterling and Paton 1996). Historical documentation indicates they prefer older construction, brick chimneys (Huey 1960, Baldwin and Hunter 1963, Baldwin and Zaczkowski 1963, Bull and Collins 1993). Vaux's swifts have been reported using chimneys at least 6.2 m (20 ft) in height, with openings ranging from 23 cm x 23 cm (9 in x 9 in) to 36 cm x 41 cm (14 in x 16 in), securing their nests in the chimney corners (Griffee 1961, Baldwin and Hunter 1963, Thompson 1977). Griffee (1961) observed up to 5 nesting pairs per chimney; however, 1 nest per chimney or tree is typical (Baldwin and Zaczkowski 1963, Thompson 1977, Bull and Collins 1993). Although chimneys are used by this species, hollow trees are favored by nesting and roosting swifts making them more vulnerable to the loss of old-growth forests as opposed to the loss of suitable artificial structures (Bull and Collins 1993).

Vaux's swifts feed exclusively while flying. Their diet consists primarily of flying insects and they forage mainly within a 0.40 km (0.25 mi) radius of the nest site when feeding their young (Bull and Beckwith 1993). Forests at various stages of development, grasslands and aquatic habitats are all used for foraging (Bull and Beckwith 1993).

LIMITING FACTORS

The strong connection of this species to old-growth forests suggest that availability of this type of forested habitat and its associated features (e.g., large, hollow snags and live trees) limit the swift's distribution and abundance during breeding season.

MANAGEMENT RECOMMENDATIONS

Vaux's swifts are found at their highest densities in old-growth forested habitat (Carey 1989, Carey et al. 1991, Gilbert and Allwine 1991, Huff and Raley 1991, Lundquist and Mariani 1991, Manuwal 1991, Bull and Hohmann 1993). The higher abundance of large, hollow snags and live trees appear to explain the greater density of swifts in old-growth versus younger forested stands (Bull and Collins 1993). Protection of existing old-growth should benefit Vaux's swifts, along with managing forest stands on long rotations (>200 years) and maintaining large hollow snags and live trees (Cline et al. 1980, Bull and Collins 1993, Bull and Blumton 1997). Large snags and live trees intended for future snag replacement should be retained and adequately distributed in harvest units (Bull and Collins 1993). Leave all hollow snags and live trees intact [preferably >50 cm (20 in) dbh]. Large defective trees, especially those showing signs of decay such as top rot, broken tops, fungal conks, dead branch stubs, or other defects, should be retained (Cline et al. 1980, Neitro et al. 1985).

Avoid disturbing chimneys that are occupied by nesting or roosting Vaux's swifts during the breeding season or during migration (early May - September). Chimneys are becoming less accessible because insulated pipe are replacing many old brick design, and others are covered with screen spark-arresters (Bull and Collins 1993). The retention of traditional chimney designs are preferred by nesting and roosting swifts. However, safe design should also be accounted for during chimney construction and modification.

Insecticides can greatly reduce Vaux's swift's primary food source and are a risk to swift populations (Brown 1985). All insecticide use should be avoided in or near nests and roosts. Organochlorine, organophosphate, and carbamate insecticides can be highly toxic to birds

(McEwen et al. 1972, Grue et al. 1983, Grue et al. 1986, Smith 1987). Synthetic pyrethroid insecticides (e.g., permethrin) may be an alternative to these compounds outside of snag-rich habitat, because these chemicals are not persistent in the environment or toxic to birds at recommended concentrations. However, synthetic pyrethroids are highly toxic to aquatic invertebrates and fish (Grue et al. 1983, Smith and Stratton 1986). Refer to Appendix A for contacts to assess pesticides, herbicides, and their alternatives.

Appropriate buffer widths for insecticide application near sensitive riparian and wetland areas range from 31-500 m (100-1,640 ft) (Kingsbury 1975, Payne et al. 1988, Terrell and Bytnar-Perfetti 1989). Buffer width calculations for insecticide application adjacent to snag-rich habitat should take into account the droplet size, volume of the compound and weather conditions that could influence wind drift (Kingsbury 1975, Brown 1978, Payne et al. 1988). Maintain a buffer of 500 m (1,640 ft) (Kingsbury 1975) from snag-rich areas when spraying insecticides (Brown 1978, Smith 1987).

REFERENCES

Baldwin, P., and W. Hunter. 1963. Nesting and nest visitors of Vaux's swift in Montana. Auk 80:81-85.

____, and N. Zaczkowski. 1963. Breeding biology of the Vaux's swift. Condor 65:400-406.

Brown, A. W. A. 1978. Ecology of pesticides. John Wiley and Sons, New York, New York, USA.

Brown, E. R. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Number 2, USDA Forest Service, PNW #R6-F&WL-192-1985, Portland Oregon, USA.

Bull, E. L. 1991. Summer roosts and roosting behavior of Vaux's swifts in old-growth forests. Northwest. Naturalist 72:78-82.

____, and H. D. Cooper. 1991. Vaux's swift nests in hollow trees. Western Birds 22:85-91.

____, and R. C. Beckwith. 1993. Diet and foraging behavior of Vaux's swift in northeastern Oregon. Condor 95:1016-1023.

____, and C. T. Collins. 1993. Vaux's swift (*Chaetura vauxi*). Number 77 *in* A. Poole and F. Gill, editors. The Birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

____, and J. E. Hohmann. 1993. The association between Vaux's swifts and old growth forests in northeastern Oregon. Western Birds 24:38-42.

____, and A. K. Blumton. 1997. Roosting behavior of postfledgling Vaux's swift in northeastern Oregon. Journal of Field Ornithology 68:302-305.

Carey, A. B. 1989. Wildlife associated with old-growth forests of the Pacific Northwest. Natural Areas Journal 9:151-162

____, M. M. Hardt, S. P. Horton, and B. L. Biswell. 1991. Spring bird communities in the Oregon Coast Range. Pages 123-141 *in* L. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service General Technical Report PNW-GTR-285, Portland, Oregon, USA.

Cline, S. P., A. B. Berg, and H. M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. Journal of Wildlife Management 44:773-786.

DeGraaf, R. M., and J. H. Rappole. 1995. Neotropical Migratory Birds: natural history, distribution, and population changes. Comstock Publishing, Ithaca, New York, USA.

Gilbert, F. F., and R. Allwine. 1991. Spring bird communities in the Oregon Cascade Range. Pages 145-158 *in* L. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service General Technical Report PNW-GTR-285, Portland, Oregon, USA.

Griffee, W. E. 1961. Nesting of the northern Vaux's swift in the Willamette Valley. Murrelet 42:25-26.

Grue, C. E., W. J. Fleming, D. G. Busby and E. F. Hill. 1983. Assessing hazards of organophosphate pesticides to wildlife. Transactions of the North American Wildlife Natural Resource Conference 48:200-220.
____, L. R. DeWeese, P. Mineau, G. A. Swanson, J. R. Foster, P. M. Arnold, J. N. Huckins, P. J. Sheehan, W. K. Marshall, and A. P. Ludden. 1986. Potential impacts of agricultural chemicals on waterfowl and other wildlife inhabiting prairie wetlands: an evaluation of research needs and approaches. Transactions of the North American Wildlife Natural Resource Conference 51:357-383.
Harris, L. D. 1984. The fragmented forest. University of Chicago Press, Chicago, Illinois, USA.
Hoffman, R. 1927. Birds of the Pacific States. The Riverside Press, Cambridge, Massachusetts, USA.
Huey, L. M. 1960. Notes on Vaux's and chimney swifts. Condor 62:483.
Huff, M. H., and C. M. Raley. 1991. Regional patterns of diurnal breeding bird communities in Oregon and Washington. Pages 177-205 *in* L. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service General Technical Report PNW-GTR-285, Portland, Oregon, USA.
Jewett, S. G., W. P. Taylor, W. T. Shaw, and J .W. Aldrich. 1953. Birds of Washington State. University of Washington Press, Seattle, Washington, USA.
Kingsbury, P. D. 1975. Effects of aerial forest spraying on aquatic fauna. *in* M. L. Prebble, editor. Aerial control of forest insects in Canada. Department of the Environment, Ottawa, Ontario, Canada.
Kitchin, E. A. 1949. Birds of the Olympic Peninsula. Olympic Stationers, Port Angeles, Washington, USA.
Lundquist, R. W., and J. M. Mariani. 1991. Nesting habitat and abundance of snag-dependent birds in the southern Washington Cascade Range. Pages 221-240 *in* L. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service General Technical Report PNW-GTR-285, Portland, Oregon, USA.
Manuwal, D. A., and M. H. Huff. 1987. Spring and winter bird populations in a Douglas-fir forest sere. Journal of Wildlife Management 51:586-595.
____, 1991. Spring bird communities in the southern Washington Cascade Range. Pages 161-174 *in* L. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service General Technical Report PNW-GTR-285, Portland, Oregon, USA.
McEwen, L. C., C. E. Knitttle, and M. L. Richmond. 1972. Wildlife effects from grasshopper insecticides sprayed on short-grass range. Journal of Range Management 25:188-194.
Neitro, W. A., R. W. Mannan, D. Taylor, V. W. Binkley, B. C. Marcot, F. F. Wagner, and S. P. Cline. 1985. Snags. Pages 129-169 *in* E.R. Brown, editor. Management of wildlife and fish habitats in forests of western Oregon and Washington. Number 1 - Chapter Narratives. USDA Forest Service, PNW #R6-F&WL-192-1985, Portland, Oregon, USA.
Payne, N .J., B. V. Helson, K. M. S. Sundaram, and R. A. Flemming. 1988. Estimating bufferzone widths for pesticide applications. Pesticide Science 24:147-161.
Sibley, D. A. 2000. National Audubon Society the Sibley guide to birds. Alfred A. Knopf, New York, New York, USA.
Smith, G. J. 1987. Pesticide use and toxicology in relation to wildlife: organophosphorous and carbamate compounds. Research Publication Number 170, U.S. Fish and Wildlife Service, Washington, D.C.
Smith, T. M., and G. W. Stratton. 1986. Effects of synthetic pyrethroid insecticides on nontarget organisms. Residue Reviews 97:93-120.
Sterling, J., and P. W. C. Paton. 1996. Breeding distribution of Vaux's swift in California. Western Birds 27:30-40.
Terrell, C. R., and P. Bytnar-Perfetti. 1989. Water quality indicators guide: surface waters. SCS-TP-161, U.S. Soil Conservation Service, Washington, D.C.
Thomas, J. W., R. G. Anderson, C. Maser, and E. L. Bull. 1979. Snags. *in* J. W. Thomas, editor. Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. USDA Forest Service, Agricultural Handbook Number 553.
____, E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. Interagency scientific committee to address the conservation of the northern spotted owl. USDA Forest Service, Washington, D.C.
Thompson, B. C. 1977. Behavior of Vaux's swifts nesting and roosting in a chimney. Murrelet 58:73-77.

KEY POINTS

Habitat Requirements

- Vaux's swifts nest in hollow chambers created by decay within live or dead trees.
- Large hollow snags and live trees averaging 25 m (82 ft) tall, and 68 cm (27 in) dbh located in old-growth and mature forests are used for nesting. Many Vaux's swifts nest in hollow trees excavated by pileated woodpeckers.
- Overall stand characteristics (e.g., age, canopy layering, stem density) do not appear to be as important to Vaux's swifts as the availability of large, hollow snags and live trees.
- Vaux's swifts will nest/roost in unused brick chimneys with openings at least 23 cm x 23 cm (9 in x 9 in).

Management Recommendations

- Maintain existing old-growth as well as mature forest habitat. Manage stands on longer rotations (>200 years).
- Retain all large, hollow large snags and large "defective" live trees, especially in younger, managed stands.
- Avoid disturbance of chimneys that are occupied by nesting and roosting Vaux's swifts during the breeding season (early May - September).
- Retain traditional chimney designs for use by nesting and roosting swifts. However, safe design should also be strongly considered for chimney construction and modification.
- Avoid using insecticides in areas inhabited by Vaux's swifts. Refer to Appendix A for contacts to assess pesticides, herbicides, and their alternatives.
- Substitute with synthetic pyrethroid insecticides (e.g., permethrin) or diflubenzuron (e.g., dimilin). Restrict the use of organophosphorous, organochlorine, and carbamate compounds to locations outside of snag-rich areas, away from swift nests and roosts.
- Maintain a 500 m (1,640 ft) buffer around snag-rich areas when spraying insecticide and apply during appropriate weather to avoid wind drift.

Lewis' Woodpecker removed from Priority Habitat and Species list in 2018

Lewis' Woodpecker

Melanerpes lewis

Last updated: 2002

Written by Jeffrey C. Lewis, Morie Whalen, and Elizabeth A. Rodrick

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The Lewis' woodpecker breeds from British Columbia and southern Alberta, south to Utah and Colorado, and from South Dakota west to the Cascades. It is either a year-round resident or winters from Oregon south to Baja, California, and east to western Texas and Oklahoma (Tobalske 1997).

Historically, this woodpecker was known to breed throughout the Puget Trough, southwest Washington, and the Olympic Peninsula (Jewett et al. 1953, Jackman 1975, MacRoberts and MacRoberts 1976). Currently in Washington, Lewis' woodpeckers only breed east of the Cascades from the Columbia Gorge north, and east into the Okanogan highlands and northeast Washington (see Figure 1). Their present breeding range also includes the Blue Mountains (Tobalske 1997).

Figure 1. General range of the Lewis' woodpecker, *Melanerpes lewis*, in Washington. Map derived from the literature and WDFW data files.

RATIONALE

The Lewis' woodpecker is a State Candidate species. This species has shown a recent decline in the Western states, possibly due to competition for snags and nest cavities and loss of their historic riparian and ponderosa pine habitat (U.S. Fish and Wildlife Service 1985, Saab and Vierling 2001, Sauer et al. 2001). In Washington, the Lewis' woodpecker is only locally abundant as a breeding bird, and its range has contracted within the last half of this century to include only habitats east of the Cascade crest. This species is vulnerable to the loss of snag habitat, and to habitat loss as a result of fire suppression and brush control (Tobalske 1997, Saab and Vierling 2001).

HABITAT REQUIREMENTS

The Lewis' woodpecker prefers a forested habitat with an open canopy and a shrubby understory, with snags available for nest sites and hawking perches (Bock 1970). Bock (1970) states that the critical features of Lewis' woodpecker habitat are forest openness, understory composition, and availability of insect fauna. Additionally, optimum habitat for the Lewis' woodpecker has been defined by the following factors (Sousa 1983):

- total tree canopy closure $\leq$ 30%,
- total shrub crown cover $\geq$ 50%,
- crown cover of mast (nut) producing shrubs $\geq$ 70%,
- percent of total tree canopy closure comprised of hard mast trees $\geq$ 70%, and
- distance to potential mast storage sites $\leq$ 0.8 km (0.5 mi).

Breeding

Breeding populations of the Lewis' woodpecker in Washington are locally distributed, often in colonies, and occur frequently in burned forests (Jewett et al. 1953, Raphael and White 1984, Block and Brennan 1987, Tobalske 1997). Riparian areas dominated by cottonwoods (*Populus trichocarpa*), and oak (*Quercus garryana*) woodlands are major breeding habitats, as are open or park-like ponderosa pine (*Pinus ponderosa*) forests (Sousa 1983, Saab and Vierling 2001). Burned stands of Douglas-fir (*Pseudotsuga menziesii*) and mixed conifers are also used by this woodpecker as breeding habitat (Bock 1970, Raphael and White 1984). Openness is the characteristic common to all breeding habitats, and is related to this woodpecker's foraging methods of hawking and gleaning in brush (Bock 1970). Brushy undergrowth that supports insects on which Lewis' woodpeckers feed is an important component of their preferred breeding habitat (Tobalske 1997). In eastern Washington, undergrowth consisting of species such as sagebrush (*Artemisia* spp.), golden currant (*Ribes aureum*), bitterbrush (*Purshia tridentata*) and rabbitbrush (*Chrysothamnus* spp.) is typically present where this woodpecker breeds.

Lewis' woodpeckers will also use selectively logged or burned coniferous forests that are structurally similar to open ponderosa pine (Raphael and White 1984). In the normal cycle of reforestation, a burn may become suitable habitat for Lewis' woodpeckers between the 10th and 30th year of regeneration, when a shrub understory develops and insects are prevalent (Bock 1970, Jackman and Scott 1975). However, Saab and Dudley (1995) found Lewis' woodpeckers using a ponderosa pine stand two years after it burned. They reported Lewis' woodpeckers displacing hairy woodpeckers and western bluebirds from nest cavities that had been excavated in snags before the fire. This behavior had not been reported before in this species. Lewis' woodpecker nesting sites within salvaged stands of burned forests had an average of 59 snags/ha (24/ac) >23 cm (9 in) diameter at breast height (dbh) and 16 snags/ha (16.5/ac) >51 cm (20 in) dbh (Saab and Dudley 1997).

Riparian areas are also used as breeding habitat for Lewis' woodpeckers. Groves of cottonwood trees are especially suitable because they are open and usually have dead trees that offer nest and roost sites. Insects are abundant due to the lush vegetation within riparian areas (Bock 1970, Jackman and Scott 1975).

