Aquatic Species Enhancement Plan

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Prepared by

The Aquatic Species Enhancement Plan Technical Committee

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Chehalis Basin Work Group

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LIST OF ACRONYMS AND ABBREVIATIONS

7DADmax	7-day average of the daily maximum temperature
ASEP	Aquatic Species Enhancement Plan
Basin	Chehalis Basin
cfs	cubic feet per second
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
EDT	Ecosystem Diagnosis & Treatment
EEZ	exclusive economic zone
ELJ	engineered log jam
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FLIR	Forward Looking Infrared Radiometer
HEC-RAS	Hydrologic Engineering Center River Analysis System
HSI	Habitat Suitability Index
km	kilometer
LWM	large woody material
m	meter
MF	managed forest
NMF	non-managed forest
NMFS	National Marine Fisheries Service
PFMC	Pacific Fishery Management Council
PHABSIM	Physical Habitat Simulation
PHS	Priority and Habitat Species
Project	Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species Project
R/S	recruits-per-spawner
RKm	River Kilometer
RM	River Mile
SaSI	Salmon Stock Inventory
SD	standard deviation
SHIRAZ	Salmon Habitat Integrated Resource Analysis
State	State of Washington
USFWS	U.S. Fish and Wildlife Service
VSP	Viable Salmonid Population
WDF	Washington Department of Fisheries
WFPA	Washington Forest Practices Act
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation
WY	Water Year

Executive Summary

Introduction

The Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species Project (Project) is a feasibility-level study of the benefits and effects of alternatives for flood reduction and a basin-wide assessment of enhancement opportunities for aquatic species. This report is one of two developed to address nine Aquatic Species Enhancement Plan (ASEP) objectives for the State of Washington. It examines several options for improving habitat for several species within the Chehalis basin (basin). The companion report titled *Effects of Flood Reduction Alternatives and Climate Change on Aquatic Species* summarizes results of studies on the potential effects of flood reduction alternatives and future climate variability on aquatic resources, and combinations of these alternatives. Additionally, several areas were identified during the development of these studies that require additional examination. These areas are compiled in a companion report titled *Aquatic Species Enhancement Plan Data Gaps Report*.

This ASEP examines enhancing aquatic species in the basin independent of the flood reduction alternatives that are being evaluated as part of this project. That is, the ASEP is not a study on how to mitigate for dam effects, but rather is an attempt to take a more holistic look at the status of ecosystem structures, functions and processes, which includes aquatic species in the basin, habitat factors limiting aquatic species populations, and actions that could be taken to increase the populations of those aquatic species.

This process was co-led by Anchor QEA and the Washington Department of Fish and Wildlife (WDFW) and Erik Neatherlin (WDFW) and John Ferguson (Anchor QEA) co-led the study. Analyses were conducted primarily by staff from WDFW and the Anchor QEA consulting team (Anchor QEA, ICF International, Confluence Environmental, and BioAnalysts, Inc.) under the general direction of the State of Washington and the Chehalis Basin Flood Study's ASEP Technical Committee (Committee). Additional staff from the Washington State Department of Ecology (Ecology), the Chehalis Tribe, the Quinault Indian Nation, local water districts, municipalities, natural resource agencies, also contributed to the implementation of the studies presented in this report. Their input was received during technical workshops, committee meetings, and numerous teleconferences. These workshops and meetings resulted in the approach, methods, assumptions, and alternatives used to develop the results presented in this report.

The basin, which covers 2,766 square miles (7,164 km^2), is the largest river basin in western Washington and one of the only remaining systems that maintains something of an active connection with the floodplain. It is the largest watershed located entirely within Washington State. Extensive in-channel and off-channel habitats for aquatic species, high salmonid fish species diversity, an endemic species of mudminnow, and the highest species richness of amphibians in Washington State are notable features of the basin. Starting in the 1850s, human-caused impacts on aquatic species habitat have been extensive. Major factors influencing salmon, steelhead, other fish, and various other species habitats include agriculture, logging, large downed-wood removal, gravel mining, large woody material (LWM) removal, urbanization, estuarine dredging and filling, dams, diversions, and industrial waste disposal.

For the ASEP, a list of approximately 70 Key Species of fish, invertebrates, mammals, and birds was compiled. These species were screened and grouped through a guilding process, and assessed using a variety of models and approaches. This screening process resulted in the following 23 species, organized into three groups (Ecosystem Diagnosis & Treatment [EDT] modeled salmonids, Other Fish, and Non-fish), being evaluated in the ASEP (Table ES-1).

Table ES-1
Key Species Analyzed in the Aquatic Species Enhancement Plan

KEY SPECIES (COMMON NAME)	SCIENTIFIC NAME	MODELING ALTERNATIVES		
		EDT (E)	HSI	CORRELATIVE
Salmonids				
Winter-run steelhead	*Oncorhynchus mykiss*	E		
Coho salmon	*Oncorhynchus kisutch*	E		
Fall-run Chinook salmon	*Oncorhynchus tshawytscha*	E		
Spring-run Chinook salmon	*Oncorhynchus salmonncorhynchus tshawytscha*	E		
Other Fish Species				
Chum salmon	*Oncorhynchus keta*		X	
Eulachon	*Thaleichthys pacificus*			X
Pacific lamprey	*Lampetra tridentata*		X	
White sturgeon	*Acipenser transmontanus*		X	
Olympic mudminnow	*Novumbra hubbsi*			X
Speckled dace	*Rhinichthys osculus*			X
Largescale sucker	*Catostomus macrocheilus*			X
Riffle sculpin	*Cottus gulosus*			X
Reticulate sculpin	*Cottus perplexus*			X
Smallmouth bass	*Micropterus dolomieu*		X	
Largemouth bass	*Micropterus salmoides*		X	
Non-fish Species				
Coastal tailed frog	*Ascaphus truei*			X
Western toad	*Bufo boreas*		X	
Northern red-legged frog	*Rana aurora*			X
Oregon spotted frog	*Rana pretiosa*			X
Dunn’s salamander	*Plethodon dunni*			X
Van Dyke’s salamander	*Plethodon vandykei*			X
North American beaver	*Castor canadensis*			X

Notes: EDT = Ecosystem Diagnosis & Treatment
HSI = Habitat Suitability Index

Current Conditions: Salmon Population Status and Trends

Based on WDFW spawner index data, coho salmon (*Oncorhynchus kisutch*) are the most abundant salmon in the basin of the four EDT modeled salmonid species or runs, with a 10-year mean escapement of 42,594 fish each year since 2004. The next most abundant species or run was fall-run Chinook salmon (*O. tshawytscha*), which had a 10-year geometric mean escapement of 9,620 fish, then winter-run steelhead (*O. mykiss*) with a 10-year geometric mean escapement of 8,731 fish, followed by spring-run Chinook salmon (*O. tshawytscha*) with a 10-year geometric mean escapement of 2,282 fish.

Based on EDT, a habitat-population model, the basin provides the greatest quantity and quality of habitat for coho and fall-run Chinook salmon. Spring-run Chinook salmon habitat potential is considerably less, and low habitat diversity for spring-run Chinook salmon suggests the habitat for this species has become markedly limited relative to historic conditions. Carrying capacity for Winter-run steelhead is relatively low but the high productivity and diversity of steelhead habitat indicates that habitat quality in the Chehalis appears generally adequate for winter-run steelhead. These results generally agree with the WDFW spawner abundance data.

Current Conditions: Other Fish and Non-fish Population Status and Trends

Abundance trends and population structure information for native Other Fish and Non-fish Key Species in the Chehalis River system is generally lacking, though some of these species are special status taxa that are at risk at varying degrees. The latter include the federally listed Oregon spotted frog (*Rana pretiosa*), the state sensitive Olympic mudminnow (*Novumbra hubbsi*), and the state candidate western toad (*Anaxyrus boreas*). Additionally, other species in this group are likely in decline such as the western pond turtle (*Actinemys marmorata*) based on a number of criteria and information from across the range of these animals. The range of the Olympic mudminnow is primarily restricted to the basin (Kuehne and Olden 2014.). A number of other species including American shad (*Alosa sapidissima*), common carp (*Cyprinus carpio*), catfishes (*Ictalurid sp*), yellow perch (*Perca flavescens*), largemouth and smallmouth bass (*Micropterus salmoides* and *Micropterus dolomieu*), bluegill (*Lepomis macrochirus*), other sunfishes (centrarchids), and the American bullfrog (*Lithobates catesbeianus*) have been introduced to the basin, usually for human use. These fishes have received only casual attention but not intensive monitoring. Based on information elsewhere, non-native fishes and bullfrogs are strongly suspected of adversely impacting native species, though these interactions and their distributions in the basin are very poorly understood.

To summarize, limited information exists on distributions, relative abundance, and life history for Other Fish and Non-fish Species, and no information is available either on abundance trends or clear indications of major limiting factors. Information on the same aspects for Non-fish Species in the basin is even sparser.