Lewis' woodpeckers have high nest site fidelity and often use the same cavity in consecutive years (Bock 1970). This woodpecker will excavate its own nest cavity, but it also uses natural cavities or holes excavated by other woodpeckers. Being a weak excavator, the Lewis' woodpecker prefers soft snags to live trees (Raphael and White 1984). Nest snags and trees in the Sierra Nevada averaged 11.4 m (37 ft) in height and 66.5 cm (26 in) dbh; mean nest height was 7.3 m (24 ft), and the mean diameter at nest-height was 52 cm (20 in) (Raphael and White 1984).

Feeding

The Lewis' woodpecker is an opportunistic feeder that breeds where insects are locally abundant, and it winters where hard nut producing trees are readily available (Bock 1970). Their diet during the spring and summer consists primarily of insects including ants, bees and wasps, beetles, grasshoppers and true bugs (Tobalske 1997). Fruits and berries were the most frequently eaten foods in late summer and fall, whereas winter foods consisted of acorns, commercial nuts, and corn. The feeding behavior of Lewis' woodpeckers is atypical among woodpeckers. Bock (1970) found that in summer they spent approximately 60% of their foraging time capturing insects in flight, 30% ground/brush foraging, and 10% gleaning insects from trees. Raphael and White (1984) reported that of Lewis' woodpeckers' foraging time, 76% was spent capturing insects in flight, 22% gleaning, and 2% drilling. During winter, Lewis' woodpeckers feed mostly on cached acorns and insects, and they spend some time flycatching and gleaning insects (Bock 1970). Although these woodpeckers protect only their immediate nest site during the breeding season, they defend a feeding area in winter (Bock 1970).

LIMITING FACTORS

The availability of snags, nest holes excavated by other woodpeckers, and abundant prey populations are the predominant factors that limit distribution and abundance of the Lewis' woodpecker (Jackman 1975). The selection of one specific area by this woodpecker probably depends on insect abundance. Certain timber management practices and heavy livestock grazing can impact an area's suitability for Lewis' woodpeckers (Jackman 1975, Jackman and Scott 1975). Fire suppression also has likely impacts on the availability of suitable habitat for this species (Saab and Dudley 1997, Tobalske 1997).

Certain habitats are only temporarily suitable, such as logged or burned forests prior to regeneration of second-growth stands. However, post-burn forests likely provide suitable habitat for longer periods within the dryer portions of Lewis' woodpecker range (e.g., eastern fringe of the Cascades) as a result of slower regrowth. Logged or burned coniferous forest is an important part of Lewis woodpecker habitat, but it is generally only suitable in the shrub stage. Unfortunately the brushy stage is undesirable for timber management, and efforts are made to eliminate it. Management practices that remove snags and damaged or diseased trees also limit the availability of nest sites. Additionally, livestock grazing can destroy native understory vegetation, which decreases insect abundance (Jackman and Scott 1975).

Frequent human disturbance at nest sites can also have a negative effect on this species. Lewis' woodpeckers become agitated by continued disturbance at the nest site and will occasionally desert their nest (Bock 1970).

MANAGEMENT RECOMMENDATIONS

In areas where the Lewis' woodpecker occurs, as many standing dead, insect infested, and damaged trees should be retained as possible during thinning and cutting operations (Jackman 1975, Saab and Dudley 1997). Large, soft snags that are suitable for Lewis' woodpecker nest sites are particularly valuable. In managed forests, retaining clusters of trees benefits this species over the retention of uniformly distributed trees for partially logged or salvaged units (Saab and Dudley 1997).

When replanting after a timber harvest, attempts should be made to duplicate natural tree species composition, rather than replanting with a single species (Jackman 1975). Sections of logged or burned forest should be left to regenerate naturally to brush (Jackman and Scott 1975). The brushy forest stage is important for maintaining a healthy insect populations and should not be suppressed (Jackman 1975).

Green forests that are either maintained for timber harvest or have a high risks of a stand-replacement fire should be managed in a way that snag numbers will replenish themselves over time (particularly by retaining broken-topped trees). This management practice will contribute to the continuous availability of easily excavated post-fire nesting trees. In burned forests, retain as many large (>50 cm (20 in) dbh) snags as possible (Saab and Dudley 1997).

Lewis' Woodpecker removed from Priority Habitat and Species list in 2018

Woodpeckers and other insectivores play an important role in naturally reducing insect populations. Management to increase woodpecker populations will likely have the secondary benefit of increasing other insectivorous birds (Takekawa et al. 1982). If pesticides or herbicide use is planned in areas inhabited by this species, refer to Appendix A which lists contacts useful when assessing pesticides, herbicides and their alternatives.

Livestock grazing should be limited where the Lewis' woodpecker occurs, so that native understory vegetation is not destroyed. However, more research is necessary to determine the specific threshold limits on grazing pressure to protect habitat for species. A brushy understory is necessary to provide an adequate insect prey base (Jackman 1975, Jackman and Scott 1975).

Frequent or prolonged human disturbance at nest sites of Lewis' woodpeckers should be avoided. Adult woodpeckers become agitated by continual disturbance at the nest site, and may desert the nest (Bock 1970).

REFERENCES

Block, W. M., and L. A. Brennan. 1987. Characteristics of Lewis' woodpecker habitat on the Modoc Plateau, California. Western Birds 18:209-212.

Bock, C. D. 1970. The ecology and behavior of the Lewis' woodpecker (*Asyndesmus lewis*). University of California, Berkeley Publications in Zoology 92:1-100

Jackman, S. M. 1975. Woodpeckers of the Pacific Northwest: their characteristics and their role in the forests. Thesis, Oregon State University, Corvallis, Oregon, USA.

Jackman, S. M., and J. M. Scott. 1975. Literature review of 23 selected forest birds of the Pacific Northwest. USDA Forest Service, Portland, Oregon, USA.

Jewett, S. A., W. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. Birds of Washington State. University of Washington Press, Seattle, Washington, USA.

MacRoberts, M. H., and B. R. MacRoberts. 1976. Social organization and behavior of the acorn woodpecker in central coastal California. Ornithological Monographs 21:1-115.

Raphael, M. G., and M. White. 1984. Use of snags by cavity using birds in the Sierra Nevada. Wildlife Monographs 86:1-66.

Saab, V. A., and J. Dudley. 1995. What does wildfire have to do with nest usurpation by Lewis' woodpeckers? Bulletin of the Ecological Society of America 76:233.

____, and ____. 1997. Bird responses to stand replacement fire and salvage logging in ponderosa pine/Douglas-fir forests of southwestern Idaho. Unpublished Report, USDA Forest Service Intermountain Research Station, Boise, Idaho, USA.

____, and K. T. Vierling. 2001. Reproductive success of the Lewis' woodpecker in burned pine and cottonwood riparian forests. The Condor 103:491-501.

Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, results and analysis 1966 - 2000. Version 2001.2, USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Sousa, P. J. 1983. Habitat suitability index models: Lewis' woodpecker. US Fish and Wildlife Service, FWS/OBS-82/10.32.

Takekawa, J. Y., E. O. Garton, and L. Langelier. 1982. Biological control of forest insect outbreaks: the use of avian predators. Transactions of the North American Wildlife and Natural Resource Conference 47:393-409.

Tobalske, B. W. 1997. Lewis' woodpecker (*Melanerpes lewis*). Number 284 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

United States Fish and Wildlife Service. 1985. Sensitive bird species, Region 1. US Fish and Wildlife Service, Portland, Oregon, USA.

Lewis' Woodpecker removed from Priority Habitat and Species list in 2018

GENERAL REFERENCES

Neitro, W. A., V. W. Binkley, S. P. Cline, R. W. Mannan, B. G. Marcot, D. Taylor, and F. F. Wagner. 1985. Snags (Wildlife trees). Pages 129-169 *in* E. R. Brown, technical editor. Management of wildlife and fish habitats in forests of Western Oregon and Washington. USDA Forest Service Publication Number R6-F&WL-192-1985.

Rose, C. L., B. G. Marcot, T. K. Mellen, J. L. Ohmann, K. L. Waddell, D. L. Lindley, and B. Schreiber. 2001. Decaying wood in Pacific Northwest forests: concepts and tools for habitat management. Chapter 24 *in* D. H. Johnson and T. A. O'Neil, managing directors. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, Oregon, USA.

KEY POINTS

Habitat Requirements

- Critical features of Lewis' woodpecker include forested habitat with an open canopy, a shrubby understory composition, insect fauna and snags available for nest sites and hawking perches.
- Optimum habitat for the Lewis' woodpecker has been defined by the following factors:

  - total tree canopy closure ≤30%,
  - shrub crown cover ≥ 50%,
  - crown cover of mast (nut) producing shrubs ≥ 70%,
  - percent of total tree canopy closure comprised of hard mast trees ≥ 70%, and
  - distance to potential mast storage sites ≤ 0.8 km (0.5 mi).

- Mainly inhabits riparian stands dominated with cottonwoods, oak woodlands, and park-like ponderosa pine forests with brushy understory. They also use Douglas-fir, and mixed-conifer forests, and logged or burned areas up to 30 years old.
- Excavates cavities or uses available nest holes in snags.
- Feeds mainly on insects and hard nut crops and uses perches to scan for and catch insects in flight.

Management Recommendations

- Retain as many standing dead, insect infested, and damaged trees as possible during thinning and cutting operations. Large, soft snags are particularly valuable. In managed forests, retaining clusters of trees benefits this species over the retention of uniformly distributed trees for partially logged or salvaged units.
- Duplicate natural tree species composition when replanting after a timber harvest rather than replanting stands with a single species of tree. Sections of logged or burned forest should be left to regenerate naturally to brush. A brushy successional stage is important for healthy insect populations and should not be suppressed.
- Manage green forests that are either maintained for timber harvest or have a high risk of a stand-replacement fire in a way that snag numbers will replenish themselves over time (particularly by retaining broken-topped trees). This management practice will contribute to the continuous availability of easily excavated post-fire nesting trees. In burned forests, retain as many large (>50 cm (20 in) dbh) snags as possible.
- Refer to Appendix A that lists useful contacts for evaluating pesticides, herbicides and other alternatives if pesticide use is planned in areas where this woodpecker occurs.
- Limit livestock grazing where the Lewis' woodpecker occurs, so that native understory vegetation is not destroyed.
- Avoid frequent or prolonged human disturbance at nest sites of Lewis' woodpeckers.

Black-backed Woodpecker

Picoides arcticus

Last updated: 2003

Written by Jeffrey C. Lewis, Elizabeth A. Rodrick, and Jeffrey M. Azerrad

GENERAL RANGE AND WASHINGTON DISTRIBUTION

The black-backed woodpecker inhabits the boreal forests of North America, including the Cascade Mountains, the northern portions of the Sierra Nevada and Rocky Mountains, much of Canada, southeastern Alaska, northern New England, and the upper Midwest

In Washington, this woodpecker is found on the eastern slopes of the Cascade Mountains and in the coniferous forests of the Okanogan Highland, Selkirk and the Blue Mountains (see Figure 1; Smith et al. 1997).

Figure 1. General range of the black-backed woodpecker, *Picoides arcticus*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The black-backed woodpecker is a State Candidate species and is in danger of population decline through loss of breeding and foraging habitat.

HABITAT REQUIREMENTS

Black-backed woodpeckers primarily inhabit standing dead lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*) and mixed coniferous forests (Dixon and Saab 2000, Kotliar et al. 2002). This species' dependence on burned forests and forests that have undergone other types of large-scale disturbances (e.g., insect infestation, blowdowns) is well documented (Hutto 1995, Caton 1996, Kreisel and Stein 1999, Dixon and Saab 2000, Kotliar et al. 2002). They have a scattered distribution with populations responding to prey abundance (Caton 1996). Disturbed forests are attractive to the black-backed woodpecker because they feed on insects (mainly larvae of wood-boring beetles) that are particularly abundant following a disturbance event. In northeast Washington, black-backed woodpeckers were 20 times more abundant in burned versus unburned forests (Kreisel and Stein 1999), and often were restricted to standing dead forests created by recent stand-replacement fires

(Hutto 1995, Caton 1996). Home ranges in mature and old-growth forests of central Oregon ranged between 59 and 193 ha (147 and 478 ac; Goggans et al. 1988).

Nesting

In mature ponderosa pine and mixed conifer forests, black-backed woodpeckers nest predominantly in ponderosa and lodgepole pine (Bull et al. 1986). However, tree species composition varies regionally (Dixon and Saab 2000) and appears not to be as important a factor as forest condition (e.g., burned, insect damaged) for explaining the presence of nesting birds. This species nests in taller, small diameter, recently dead trees (>15 m [50 feet] in height, <50 cm [20 inches] in diameter-at-breast-height [dbh], and dead for five years or less) (Raphael and White 1984, Bull et al. 1986). They excavate nest cavities in live trees and hard snags (Spring 1965, Raphael and White 1984, Saab and Dudley 1997). Black-backed woodpeckers were commonly found in unlogged ponderosa pine/Douglas-fir forests with a high density of relatively small, hard snags (Saab and Dudley 1997). Johnsgard (1986) found black-backed woodpeckers nesting in similar habitat as the three-toed woodpecker (*Picoides tridactylus*).

In central Oregon's mixed conifer and lodgepole pine forests, black-backed woodpeckers selected mature and old-growth stands, and nested exclusively in lodgepole pine (Goggans et al. 1988). They avoided young stands and logged areas for both nesting and feeding. Live trees and snags used for nesting had heartrot and a mean dbh of 28 cm (11 in). However, it should be noted that lodgepole pine-dominated forests, such as the forests examined in the central Oregon research, are uncommon in Washington (J. Buchanan, personal communication).

Feeding

In northeastern Oregon, black-backed woodpeckers foraged in both live and dead trees, and showed a preference for ponderosa pine (Bull et al. 1986). During winter months, black-backed woodpeckers foraged almost entirely upon standing dead trees, and preferred western larch within burned forests of northeast Washington (Kreisel and Stein 1999). The larvae of wood-boring beetles such as the pine beetle (*Dendroctonus* spp.) constituted most of their diet (Goggans et al. 1988, Dixon and Saab 2000). Trees used for foraging averaged 19 m (62 ft) in height with a dbh of 34 cm (13 in) and had been dead less than 2 years (Bull et al. 1986). Black-backed woodpeckers most often used the trunk as foraging substrate (Raphael and White 1984, Villard 1994). They frequently obtained insects by chipping bark from dead and dying trees (Short 1974, Kreisel and Stein 1999), but also excavated into the wood of tree trunks and logs in search of insect larvae (Raphael and White 1984, Villard 1994).

Roosting

In Oregon's mixed conifer and lodgepole pine forests, black-backed Woodpeckers roosted mainly in cankers, trunk scars, mistletoe clumps or directly on pine trunks (Goggans et al. 1988). They chose mature and old-growth forests with an average canopy closure of 40%. Trees used for roosting averaged 28 cm (11 in) in diameter and 20 m (65 ft) in height. Studies examining roosting patterns in habitat-types more closely associated with the Washington landscape are lacking.

LIMITING FACTORS

The availability of burned areas that are not subjected to salvage logging, and of insect-damaged forests with numerous snags, limits the distribution of the black-backed woodpecker (Kotliar et al. 2002). Hutto (1995) found that this species is highly restricted to early post-fire conditions that become less suitable 5 to 6 years after a fire due to declining prey availability. Historical and recent fire management policies have negatively impacted this species by reducing the chance of large, high intensity wildfires that create suitable conditions for the black-backed woodpecker (Dixon and Saab 2000).

MANAGEMENT RECOMMENDATIONS

Suitable mature, old-growth and recently dead lodgepole pine, ponderosa pine and pine-dominated mixed coniferous forest stands that have experienced recent pine beetle infestation, large blowdowns or fire are important for the black-backed woodpecker (Dixon and Saab 2000). A recent review of studies in the western United States on post-fire salvage logging documented the serious negative impacts of this activity to the viability of black-backed woodpeckers (Kotliar et al. 2002). The review concluded that this species rarely used even partially-logged post-fire forests. Therefore, where salvage logging is planned, it is important to delay any work for the first five years after the disturbance event (Hutto 1995, Dixon and Saab 2000). This span is critical in providing habitat because the woodpecker's primary food source (wood-boring beetles) becomes less abundant after this period (Caton 1996). Salvage operations should also retain >104-123 snags/ha (>42-50 snags/ac) that are >23 cm dbh (>9 in dbh) (Dixon and Saab 2000, Wisdom et al. 2000).

Goggans et al. (1988) suggested that the traditional approach of managing cavity nesters by retaining a relatively small number of snags and green replacement trees in harvested stands may not maintain enough foraging substrate to sustain viable black-backed woodpecker populations. Instead, this specialized species may require larger areas of decaying, multi-layered older forests. They proposed that Woodpecker Management Areas (WMAs) be identified and withdrawn from commercial or salvage forestry and placed under special management to promote mature and old-growth conditions (Goggans et al. 1988). They suggest that WMAs should each encompass at least 387 ha (956 ac) of pine-dominated, mixed-conifer forest in mature or old-growth condition. This area is estimated based on average home-range sizes for nesting pairs during periods of abundant food. The researchers also recommended that WMAs be located below 1,372 m (4,500 ft) because this species is better adapted to conditions at lower elevations.