Limiting Factors and Enhancement Potential: Salmon

Three primary sources of information were used to identify habitat factors that limit salmonids within the basin. First is the work by Smith and Wenger (2001), which identified habitat factors limiting salmonid abundance and production. Second is the 2004 Chehalis Basin Watershed Management Plan (Hilborn and Mangel 1997) and the Chehalis Basin Salmon Habitat Restoration and Preservation Strategy (Grays Harbor Lead Entity 2011; Table ES-2). The latter was prepared by the Grays Harbor County Lead Entity Habitat Work Group in 2011. Lastly are the results from EDT, which evaluated habitat that is used by four species of salmon in the basin. This information was reviewed by local experts and was used to help identify appropriate enhancement actions.

Table ES-2
Summary of Habitat Factors Limiting the Productivity of Salmon Developed by Smith and Wenger and the Grays Harbor County Lead Entity Habitat Work Group

SUB-BASIN UNITS	LIMITING FACTORS	
	SMITH AND WENGER DETERMINATIONS	LEAD ENTITY'S SALMON HABITAT RESTORATION AND PRESERVATION STRATEGY
Wynoochee River	Floodplain habitat; Sediment; Riparian habitat; Stream flows; Water quality	Migration barriers*; Riparian habitat*; Floodplain habitat*; Water quality (temperature); Sediment; Habitat diversity (LWM); Stream flows
Satsop River	Migration barriers; Sediment; Channel stability; Riparian habitat; Stream flows; Water quality	Floodplain habitat*; Water quality (suspended sediment)*; Riparian habitat*; Migration barriers*; Sediment*; Stream flows*; Habitat diversity (LWM)
Lower Chehalis Tributaries	Floodplain habitat; Sediment; Habitat diversity; Riparian habitat; Stream flows; Water quality	Migration barriers*; Riparian habitat*; Habitat diversity (LWM)*; Stream flows*; Sediment; Floodplain habitat; Water quality (temperature)
Lower Chehalis Mainstem	Floodplain habitat; Sediment; Habitat diversity; Riparian habitat; Stream flows; Water quality	Riparian habitat*; Water quality (temp, DO, fecal coliform)*; Floodplain habitat*; Habitat diversity (LWM); Stream flows; Sediment
Black River	Migration barriers; Floodplain habitat; Sediment; Riparian habitat; Stream flows; Water quality	Water quality (temp, DO)*; Riparian habitat*; Stream flows*; Habitat diversity (LWM); Migration barriers; Floodplain habitat; Sediment
Scatter Creek	Sediment; Channel stability; Riparian habitat; Stream flows; Water quality	Riparian habitat*; Water quality (temp, fecal coliform, pH)*; Stream flows*; Sediment; Migration barriers; Floodplain habitat; Habitat diversity (LWM)
Skookumchuck River	Migration barriers; Floodplain habitat; Sediment; Channel stability; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Floodplain habitat*; Riparian habitat*; Migration barriers*; Stream flows; Water quality (temp, pH, DO, fecal coliform); Sediment; Habitat diversity (LWM)
Newaukum River	Migration barriers; Floodplain habitat; Sediment; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Riparian habitat*; Water quality (temp, turbidity, fecal coliform)*; Stream flows*; Migration barriers*; Sediment*; Floodplain habitat; Habitat diversity (LWM)
Middle Chehalis Tributaries	Migration barriers; Floodplain habitat; Sediment; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Sediment*; Riparian habitat*; Migration barriers*; Floodplain habitat*; Water quality (temperature, DO, fecal coliform); Habitat diversity (LWM); Stream flows
South Fork Chehalis	Migration barriers; Sediment; Channel stability; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Riparian habitat*; Sediment*; Migration barriers*; Habitat diversity (LWM); Water quality (pH, temperature, DO); Stream flows; Floodplain habitat

SUB-BASIN UNITS	LIMITING FACTORS	
	SMITH AND WENGER DETERMINATIONS	LEAD ENTITY'S SALMON HABITAT RESTORATION AND PRESERVATION STRATEGY
Upper Chehalis	Migration barriers; Floodplain habitat; Sediment; Channel stability; Habitat diversity; Riparian Habitat; Stream flows	Migration barriers*; Sediment*; Riparian habitat*; Habitat diversity (LWM); Water quality (temperature, DO); Stream flows; Floodplain habitat

Notes:
Limiting factors from Smith and Wenger (2001) were sources from Table 40 in their report. Limiting factors from the Lead Entity's Strategy come from their Section 3 (Sub-basin Profiles). Limiting factors with asterisks (*) are considered Tier 1 Concerns in the Lead Entity's Strategy.
DO = dissolved oxygen
LWM = large woody material

Results of EDT model studies identified the following primary limiting factors for salmon in the basin:

- Migration barriers
- Riparian degradation
- Water quantity and quality (flows and temperature)
- Sedimentation
- Channel complexity and stability (lack of wood)
- Loss of floodplain habitat/connectivity

Thus, all three sources of information identified similar habitat factors limiting the productivity of salmon in the basin. Throughout the entire basin, key factors that were identified included a lack of channel structure (e.g., lack of wood, channelization, loss of floodplain connectivity), water quality (e.g., temperature, flow), lack of wood in general (i.e., currently in stream and also natural recruitment via riparian input and active in-stream wood removal), sedimentation, and barriers.

Limiting Factors and Enhancement Potential: Other Fish and Non-fish Species

Although knowledge is limited for some Other Fish and Non-fish Species, commonalities exist among factors known to be limiting for salmon and Other Fish and Non-fish Species. For example, barriers are limiting to most fish species, as they limit the available area for life functions. It was also generally noted that the upper basins were more limited by habitat conditions compared to lower basins. The lack of habitat diversity (in-stream structure and wood) is a pervasive limiting factor throughout the basin. The lack of large wood is prevalent throughout the basin due to much of the basin lacking riparian buffers that provide the source for wood recruitment and the active removal of wood from the basin by other user groups. Large wood is also the key driver in the creation and maintenance of side-channel habitat associated with river or stream channels and off-channel habitat associated with floodplains. Habitat formation and maintenance from large woody material occurs in association with freshets, some as small as bankful events, where wood diverts flow across the river channel and floodplain creating new channels, scouring old channels and re-watering wetlands.

Limiting factors include channel stability, sedimentation, and predation. Predation is of concern especially in the lower Chehalis River where warmer temperatures result in more numerous native and non-native piscivorous fish species (i.e., key predators).

For Non-fish Species, little is known regarding limiting factors, although similarities exist to factors limiting Other Fish Species. The lack of suitable riparian areas is a limiting factor for all Key Non-fish Species. Predation from the presence of non-natives is also suspected of limiting all Key native species, other than the stream margin dwelling terrestrial salamanders and North American beaver (*Castor canadensis*). The lack of habitat diversity is also a limiting factor for Key Non-fish Species; however, the preferred habitats differ among species.

Modeling Framework

The biological effects of environmental changes were evaluated using the best available information for each Key Species analyzed to represent a guild. This resulted in a variety of models being used to relate habitat characteristics to species distribution, occurrence, or abundance, among three categories:

- Salmon habitat-population models:
  - EDT: Spring- and fall-run Chinook salmon, coho salmon, and winter-run steelhead
- Habitat Suitability Indexes (HSIs), which provide the structure needed to model in Physical Habitat Simulation (PHABSIM):
  - Chum salmon (*Oncorhynchus keta*), Pacific lamprey, white sturgeon (*Acipenser transmontanus*), smallmouth bass, largemouth bass, and western toad
- Correlative models:
  - Eulachon, Olympic mudminnow, speckled dace, largescale sucker, riffle sculpin, reticulate sculpin, Dunn's salamander (*Plethodon dunni*), Van Dyke's salamander (*Plethodon vandykei*), coastal tailed frog (*Ascaphus truei*), northern red-legged frog, Oregon spotted frog, and North American beaver

Table ES-1 also indicates which models were used for each Key Species.

Variability and uncertainty is inherent in each of these models, and all models have strengths and weaknesses. The validity of any model is based on the validity of the assumptions used to develop the model. Assumptions used to model the biological effects of proposed actions include the relationship between aquatic species abundances and habitat quality, responses of aquatic species to changes in habitat quality, and the characterization of existing and historical habitat quality. The models selected for use in the ASEP analyses all describe the relationship between aquatic species and their habitat, but varied in the amount of underlying information required and available to support model development and implementation. In general, the analyses did not incorporate uncertainty into the outcome (with the exception of SHIRAZ), even though variability in biological responses would certainly be expected and could dramatically affect the range of expected outcomes. Also, the alternatives developed and assessed were designed to capture a broad range in potential responses. The alternatives were largely intended to inform decision makers of the direction and magnitude of the responses to enhancement actions, not to evaluate specific restoration projects. For these reasons, the model results should be viewed in terms of their general trends and relative relationships (e.g., effects on Chinook salmon versus steelhead, or culverts versus riparian buffer enhancement in non-managed forests [NMFs]), and not in terms of absolute values or percent change.

All model-based studies require assumptions about the starting condition of the attributes being modeled (e.g., habitat, population dynamics, and migration characteristics). Each of the assumptions can influence model outcomes in ways that can lead to over- or under-estimating the actual condition of the response being modeled. As pointed out by Hilborn and Mangel (1997), models are descriptions of nature, and there can never be a "correct" model, but there may be a "best" model. A great deal of science is based on inductive inference, where conclusions about the past are extrapolated into the future to forecast or predict how a population might respond to changing conditions. This inference is an act or a process (Anderson 2008).