Goggans et al. (1988) recommended using the black-backed woodpecker rather than the three-toed woodpecker (*Picoides tridactylus*) as a management indicator species for mature and old-growth lodgepole pine forests. Black-backed woodpeckers are a better indicator species because they use a wider elevation range and are easier to monitor.

Woodpeckers and other insectivores play an important role in naturally reducing insect populations. Management to increase woodpecker populations should have the secondary benefit of increasing other insectivorous birds (Takekawa et al. 1982).

If pesticide or herbicide use is planned in areas inhabited by black-backed woodpeckers, refer to Appendix A, which lists contacts for assessing the use of pesticides, herbicides and other alternatives.

REFERENCES

Bull, E. L., S. R. Peterson, and J. W. Thomas. 1986. Resource partitioning among woodpeckers in northeastern Oregon. USDA Forest Service Research Note PNW-444.

Caton, E. L. 1996. Effects of fire and salvage logging on the cavity-nesting bird community in northwestern Montana. Dissertation, University of Montana, Missoula, Montana, USA.

Dixon, R. D., and V. A. Saab. 2000. Black-backed woodpecker (*Picoides arcticus*). Number 509 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Goggans, R., R. D. Dixon, and L. C. S. Seminara. 1988. Habitat use by three-toed and black-backed woodpeckers, Deschutes National Forest, Oregon. Nongame Project Number 87-3-02, Oregon Department of Fish and Wildlife, Bend, Oregon, USA.

Hutto, R. L. 1995. Composition of bird communities following stand-replacement fires in northern Rocky Mountain (USA) conifer forests. Conservation Biology 9:1041-1058.

Johnsgard, P. A. 1986. Birds of the Rocky Mountains with particular reference to national parks in the northern Rocky Mountain region. Colorado Associated University Press, Boulder, Colorado, USA.

Kotliar, N. B., S. Heil, R. L. Hutto, V. A. Saab, C. P. Melcher, M. E. McFadzen. 2002. Effects of fire and post-fire salvage logging on avian communities in conifer-dominated forests of the western United States. Studies in Avian Biology 25:49-64.

Kreisel, K. J., and S. J. Stein. 1999. Bird use of burned and unburned coniferous forests during winter. Wilson Bulletin 111:243-250.

Raphael, M. G., and M. White. 1984. Use of snags by cavity using birds in the Sierra Nevada. Wildlife Monographs 86:1-66.

Saab, V. A., and J. Dudley. 1997. Bird responses to stand replacement fire and salvage logging in ponderosa pine/Douglas-fir forests of southwestern Idaho. Unpublished Report, USDA Forest Service Intermountain Research Station, Boise, Idaho, USA.

Short, L. L. 1974. Habits and interactions of North American three-toed woodpeckers (*Picoides arcticus* and *Picoides tridactylus*). American Museum Novitiates 2547:1-42.

Sibley, D. A. 2000. National Audubon Society: the Sibley guide to birds. Alfred A. Knopf, New York, New York, USA.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington GAP Analysis - Final Report. Seattle Audubon Society Publication in Zoology Number 1, Seattle, Washington, USA.

Spring, L. W. 1965. Climbing and pecking adaptations in some North American woodpeckers. Condor 67:457-488.

Takekawa, J. Y., E. O. Garton, and L. Langelier. 1982. Biological control of forest insect outbreaks: the use of avian predators. Transactions of the North American Wildlife and Natural Resource Conference 47:393-409.

Villard, P. 1994. Foraging behavior of black-backed and three-toed woodpeckers during spring and summer in a Canadian boreal forest. Canadian Journal of Zoology 72:1957-1959.

Wisdom, M. J., R. S. Holthausen, B. C. Wales, C. D. Hargis, V. A. Saab, D. C. Lee, W. J. Hann, T. D. Rich, M. M. Rowland, W. J. Murphy, and M. R. Eames. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia Basin: broad-scale trends and management implications. UDSA Forest Service General Technical Report PNW-GTR-485, Portland, Oregon, USA.

PERSONAL COMMUNICATIONS

Joe Buchanan, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

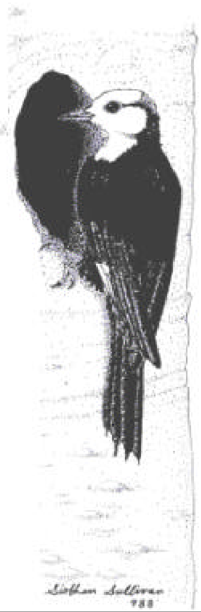
KEY POINTS

Habitat Requirements

- Inhabit mature and old-growth lodgepole pine, ponderosa pine, and mixed-conifer forests with numerous standing dead trees. Most abundant in burned and insect-infested stands.
- Forage on insects, mainly beetle larvae, in pole- and small sawtimber-sized snags.

Management Recommendations

- Avoid salvage logging of suitable mature and old-growth lodgepole pine forest stands that have experienced pine beetle infestation or large blowdowns.
- Retain >104-123 snags/ha (>42-50 snags/ac) that are >23 cm dbh (>9 in dbh) where salvage logging is planned. It is important to delay any salvage operation for approximately five years in woodpecker habitat areas after a disturbance event.
- Establish Woodpecker Management Areas of at least 387 ha (956 ac) within managed forests. The areas should be in pine-dominated, mixed-conifer forest in mature or old-growth condition located below an elevation of 1,372 m (4,500 ft).
- Refer to Appendix A if pesticide or herbicide use is planned in areas inhabited by this species. This lists useful contact for assessing the use of pesticides, herbicides, and other alternatives.



White-headed Woodpecker

Picoides albolarvatus

Last updated: 2002

Written by Jeffrey C. Lewis and Elizabeth Rodrick

GENERAL RANGE AND WASHINGTON DISTRIBUTION

White-headed woodpeckers breed from southern British Columbia and Idaho to southern California (Garrett et al. 1996).

In Washington they are found in ponderosa pine (*Pinus ponderosa*) forests on the east slopes of the Cascade Mountains as well as in the Okanogan Highland, Selkirk and Blue Mountain areas of the state (see Figure 1). They are uncommon throughout their range, but they can be locally abundant in optimal habitat.

Figure 1. Range of the white-headed woodpecker, Picoides albolarvatus, in Washington. Map derived from the literature.

RATIONALE

The white-headed woodpecker is a State Candidate species. This species is vulnerable to loss of older, pine-dominated forests, and to the loss of large trees and snags within these forests.

HABITAT REQUIREMENTS

White-headed woodpeckers are primarily associated with open-canopied, mature and old-growth ponderosa pine forests. They require large, decayed snags for nesting and roosting while they forage primarily in the bark of large ponderosa pines [>60 cm (24 in) dbh] (Thomas et al. 1979, Raphael and White 1984, Garrett et al. 1996). White-headed woodpeckers prefer to forage for insects on the scaly bark of live trees (Raphael and White 1984, Morrison et al. 1987), and they feed heavily on seeds from unopened pine cones during winter (Ligon 1973, Garrett et al. 1996).

Nesting

The white-headed woodpecker usually nests low to the ground [<10 m (33 ft), mean = 2-3 m (6.5-10 ft)] in cavities within snags and stumps (Raphael and White 1984, Milne and Hejl 1989). This species infrequently nests in live trees (J. Buchanan, personal communication). Nest trees include ponderosa pine, jeffrey pine (*Pinus jeffreyi*), lodgepole pine (*Pinus contorta*), sugar pine (*Pinus lambertiana*), white fir (*Abies concolor*), red fir (*Abies magnifica*), and occasional quaking aspen (*Populus tremuloides*) (Raphael and White 1984, Milne and Hejl 1989, Dixon 1995b, Garrett et al. 1996). Studies conducted outside of Washington found that white-headed woodpeckers prefer nesting in snags or trees that are 4-8 m (13-26 ft) tall with a dbh of 65-80 cm (26-31 in) (Raphael and White 1984; Milne and Hejl 1989; Dixon 1995a, b; Garrett et al. 1996). Recent findings in eastern Washington concluded that this species nests primarily in ponderosa pine snags averaging 12.6 m (41.3 ft) in height with a mean dbh of 51.5 cm (20.3 in) (J. Buchanan, personal communication). Larger trees and snags characterized the immediate surroundings of active nest sites. The canopy closure in sites containing nesting birds was considerably open, averaging 7.2%.

Nest excavation begins in April to early May, while nesting occurs from late May to late June (Garrett et al. 1996). Incubation takes 14 days, and young leave the nest in late June to early July after a 26-day fledging period (Garrett et al. 1996).

Foraging

A significant portion of white-headed woodpecker diet consists of pine seeds, especially during winter and early spring (Ligon 1973). Other food sources include invertebrates, sap and other plant matter (Ligon 1973, Garrett et al. 1996). Their diet displays significant seasonal variation. The importance of pine seed in the white-headed woodpeckers diet appears to vary regionally (Morrison and With 1987).

Foraging involves gleaning insects from the trunks of live trees and snags, typically pines and firs (Raphael and White 1984, Morrison et al. 1987). Foliage gleaning and drilling into pine cones are also typical foraging techniques. Feeding on sap occurs only occasionally for this species (Garrett et al. 1996). White-headed woodpeckers regularly drink from open water sources, including pools, creeks, and puddles (Garrett et al. 1996).

Roosting

White-headed woodpeckers most frequently roost in cavities, but also roost in spaces behind peeling bark and in crevices within tree trunks (Dixon 1995a, b; Garrett et al. 1996). They typically roost in ponderosa pines (live trees and snags) averaging 60 cm (24 in) dbh and 7 m (23 ft) tall. Males roost in the nest cavity with their young until they fledge. Cavities are used as winter roosts, and frequently the same cavity is used over an entire season (Dixon 1995a, b; Garrett et al. 1996).

Home Range

Home ranges of white-headed woodpeckers in old-growth habitat averaged 104 ha (257 ac) and 212 ha (524 ac) for central and south-central Oregon, respectively. Home ranges in fragmented habitat average 321 ha (793 ac) and 342 ha (845 ac) for the same regions, respectively (Dixon 1995a, b).

LIMITING FACTORS

Availability of mature and old growth ponderosa pine forests with adequate snags for nesting and winter foraging has resulted in the decline of this species (Garrett et al. 1996). Logging of old ponderosa pine reduces suitable habitat and maintaining even-aged stands limits a site's capacity to replenish itself with large trees and snags. Fire suppression results in closed canopy, less suitable habitat, and eventually displaces important ponderosa pine with firs.

MANAGEMENT RECOMMENDATIONS

Management of habitat for this species should focus on providing snags suitable for nesting and the retention of large live trees for foraging (J. Buchanan, personal communication). Large trees should constitute 40-70% of the forest trees (Neitro et al. 1985).

Connor (1979) states that managing for the minimum habitat requirements may cause gradual population declines. Therefore, it is recommended that forests be managed using average rather than minimum suggested values. Based on research in eastern Washington, forest management should seek to retain 6-8 snags averaging 42.1 cm (16.6 in) dbh/0.8 ha (2-4 snags/ac) and 8 - 10 live trees averaging 63.4 cm (25.0 in) dbh/0.8 ha (4-5 trees/ac) in the immediate vicinity of nesting areas (J. Buchanan, personal communication). These figures are based on a sample of snags $ 20 cm (7.9 in) dbh and live trees $ 50 cm (19.7) dbh. Additionally, open canopy conditions are recommended for these same sites.

Woodpeckers and other insectivores play an important role in naturally reducing insect populations. Management to increase woodpecker populations should have the secondary benefit of increasing other insectivorous birds (Takekawa et al. 1982). If pesticides or herbicide use is planned in areas inhabited by this species, refer to Appendix A, which lists useful contacts for assessing pesticides, herbicides, and other alternatives.

REFERENCES

Connor, R. N. 1979. Minimum standards and forest wildlife management. Wildlife Society Bulletin 7:293-296.

Dixon, R. D. 1995a. Density, nest-site and roost-site characteristics, home-range, habitat-use, and behavior of white-headed woodpeckers: Deschutes and Winema National Forests, Oregon. Oregon Department of Fish and Wildlife Nongame Report 93-3-01, Portland, Oregon, USA.

____. 1995b. Ecology of the white-headed woodpecker in the Central Oregon Cascades. Thesis, University of Idaho, Moscow, Idaho, USA.

Garrett, K. L., M. G. Raphael, and R. D. Dixon. 1996. White-headed woodpecker (*Picoides albolarvatus*). Number 252 *in* A. Poole and F. Gill, editors. The Birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Ligon, J. D. 1973. Foraging behavior of the white-headed woodpecker in Idaho. Auk 90:862-869.

Milne, K. A., and S. J. Hejl. 1989. Nest-site characteristics of white-headed woodpeckers. Journal of Wildlife Management 53:50-55.

Morrison, M. L., and K. A. With. 1987. Interseasonal and intersexual resource partitioning in the white-headed and hairy woodpeckers. Auk 104:225-233.

____, ____, I. C. Timossi, W. M. Block, and K. A. Milne. 1987. Foraging behavior of bark-foraging birds in the Sierra Nevada. Condor 89:201-204.

Neitro, W. A., V. W. Binkley, S. P. Cline, R. W. Mannan, B. G. Marcot, D. Taylor, and F. F. Wagner. 1985. Snags (Wildlife trees). Pages 129-169 *in* E. R. Brown, technical editor. Management of wildlife and fish habitats in forests of Western Oregon and Washington. USDA Forest Service Publication. R6-F&WL-192-1985, Portland, Oregon, USA.

Raphael, M. G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildlife Monographs 86:1-66.

Takekawa, J. Y., E. O. Garton, and L. Langelier. 1982. Biological control of forest insect outbreaks: the use of avian predators. Transactions of the North American and Natural Resource Conference 47:393-409.

Thomas, J. W., R. G. Anderson, C. Maser, and E. L. Bull. 1979. Snags. Number 553 *in* J. W. Thomas, technical editor. Wildlife habitats in managed forests- the Blue Mountains of Oregon and Washington. USDA Forest Service Handbook, Portland, Oregon, USA.

PERSONAL COMMUNICATIONS

Joe Buchanan, Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

KEY POINTS

Habitat Requirements

- Mature and old-growth ponderosa pine and mixed conifer forests.
- Nests in snags averaging >65 cm (26 in) dbh.
- Home ranges in Oregon average 100-200 ha (247-484 ac) in old-growth habitat, and over 300 ha (741 ac) in fragmented habitat.
- Forages on insects in large [>60 cm (24 in) dbh] snags and live trees, and on pine seeds during winter and early spring.

Management Recommendations

- Maintain mature forest conditions or limit timber removal to moderate levels of selective cutting to maintain white-headed woodpecker populations. Mature ponderosa pine should constitute 40-70% of the forest trees.
- Retain 6-8 snags averaging 42.1 cm (16.6 in) dbh/0.8 ha (2-4 snags/ac) and 8 - 10 live trees averaging 63.4 cm (25.0 in) dbh/0.8 ha (4-5 trees/ac) where nesting occurs.
- Maintain open canopy conditions for sites within the immediate vicinity of nesting white-headed woodpeckers.
- Refer to Appendix A, that lists useful contacts for assessing pesticides, herbicides, and their alternatives, if pesticide or herbicide use is planned in areas inhabited by this species.

Pileated Woodpecker

Dryocopus pileatus

Last updated: 2003

Written by Jeffrey C. Lewis and Jeffrey M. Azerrad

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Pileated woodpeckers are year-round residents from northern British Columbia, across Canada to Nova Scotia, south through central California, Idaho, Montana, eastern Kansas, the Gulf Coast and Florida (Bull and Jackson 1995). The Washington range encompasses the forested areas of the state (see Figure 1; Smith et al. 1997).

Figure 1. General range of the pileated woodpecker, *Dryocopus pileatus*, in Washington (Smith et al. 1997).

RATIONALE

The pileated woodpecker is listed as a State Candidate species in Washington. The pileated woodpecker is a significant functional component of a forest environment because it creates nesting cavities used by other forest wildlife species (Aubry and Raley 2002a). Their deep foraging excavations provide foraging opportunities for weak excavators, and they accelerate the decay process by physically breaking apart wood and exposing prey that can be consumed by other species (Aubry and Raley 2002a). For these reasons the pileated woodpecker is considered a "keystone habitat modifier" (Aubry and Raley 2002a). The availability of large snags (standing dead trees) and large decaying live trees used for nesting and roosting by pileated woodpeckers has declined in many areas as a result of forest conversion (e.g, removal of forest for urban development) and timber management practices (Bull and Jackson 1995, Ferguson et al. 2001).

HABITAT REQUIREMENTS

Pileated woodpeckers inhabit mature and old-growth forests, and second-growth forests with large snags and fallen trees (Bull and Jackson 1995, Aubry and Raley 1996). Large snags and large decaying live trees in older forests are used by pileated woodpeckers for nesting and roosting throughout their range (Mellen et al. 1992, Bull and Jackson 1995, Aubry and Raley 2002b). In western Oregon and western Washington, they may use younger forests (<40 years old) as foraging habitat (Mellen et al. 1992, Aubry and Raley 1996).