The ASEP modeling studies, therefore, were acts of inference. For example, in applying the EDT model to the basin, ASEP modelers developed conceptual models or hypothesis about how the system functions and parameterized the EDT model using available data and in a manner consistent with the conceptual model. The modelers then tested how the system may respond to various alternatives (i.e., dams, habitat enhancement and future climate scenarios) using the parameterized model.

When interpreting ASEP model results, it is important for policy makers to understand how assumptions made about how salmon will respond to changes in habitat conditions in the basin may affect model outcomes. Therefore, assumptions are identified throughout the ASEP to assist the reader in interpreting the model results. The companion report titled *Effects of Flood Reduction Alternatives and Climate Change on Aquatic Species* summarizes assumptions made on the potential effects of flood reduction alternatives and future climate variability on aquatic resources, and combinations of these alternatives along with the ASEP habitat enhancement alternatives.

Actions to Address Habitat Limiting Factors: Salmon

A 3-day salmon habitat restoration workshop was held to identify the primary enhancement actions that should be considered for implementation to address limiting factors in the basin. Representatives from the following state and federal agencies and groups were invited to attend the workshop:

- WDFW
- Washington Department of Natural Resources (WDNR)
- Ecology
- Washington State Department of Transportation (WSDOT)
- National Marine Fisheries Service
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Department of Agriculture
- Chehalis and Quinault Tribes
- Local conservation agencies: Lewis, Thurston, and Mason County Conservation Districts
- Conservation organizations: Trout Unlimited, The Nature Conservancy, Wild Fish Conservancy
- ASEP Technical Committee
- Various representatives from the Chehalis Lead Entity organization

Workshop attendees identified seven primary actions to address limiting factors: barrier removal, restoration of riparian buffers, installing wood structures within the channel, floodplain reconnections, conservation easements, moving building structures out of the floodplain, and land acquisition.

This list of actions developed in this first workshop is very similar to the list of seven strategies developed by the Lead Entity:

- Attain a healthy and diverse population of wild salmonids.
- Restore, enhance, and protect the Grays Harbor Estuary.

- Restore and preserve properly functioning riparian areas.
- Restore habitat access.
- Restore properly functioning hydrology.
- Restore floodplain and stream channel function.
- Prioritize habitat projects and activities within sub-basins that provide the highest benefit to priority stocks.

A follow-on workshop was held with additional WDFW representatives to refine the information obtained from the three-day workshop and gather additional information from WDFW experts unable to attend the three-day workshop. At this meeting, it was decided to focus restoration activities on spring-run Chinook salmon, as their overall abundance is low and the habitat they depend on is highly degraded, based on WDFW information and results from EDT model analyses. They are also the species most at risk due to existing low populations levels and are culturally important to local tribes.

Based on the information collected from the data reviews, EDT modeling, and the workshops, it was decided to model the effects of the following scenarios on aquatic resources:

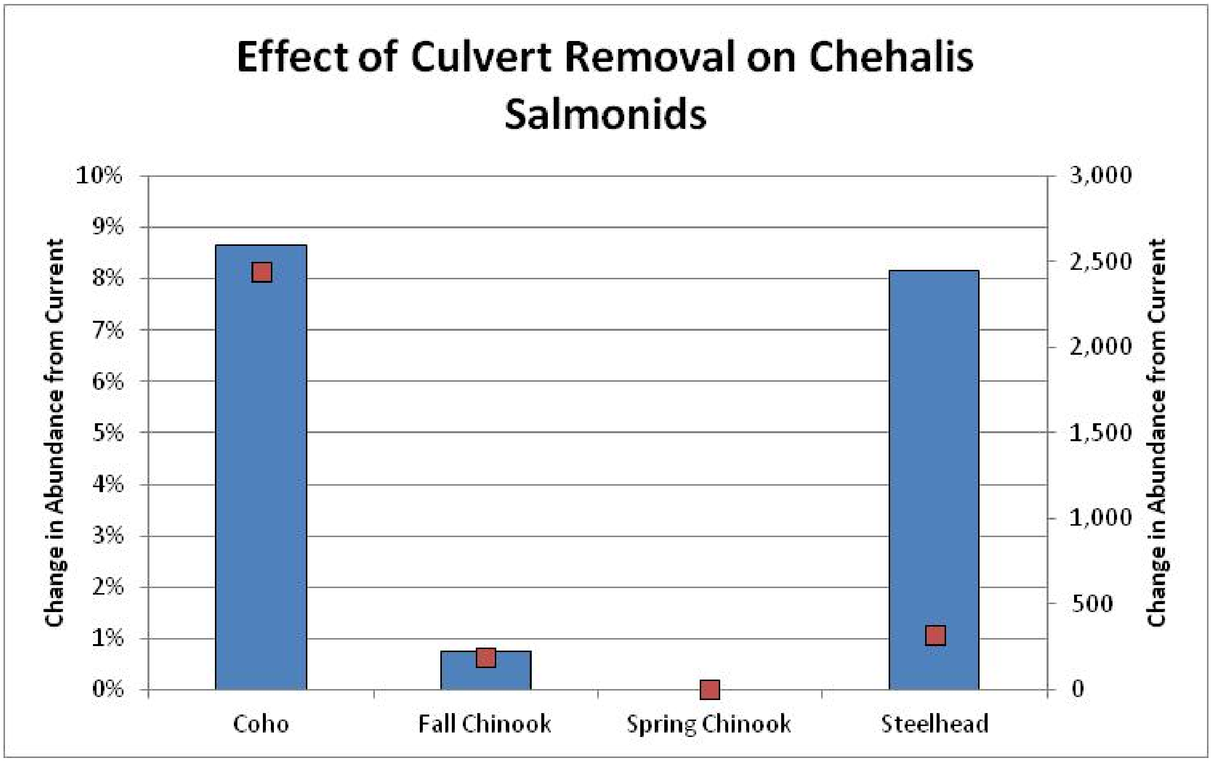
- Culvert removal basin-wide
- The maturation of riparian areas in all the upper, managed forest (MF) reaches
- Protecting and enhancing riparian areas in spring-run Chinook salmon spawning reaches located outside of MFs
- Adding LWM to spring-run Chinook salmon spawning reaches located outside of MFs
- Reconnecting cut-off channels in the floodplain with a focus on juvenile salmon rearing and Other Fish and Non-fish Species

Culvert Removal: Salmon

Obstructions to fish migration are pervasive throughout the basin. The EDT analysis of culverts focused on 169 culverts ranked as high priority (Anchor QEA 2012a), and above which WDFW indicated that adult salmonids, with the exception of spring-run Chinook, either do currently or could potentially spawn. Removing all 169 culverts in the EDT model increased habitat potential across the entire basin by 8.5% for coho salmon, 8.2% for winter-run steelhead and approximately 1% for fall-run Chinook salmon (Figure ES-1).

Results of EDT modeling indicated that no benefits would accrue to spring-run Chinook salmon associated with the culvert alternative where 169 high-priority culverts in the basin were removed. This assumption was based on WDFW's observations of where spring-run Chinook salmon spawn, the proximity of key barriers to these spawning locations, and the professional opinion of WDFW biologists that this run of Chinook salmon would not move upstream of the barriers to spawn or rear once the barriers had been removed. If this assumption is incorrect, spring-run Chinook salmon in the basin may benefit from culvert removal, but the level of benefit was not estimated in this stage of ASEP feasibility analysis.

Figure ES-1
Effect of Removing High-priority Culverts in the Chehalis Basin on Salmon Species



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

To estimate costs associated with culvert removal, a range of current costs was developed that include initial design, permitting, final design, construction, and monitoring costs (Table ES-3). In addition, Washington State (State) ownership was determined using GIS for each of the 169 culverts evaluated in EDT. This determination was completed because of a pending lawsuit which requires culverts on State-owned lands that are barriers to fish to be repaired by 2016 for State agencies, with the exception of WSDOT, which must complete repairs by 2030.

Table ES-3
Culvert Project Cost Summary

OWNERSHIP	NUMBER OF PROJECTS	LOW RANGE	MEDIUM RANGE	HIGH RANGE
Total	169	$23,950,000	$35,030,000	$48,180,000
State Owned	11	$2,410,000	$3,480,000	$4,770,000
Other Ownership	158	$21,540,000	$31,550,000	$43,410,000

Notes:
1. Totals and averages have been rounded up to the nearest $10,000.
2. Culvert points located within 50 feet (15.2 m) of State-owned land were assumed to have state ownership, unless otherwise noted.
3. State-owned lands included WSDOT right-of-way, WDNR major public lands, and WDNR parcels.
4. If culvert data specifically identified the ownership type, those data were used rather than the alignment with parcels.

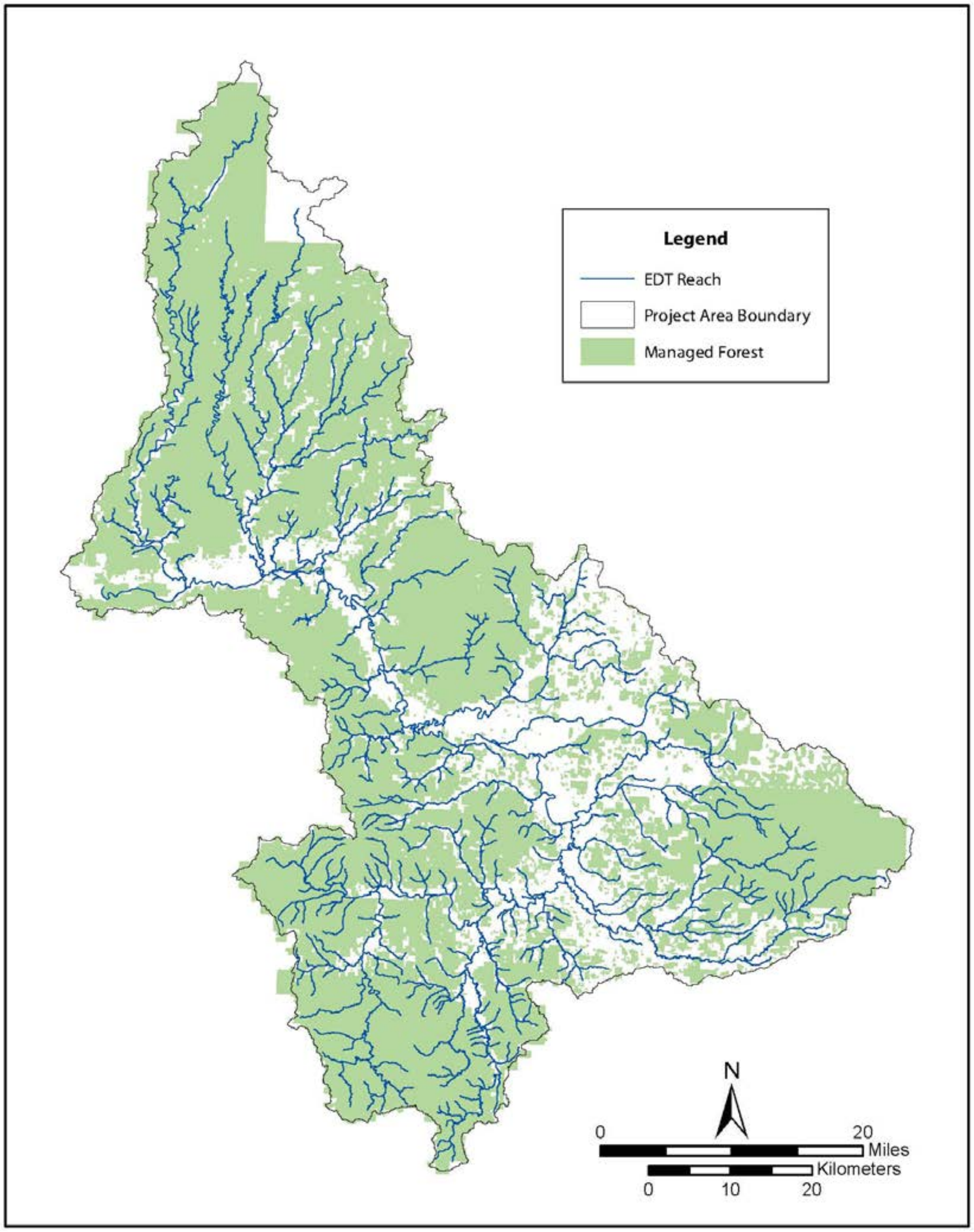
As previously mentioned, the ASEP results may under or overestimate the actual benefits to EDT modeled salmonids to some degree because of the assumptions that were made. For example, EDT may underestimate the actual benefits associated with culvert removal because there are approximately 2,200 identified culverts in the basin, but the ASEP analysis estimated benefits associated with only 169 of the culverts that were identified in previous surveys as high-priority blockages. The companion *Data Gaps Report* identifies additional culvert surveys as a need to address this issue. Also, the culverts modeled were not selected with any special consideration of particular species or sub-basin of the watershed. Actions targeted on specific habitats and species may produce enhanced responses and spring-run Chinook salmon may see a benefit that is not currently identified.

Conversely, results of ASEP model studies of culvert removal may overestimate the actual benefits associated with culvert removal because of the lack of culvert survey data. Few (if any) river systems have current and comprehensive culvert surveys that identify all barriers, and it is possible that there are barriers upstream from modeled culverts that would still prevent fish access. In addition, a significant proportion of mapped culverts (approximately 30%) that were permitted as fish passage culverts by WDFW within 10 years and were constructed, failed, and continued to block passage (Price et al. 2010). Because culvert surveys are not conducted regularly, these failures can go undetected (Price et al. 2010). Hence, the net result is that barrier removal models may overestimate the positive contribution of barrier corrections, and to be effective, barrier enhancement actions need to be completed in a manner that adheres to the permit specifications to ensure they are constructed correctly and function properly once constructed.

Riparian Maturation/Enhancement in Managed Forests: Salmon

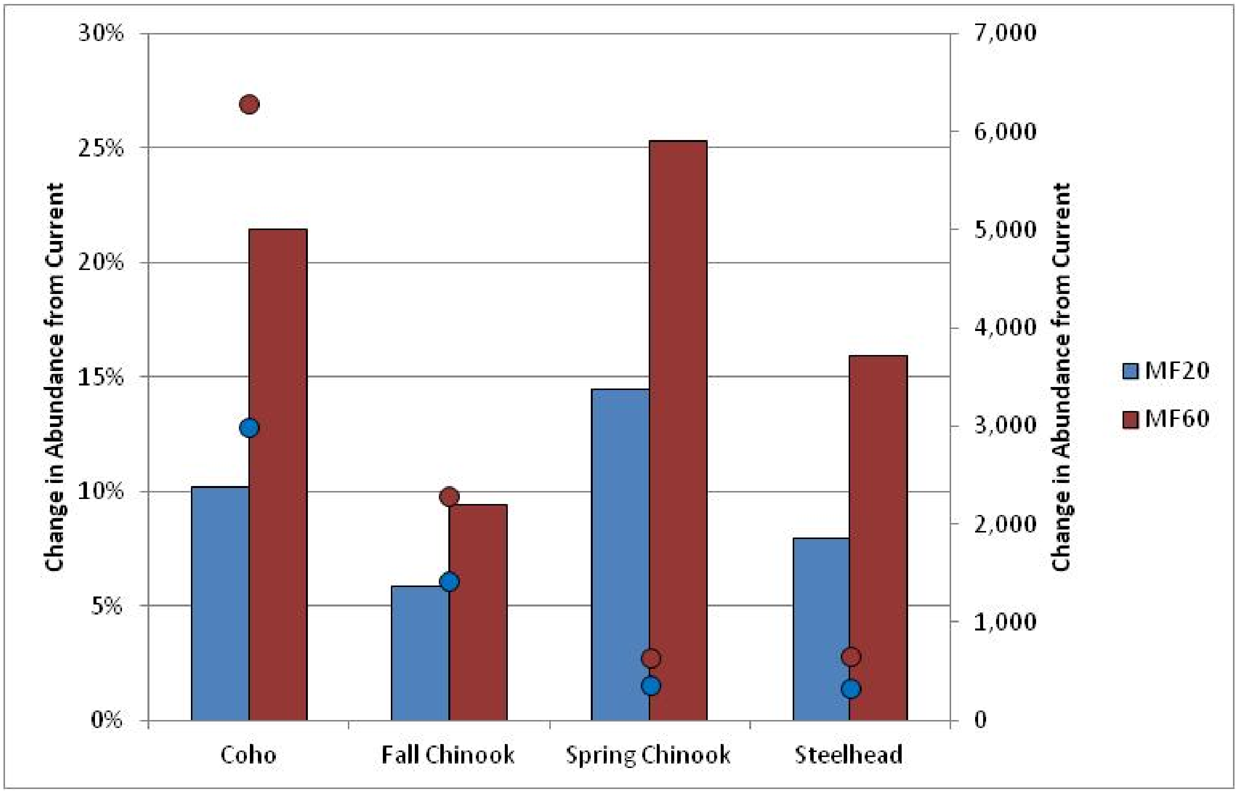
To model the effects on salmon habitat from allowing riparian areas in MFs to mature, a hypothesis was developed based upon relationships developed for the Final Environmental Impact Statement for the Washington Forest Practices Act (WFPA; NMFS and USFWS 2006). The WFPA applies no-harvest zones of varying widths to riparian areas in lands managed under the WFPA. Discussions with WDFW, Washington Department of Natural Resources (WDNR), and several timber companies during ASEP implementation resulted in a wide range of comments regarding the hypothesis used to determine the contribution of riparian areas to salmon habitat, widths, and age of riparian areas in MFs, and how long it would take riparian areas to provide this contribution. Based on these discussions, two potential riparian enhancement alternatives were modeled to account for this variation. These two scenarios increased the estimated restoration potential of riparian areas in MFs by 20% or 60% from the current value used in EDT. It is important to note that increasing restoration potential of riparian areas by percentages based on this hypothesis is non-linear. For example, a 60% increase in the shade function for MFs landscapes that are already providing approximately 50% level of shade results in a level of approximately 95% of maximum value for shade and a 20% increase would result in a value of approximately 70% . These two estimates, 20% and 60% increase from existing levels, of response potential were then modeled for all MFs in the basin as shown in Figure ES-2.