Nesting and Roosting

Pileated woodpeckers excavate large nest cavities in snags or large decaying live trees (Bull et al. 1986, Aubry and Raley 2002b). In northeast Oregon, Bull (1987) reported the dimension of the nest entrances were 12 cm (5 in) in height and 9 cm (4 in) in width; the internal dimensions were 57 cm (22 in) deep and 21 cm (8 in) wide. Wood chips are typically found on the cavity floor (Bull and Jackson 1995). During the breeding season, birds may start a number of cavity excavations, but only complete one nest cavity (Bull and Jackson 1995, Aubry and Raley 2002a). The breeding and nesting periods of the pileated woodpecker extends from late March to early July (Bull et al. 1990). Pileated woodpeckers lay 1-6 eggs/clutch; the eggs are white in coloration and are about 3.3 cm (1.3 in) in length and 2.5 cm (1 in) in breadth (Bull and Jackson 1995).

Preferred nest tree species and characteristics vary to some degree among different regions of the northwest (Table 1). Most nest cavities were observed in hard snags with intact bark and broken tops, or live trees with dead tops. Hard snags are characterized as being comprised of sound wood while soft snags are composed primarily of wood in advanced stages of decay or deterioration (Brown 1985). Researchers studying pileated woodpeckers on the Olympic Peninsula found that woodpeckers used snags and large decaying live trees for nesting (Aubry and Raley 2002b). Sites used for nesting and roosting in the Olympics had a higher diversity of tree species and a greater density of large decaying live trees and large snags than surrounding forested areas (Aubry and Raley 2002b).

Table 1. Diameter at breast height (DBH), height, and tree species reported for pileated woodpecker nest trees in Oregon and Washington.

Location	DBH (average)	DBH (range)	Height (average)	Height (range)	Species	References
Olympic Peninsula	101 cm (40 in)	65-154 cm (26-61 in)	39 m (128 ft)	17-56 m (56-184 ft)	Pacific silver fir (*Abies amabilis*), western hemlock (*Tsuga heterophylla*)	Aubry and Raley 2002b
Western Oregon	69 cm (27 in)	--	27 m (87 ft)	--	Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*)	Mellen 1987, Nelson 1989
Northeastern Oregon	80-84 cm (31-33 in)	52-119 cm (20-47 in)	28 m (92 ft)	10-43 m (33-141 ft)	grand fir, ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*)	Bull 1987; Bull et al. 1992b; E. Bull, personal communication

Pileated woodpeckers roost in hollow trees or vacated nest cavities at night and during inclement weather (Bull and Jackson 1995). Excavation of roost cavities may occur at any time during the year (E. Bull, personal communication). Pileated woodpeckers may use up to 11 roosts over a 3-10 month period; however, some individuals will use one roost for a long period before switching to a new roost, while others regularly switch among several roosts (Bull et al. 1992b). The availability of roost trees apparently explained why some birds roosted in a limited number of trees (Bull et al. 1992b)

Roost and nest trees of pileated woodpeckers differ with respect to species and physical characteristics. Pileated woodpeckers used live trees or snags for roosting and nesting and selected these based on tree species, wood condition and diameter at breast height (dbh) in both northeastern Oregon and the Olympic peninsula (Bull et al. 1992b, Aubry and Raley 2002b). Bull et al. (1992b) reported that roost trees [mean = 70 cm dbh (28 in)] were smaller than nest trees [mean = 80 cm dbh (31 in)]; in contrast to nest trees, roosts trees in northeastern Oregon were often hollow. The hollow interior of roost chambers was typically the result of heartwood decay rather than excavation (Bull et al. 1992b, Aubry and Raley 2002b). In northeastern Oregon, roost chambers had more entrance holes than nests, and roosts were predominantly in grand fir, whereas nest trees were predominantly ponderosa pine and western larch (Bull et al. 1992b). In the Olympics, pileated woodpeckers preferred to roost within western redcedar (*Thuja plicata*) (Aubry and Raley 2002b). The extensive use of grand fir in northeast Oregon and western redcedar in the Olympics was attributed to the greater propensity for these species to form large, hollow chambers (Bull et al. 1992b, Aubry and Raley 2002b). Aubry and Raley (1996) found that 88% of all roosts were located in old or mature forests. The remaining roosts were primarily found in naturally regenerated young forests that were approximately 75 years old (Aubry and Raley 1996). Roosts east of the Cascades were also primarily found in old-growth forests (Bull et al. 1992b, McClelland and McClelland 1999). General characteristics of roost trees in Oregon and Washington are described in Table 2.

Table 2. DBH, height, and tree species reported for pileated woodpecker roost trees in Oregon and Washington.

Location	DBH (average)	DBH (range)	Height (average)	Height (range)	Species	References
Olympic Peninsula	149 cm (59 in)	37-309 cm (15-122 in)	36.5 m (120 ft)	11-63 m (36-207 ft)	Pacific silver fir, western hemlock, western redcedar	Aubry and Raley 2002b
Western Oregon	112 cm (44 in)	40-208 cm (16-82 in)	--	--	--	Mellen et al. 1992
Northeastern Oregon	71 cm (28 in)	40-131 cm (16-52 ft)	22 m (72 ft)	6-44 m (20-144 ft)	grand fir, ponderosa pine, western larch	Bull et al. 1992b; E. Bull, personal communication

Foraging

Pileated woodpeckers forage in forests containing large trees and snags that support abundant insect prey associated with dead and dying wood. Large rectangular/oval excavations in snags are indicative of pileated woodpecker foraging (McClelland 1979, Neitro et al. 1985, Bull and Jackson 1995). In Oregon and Washington, prey consisted of carpenter and thatching ants (Hymenoptera), beetle larvae (Coleoptera), termites (Isoptera), and other insects (Bull et al. 1992a, Torgersen and Bull 1995, Aubry and Raley 1996). Mature and old-growth coniferous forest are considered high quality foraging habitat (Aubry and Raley 1996), but forests as young as 40 years of age are used if snags, particularly large residual snags from burns or harvests, are present (Mellen et al. 1992). Pileated woodpeckers seldom use clearcuts, but will forage in clearcuts or shelterwood cuts if substantial foraging habitat is retained (see Mannan 1984, Mellen 1987). Researchers working in the Oregon Coastal Range determined that pileated woodpeckers used deciduous riparian for foraging activities (Mellen et al. 1992).

Pileated woodpeckers forage on large snags [>50 cm (20 in) dbh], live trees, logs, and stumps (Bull et al. 1986, Bull 1987, Torgersen and Bull 1995). Snags and live trees take on special importance in winter when logs and stumps may be covered with snow (McClelland 1979, Bull and Holthausen 1993). Pileated woodpeckers forage on snags in a broad range of decay conditions but appear to prefer large snags that may harbor more insects and larvae than smaller snags (Mannan et al. 1980). In contrast to foraging behavior east of the Cascade Range, downed logs are rarely used as foraging substrate in wet coastal forests (Aubry and Raley 2002b).

Home Range

Home ranges vary in size within the Pacific Northwest, ranging from 407 ha (1,006 ac)/breeding pair (data collected between June and March) in northeastern Oregon (Bull and Holthausen 1993), 480 ha (1,186 ac)/breeding pair during the summer in the central Oregon Coast Range (Mellen et al. 1992), and 863 ha (2,132 ac)/breeding pair annually on the Olympic Peninsula (Aubry and Raley 1996). The home range figures reported in the central Oregon Coast Range are likely smaller than the actual year-round home range for the pileated (Mellen et al. 1992). Home ranges for individuals that lost mates are larger than those of mated individuals (Bull and Holthausen 1993, Aubry and Raley 1996), and pairs with young have larger home ranges than pairs without young (Mellen et al. 1992). Although home ranges in the central Oregon Coast Range were actively defended, the ranges of adjacent birds overlapped (9-30% of an individual's home range overlapped) (Mellen et al. 1992). Home ranges in northeastern

Oregon generally consisted of >85% forested habitat (Bull and Holthausen 1993). Home ranges consisted primarily of late-successional forested habitat or second-growth forest with residual large snags (Bull and Holthausen 1993, Bull and Jackson 1995, Aubry and Raley 1996).

Urban/Suburban Habitat Use

Pileated woodpeckers are residents in some developing areas throughout Washington (M. Tirhi; P. Thompson; H. Ferguson, personal communications). In these areas they occupy remnant patches of forest, parks, and green-belts. Because of their need for large trees and their sizeable territory requirements, loss or reduction of extensive wooded tracts and large trees will impact the species (Moulton and Adams 1991). Pileated woodpeckers in suburban areas forage on a variety of substrates, including large and small diameter coniferous and hardwood trees and snags (P. Thompson, personal communication; J. Lewis, unpublished data), and occasionally on suet feeders, utility poles, and fruit trees (Bull and Jackson 1995; J. Buchanan, personal communication).

Although habitat use in urbanizing environments in Washington has been given little attention, it is likely that pileated woodpeckers select large diameter trees and snags for nesting and roosting. Similarly, sizes of home ranges in urban environments are unknown, but they may be relatively large due to the fragmented nature of remnant forest habitats in most suburban landscapes. The relationship between cavity-nesters and urbanizing areas in Washington has only been investigated by a single study in the greater Seattle area (see Rohila 2002)

LIMITING FACTORS

Timber harvest can significantly impact pileated woodpecker habitat (Bull and Jackson 1995). The removal of large snags, large decaying live trees and downed woody debris of the appropriate species, size and decay class eliminates nest and roost sites and foraging habitat. Intensively managed forests typically do not retain these habitat features (Spies and Cline 1988). However, more recent state and federal forest management guidelines call for the retention of a specified number of wildlife trees during timber harvest (Washington Forest Practices Board 2001, Aubry and Raley 2002a). Bull and Jackson (1995) suggest that fragmentation of forested habitat may lead to reduced population density and increased vulnerability to predation as birds are forced to fly between fragmented forested stands; however, information on predation effects is currently lacking. Known predators include the northern goshawk (*Accipiter gentiles*), Cooper's hawk (*A. cooperii*), red-tailed hawk (*Buteo jamaicensis*), great horned owl (*Bubo virginianus*), American martin (*Martes americana*), and gray fox (*Urocyon cinereoargenteus*) (Bull and Jackson 1995).

The amount of forest retained in the suburban and urbanizing environment will influence the degree to which an area is used by pileated woodpeckers for foraging and reproduction (Moulton and Adams 1991, Rohila 2002). If the collective area of these retained forest tracts is large enough, suburban and other urbanizing environments could support pileated woodpeckers (Rohila 2002). However, because of their need for larger trees and their sizeable territory requirements, loss or reduction of wooded tracts and large trees could eliminate or preclude pileated woodpeckers from an urbanizing area (Moulton and Adams 1991).

MANAGEMENT RECOMMENDATIONS

General Recommendations

Specific management prescriptions should be developed for actions that will be undertaken at the home range scale (Mellen et al. 1992, Bull and Holthausen 1993) as discussed later in this chapter. Management activities for pileated woodpeckers should focus on providing and maintaining a sufficient number of appropriate large snags and large decaying live trees for nesting and roosting (Aubry and Raley 2002b). Retaining snags and decaying live trees (of appropriate size, species and decay classes) provides suitable nesting and roosting structure for a longer period of time than retaining only hard snags (Aubry and Raley 2002b). Trees, snags and stumps with existing pileated nest cavities and foraging excavations should be retained (Bonar 2001).

Management of nesting and roosting habitat may be accomplished in several ways in managed forests. A variety of snag creation techniques are being developed and it is likely that such techniques can produce suitable snags in older second growth forests (e.g., removal of tree-top, girdling) (Neitro et al. 1985, Bull and Partridge 1986, Lewis 1998). Properly conducted uneven-aged management of forest stands can create adequate canopy closure and sufficient large snags and large decaying live trees to maintain suitable nesting and roosting habitat for pileated woodpeckers. Defective or cull trees can be retained during commercial thinning operations, or these can be recruited to become snags in subsequent rotations (Neitro et al. 1985). Because of the difficulties in recruiting large snags in managed forests (Wilhere 2003), one of the most effective means to improve snag densities may involve extending the length of harvest rotations (Neitro et al. 1985).

Managers may have some flexibility when providing foraging habitat. Naturally formed stumps and numerous large logs in various stages of decay can be retained to improve foraging habitat (Torgersen and Bull 1995). Management for large snags, culls, and green replacement trees can ultimately provide large downed logs as foraging habitat. Protection of riparian habitat throughout Washington and the provisions of buffers along streams may also ensure that adequate foraging habitat exists for pileated woodpeckers (Mellen et al. 1992, Knutson and Naef 1997). However, we currently lack adequate information to define appropriate riparian buffers for pileated woodpeckers in managed forests.

Forest managers often apply minimum size standards that are determined through research (e.g., the smallest recorded nest tree dbh) to achieve a combination of wildlife conservation and resource extraction goals (McClelland and McClelland 1999). Conner (1979) argued that managing forests using minimum size standards may cause gradual population declines and suggested that average values for habitat components should be used in forest management. The following set of recommendations is based primarily on average (rather than minimum) standards.

Western Washington

The following recommendations are primarily based on the goals identified by the Partners in Flight (PIF) Conservation Plan for the Westside Coniferous Forest region (Altman 1999). These goals were derived from research conducted in the Oregon Coast Range and Washington's Olympic Peninsula (Nelson 1989, Mellen et al. 1992, Aubry and Raley 1996, 2002b). The PIF recommendations for managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older include maintaining >70% canopy closure and an average of ≥5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in). In areas used for both nesting and roosting, an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) should be retained (Aubry and Raley 2002b). Trees ≥27.5 m (≥90 ft) in height should be retained to provide nesting and roosting structures (Aubry and Raley 2002b). Overall, pileated woodpeckers selected larger trees for roosting than those used for nesting (see Buchanan, in press). Based on Aubry and Raley's (2002b) work in the Olympics, trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting. In addition, an average of 30 foraging snags/ha (12 snags/ac) (mix of hard and soft snags) should be provided in the following size classes (see Table 3; Altman 1999).

Table 3. Suggested number of foraging snags to retain.

Size class	Foraging snags retained
• 25-50 cm dbh (10-20 in)	= ≥18 snags/ha (7 snags/ac)
• 51-76 cm dbh (20-30 in)	= ≥8 snags/ha (3 snags/ac)
• >76 cm dbh (>30 in)	= ≥5 snags/ha (2 snags/ac)

Population targets suggested by the PIF conservation plan called for about nine pairs of pileated woodpeckers per township (9.7 pairs/100 km^2), based on an average breeding season home range of 600 ha (Altman 1999:36-37). Using the annual home range size of 863 ha for the Olympic Peninsula (Aubry and Raley 1996), a comparable target could be adjusted to about six pairs per township (6.4/100 km^2) on the Olympic Peninsula (Buchanan, in press). At the landscape-level, an average of 60% of a landscape management unit (e.g., watershed, township) should be retained as suitable habitat (early successional forest with adequate snag densities, young forest [40-80 years] with adequate snag densities, and late successional forest), and >40% of this suitable habitat should be retained in late-successional forest. Adequate snag densities are defined as the combination of nesting, roosting and foraging snag numbers (see above).

Eastern Washington

The following recommendations are based on research conducted in the Blue Mountains of northeastern Oregon (Bull 1987, Bull and Holthausen 1993) as well as research conducted in northwestern Montana (McClelland and McClelland 1999). Because most work on pileated woodpeckers in the inland northwest was conducted in the Blue Mountains, it should be noted that the following recommendations might be less applicable to areas outside of this region.

Several key habitat components are necessary to maintain suitable pileated woodpecker habitat. These include a mature forest with ≥2 canopy layers, the uppermost being 25-30 m (82-98 ft) in height; large live trees to provide cover and eventual replacement of dead trees; large dead trees for nesting; and dead trees and downed woody material for foraging (Bull 1987). Territory size for breeding pairs in the Blue Mountains averaged 407 ha (1006 ac) and was considered an adequate size to manage for each breeding pair in that region (Bull and Holthausen 1993). Researchers working in the Blue Mountains recommended that 75% of management areas be in grand fir forest types and they suggested that the composition of this area include 25% old growth and 75% mature stands. Additionally, they suggested that ≥50% of the management areas have ≥60% canopy closure and that at least 40% of the stands remain unlogged (Bull and Holthausen 1993).

Bull and Holthausen (1993) recommended retaining 8 snags/ha (3.2 snags/ac) with at least 20% being ≥ 51 cm (20 in) dbh for both nesting and roosting. Based on Bull's (1987) research, trees ≥ 28 m (92 ft) should be retained to provide nesting structures. Bull and Holthausen (1993) recommended retaining ≥100 logs/ha (40/ac) as foraging substrate in management areas, with a preference for logs ≥38 cm (15 in) dbh that include all species except lodgepole pine (*Pinus contorta* var. *latifolia*). McClelland and McClelland (1999) suggested that the optimum dbh for nest and roost trees should be: 77-91 cm (30-36 in) for western larch, 76-96 cm (30-38 in) for ponderosa pine, and 75-100 cm (30-39 in) for black cottonwood (*Populus balsamifera*).

Urban/Suburban Areas

Although pileated woodpeckers are known to use suburban and other urbanizing areas (Moulton and Adams 1991, Rohila 2002), few studies have examined habitat use in these areas. Consequently, the following generalized recommendations address the principle needs of pileated woodpeckers based primarily on the findings of a recent study conducted in the greater Seattle area (Rohila 2002). Additional research will be necessary to develop specific guidelines for urban and suburban areas.

In urbanizing areas, the greatest negative influence to pileated woodpeckers is likely the clearing of remnant forest patches. Based on research in greater Seattle, Rohila (2002) recommended that planners retain forest in the largest patches available (>30 ha [74 ac] would be considered large). Where large patches are unavailable, smaller patches should be retained; where the average size of smaller patches should be no less than approximately 3 ha (7 ac) (see Rohila 2002). Forest patches with high densities of existing snags and live trees should be targeted when selecting areas to retain during the planning process (Rohila 2002). The creation of snags or decaying live trees (Lewis 1998) may benefit pileated woodpeckers in suburban areas (see previous sections for preferred snag and tree size guidelines). Pileated woodpeckers and other cavity-dependent species would benefit from the retention of snags as well as the retention of live trees in the largest size classes available in the stand (Rohila 2002). Because designated suburban and urban parks often contain large forested tracts, park managers should also consider pileated woodpecker requirements.

REFERENCES

Altman, B. 1999. Conservation strategy for landbirds in coniferous forests of western Oregon and Washington. Version 1.0. Unpublished report prepared for Oregon-Washington Partners in Flight.

Aubry, K. B., and C. M. Raley. 1996. Ecology of pileated woodpeckers in managed landscapes on the Olympic Peninsula. Annual Report, USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington, USA.

____, and ____. 2002a. The pileated woodpecker as a keystone habitat modifier in the Pacific Northwest. Pages 257-274 *in* W. F. Laudenslayer, Jr., P. J. Shea, B. E. Valentine, C. P. Weatherspoon, and T. E. Lisle, technical coordinators. Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests. USDA Forest Service General Technical Report PSW-GTR-181, Berkeley, California, USA.

____, and ____. 2002b. Selection of nest and roost trees by pileated woodpeckers in coastal forests of Washington. Journal of Wildlife Management 66:392-406.

Bonar, R. L. 2001. Pileated woodpecker habitat ecology in the Alberta foothills. Dissertation, University of Alberta, Edmonton, Alberta, Canada.

Brown, E. R., technical editor. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. USDA Forest Service Publication Number R6-F&WL-192-1985, Portland, Oregon, USA.

Buchanan, J. B. in press. Challenges of avian conservation on non-federal forestlands in the Pacific Northwest. *In* C. J. Ralph and T. Rich. editors. Bird conservation implementation and integration in the Americas. USDA Forest Service General Technical Report GTR-SW-XXX.

Bull, E. L. 1987. Ecology of the pileated woodpecker in northeastern Oregon. Journal of Wildlife Management 51:472-481.

____, R. C. Beckwith, and R. S. Holthausen. 1992a. Arthropod diet of pileated woodpeckers in northeastern Oregon. Northwestern Naturalist 73:42-45.

____, and R. S. Holthausen. 1993. Habitat use and management of pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management 57:335-345.

____, ____, and M. G. Henjum. 1990. Techniques for monitoring pileated woodpeckers. USDA Forest Service General Technical Report PNW-GTR-269, Portland, Oregon, USA.

____, ____, and ____. 1992b. Roost trees used by pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management 56:786-793.

____, and J. E. Jackson. 1995. Pileated woodpecker (*Dryocopus pileatus*). Number 148 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

____, and A. D. Partridge. 1986. Methods of killing trees for use by cavity nesters. Wildlife Society Bulletin 14:142-146.

____, S. R. Peterson, and J. W. Thomas. 1986. Resource partitioning among woodpeckers in northeastern Oregon. USDA Forest Service Research Note PNW-444, Portland, Oregon, USA.

Conner, R. N. 1979. Minimum standards and forest wildlife management. Wildlife Society Bulletin 7:293-296.

Ferguson, H. L, K. Robinette, and K. Stenberg. 2001. Wildlife of urban habitats. Pages 317-341 *in* D. Johnson and T. O'Neill, editors. Wildlife Habitats and Species Associations in Oregon and Washington: Building a Common Understanding for Management. Oregon State University Press, Corvallis, Oregon, USA.

Knutson, K. L., and V. L. Naef. 1997. Management recommendations for Washington's priority habitats: riparian. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Lewis, J. C. 1998. Creating snags and wildlife trees in commercial forest landscapes. Western Journal of Applied Forestry 13:97-101.

Mannan, R. W. 1984. Summer area requirements of pileated woodpeckers in western Oregon. Wildlife Society Bulletin 12:265-268.

____, E. C. Meslow, and H. M. Wight. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. Journal of Wildlife Management 44:787-797.

McClelland, B. R. 1979. The pileated woodpecker in forests of the northern Rocky Mountains. Pages 283-299 *in* J.G. Dickson, R. N. Conner, J. C. Fleet, and J. A. Jackson, editors. The role of insectivorous birds in forest ecosystems. Academic Press, New York, New York, USA.

____, and P. T. McClelland. 1999. Pileated woodpecker nest and roost trees in Montana: links with old growth and forest "health." Wildlife Society Bulletin 27:846-857.

Mellen, T. K. 1987. Home range and habitat use by pileated woodpeckers. Thesis, Oregon State University, Corvallis, Oregon, USA.

____, E. C. Meslow, and R. W. Mannan. 1992. Summertime home range and habitat use of pileated woodpeckers, western Oregon. Journal of Wildlife Management 56:96-102.

Moulton, C. A., and L. W. Adams. 1991. Effects of urbanization on foraging strategy of woodpeckers. Pages 67-73 *in* L. W. Adams and D. L. Leedy, editors. Wildlife Conservation in Metropolitan Environments. National Institute for Urban Wildlife, Columbia, Maryland, USA.

Neitro, W. A., V. W. Binkley, S. P. Cline, R. W. Mannan, B. G. Marcot, D. Taylor, and F. F. Wagner. 1985. Snags (Wildlife trees). Pages 129-169 *in* E. R. Brown, technical editor. Management of wildlife and fish habitats in forests of western Oregon and Washington. USDA Forest Service Publication Number R6-F&WL-192-1985, Portland, Oregon, USA.

Nelson, S. K. 1989. Habitat use and densities of cavity nesting birds in the Oregon Coast Ranges. Thesis, Oregon State University, Corvallis, Oregon, USA.

Rohila, C. M. 2002. Landscape and local effects on snags and and cavity-nesting birds in an urbanizing area. Thesis, University of Washington, Seattle, Washington, USA.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington GAP Analysis - Final Report. Seattle Audubon Society Publication in Zoology Number 1, Seattle, Washington, USA.

Spies, T. A., and S. P. Cline. 1988. Coarse woody debris in forests and plantations of coastal Oregon. Pages 4-24 *in* C. Maser, R. F. Tarraut, J. M. Trappe, and J. F. Franklin, technical editors. From the Forest to the Sea: a Story of Fallen Trees. USDA Forest Service General Technical Report PNW-GTR-229, Portland, Oregon, USA.

Torgersen, T. R. and E. L. Bull. 1995. Down logs as habitat for forest-dwelling ants - the primary prey of pileated woodpeckers in northeastern Oregon. Northwest Science 69:294-303.

Washington Forest Practices Board. 2001. Forest Practices Rules: Title 222 Washington Administrative Code. Washington Department of Natural Resources, Olympia, Washington, USA.

Wilhere, G. F. 2003. Simulations of snag dynamics in an industrial Douglas-fir forest. Forest Ecology and Management 174:521-539.

PERSONAL COMMUNICATIONS

Joe Buchanan
Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

Evelyn Bull
Research Wildlife Biologist
USDA Forest Service
La Grande, Oregon

Howard Ferguson
District Wildlife Biologist
Washington Department of Fish and Wildlife
Spokane, Washington

Patricia Thompson
Urban Wildlife Biologist
Washington Department of Fish and Wildlife
Mill Creek, Washington

Michelle Tirhi
Urban Wildlife Biologist
Washington Department of Fish and Wildlife
Kent, Washington

KEY POINTS

Habitat Requirements

- Inhabits mature and old-growth forests, and second-growth forests with large snags and fallen trees
- Excavates large nest cavities in snags or large decaying live trees
- Breeds and nests between late March to early July
- Roosts in hollow trees or vacated nest cavities at night and during inclement weather
- Forages in forests containing large trees and snags, and dead and dying wood

- Preys on carpenter and thatching ants, beetle larvae, termites, and other insects
- Present in some urban and suburban areas throughout Washington

Management Recommendations

General Recommendations

- Maintain large snags and large decaying live trees for nesting and roosting
- Retain naturally formed stumps and numerous large logs in various stages of decay to improve foraging habitat
- Use average size standards (rather than minimums) for managing pileated woodpecker habitat components (e.g., nest size standards).

Western Washington

- Maintain managed coniferous forests (stands with >70% conifer stems) of about 60 years of age or older at>70% canopy closure and an average of ≥5 nest snags/10 ha (2 snags/10 ac) that are >76 cm dbh (30 in)
- Retain an average of 18 large snags/ha (7 snags/ac) and 8 decaying large trees/ha (3 trees/ac) in areas used for both nesting and roosting
- Retain trees ≥27.5 m (≥90 ft) in height to provide nesting and roosting structures. Trees between 155 and 309 cm dbh (61-122 in) should be retained for roosting
- Retain an average of 30 foraging snags/ha (12 snags/ac)

Eastern Washington

- Maintain mature forest with ≥2 canopy layers, the uppermost being 25-30 m (82-98 ft) in height; large live trees to provide cover and eventual replacement of dead trees; large dead trees for nesting; and dead trees and downed woody material for foraging
- Retain 8 snags/ha (3.2 snags/ac) with at least 20% being ≥ 51 cm (20 in) dbh for both nesting and roosting
- Retain ≥100 logs/ha (40/ac) as foraging substrate in management areas, with a preference for logs ≥38 cm (15 in) dbh

Urban/Suburban Areas

- Conserve larger forest patches with large trees and snags
- Retain forest in the largest patches available (≥30 ha [74 ac] would be considered large). Where large patches are unavailable, smaller patches should be retained; where the average size of smaller patches should be no less than approximately 3 ha (7 ac).
- Retain or create snags as well as retain live trees in the largest size classes available in the stand

Loggerhead Shrike

Lanius ludovicianus

Last updated: 2003

Written by Matthew Vander Haegen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Loggerhead shrikes are found in portions of British Columbia, Alberta and Saskatchewan, and throughout much of the United States (although rare in the northeastern U.S.) south to southern Mexico (Yosef 1996, Sibley 2000).

In Washington, the shrike is primarily a breeding resident of the shrub-steppe zone (see Figure 1; Miller 1931, Poole 1992). Shrikes depart for their migration south by September (Morrison 1981, Burnside 1987) and return around March (Poole 1992). Some individuals remain year-round in eastern Washington (Washington Department of Fish and Wildlife's Wildlife Information System, unpublished data).

Figure 1. General breeding range of the loggerhead shrike, *Lanius ludovicians*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The Loggerhead shrike is a State Candidate species that has shown decreases in population from historical densities and distribution (Morrison 1981, Fraser and Luukkonen 1986, Sauer et al. 1995, Cade and Woods 1997). A recent analysis of Breeding Bird Survey data for the Columbia River Basin shows a significant decline in the shrike population over the last 26 years (Saab and Rich 1997). Loss of shrub-steppe habitat partially explains local declines of this species (Cade and Woods 1997). The Interior Columbia River Basin Ecosystem Management Project has listed loggerhead shrike as a species of high management concern for the region (Saab and Rich 1997).

HABITAT REQUIREMENTS

Loggerhead shrikes use open habitat during both breeding and nonbreeding seasons. Grasslands or pastures with short or patchy grasses are usually used for foraging. Scattered trees, shrubs or hedgerows are most often used for nesting and perching (Kridelbaugh 1983, Bohall-Wood 1987, Gawlik and Bildstein 1990). In the shrub-steppe of eastern Washington, Poole (1992) found shrikes were most abundant in lowland communities of sagebrush (*Artemisia* spp.), Sandberg's bluegrass (*Poa sandbergii*), and cheatgrass (*Bromus tectorum*); mixed shrub communities containing big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), Sandberg's bluegrass, Indian ricegrass (*Oryzopsis hymenoides*), and needle and thread grass (*Stipa comata*); and bitterbrush communities containing bitterbrush, Indian ricegrass, and needle and thread grass. Surveys in eastern Washington shrub-steppe revealed a greater abundance of loggerhead shrikes in deep, sand soil communities than in communities with loamy or shallow soils (Vander Haegen et al. 2000). The shrub-steppe communities occupied by shrikes could be described as a mixture of shrub patches and grassy or sandy openings (Poole 1992). Leu (1995) reported greater foraging success by juvenile shrikes in shrub-steppe stands having a more open grass/forb layers, where birds could readily spot and capture prey on the ground.

Trees or shrubs used for nesting share the common characteristics of having dense foliage (Poole 1992), being very bushy, and/or thorny (Kridelbaugh 1983, Brooks and Temple 1990a). Selection criteria for nesting trees or shrubs appear to be based on the amount of cover and protection the plant provides rather than a preference for a particular species of tree or shrub (Porter et al. 1975, Gawlik and Bildstein 1990). In eastern Washington, shrub species with the greatest number of nests were big sagebrush and bitterbrush, but nests also were found in mock orange (*Philadelphus lewisii*), greasewood (*Sarcobatus vermiculatus*) and clematis (*Clematis* spp.) (Miller 1931, Poole 1992). Shrikes in Idaho shrub-steppe nested in big sage (65.4%), bitterbrush (20.4%) and greasewood (12.3%), with shrubs used for nesting averaging 162 cm (64 in) in height (Woods and Cade 1996). Choice of nest shrub seemed unrelated to the success or failure of shrike nests in Idaho; other variables such as presence of foraging perches may have been more important in determining adequate shrike habitat (Woods and Cade 1996).

Loggerhead shrikes are highly territorial, maintaining larger territories than other insectivorous perching bird species of similar size (Yosef 1996). Mean territory size from 8 different studies ranged from 7.5 ha to 34 ha (18.5 - 84 ac) (Yosef 1996). Poole (1992) found that shrikes defended territories averaging 13.9 ± 2.0 ha (34.35 ± 4.9 ac) on the Hanford Site in Washington. The average distance a shrike nested to the closest adjacent nesting shrike was 610 m (2,000 ft) in shrub-steppe habitat in Washington (Poole 1992) and ranged from 115-670 m (377-2198 ft)in Idaho shrub-steppe (Woods 1995). In the upper Midwest, Brooks and Temple (1990a) observed shrikes hunting up to 400 m (1,312 ft) away from their nest site during nesting season.

Loggerhead shrikes are generalists, feeding on any animal they can subdue (Fraser and Luukkonen 1986, Gawlik and Bildstein 1990, Scott and Morrison 1990). Their diet consists of insects, small mammals, birds, reptiles and amphibians. On the Hanford Site, shrikes preferred grasshoppers, lizards and small mammals (Poole 1992). These prey items were more abundant in sagebrush and bitterbrush communities than in grassland and rabbitbrush (*Chrysothamnus* spp.) communities. Shrikes are the only perching birds that regularly kill and consume vertebrate prey by means of impaling (Fraser and Luukkonen 1986).

LIMITING FACTORS

Specific factors limiting loggerhead shrikes are unknown. Suggested causes of population decline include loss of breeding habitat (Kridelbaugh 1981, Burnside and Shepherd 1985, Tyler 1992), low overwinter survival through loss of wintering areas (Hass and Sloane 1989, Brooks and Temple 1990a,b), contamination by pesticides (Kridelbaugh 1981, Fraser and Luukkonen 1986) and high mortality due to vehicle collision (Gawlik and Bildstein 1990, Flickinger 1995).

MANAGEMENT RECOMMENDATIONS

Shrub-steppe communities should be left in reasonably undisturbed condition and fragmentation should be minimized (Woods and Cade 1996). Management activities that increase cheatgrass invasion or increase risk of wildfire also must be avoided (Leu and Manuwal 1996).

In shrub-steppe and associated riparian habitats, retain patches of tall shrubs for nesting and perching (Leu and Manual 1996). Herbaceous cover should average <20% and should be dominated by native species >30% of the ground should be bare (including areas of cryptogramic crust) (Altman and Holmes 2000). In agricultural areas, retain scattered trees, shrubs, hedgerows, as well as trees along fence lines for nesting and perching (Yosef 1996).

Removal of sagebrush should be considered only in rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration. Sagebrush cover should be reduced on a site only after careful consideration of how the methods used may affect sagebrush regeneration and the opportunity for exotic vegetation to invade the site. Burning may create the greatest risk to local shrike populations because the damage is immediate and regeneration to pre-burn condition may take up to 30 years (Harniss and Murray 1973). Fire is not a suitable tool to reduce sagebrush cover in low rainfall zones because disturbance often leads to cheatgrass invasion and because sagebrush recovery is slow (e.g., Benton, Franklin and Grant Counties) (Wisdom et al. 2000). If chemical use is planned for areas where loggerhead shrikes occur, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

Livestock grazing at low to moderate levels has not been shown to be detrimental to loggerhead shrike habitat (Saab et al. 1995); however, sustained grazing likely will reduce habitat suitability (Altman and Holmes 2000). In keeping with recommendations published for other shrub-steppe passerines (Altman and Holmes 2000), we recommend that grazing levels should be sufficiently low to allow >50% of the year's growth of perennial bunchgrass to persist through the following breeding season.