Figure ES-2
Managed Forests (Lands More Than 80 Acres in Size) in the Basin Modeled for Salmon Species Using EDT



Results of EDT model studies indicated that on a percentage basis, spring-run Chinook salmon benefited the most from riparian changes in MFs followed by coho salmon, winter-run steelhead, and fall-run Chinook salmon (Figure ES-3). As expected, the 60% increase from current values for riparian attributes in the EDT model benefited salmon more than the 20% scenario. These differences largely reflected the distribution of modeled spawning reaches for each species, and the application of the MF riparian change scenarios to those reaches. For example, fall-run Chinook salmon are distributed lower in the Chehalis system, and less so in the MF reaches compared to the other species. Therefore, fall-run Chinook salmon benefitted less from the effect of these scenarios compared to other salmon species.

Figure ES-3
Effects of Enhancement Actions in Managed Forests



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

The benefits to salmon associated with the maturation of riparian areas in MFs were influenced by several factors, at both basin-wide and sub-population scales. Reaches that were affected by the changes were predominantly smaller headwater reaches with limited habitat capacity. Furthermore, the benefits of changes in the upper watershed were also influenced by conditions in the lower reaches, which were set in the EDT model to the current condition. This latter point is especially important—conditions in the lower reaches, particularly the mainstem Chehalis River, constrain the biological benefits of improved environmental conditions in the upper reaches. In other words, investments in habitat improvements in the upper watershed would be enhanced by improvements in conditions in lower river reaches.

ASEP model studies of riparian buffer restoration in MFs assumed two different levels of functional response (i.e., 20% and 60% increase from current). However, to realize these responses, LWM that develops in MF riparian buffers needs to be available to recruit into the stream channel and stay in the channel once recruited. ASEP model studies assumed this was the case. However, if this LWM is not available for recruitment or is retained, modeled outputs would overestimate the restoration benefits associated with riparian buffer maturation in MFs. LWM, an important habitat component of many salmon species, has been systematically removed, and continues to be removed, or is currently degraded in many river systems in western Washington, including the Chehalis. In fact, most LWM has been removed following important wood recruitment events, such as the 2007 flood. The addition of LWM via maturation of riparian areas was modeled with EDT with resultant benefits to multiple salmon species. If the removal of LWM continues (by landowners, state agencies and others who view large wood as posing risks to farm lands, bridges, culverts, roads and boaters on the river), the modeled benefits to salmon from riparian buffer maturation would be overestimated. In other words, the benefits from LWM recruiting into the stream channel from riparian buffers can only be realized if the material stays in channel or on the floodplain.

Non-managed Forest Areas: Salmon

Areas of the basin outside of the MFs (the white areas in Figure ES-2) have a more complicated regulatory and social context with no overarching mechanism to regulate riparian conditions, such as how the WFPA regulates riparian conditions in MFs. As a result, a broad set of scenarios was analyzed to address the types, spatial coverage, and intensity of riparian enhancement actions that could be implemented in the basin (Table ES-4).

Two general types of restoration were evaluated: placing wood into river and stream channels and riparian enhancement. These scenarios assumed that wood would be increased in designated stream reaches through placement of engineered log jams (ELJs) and/or other structures. This was considered a short-term action to provide benefits pending the natural increase in LWM in stream channels through the maturation of riparian forests over time.

The spatial distribution of riparian improvements outside of the MFs was based on the decision to focus riparian restoration on spring-run Chinook salmon. Thus, the first criterion for restoring riparian conditions in areas outside of MFs was that changes would only be applied to reaches with spring-run Chinook spawning habitat. Because there is overlap in the spatial distribution of the four salmonid species, these changes affected all four salmon species modeled. However, it is important to note that similar benefits to other species could be achieved if the spawning and rearing habitat for those species were targeted. For example, in ASEP studies, no changes were made to areas outside of the MFs in the Wynoochee or Satsop sub-basins, because these areas were identified by WDFW as having no spawning for spring-run Chinook salmon. If habitat enhancement were to occur in those sub-basins, there would likely be an increase in habitat potential for other salmon species using those sub-basins.

The second criteria for spatial distribution of riparian improvements hypothesized different levels of application of the actions. Actions were applied to either 50% or 75% of the reaches outside the MFs that were spring-run Chinook salmon spawning reaches. These reaches were chosen systematically. For the 50% alternatives, actions were applied to every other reach with spring-run Chinook salmon spawning. For the 75% alternatives, actions were also applied to every other reach that did not receive the treatment under the 50% alternatives. his method was chosen over identifying specific reaches with the highest restoration potential because at this time, there is no way of knowing if those reaches are available for enhancement actions and focusing on reaches with the greatest restoration potential could overestimate the actual benefits realized. For both applications (to enhance 50% or 75% of the spring-run Chinook salmon spawning reaches outside of MFs), the LWM scenarios assumed that 50% of the restoration potential for LWM would be provided in each modeled reach.

The LWM scenarios for the non-MFs assumed that 50% of the restoration potential for LWM would be provided in the modeled reaches. The LWM scenarios were also modeled for 50% and 75% of the spring-run Chinook salmon spawning habitat.

The riparian restoration scenarios assumed the same changes to attributes for the MF alternatives where a 20% or 60% increase in the restoration potential from current conditions for the riparian attributes was assumed to occur. The attributes modeled for the NMF areas are summarized in Table ES-4.

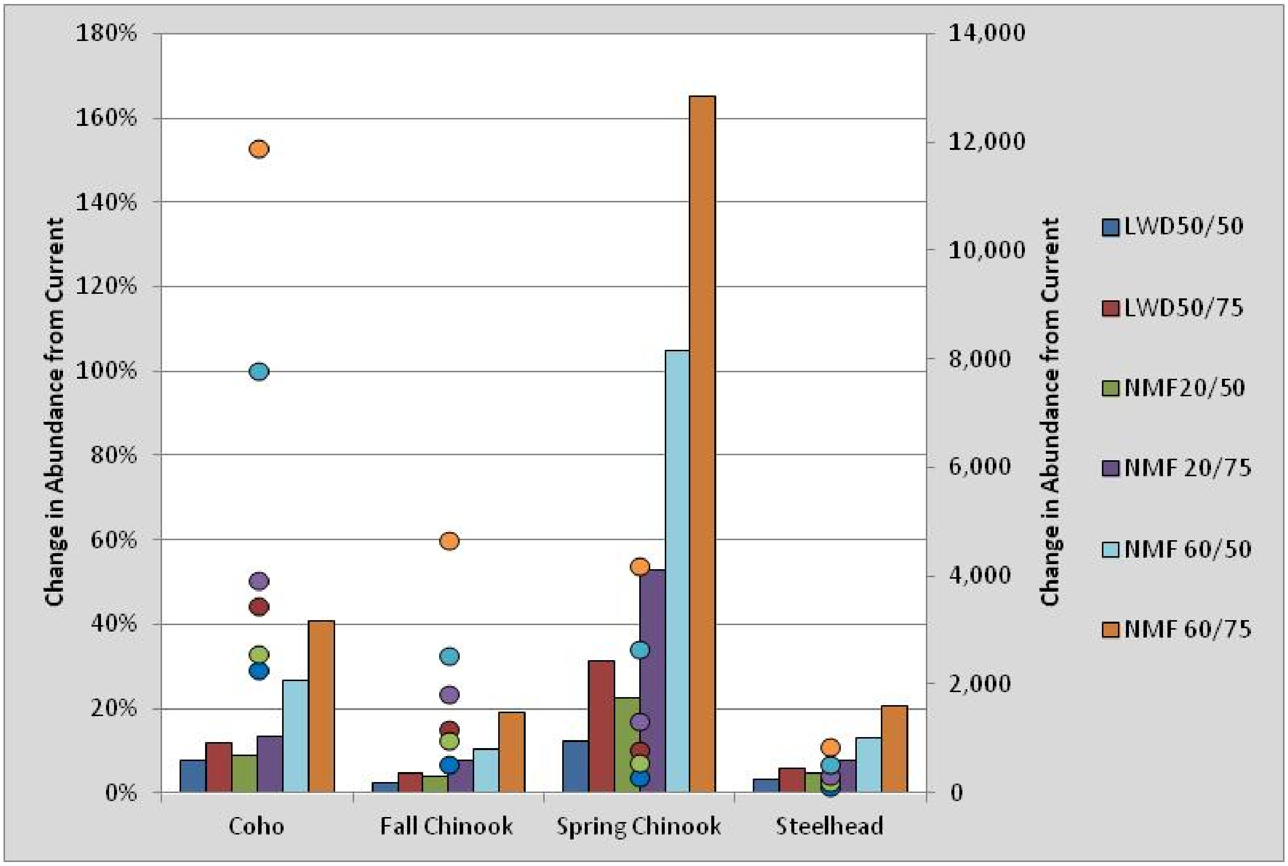
Table ES-4
Description of Modeled Enhancement Action Scenarios in Non-managed Forest Lands