REFERENCES

Altman, B. and A. Holmes. 2000. Conservation strategy for landbirds in the Columbia Plateau of eastern Oregon and Washington. Final Report Version 1.0. Oregon-Washington Partners in Flight, Boring, Oregon, USA.

Bohall-Wood, P. 1987. Abundance, habitat use, and perch use of loggerhead shrikes in north-central Florida. Wilson Bulletin 99:82-86.

Brooks, B. L., and S. A. Temple. 1990a. Habitat availability and suitability for loggerhead shrikes in the upper midwest. American Midland Naturalist 123:75-83.

____, ____. 1990b. Dynamics of a loggerhead shrike population in Minnesota. Wilson Bulletin 102:441-450.

Burnside, F. L. 1987. Long-distance movements by loggerhead shrikes. Journal of Field Ornithology 58:62-65.

____, and W. M. Shepherd. 1985. Population trends of the loggerhead shrike (*Lanius ludovicianus*) in Arkansas. Proceedings of the Arkansas Academy of Science 39:25-28.

Cade, T. J., and C. P. Woods. 1997. Changes in distribution and abundance of the loggerhead shrike. Conservation Biology 11:21-31.

Flickinger, E. L. 1995. Loggerhead fatalities on a highway in Texas. Pages 67-69 *in* R. Yosef and F. E. Lohrer, editors. Proceedings of the Western Foundation of Vertebrate Zoology Volume 6.

Fraser, J. D., and D. R. Luukkonen. 1986. The loggerhead shrike. *in* R. L. Di Silvestro, editor. Audubon Wildlife Report 1986. National Audubon Society, New York, New York, USA.

Gawlik, D. E., and K. L. Bildstein. 1990. Reproductive success and nesting habitat of loggerhead shrikes in north-central South Carolina. Wilson Bulletin 102:37-48.

Haas, C. A., and S. A. Sloane. 1989. Low return rates of migratory loggerhead shrikes: winter mortality or low site fidelity? Wilson Bulletin 101:458-460.

Harniss, R. O. and R. B. Murray. 1973. 30 years of vegetal change following burning of sagebrush-grass range. J. Range Manage. 26:322-325.

Kridelbaugh, A. L. 1981. Population trend, breeding and wintering distribution of loggerhead shrikes (*Lanius ludovicianus*) in Missouri. Transactions of the Missouri Academy of Science 15:111-119.

____, 1983. Nesting ecology of the loggerhead shrike in central Missouri. Wilson Bulletin 95:303-308.

Leu, M. 1995. The feeding ecology and the selection of nest shrubs and fledgling roost sites by loggerhead shrikes (*Lanius ludovicianus*) in the shrub-steppe habitat. Thesis, University of Washington, Seattle, Washington, USA.

____, and D. A. Manuwal. 1996. Habitat requirements, status,and management of the loggerhead shrike of the Yakima Training Center. Final Report, College of Forest Resources, University of Washington, Seattle, Washington, USA.

Miller, A. H. 1931. Systematic revision and natural history of the American shrikes, *Lanius*. University of California Press, Berkeley, California, USA.

Morrison, M. L. 1981. Population trends of the loggerhead shrike in the United States. American Birds 35:754-757.

Poole, L. D. 1992. Reproductive success and nesting habitat of loggerhead shrikes in shrub-steppe communities. Thesis, Oregon State University, Corvallis, Oregon, USA.

Porter, D. K., M. A. Strong, J. B. Giezentanner, and R. A. Ryder. 1975. Nest ecology, productivity, and growth of the loggerhead shrike on the shortgrass prairie. Southwestern Naturalist 19:429-436.

Saab, V. A. and T. Rich. 1997. Large-scale conservation assessment for neotropical migratory landbirds in the Interior Columbia River Basin. USDA Forest Service General Technical Report PNW-GTR-399.

____, C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. *in* T. E. Martin and D. M. Finch, editors. Ecology and management of Neotropical migratory birds. Oxford University Press, New York, New York, USA.

Sauer, J. R., S. Orsillo, and B. G. Peterjohn. 1995. Geographic patterns and population trends of breeding and wintering loggerhead shrikes in North America. Proceedings of the Western Foundation of Vertebrate Zoology 6:128-141.

Scott, T. A., and M. L. Morrison. 1990. Natural history and management of the San Clemente loggerhead shrike. Proceedings of the Western Foundation of Vertebrate Zoology 4:23-57.

Sibley, D. A. 2000. National Audubon Society: the Sibley guide to birds. Alfred A. Knopf, New York, New York, USA.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington GAP Analysis - Final Report, Seattle Audubon Society Publication in Zoology Number 1, Seattle, Washington, USA.

Tyler, J. D. 1992. Nesting ecology of the loggerhead shrike in southwestern Oklahoma. Wilson Bulletin 104:95-104.

Vander Haegen, W. M., Dobler, F. C., D. J. Pierce. 2000. Shrubsteppe bird response to habitat and landscape variables in eastern Washington, USA. Conservation Biology 14:1145-1160.

Wisdom, M. J., R. S. Holthausen, B. C. Wales, C. D. Hargis, V. A. Saab. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia Basin: broad-scale trends and management implications. UDSA Forest Service General Technical Report PNW-GTR-485, Portland, Oregon, USA.

Woods, C. P. 1995. Status of loggerhead shrikes in the sagebrush habitat of southwestern Idaho. Proceedings of the Western Foundation of Vertebrate Zoology 6:117-121.

____, and T. J. Cade. 1996. Nesting habitat of the loggerhead shrike in sagebrush. The Condor 98:75-81.

Yosef, R. 1996. Loggerhead shrike (*Lanius ludovicianus*). Number 231 *in* A. Poole and F. Gill, editors. The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

KEY POINTS

Habitat Requirements

- Open habitats with short and/or patchy grasses for foraging and scattered trees, shrubs, or hedgerows for nesting and perching sites.
- The shrub-steppe communities occupied by shrikes could be described as a mixture of shrub patches and grassy or sandy openings.

Management Recommendations

- Retain shrub-steppe communities, especially big sagebrush and mixed shrub communities.
- Avoid wildfires and activities that may increase invasion by exotic vegetation.
- Retain patches of tall shrubs for nesting and perching in shrub-steppe and associated riparian habitats.
- Livestock grazing should be kept at low to moderate levels, with >50% of the year's growth of perennial bunchgrass persisting through the following breeding season.
- In agricultural areas (e.g., pastures), establish or retain scattered trees and tall shrubs, wind break, and hedgerow vegetation.
- Refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives if chemical use is planned for areas where this species occurs.

Purple Martin removed from Priority Habitat and Species list in 2018

Purple Martin

Progne subis

Last updated: 2003

Written by David W. Hays and Ruth Milner

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Purple martins breed locally from southern Canada to central Mexico (Brown 1997) and winter in South America (Ehrlich et al. 1988)

In Washington, they typically breed near the waters around the Puget Sound, along the Strait of Juan de Fuca, the southern Pacific coastline, and near the Columbia River (see Figure 1; S. Kostka, personal communication). Unconfirmed records suggest that other potential breeding areas might also be found from the Willamette Valley up through Thurston County.

Figure 1. Generalized breeding range of the purple martin (*Progne subis*) in Washington based a compilation of confirmed sightings (S. Kostka, personal communication).

RATIONALE

The purple martin is a State Candidate species. This species has a high public profile and are vulnerable to population fluctuations due to a limited distribution and loss of suitable natural nesting cavities (Brown 1997).

HABITAT REQUIREMENTS

Purple martins are insectivorous, colonial nesting swallows that nest in cavities (Brown 1997). In Washington, most martins have been reported nesting in artificial structures near cities and towns in the lowlands of western Washington. Historically, they probably bred in old woodpecker cavities in large dead trees, but only a few such nests are known to exist in Washington today (Brown 1997, Russell and Gauthreaux 1999). The eastern race of purple martins often nest in apartment-style nest-boxes, while the western subspecies, found here in Washington, prefer to nest individually (Pridgeon 1997).

The nest site preferences of the purple martin have been studied at Fort Lewis in Pierce County (Bottorff et al. 1994). Martins nested in a variety of artificial nesting structures, including wood duck boxes. No purple martin nesting activity was detected in artificial nesting structures on land; all artificial cavities were over freshwater wetlands, ponds or saltwater. Swallows were found nesting in both natural and artificial cavities intermingled with martin nests, possibly competing for nest sites. More recent observations documented four pairs nesting in natural snag cavities near water at Fort Lewis (S. Kostka, personal communication). Martins were also recently found nesting in boxes well away from water just outside of the fort in Spanaway.

Purple martins feed in flight on insects (Ehrlich et al. 1988, Brown 1997). Favorable martin foraging habitat includes open areas, often located near moist to wet sites, where flying insects are abundant.

LIMITING FACTORS

The decline of the purple martin is attributed to the lack of snags containing nest cavities (Bottorff et al. 1994) as well as competition for nesting cavities with more aggressive European starlings (*Sturnus vulgaris*) and house sparrows (*Passer domesticus*; Bottorff et al. 1994, Brown 1997).

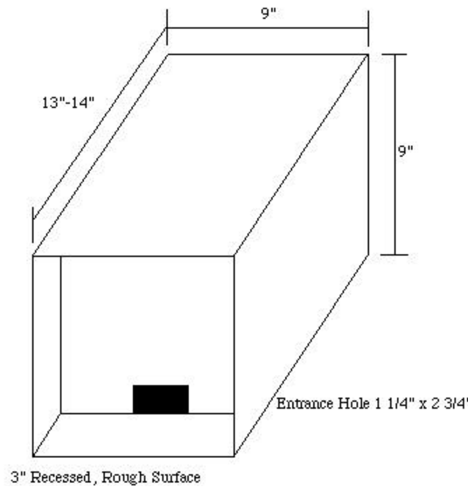


Figure 2. Purple martin nest box plan (Courtesy of Tom Lund, USFWS 1985).

MANAGEMENT RECOMMENDATIONS

In Washington, purple martins are known to nest in cavities located in old pilings over water and occasionally in snags (United States Fish and Wildlife Service 1985, Milner 1987). These pilings and snags (especially snags near water) should be protected and left standing. The removal of creosote-coated pilings that contain a purple martin nest box or that possibly contain cavities used by martins should be closely coordinated with the Washington Department of Fish and Wildlife (M. Tirhi, personal communication). Snags should be retained during timber harvesting operations near saltwater and wetlands (Milner 1988), including salvage operations after burns, blow-downs, and insect infestations (United States Fish and Wildlife Service 1985). Prescribed burns can be used as a tool to create favorable martin foraging habitat. Snags can be created in forest openings, or at forest edges (e.g., by topping trees) where nesting cavities are lacking, especially within 16 km (10 mi) of an existing purple martin colony (United States Fish and Wildlife Service 1985). Because northern flickers and pileated woodpeckers excavate cavities used by martins, managing for these species will indirectly benefit martins (K. Bettinger, personal communication).

Because of their dependence on insects for food, purple martins can be impacted by the broad use of pesticides (United States Fish and Wildlife Service 1985). If insecticide or herbicide use is planned for areas where this species occurs, review Appendix A for contacts to assist in assessing the use of chemicals and their alternatives.

Although artificial nesting structures are an important tool for the conservation of purple martins, they should not replace the protection of natural nesting structures (e.g., snags) and the habitat used by this species (S. Kostka, personal communication). If natural sites are lacking and cannot be provided by manipulating habitat, artificial nesting structures can be provided. A number of artificial nest designs have been developed and work relatively well. Below are the specifications for one such design (United States Fish and Wildlife Service 1985):

1) Construct nest boxes using a design such as that shown in Figure 2. Box dimensions should be at least 10" x 7" x 7". It is important to make the entrance 1 1/4" high, continuous with the porch floor. The top of the opening should be sanded smooth. The porch is a necessary feature, and the floorboard should be rough to provide traction. These features, particularly the size of the opening, will aid in dissuading house sparrows and starlings from taking over the nest boxes.

2) Protect boxes from wet weather by sealing edges with caulking material. Painting or varnishing the wood, using cedar for construction or protecting the roof with galvanized tin, can provide additional protection. Provide drainage holes in the box floor and ventilation holes near the top.

Purple Martin removed from Priority Habitat and Species list in 2018

3) Locate boxes in existing colonies first. Locate additional boxes in suitable habitat within 16 km (10 mi) of existing colonies. A minimum of 3 boxes should be erected at each site for this colonial nesting species (J. Bottorff, personal communication); however, populations in the west do not appear to use the apartment style houses that eastern populations are so well known for (B. Tweit, personal communication).

4) Locate boxes near (preferably above) water or wetlands with minimum clear air space of 4.5 m (15 ft), preferably 30 m (100 ft), for circling and foraging around the nest. Erect houses high enough above the ground or water to avoid vandalism and high tides. J. Bottorff, personal communication) noted no difference in use of boxes erected from 1 m (3 ft) to 3 m (10 ft) above the water.

5) It is not necessary to remove martin nests from previous years. If nesting material is removed, it should be done in the spring and the contents placed in a dry spot beneath the nest. This is to allow for the emergence of chalcid wasps, which help to control Protocalliphora, a parasite on martin nestlings. The wasp larvae live in nest materials and will return to the martin boxes if old nests are left nearby.

6) Where European starlings and house sparrows are a problem, plug the box entrances from October to mid-April. If starlings establish themselves in a box, remove their nests, eggs, and young on a routine basis (they will renest several times in a breeding season). The same measures can be taken with house sparrows early in the breeding season; however, removal of sparrow nests later in the cycle may cause sparrows to wander into martin nests and destroy their young. Adult sparrows may be controlled. If this is impossible, remove eggs and young, but leave sparrow nests in later months to prevent sparrows from taking over martin nests.

7) Starlings and house sparrows are not classified as a protected species. However, other cavity-nesters that may inhabit martin boxes, such as swallows, are protected, and occupied swallow nests should not be removed.

REFERENCES

Bottorff, J., B. Richards, and G. Schroer. 1994. A study of three cavity nesting birds, pileated woodpecker, Vaux's swift, and purple martin on the Fort Lewis Military Reservation. Department of the Army, Fort Lewis Headquarters, I Corps and Environmental and Natural Resource Division.

Brown C. R. 1997. Purple martin (*Progne subis*). Number 287 *in* A. Poole and F. Gill, editors, The birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The birder's handbook: a field guide to the natural history of North American birds. Simon and Schuster, New York, New York, USA.

Milner, R. L. 1987. Status of the Purple Martin (*Progne subis*) in southwestern Washington: Results of the 1987 survey. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.

____. 1988. Guidelines for establishing and maintaining a purple martin nest box colony. Unpublished Report, Washington Department of Wildlife, Olympia, Washington, USA.

Pridgeon, S. 1997. Wildlife in British Columbia at risk: purple martin. British Columbia Ministry of Environment and Lands, Victoria, British Columbia, Canada.

Russell, K.R., and S. A. Gauthreaux. 1999. Spatial and temporal dynamics of a Purple Martin pre-migratory roost. Wilson Bulletin. 111:354-362.

United States Fish and Wildlife Service. 1985. Guidelines for the management of the purple martin, Pacific Coast population. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

Purple Martin removed from Priority Habitat and Species list in 2018

PERSONAL COMMUNICATIONS

Kelly Bettinger, Avian Researcher
Northwest Habitat Institute
Corvallis, Oregon

Jim Bottorff, Fish and Wildlife Biologist
Washington Department of Natural Resources
Olympia, Washington

Stan Kostka
Western Purple Martin Working Group
Arlington, Washington

Michelle Tirhi, Urban Wildlife Biologist
Washington Department of Fish and Wildlife
Kent, Washington

Bill Tweit, Fish and Wildlife Biologist
Washington Department of Fish and Wildlife
Olympia, Washington

KEY POINTS

Habitat Requirements

$ Nests in natural and artificial cavities, usually over water.
$ Readily nest in bird boxes in areas where the species is already established.
$ Usually nest in colonies.
$ Foraging habitat includes open areas, often located near moist to wet sites, where flying insects are abundant.

Management Recommendations

$ Retain snags during timber harvesting (especially near saltwater and wetland sites).
$ Retain old pilings. The removal of creosote-coated pilings that contain a purple martin nest box or that contain cavities used by martins should be coordinated closely with the Washington Department of Fish and Wildlife.
$ Create snags in forest openings and along forest edges if snags are lacking or limited.
$ Use fires to create or maintain favorable martin foraging habitat, where appropriate.
$ If pesticides are to be used in areas inhabited by martins, refer to Appendix A for contacts useful in assessing pesticides, herbicides, and their alternatives.
$ Put up nest boxes when natural cavities are lacking or limited and cannot be created (see text for details).

Sage Thrasher

Oreoscoptes montanus

Last updated: 2003

Written by Matthew Vander Haegen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Sage thrashers breed from British Columbia to eastern Montana, south to northern Arizona and west to California. They winter from central California to central Texas, south to southern Baja California into northern Mexico (American Ornithologists' Union 1983).