SCENARIO: INTENSITY OF CHANGE/SPATIAL APPLICATION	TYPE OF ACTION	REACHES APPLIED	CHANGE IN ATTRIBUTE
NMF-LWM50/50	Add large wood structures	50% of NMF reaches having spring-run Chinook spawning	50% of restoration potential of LWM attribute
NMF-LWM50/75	Add large wood structures	75% of NMF reaches having spring-run Chinook spawning	50% of restoration potential of LWM attribute
NMF-Riparian20/50	General riparian improvement	50% of NMF reaches having spring-run Chinook spawning	20% increase of restoration potential from current for all riparian attributes
NMF-Riparian20/75	General riparian improvement	75% of NMF reaches having spring-run Chinook spawning	20% increase of restoration potential from current for all riparian attributes
NMF-Riparian60/50	General riparian improvement	50% of NMF reaches having spring-run Chinook spawning	60% increase of restoration potential from current for all riparian attributes
NMF-Riparian60/75	General riparian improvement	75% of NMF reaches having spring-run Chinook spawning	60% increase of restoration potential from current for all riparian attributes

Notes: LWM = large woody material
NMF = non-managed forests

The predicted benefits of enhancement actions in NMF were greatest for spring-run Chinook salmon followed by coho salmon. Relatively small benefits were predicted for fall-run Chinook salmon and winter-run steelhead (Figure ES-4). This was partially because the actions focused on spring-run Chinook salmon spawning reaches and the actions (excluding the LWM alternatives) reduced temperature due to added shading, which generally had a beneficial effect for spring-run Chinook salmon throughout the analysis. For the most part, the results of enhancement actions modeled for NMFs formed a progression, reflecting the intensity of treatment and spatial distribution of the application of the treatments in the model (Figure ES-4).

Figure ES-4
Effects of Enhancement Actions in Non-managed Forest Areas



Note: Bars represent percent change and dots represent numeric change in abundance relative to current condition.

The costs of the enhancement actions in NMFs are tabulated in Table ES-5. Assumptions used in determining these costs are summarized in the notes after Table ES-5 and included in Appendix G.

Table ES-5
Summary of Costs of Enhancement Actions on Non-managed Forest Areas

ENHANCEMENT ACTION	LOW RANGE	MEDIUM RANGE	HIGH RANGE
50% Action Area			
Riparian Treatments	$26,800,000	$45,400,000	$66,300,000
LWM Placements	$12,900,000	$18,500,000	$25,100,000
Total	$39,700,000	$63,900,000	$91,400,000
75% Action Area			
Riparian Treatments	$40,200,000	$68,100,000	$99,500,000
LWM Placements	$19,400,000	$27,800,000	$37,700,000
Total	$59,600,000	$95,900,000	$137,200,000

Notes:
Totals have been rounded up to the nearest $100,000.

1. Total miles of treated channel are 82 for 50% and 123 for 75%. Length data were taken from GIS on May 13, 2014. EDT data were provided by ICF on May 13, 2014.

2. Areas identified for spring-run Chinook spawning are per WDFW and do not include areas within WFPA land more than 80 acres (32.4 ha).
3. Riparian treatments are applied only to a portion of the reaches identified for spring-run Chinook spawning assumptions include:
    a. Approximately 50% and 75% of the spawning channels will be restored outside the WFPA areas.
    b. A proposed riparian buffer width of 250 feet (76.2 m) on each side of the stream.
    c. A 50/50 spilt between revegetation and preservation was assumed for the riparian areas to be treated.
    d. Easements required for 25% of the riparian planting areas.
    e. Purchase required for 25% of the riparian planting areas.
4. LWM placements are a combination of ELJs and smaller LWM structures placed at a net average rate of 124 pieces of LWM per mile.

LWM = large woody material

Combinations of Enhancement Actions: Salmon

Two scenarios of riparian and culvert enhancements were modeled to assess the potential effects on salmon from combining enhancement actions (Table ES-6). Low and High Enhancement Alternatives were created by combining the Low Enhancement Alternatives for NMF areas and for MF, and the High Enhancement Alternatives for NMF and MF, respectively. The same culvert removal action was then added to each of the combined enhancement scenarios.

These two scenarios were selected to capture a wide range of responses to enhancement. A Combination scenario including NMF enhancement with the greatest level of spatial distribution (75% of spring-run Chinook salmon habitat) but assuming the lowest delivery of riparian attributes (20% increase in riparian attributes) was not run but results from the combination would fall somewhere within the modelled range. However, such a result is equally feasible at this stage of the process.

Table ES-6
Description of Combination Scenarios Analyzed for Chehalis Basin Salmonids

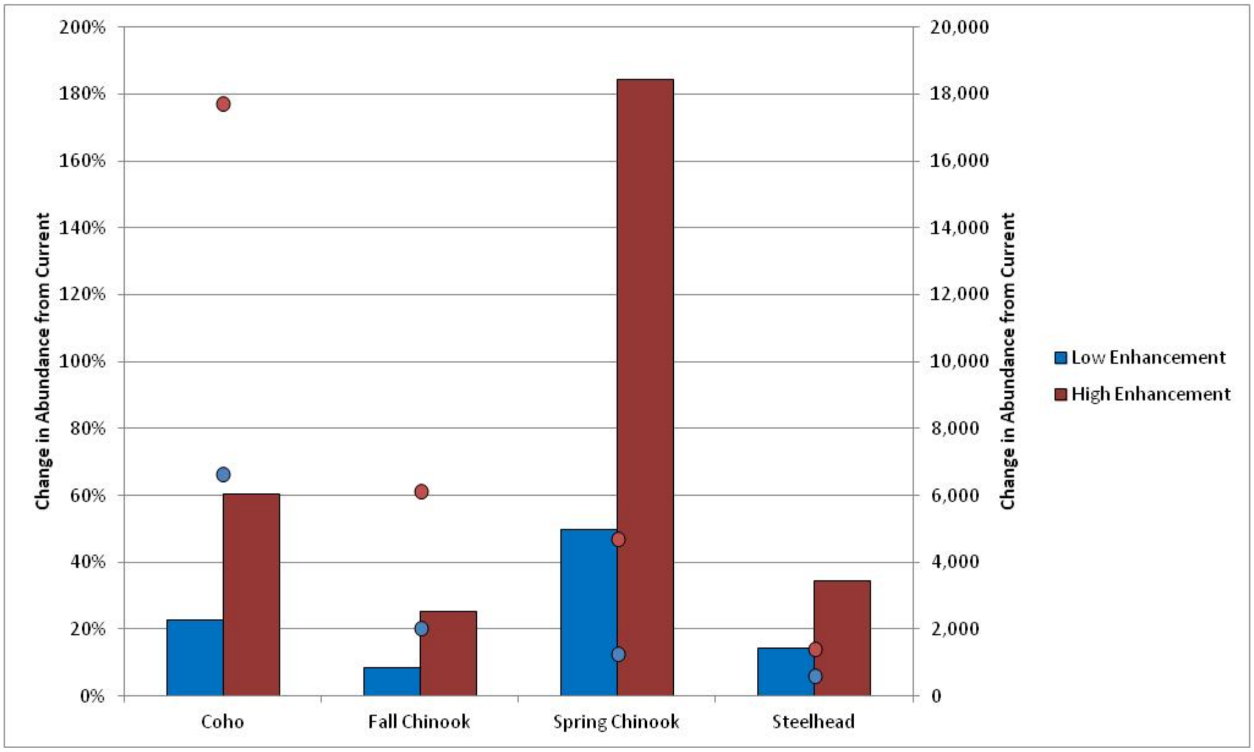
SCENARIO	DESCRIPTION
Low Enhancement	NMF 20/50 + MF 20 + Culvert removal
High Enhancement	NMF 60/75 + MF 60 + Culvert removal

Notes: MF = managed forest
NMF = non-managed forest

Results of the enhancement combination scenarios among species and at the basin-wide scale are shown in Figure ES-5. The changes in abundance shown represent changes in absolute numbers of fish and the percentage change represents the proportional change in population size. As expected, the change in abundance associated with the Low and High Enhancement combinations was greater than the change from any of the individual enhancement actions alone. Also, the changes under High Enhancement were larger than under the Low Enhancement scenario. However, the changes for the combination scenarios were less than the sum of the individual actions used to formulate each scenario, indicating there was some (negative) synergism among the individual enhancement actions when combined.

As a proportion of the population, the enhancement measures benefited spring-run Chinook salmon the most. This was because some of the individual enhancement actions targeted spring-run Chinook salmon (the NMF area alternatives). Coho salmon had the largest numeric change in response to the enhancement scenarios, primarily because this is the most abundant salmon species in the basin (and the EDT model) and most actions affect coho salmon. Fall-run Chinook salmon had the next largest response in absolute abundance, but had a small proportional change due to their relatively high overall abundance in the basin.

Figure ES-5
Changes in Chehalis Basin Salmonids from Current Abundance Due to Riparian Enhancements, Culvert Removal



Note: Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Off-channel (Floodplain) Habitat: Salmon

Two potential off-channel habitat restoration projects were evaluated for their effects on Chehalis salmon populations (Table ES-7). Project CH-13 was selected to represent the types of actions that could be implemented to restore large amounts of off-channel habitat along the mainstem Chehalis River. Project CH-13 was located near Porter, Washington, at River Mile (RM) 43 (69.2 RKm). Project SK-14 was selected to represent the types of actions that could be implemented to restore off-channel habitat in tributaries. Project SK-14 was located on the Skookumchuck River at RM 15 (24.1 RKm). These are two representative examples of off-channel habitat restoration, but are not necessarily indicative of the potential benefits associated with all types or sizes of potential off-channel restoration projects.

Table ES-7
Selected Off-channel Restoration Projects in Spring-run Chinook Salmon Spawning Reaches

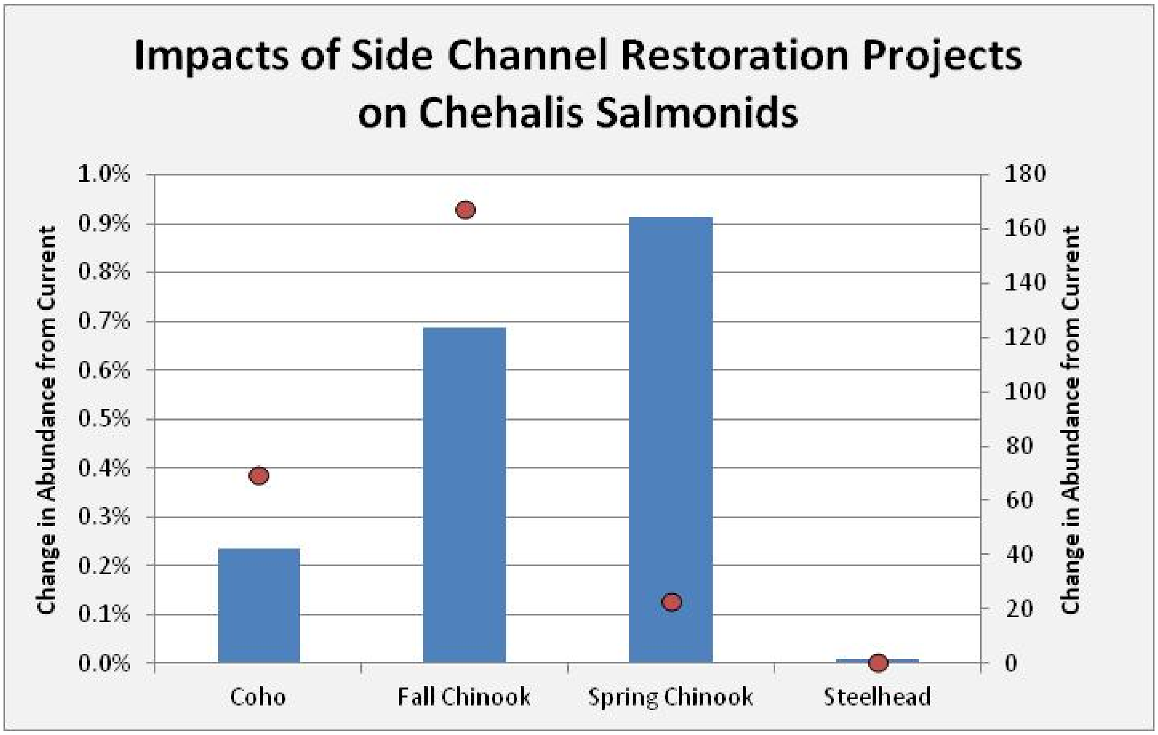
RIVER	SELECTED PROJECT	RM	2014 ASEP COST EST.	PROJECT DESCRIPTION	LIMITING FACTORS ADDRESSED
Mainstem Chehalis	CH-13	43	$5,900,000	Reconnect oxbow with mainstem Chehalis. Enhance low elevation areas, off-channels, and floodplain habitat with vegetated benches and LWM.	Floodplain Conditions, LWM, Riparian Conditions
Skookumchuck	SK-14	15	$550,000	Off-channel/floodplain enhancement. Includes removing invasive species/planting native forest trees and understory.	Floodplain Conditions, Riparian Conditions, LWM

Note:
EST = estimate
LWM = large woody material
RM = River Mile

At the basin-wide scale, the selected off-channel restoration projects had small effects on the overall abundance of salmon and ranged from 0.025% for coho salmon to 0.90% for spring-run Chinook salmon (Figure ES-6). In the model, winter-run steelhead were assumed to not utilize side-channel habitats and so these projects provided no benefit to this species. Overall, the projects contributed small numbers of salmon to the basin.

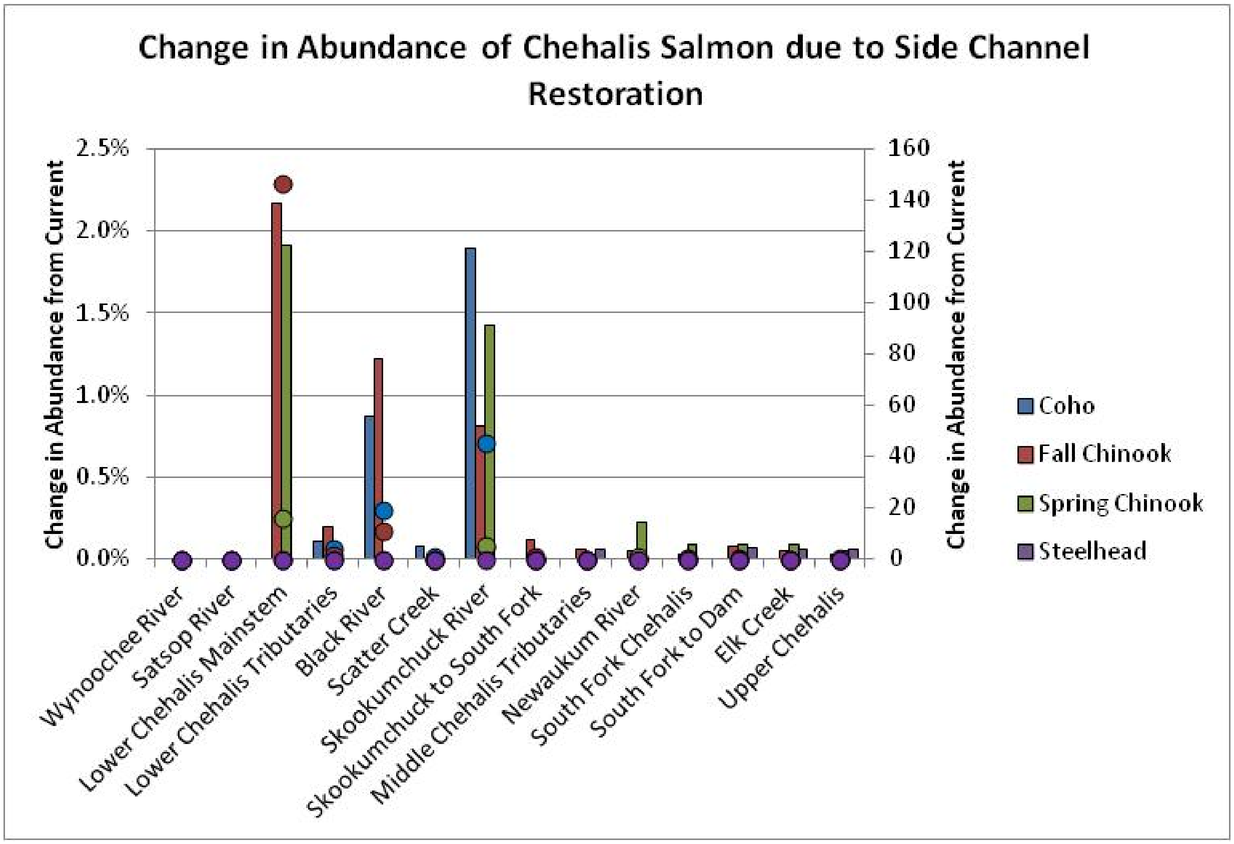
The Skookumchuck off-channel project would only benefit fish from the Skookumchuck sub-basin, while the project on the mainstem Chehalis would mainly benefit nearby populations and provide less benefit to upper Chehalis River populations. For these reasons, analysis at the population level is more relevant (Figure ES-7). The changes in abundance of coho salmon, fall-run and spring-run Chinook salmon were greatest for the mainstem Chehalis River, Black River, and Skookumchuck River populations. Effects to other populations were minimal or zero. The mainstem Chehalis River and Black River populations benefited from the mainstem Chehalis off-channel project (CH-13), while the Skookumchuck project (SK-14) benefited Skookumchuck populations. Skookumchuck populations could also receive some benefit from the mainstem Chehalis off-channel restoration.