In Washington, they are found in the Columbia Basin shrub-steppe region (see Figure 1). Sage thrashers are documented in Adams, Asotin, Benton, Douglas, Franklin, Grant, Kittitas, Lincoln, Okanogan, Walla Walla and Yakima counties (Smith et al. 1997).

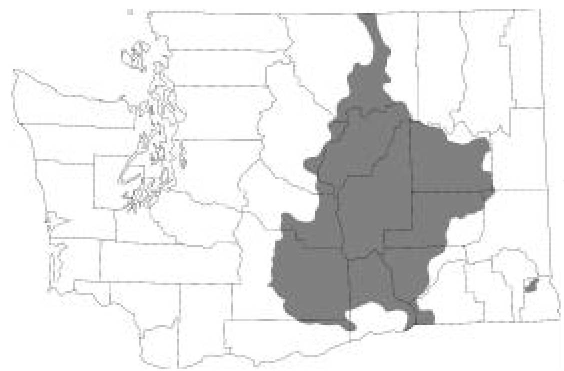


Figure 1. Breeding range of the sage thrasher, *Oreoscoptes montanus*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The sage thrasher is a State Candidate species that is highly dependent on healthy shrub-steppe communities comprised of tall, dense sagebrush (*Artemisia* spp.) (Rich 1980, Reynolds 1981, Reynolds and Rich 1978, Petersen and Best 1991). Shrub-steppe in Washington has become severely fragmented and reduced in extent over the last century (Dobler et al. 1996). Furthermore, the Interior Columbia River Basin Ecosystem Management Project listed the sage thrasher as a species of high management concern for the region (Saab and Rich 1997).

HABITAT REQUIREMENTS

Sage thrashers are closely associated with sagebrush and are considered obligates of sagebrush communities (Braun et al. 1976). In Idaho, sage thrashers used sites that were characterized as having high sagebrush cover within large blocks of shrub-steppe (Knick and Rotenberry 1995). Shrub-steppe describes a plant community consisting of one or more layers of grasses with a discontinuous overstory of shrub cover (Daubenmire 1988). Sage thrashers nest in stands of big sagebrush (*Artemisia tridentata*), placing their nests in or beneath shrubs that are generally 55 to 90 cm (22-36 in) tall (Reynolds and Rich 1978, Rich 1980, Reynolds 1981, Petersen and Best 1991). In Washington, nest shrubs averaged 102 cm tall (n = 122) (Washington Department of Fish and Wildlife, unpublished data). Thrasher nests are bulky and usually located in large bushes with substantially thick branches that provide adequate support

(Reyser 1985, Rich 1985). Reynolds (1981) found that nests built either on the ground or within shrubs had approximately the same depth of foliage over their nests (57.5 cm [23 in]). Petersen and Best (1991) reported that sage thrashers favored shrubs with high foliage density. They also found that thrashers preferred nesting in shrubs having branches or foliage within 30 cm (11.7 in) of the ground. Sage thrashers require a relatively open understory for foraging (Reynolds et al. 1999); however, the amount of bare ground around a typical nest site is usually less than that of the surrounding area (Petersen and Best 1991).

Sage thrashers in Washington occurred in greater abundance in shrub-steppe communities that ranged from fair to good condition (characterized by fewer invasive exotic plants) than at poor condition sites (Vander Haegen et al. 2000). Additionally, sage thrashers were more abundant in shrub-steppe communities with loamy and shallow soils rather than sandy soils.

Mean territory size for sage thrashers ranged from 0.39 ha (1 ac) in Washington (Stephens 1985) to 0.96 ha ± 0.12 ha (2.37 ac ± 0.3 ac) in Idaho (Reynolds and Rich 1978). Sage thrashers will nest in fragments of shrub-steppe set within agricultural areas (Vander Haegen et al. 2002). However, birds using these fragmented sites may experience greater rates of nest predation than their counterparts nesting in large blocks of shrub-steppe.

Sage thrashers forage primarily on the ground and mainly consume grasshoppers, ants, beetles and other insect larvae during the spring (Ryser 1985, Stephens 1985, Petersen and Best 1991). In summer, small fruits are added to their diet (Ryser 1985).

LIMITING FACTORS

Availability of shrub-steppe communities containing tall sagebrush for nesting likely limit the distribution of sage thrashers in Washington (Reynolds et al. 1999). Additionally, degradation of sagebrush stands by invasive plants such as cheatgrass (*Bromus tectorum*) also render sites less suitable to sage thrashers. Fragmentation of shrub-steppe by agriculture apparently does not exclude sage thrashers but will result in lost breeding habitat (Reynolds et al. 1999).

MANAGEMENT RECOMMENDATIONS

In order to maintain sage thrasher populations, shrub-steppe communities should be left in reasonably undisturbed condition and fragmentation should be minimized (Reynolds et al. 1999, Wisdom et al. 2000). Management activities that increase cheatgrass invasion or increase risk of wildfire also must be avoided.

Optimum habitat for sage thrashers in Washington consists of blocks of shrub-steppe > 16 ha (40 ac) with sagebrush cover ranging between 5-20% and shrubs averaging >80 cm (32 in) tall (Altman and Holmes 2000). An herbaceous cover of native species should average 5-20%, with $10% of the ground bare (including areas of cryptogramic crust) to allow movement on the ground. Exotic annual grasses should cover <10% of the ground. Although much of Washington's shrub-steppe is fragmented by agriculture, habitat restoration on formerly tilled fields could expand the range of shrub-steppe obligate birds in fragmented landscapes (Vander Haegen et al. 2000).

Removal of sagebrush should be considered only in rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration (Wisdom et al. 2000). Sagebrush cover should only be reduced after careful consideration of how the removal methods may affect sagebrush regeneration and the spread of exotic vegetation. Burning may lead to serious negative impacts to local sage thrasher populations because the damage is immediate and regeneration to pre-burn condition may take up to 30 years (Harniss and Murray 1973). Fire is not a suitable tool to reduce sagebrush cover in low rainfall zones (e.g., Benton, Franklin and Grant Counties) because exotic plants overwhelm the natives plants and sagebrush is slow to recover (Knick and Rotenberry 1995, Reynolds et al. 1999, Wisdom et al. 2000). If chemical use is planned for areas where this species occurs, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

Although data are limited on this subject, livestock grazing at low to moderate levels has not been shown to be detrimental to sage thrasher habitat (Saab et al. 1995). Because sage thrashers frequently nest and forage at ground level, Altman and Holmes (2000) state that grazing levels should be kept at low intensities. They also suggest allowing >50% of the year's growth of perennial bunchgrass to persist through the following breeding season.

REFERENCES

Altman, B. and A.L. Holmes. 2000. Conservation strategy for landbirds in the Columbia Plateau of eastern Oregon and Washington. American Bird Conservancy and Point Reyes Bird Observatory.

American Ornithologists' Union. 1983. The American Ornithologists' Union checklist of North American birds. Sixth edition. Allen Press, Lawrence, Kansas, USA.

Braun, C. E., M. F. Baker, and R. L. Eng. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bulletin 88:165-171.

Daubenmire, D. 1988. Steppe vegetation of Washington. Bulletin EB 1446. Washington State University Cooperative Extension, Pullman, Washington, USA.

Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Research Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Harniss, R. O., and R. B. Murray. 1973. Thirty years of vegetational change following burning of sagebrush-grass ranges. Journal of Range Management 26:322-325.

Knick, S. T., and J. T. Rotenberry. 1995. Landscape characteristics of fragmented shrubsteppe habitats and breeding passerine birds. Conservation Biology 9:1059-1071.

Petersen, K. L., and L. B. Best. 1991. Nest-site selection by sage thrashers in southeastern Idaho. Great Basin Naturalist 51:261-266.

Reynolds, T. D. 1981. Nesting of sage thrasher, sage sparrow and Brewer's sparrow in southeastern Idaho. Condor 83:61-64.

____, and T. D. Rich. 1978. Reproductive ecology of the sage thrasher (*Oreoscoptes montanus*) on the Snake River Plains in south central Idaho. Auk 95:580-582

Reynolds, T. D., T. D. Rich, and D. A. Stephens. 1999. Sage Thrasher (Oreoscoptes montanus). Number 463 *in* A. Poole and F. Gill, editors. The Birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Rich, T. 1980. Nest placement in sage thrashers, sage sparrows and Brewer's sparrows. Wilson Bulletin 92:362-368.

____. 1985. A sage thrasher nest with constructed shading platform. Murrelet 66:18-19.

Ryser, F. A. 1985. Birds of the Great Basin: A Natural History. University of Nevada Press, Reno, Nevada, USA.

Saab, V., and T. Rich. 1997. Large-scale conservation assessment for neotropical migratory landbirds in the Interior Columbia River Basin. USDA Forest Service General Technical Report PNW-GTR-399, Portland, Oregon, USA.

Saab, V. A., C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. Pages 311-353 *in* T. E. Martin and D. M. Finch, editors. Ecology and management of Neotropical migratory birds. Oxford University Press, New York, New York, USA.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington GAP Analysis - Final Report Seattle Audubon Society Publication in Zoology Number 1, Seattle, Washington, USA.

Stephens, D. A. 1985. Foraging ecology of shrubsteppe birds in central Washington. Thesis, Central Washington University, Ellensburg, Washington, USA.

Vander Haegen, W. M., F. C. Dobler, and D. J. Pierce. 2000. Shrubsteppe bird response to habitat and landscape variables in eastern Washington, USA. Conservation Biology 14:1145-1160.

____, W. M., M. A. Schroeder, and R. M. DeGraaf. 2002. Predation on real and artificial nests in shrub-steppe landscapes fragmented by agriculture. Condor 104:496-506.

Wisdom, M. J., R. S. Holthausen, B. C. Wales, C. D. Hargis, V. A. Saab. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia Basin: broad-scale trends and management implications. UDSA Forest Service General Technical Report PNW-GTR-485, Portland, Oregon, USA.

KEY POINTS

Habitat Requirements

- Closely associated with sagebrush and considered obligates of sagebrush communities. Require extensive stands of shrub-steppe.
- Nest in stands of big sagebrush, placing their nests in or beneath shrubs. Nests are bulky and usually located in large bushes having substantially thick branches that provide adequate support. Favor shrubs with high foliage density that have branches or foliage within 30 cm (11.7 in) of the ground.
- Abundant in shrub-steppe communities with loamy and shallow soils rather than communities with sandy soils.
- Feed primarily on insect larvae.

Management Recommendation

- Retain sagebrush communities and avoid fragmentation of existing sagebrush stands.
- Avoid activities that may increase invasion of cheatgrass and other exotic vegetation.
- Grazing of livestock should be kept at low to moderate levels, with >50% of the year's growth of perennial bunchgrass persisting through the following breeding season.
- Control wildfires in sagebrush habitat, especially in low rainfall zones.
- Removal of sagebrush should be considered only in rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration.
- Retain blocks of shrub-steppe > 16 ha (40 ac) with sagebrush cover ranging from 5-20% and shrubs averaging >80 cm (32 in) tall. An herbaceous cover of native species should average 5-20%, with ≥10% of the ground bare (including areas of cryptogramic crust). Exotic annual grasses should cover <10% of the ground.
- Refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

Sage Sparrow

Amphispiza belli

Last updated: 2003

Written by Matthew Vander Haegen

GENERAL RANGE AND WASHINGTON DISTRIBUTION

Sage sparrows breed from southeastern Washington to northwestern Colorado, and south to southern California, northern Arizona and northwestern New Mexico (Martin and Carlson 1998). They winter at low elevations in southern portions of their range (Farrand 1983).

In Washington, their distribution coincides with sagebrush (*Artemisia* spp.) and bunchgrass (*Agropyron* spp.) communities of the central portion of the state (Larrison and Sonnenberg 1968). Sage sparrows are documented in Adams, Benton, Douglas, Franklin, Grant, Kittitas, Lincoln, Okanogan and Yakima Counties (see Figure 1; Smith et al. 1997).

Figure 1. General breeding range of the sage sparrow, *Amphispiza belli*, in Washington. Map derived from Smith et al. 1997.

RATIONALE

The sage sparrow is a State Candidate species that depends almost entirely on sagebrush-steppe habitat (Braun et al. 1976, Rich 1980, Reynolds 1981, Petersen and Best 1985). This habitat in Washington has become severely fragmented and reduced in extent over the last century (Dobler et al. 1996), particularly the deep-soil communities that this species apparently prefers (Vander Haegen et al. 2000). Furthermore, the Interior Columbia River Basin Ecosystem Management Project listed the sage sparrow as a species of high management concern for the region (Saab and Rich 1997).

HABITAT REQUIREMENTS

Sage sparrows are closely associated with sagebrush-steppe plant communities (Braun et al. 1976, Wiens and Rotenberry 1981). Sagebrush-steppe describes a plant community consisting of one or more layers of grasses and forbs with a discontinuous overstory of sagebrush shrub cover (Daubenmire 1988). Sage sparrows are sensitive to fragmentation of sage cover and are found more frequently in extensive areas of continuous sage (Knick and Rotenberry 1995, Vander Haegen et al. 2000).

Sage sparrows commonly nest within or beneath sagebrush plants (Martin and Carlson 1998). Nesting takes place from late March through June, with pairs typically producing 1-2 broods/year (Bent 1968, Alcorn 1978, Rich 1980, Ryser 1985, Petersen and Best 1987). Shrubs that are at least 75% living are selected for nesting, and nests are always located outside of the dead portion of the shrub (Petersen and Best 1985). The height of shrubs used for nesting generally ranged between 40 and 100 cm (16-40 in) (Rich 1980, Reynolds 1981, Petersen and Best 1985) and averaged 90 cm (35 in) in eastern Washington (Washington Department of Fish and Wildlife, unpublished data).

Contiguous breeding territories generally are established by males in March (Petersen and Best 1987). Territory sizes of mated males vary greatly (Weins et al. 1985), ranging from 0.8 ha (2 ac) (Petersen and Best 1987) to 4.4 ha (11 ac) (Rich 1980). A study in southeastern Washington found that the size of breeding territories ranged between 0.65 ha (1.6 ac) and 1.57 ha (3.9 ac); territories also tended to decrease in size with an increase in population density (Weins et al. 1985). Boundaries between adjacent territories have been found to overlap, and the size and shape may fluctuate daily during the breeding season (Rich 1980).

In spring, sage sparrows are primarily insectivorous, feeding on grasshoppers, beetles and moth larvae (Martin and Carlson 1998). They glean food from the ground and from shrub branches within reach of the ground (Moldenhauer and Wiens 1970, Petersen and Best 1985, Ryser 1985). Sparrows also have been observed walking to and from their nests (T. Rich personal communication and B.M. Winter personal communication *in* Petersen and Best 1985). Thus, optimal foraging habitat should include an overstory of shrubs with clearings in the grass/forb layer to allow movement on the ground (Petersen and Best 1985).

LIMITING FACTORS

Availability of extensive sagebrush-steppe habitat is a primary factor limiting sage sparrow populations (Martin and Carlson 1998, Vander Haegen et al. 2000). Sage sparrows are sensitive to fragmentation of sagebrush stands and are found more frequently in large, undisturbed stands (Vander Haegen et al. 2000). Degradation of sagebrush stands by invasive plants such as cheatgrass (*Bromus tectorum*) also may render sites less suitable to sage sparrows (Dobler et al. 1996).

MANAGEMENT RECOMMENDATIONS

Sage sparrows are dependent on stands of sagebrush for nest sites, food, and cover (Martin and Carlson 1998). In order to maintain sage sparrow populations, sagebrush communities should be left in relatively undisturbed condition and fragmentation should be avoided. Management activities that increase cheatgrass and other exotic species that increase the risk of wildfire also should be avoided.

Optimum habitat for sage sparrows in Washington consists of large (>1000ha) blocks of sagebrush-steppe with sagebrush cover ranging from 10-25% and shrubs averaging >50 cm in height (Altman and Holmes 2000). Herbaceous cover of native species should average >10%, with ≥10% of the ground remaining bare (including areas of cryptogramic crust) to allow movement on the ground. Exotic annual grasses should cover <10% of the ground. Although much of Washington's sagebrush-steppe is fragmented by agriculture, habitat restoration on formerly tilled fields could expand the range of sagebrush-steppe obligate birds in fragmented landscapes (Vander Haegen et al. 2000).

Removal of sagebrush should be avoided, with the exception of rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration (Wisdom et al. 2000). Sagebrush cover should be reduced on a site only after careful consideration of how the methods used may affect sagebrush regeneration and the opportunity for exotic vegetation to invade the site. Burning may lead to serious negative impacts to local sage sparrow populations because the damage is immediate and regeneration to pre-burn condition may take up to 30 years (Harniss and Murray 1973). Fire is not a suitable tool to reduce sagebrush cover in low rainfall zones (e.g., Benton, Franklin, and Grant Counties) where exotic vegetation often becomes dominant and sagebrush is slow to recover (Knick and Rotenberry 1995, Wisdom et al. 2000). If chemical use is planned for areas where this species occurs, refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and their alternatives.

Although limited data are available on this subject, livestock grazing at low to moderate levels has not been shown to be detrimental to sage sparrow habitat (Saab et al. 1995). Because sage sparrows in Washington frequently nest on the ground early in the spring (Washington Department of Fish and Wildlife, unpublished data), and because they primarily forage at ground level, grazing levels should be kept at low levels (Altman and Holmes 2000). Researchers suggest allowing >50% of the year's growth of perennial bunchgrass to persist through the following breeding season.

REFERENCES

Alcorn, G. D. 1978. Northwest birds: Distribution and eggs. Western Media Print, Tacoma, Washington, USA.

Altman, B., and A. L. Holmes. 2000. Conservation strategy for landbirds in the Columbia Plateau of eastern Oregon and Washington. Prepared for Oregon and Washington Partners in Flight. The American Bird Conservancy and Point Reyes Bird Observatory.

Bent, A. C. 1968. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies: Part II. Dover, New York, New York, USA.

Braun C. E., R. L. Eng, J. S. Gashwiler, M. H. Schroeder, and M. F. Baker. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bulletin 88:165-171.

Daubenmire, D. 1988. Steppe vegetation of Washington. Bulletin EB 1446, Washington State University Cooperative Extension, Pullman, Washington, USA.

Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Research Report, Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Farrand, J., Jr., editor. 1983. The Audubon Society master guide to birding. Volume 3. A.A. Knopf, New York, New York, USA.

Harniss, R. O., and R. B. Murray. 1973. Thirty years of vegetational change following burning of sagebrush-grass ranges. Journal of Range Management 26:322-325.

Knick, S. T., and J. T. Rotenberry. 1995. Landscape characteristics of fragmented shrub-steppe habitats and breeding passerine birds. Conservation Biology 9:1059-1071.

Larrison, E. J., and K.G. Sonnenberg. 1968. Washington birds: Their location and identification. Seattle Audubon Society, Seattle, Washington, USA.

Martin, J. W., and B. A. Carlson. 1998. Sage Sparrow (Amphispiza belli). Number 326. *in* A. Poole and F. Gill, editors. The Birds of North America. Academy of National Science and American Ornithologists' Union, Philadelphia, Pennsylvania, USA.

Moldenhauer, R. R., and J.A. Wiens. 1970. The water economy of the sage sparrow, Amphispiza belli nevadensis. Condor 72:265-275.

Petersen, K. L., and L. B. Best. 1985. Nest-site selection by sage sparrows. Condor 87:217-221.

____, and ____. 1987. Territory dynamics in a sage sparrow population: are shifts in site use adaptive? Behavioral Ecology and Sociobiology 21:351-358.

Reynolds, T. D. 1981. Nesting of sage thrasher, sage sparrow and Brewer's sparrow in southeastern Idaho. Condor 83:61-64.

Rich, T. 1980. Nest placement in sage thrashers, sage sparrows and Brewer's sparrows. Wilson Bulletin 92:362-368.

Ryser, F. A., Jr. 1985. Birds of the Great Basin: A natural history. University of Nevada Press, Reno, Nevada, USA.

Saab, V., and T. Rich. 1997. Large-scale conservation assessment for neotropical migratory landbirds in the Interior Columbia River Basin. USDA Forest Service General Technical Report PNW-GTR-399, Portland, Oregon, USA.

Saab, V. A., C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. Page 311-353 *in* T. E. Martin and D. M. Finch, editors, Ecology and management of Neotropical migratory birds. Oxford University Press, New York, New York, USA.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state. Volume 4 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington GAP Analysis - Final Report Seattle Audubon Society Publication in Zoology Number 1, Seattle, Washington, USA.

Vander Haegen, W. M., F. C. Dobler, and D. J. Pierce. 2000. Shrubsteppe bird response to habitat and landscape variables in eastern Washington, USA. Conservation Biology 14:1145-1160.

Wiens, J. A., and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecological Monographs 51:21-41.

____, ____, and B. Van Horne. 1985. Territory size variations in shrub-steppe birds. Auk 102:500-505.

Wisdom, M. J., R. S. Holthausen, B. C. Wales, C. D. Hargis, V. A. Saab. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia Basin: broad-scale trends and management implications. UDSA Forest Service General Technical Report PNW-GTR-485, Portland, Oregon, USA.

KEY POINTS

Habitat Requirements

- Strong association with sagebrush habitat, especially in extensive, unfragmented stands.
- Sagebrush cover between 10 and 25%, with shrubs averaging >50 cm in height.
- Herbaceous cover (native species) >10%, with ≥10% of the ground bare (including areas of cryptogramic crust); exotic annual grasses should cover <10% of the ground.

Management Recommendation

- Retain large blocks of sagebrush communities and avoid fragmentation of existing stands.
- Establish or retain 10-25% sagebrush cover and shrubs averaging >50 cm in height. Maintain an herbaceous cover of native species averaging >10%, with ≥10% of the ground bare (including areas of cryptogramic crust). Reduce exotic annual grasses to <10% of the ground cover.
- Avoid activities that may increase invasion of cheatgrass and other exotic vegetation.
- Livestock grazing should be kept at low to moderate levels, with >50% of the year's growth of perennial bunchgrass persisting through the following breeding season.
- Control wildfires in sagebrush habitat, especially in low rainfall zones.
- Refer to Appendix A for a list of contacts to consult when using and assessing pesticides, herbicides and other alternatives.
- Avoid the removal of sagebrush, with the exception of rare instances when reducing shrub cover is necessary to meet ecological goals of habitat restoration.

APPENDIX A: Contacts to assist in evaluating the use of herbicides, pesticides, and their alternatives

Government Organizations

United States Environmental Protection Agency

Provides information, brochures, and technical help on pesticide application.

Region 10 Public Affairs Office, Seattle 1-800-424-4372

Washington State Department of Agriculture

Pesticide Management

General Information..(360) 902-2010
Toll Free General Information..(877) 301-4555
Assistant Director..(360) 902-2011

Compliance

Enforces state and federal pesticide laws; investigates complaints of pesticide misuse.

Manager ....(360) 902-2036
Olympia Compliance ....(360) 902-2040
Moses Lake ....(509) 766-2575
Spokane Compliance ....(509) 533-2690
Wenatchee Compliance...(509) 664-3171
Yakima Compliance ....(509) 225-2647

Registration and Licensing

Registers pesticides sold and used in Washington.

Manager ....(360) 902-2026
Pesticide Registration - Olympia ....(360) 902-2030
Pesticide Registration - Yakima ....(509) 255-2647

Program Development

Licenses pesticide application equipment and pesticide dealers; commercial, public, and private pesticide applications; and operators and consultants. Conducts waste pesticide disposal program; responsible for public outreach and education.

Manager ....(360) 902-2051
Pesticide Licensing and Recertification
Eastern Washington...(509) 225-2639
Western Washington..(360) 902-1937

Waste Pesticide Collection..(360) 902-2050
Farmworker Ed. and Pest. Licensing - Yakima ....(509) 255-2639

Washington Department of Ecology, Regional Contacts

DOE provides information and permits on applying pesticides directly or indirectly into open bodies of water.

Eastern Region, Spokane ....(509) 456-2926
Central Region, Yakima ....(509) 575-2490
Northwest Region, Bellevue ....(206) 649-7000
Southwest Region, Lacey....... ....(360) 407-6300

Washington Department of Fish and Wildlife

Regional Contacts

Your regional program manager will direct your questions to a biologist. The department can provide information on what priority habitats and species are known to be in your area, and the life requisites of priority species.

Region 1, Spokane ....(509) 456-4082
Region 2, Ephrata.. ....(509) 754-4624
Region 3, Yakima ....(509) 575-2740
Region 4, Mill Creek.................................... ....(206) 775-1311
Region 5, Vancouver.................................... ....(360) 696-6211
Region 6, Montesano ....(360) 249-4628

Habitat Research and Information Services

Mapped information and management recommendations for Washington's priority habitats and species can be obtained by calling (360) 902-2543.

Washington Poison Control Center .. ..(800) 222-1222

Provides information on who to contact in case of exposure to or spill of pesticides or other toxic substances.

Non-Government Organizations

Agricultural Support Groups

Tilth Producers....................... ....(206) 442-7620
Chapter of Washington Tilth
P.O. Box 85056
Seattle, WA 98145-1056

Provides a directory of organic growers, food and farm suppliers, and resources, called the Washington Tilth Directory. Can help place farmers wishing to reduce pesticide use in touch with those who have already done so.

Northwest Coalition for Alternatives to Pesticides................(541) 344-5044
P.O. Box 1393
Eugene, OR 97440-1393

Provides information on a network of farmers practicing sustainable agriculture.

Palouse-Clearwater Environmental Institute .. ..(208) 882-1444
P.O. Box 8596
112 W. 4th, Suite 1
Moscow, ID 83843

Coordinates farm/consumer improvement clubs in eastern Washington and is the western coordinator of the Campaign for Sustainable Agriculture.

Alternative Energy Resources Organization... ....(406) 443-7272
25 S. Ewing Suite 214
Helena, MT 59601

Coordinates a network of farm improvement clubs and produces a list of organic growers in Montana. Has information on growing grains in the Palouse region.

Financial Support for Farmers Shifting to Sustainable Agriculture

Cascadia Revolving Loan Fund ....(206) 447-9226
1901 NW Market Street
Seattle, WA 98107

A non-profit organization that lends money to small businesses.

Sustainable Agriculture Research and Education ....(435) 797-2257
Western Region SARE
Room 305 Agricultural Science Building
4865 Old Main Hill Road
Logan, UT 84322-4865

A federal grant program for farmer-directed, on-farm research. The grants are called Farmer/Rancher Research Grants.

The Organic Farming Research Foundation..........................(831) 426-6606
P.O. Box 440
Santa Cruz, CA 95061

Provides funding for organic farming methodology research.

Insectaries

Northwest Biocontrol Insectary/Quarantine Insectary...........(509) 335-5504
Terry Miller

Can provide limited technical advice on using beneficial insects as biological control agents.

Integrated Pest Management and Non-Chemical Alternatives

Bio-Integral Resource Center) ....(510) 524-2567
P.O. Box 7414
Berkeley, CA 94707

Publishes "Common Sense Pest Control Quarterly", and "The IPM Practitioner Monitoring the Field of Pest Management."

Integrated Fertility Management...(800) 332-3179
333 Ohme Gardens Rd.
Wenatchee, WA 98801

Provides information on organic farming, biological pest control, and soil amendments. Also provides a network with which growers can contact each other.

Northwest Coalition for Alternatives to Pesticides................(541) 344-5044

Located in Oregon, provides information regarding integrated pest management, a list of private consultants, as well as other sources and contacts.

Washington Toxics Coalition..(206) 632-1545

Has an information file on many topics involving chemical pesticides, including effects on the environment and on human health, as well as alternatives to household and garden chemicals.

National Organizations

Appropriate Technology Transfer for Rural Areas................(800) 346-9140
P.O. Box 3657
Fayetteville, AR 72702

Information service on sustainable agriculture. Not ideal for questions that are regionally specific, but good for crop production questions.

Chemical Referral Center ....(800) 262-8200

This center, which is sponsored by the Chemical Manufacturers Association, will refer the caller to the manufacturer of the chemical in question, and provide telephone numbers of other hotlines.

National Agricultural Library ....(301) 504-6559
Alternative Farming Systems Information Center
10301 Baltimore Blvd.
Beltsville, MD 20705-2351

Provides bibliographies on topics such as cover crops, living mulches, compost, etc. Will do individual searches on national agricultural databases for free. This organization's strong point is specific, technical information.

National Pesticide Telecommunication Network ....(800) 858-PEST (7378)

Provides 24-hour information on pesticide products, poisoning, cleanup and disposal, enforcement contacts, certification and training programs, and pesticide laws.

Safety, Storage, Handling, and Disposal

Washington Toxics Coalition..(206) 632-1545

Has an information file on many topics involving chemical pesticides, including effects on the environment and on human health.

Local Solid Waste/Recycling Centers

Your county or municipal solid waste center may be of assistance when disposing of pesticides and herbicides.

Washington State University Cooperative Extension Service, County Agents

County	Address	City	Phone #		County	Address	City	Phone #
Adams	210 W. Broadway	Ritzville 99169	(509) 659-3209		Lewis	360 NW North St. MS: AES01	Chehalis 98532	(360) 740-1212
Asotin	2535 Riverside Drive	Asotin 99402	(509) 758-5147		Lincoln	PO Box 399	Davenport 99122	(509) 725-4171
Benton	5600-E W Canal Drive	Kennewick 99336	(509) 735-3551		Mason	11840 Hwy 101 N.	Shelton 98584	(360) 427-9670 Ext. 395
Chelan	303 Palouse Street	Wenatchee 98801	(509) 667-6540		Okanogan	PO Box 391	Okanogan 98840	(509) 422-7245
Clallam	223 East 4th St.	Port Angeles 98362	(360) 417-2279		Pacific	PO Box 88	South Bend 98586	(360) 875-9331
Clark	11104 NE 149th Street	Bush Prairie 98606	(360) 397-6060		Pend Oreille	PO Box 5045	Newport 99156	(509) 447-2401
Columbia	202 S. 2nd Street	Dayton 99328	(509) 382-4741		Pierce	3049 S 36th, Suite 300	Tacoma 98409	(253) 798-7180
Cowlitz	207 4th Ave N	Kelso 98626	(360) 577-3014		San Juan	221 Weber Way, Suite LL	Friday Harbor 98250	(360) 378-4414

County	Address	City	Phone #	County	Address	City	Phone #
Douglas	PO Box 550	Waterville 98858	(509) 745-8531	Skagit	306 S First Street	Mount Vernon 98273	(360) 428-4270
Ferry	350 E. Delaware Ave #9	Republic 99166	(509) 775-5235	Skamania	PO Box 790	Stevenson 98648	(509) 427-9427
Franklin	Courthouse 1016 N. 4th	Pasco 99301	(509) 545-3511	Snohomish	600 128th St. SE	Everett 98208	(425) 338-2400
Garfield	PO Box 190	Pomeroy 99347	(509) 843-3701	Spokane	222 N Havana	Spokane 99202	(509) 477-2048
Grant	PO Box 37 35 C Street NW	Ephrata 98823	(509) 754-2011 Ext. 413	Stevens	985 S Elm, Suite A	Colville 99114	(509) 684-2588
Grays Harbor	PO Box R 32 Elma-McCleary Road	Montesano 98541	(360) 482-2934	Thurston	720 Sleater Kinney Road SE, Suite Y	Lacey 98503	(360) 786-5445
Island	PO Box 5000 101 NE 6th	Coupeville 98239	(360) 679-7327	Wahkiakum	PO Box 278	Cathlamet 98612	(360) 795-3278
Jefferson	201 W. Patison	Port Hadlock 98339	(360) 379-5610	Walla Walla	328 W Poplar Street	Walla Walla 99362	(509) 527-3260
King	919 SW Grady Way, Suite 120	Renton 98055	(206) 205-3100	Whatcom	1000 N Forest Street, Suite 201	Bellingham 98225	(360) 676-6736
Kitsap	614 Division Street MS-16	Port Orchard 98366	(360) 337-7157	Whitman	310 N Main, Room 209	Colfax 99111	(509) 397-6290
Kittitas	507 Nanum Ave, Room 2	Ellensburg 98926	(509) 962-7507	Yakima	128 N 2nd Street, Room 233	Yakima 98901	(509) 574-1600
Klickitat	228 W Main, MS-CH 12	Goldendale 98620	(509) 773-5817				

Appendix B. Native plants suitable for a thicket-like visual barrier around a heron colony.

Scientific Name	Common Name [a]	Comments
Cornus sericea	red-osier dogwood	• Wet and moist soils • Full sun • Native throughout Washington and British Columbia.
Crataegus douglasii	black hawthorn	• Moist soils • Partial shade • Thorny • Ensure you know the variety and care necessary to encourage growth as a shrub rather than a tree • Native throughout Washington and British Columbia
Crataegus suksdorfii	Suksdorf's hawthorn	• Moist soils • Partial shade • Thorny • Ensure you know the variety and care necessary to encourage growth as a shrub rather than a tree • Native to areas west of the Cascades
Malus fusca	western crabapple	• Wet and moist soils • Full to some shade • Thorny • Native to areas west of the Cascades
Prunus emarginata	bitter cherry	• Moist soils • Full sun • Native to coastal and interior Washington and British Columbia • For creating a barrier, plant the shrub variety (*Prunus emarginata* var. *emarginata*)
Ribes divaricatum	straggly gooseberry	• Dryer soils • Full to partial sun • Thorny • Native to areas west of the Cascades
Rosa spp.	native rose	• Native species include nootka rose, bald hip rose, and clustered rose.
Rubus parviflorus	thimbleberry	• Dryer soils • Mostly sunny • Native to areas west of the Cascades
Rubus spectabilis	salmonberry	• Wet and moist soils • Full to partial sun • Native from the East Cascades to the coast
Spiraea douglasii	hardhack	• Wet and moist soils • Full to mostly sunny • Native throughout region, except for in the Columbia Basin
Symphoricarpos albus	common snowberry	• Moist and dry soils • Mostly to part sun • Native throughout Washington and British Columbia

[a.] Click on common names for more information about requirements of each plant species.