Figure ES-6
Changes in Abundance of Chehalis Salmonids Due to Off-channel Restoration Projects



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Figure ES-7
Changes to Individual Populations of Chehalis Salmonids Due to Off-channel Restoration Projects



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

The low gradient, poorly confined geomorphology of the basin is characterized by a diverse and complex network of off-channel aquatic areas that provide critical habitat for a suite of fish (including juvenile salmonids), amphibians and aquatic reptiles (including the western pond turtle). In river systems such as the Chehalis, off-channel habitats are inherently dynamic and undergo a physical and vegetation process of succession over time. This process relies on both the creation of newly connected side-channel areas during freshets (flood events) and maintenance of existing connectivity between the main stem and off-channel areas. Land use practices that straighten or confine the river channel or dewater or eliminate off-channel areas can negatively influence the quantity and quality of habitat for this suite of species. Moreover, altered connectivity between off-channel areas and the main river channel could hinder the ability of many of these species to re-colonize or seasonally access off-channel habitats. As such, restored connectivity has high potential to benefit aquatic species in the portions of the basin with well-developed off-channel habitats. However, a key uncertainty associated with this potential benefit is whether and how the presence of non-native species (e.g., largemouth bass and American bullfrogs) may effect (and perhaps detract from) the benefits that off-channel habitats and their ecosystem dynamics accrue for native species (e.g., juvenile coho salmon, Olympic mudminnow, northern red-legged frog, Oregon spotted frog). Hence, the distributions of off-channel habitat-dependent species and their interactions with both seasonal changes in habitat and the non-native predators occupying those habitats need to be better understood prior to providing confident technical guidance on the benefits of connecting and creating side-channel habitats in the basin.

When identifying locations for off-channel projects, adjacent upland components should be taken into consideration. Several non-fish species require extensive adjacent riparian and upland habitats to complete their life cycles. In discussions with WDFW (Hayes pers. comm. 2014a), it was estimated that for planning purposes, establishing a 1,500-foot-wide (457-meter-wide) upland segment, at least one side, of off-channel projects would provide adequate habitat for those species that require uplands adjacent to off-channel for their seasonal life history needs, such as the northern red-legged frog. The distance along the side-channel habitat that this increased width of uplands would extend would vary with the size of project. For smaller projects, in the range of 1,000 linear feet (304.8 meters [m]) or less of aquatic habitat, an upland segment over a distance of 50% of the aquatic off-channel habitat length was estimated as adequate as a first cut to evaluate the effects of these projects on target species. This distance could be reduced on larger projects, but would depend on the project site and existing adjacent habitats. The experimental nature of these projects would require monitoring to verify the effectiveness of these estimates.

Because of the high value of these ecosystems to salmonids, other fish, and non-fish, off-channel restoration projects should be a part of the overall restoration strategy for the basin. As mentioned, they need to be approached with caution to ensure they provide the intended benefits and not increase habitat for non-native invasive species. To address these issues, control sites should be established in appropriate areas in the basin to determine what species are present in existing off-channel areas and how prevalent they are. The specifics of these control projects are detailed more fully in the companion *Data Gaps Report*.

After the control projects determine presence and abundance of species, this information should be used to inform where off-channel projects should be implemented. Until results from the control projects are available, the exact location of floodplain restoration projects should not be determined. However, once preliminary data is collected from the control projects, implementing two large and four smaller projects would be an advisable approach for these types of projects. This approach will provide valuable information on the effects of implementing these projects and aid in determining which projects provide the greatest benefit for target species. Using the two projects that had cost estimates completed for the ASEP as a guideline, the figure $15 million should be considered to be included in the overall restoration package to implement two large projects and four smaller floodplain restoration projects.

Combinations of Enhancement Actions and Future Climate Change Scenarios: Salmon

The effects of the riparian enhancement alternatives on basin salmonids under future conditions were examined to assess the sensitivity of enhancement actions to potential climate change. The future climate conditions modeled are consistent with regional projections of climate change in the Pacific Northwest and are described in detail in the companion ASEP report titled *Effects of Flood Reduction Alternatives and Climate Change on Aquatic Species*.

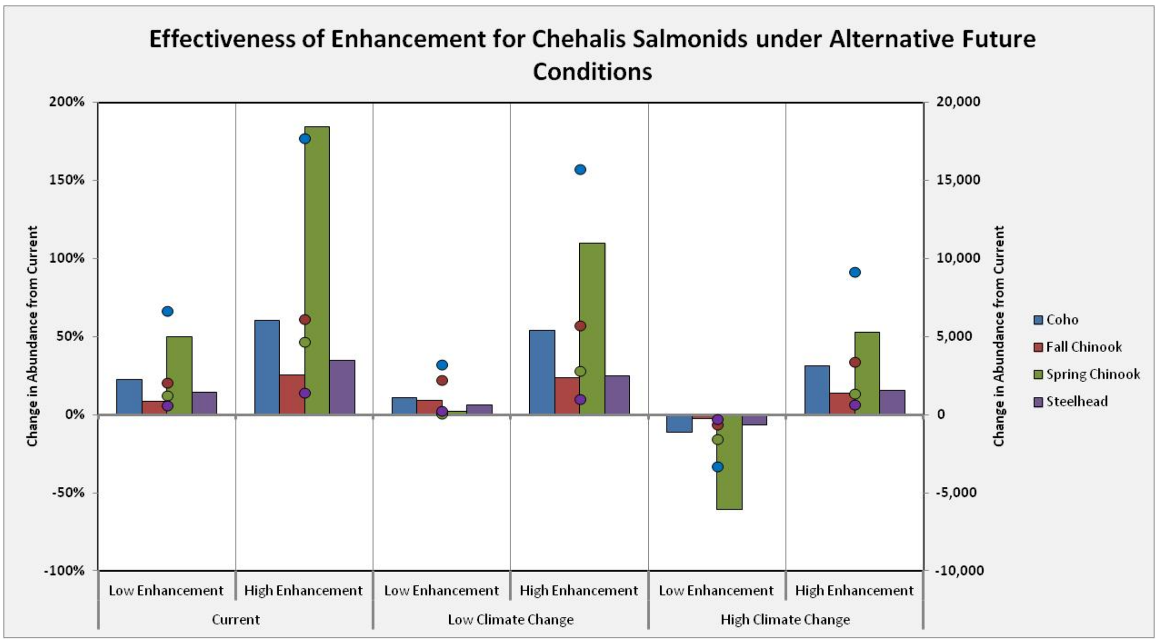
The Low and High Enhancement combinations described in Table ES-6 were modeled under two future climate conditions: Low and High Climate Change. The Low Climate Change scenario was constructed by combining the Hydrologic Engineering Center River Analysis System (HEC-RAS) analyses of Normal Wet and Normal Dry water year (WY) conditions, consistent with the assumption of wetter winter and drier summers. The High Climate Change scenario was constructed by combining the HEC-RAS analyses of Wet and Dry WY conditions, consistent with the assumption of much wetter winters and much drier summers.

The benefits to salmon abundance estimated to occur under the High and Low Enhancement combinations are diminished under both future climate change scenarios (Figure ES-8). Under the Low Enhancement and High

Climate Change combination, the effects to all four species associated with the High Climate Change scenario are greater than the benefits realized from the Low Enhancement, resulting in decreases in abundance for the species overall.

The other three combination scenarios show an overall increase in abundance to the four species of salmon. However, the low enhancement combined with Low Climate Change resulted in a very moderate increase in abundance for all four salmon species. Under the High Enhancement scenarios, the four species of salmon show an increase in abundance for both High and Low Climate Change combinations, with the High Climate Change scenario having a greater effect than the Low Climate scenario, as to be expected.

Figure ES-8
Changes in Chehalis Basin Salmonid Abundance Under Combinations of High and Low Habitat Enhancement and High and Low Climate Change Scenarios Relative to the Current Condition



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Other Fish and Non-fish Species Habitat Enhancement

Because much less information is available on the types of enhancement actions needed to address limiting factors for Other Fish species, ASEP authors grouped the actions into general categories. This grouping showed that the effects of restoration projects on Other Fish vary with the specific habitat requirements of the species and life stages. While in very general terms the restoration projects that benefit salmon are thought to be neutral or positive to Other Fish species in most cases, the specific design and location of a restoration project for salmon needs to be reviewed for its potential to impact other species during the design phase of the project. For example, reconnecting off-channel habitats to provide overwintering habitat for coho salmon might allow non-native predator species to occupy these habitats during summer, which could have a negative effect on native fishes other than, and including, salmonids. It is important to consider that the creation and maintenance of connected habitat is in large measure what makes the Chehalis a relatively unique river system in western

Washington. Thus, to realize the full benefits of these floodplain habitats for native species in the basin, the issue of non-native predators needs to be fully addressed.

It has also been suggested that prior to and during any enhancement actions, an inventory of existing species should be conducted to determine what species are currently there and what effect the projects have on those species. It is also recommended that control areas be identified and similarly inventoried and monitored to compare against the enhancement actions and ensure that the cause of any changes can be attributed to, or eliminated from, the enhancement actions.

Given the limited information on Other Fish species' ecological requirements, it is difficult to quantify the potential benefits of enhancement actions for Other Fish in most cases. Until an assessment of overall population trends, habitat preferences, and Key Habitats that should be preserved or restored has been completed, the most appropriate approach for restoration of habitat for Other Fish is to use anecdotal information and the best professional judgment of local experts.

Similar to Other Fish Species, habitat restoration projects needed to enhance Non-fish Species vary with the specific habitat requirements of the species and its life stages. Because the basin is unique in possessing the highest species richness of amphibians in Washington State, many of the specific habitat requirements of the different life stages and species are known. Therefore, the specific design and location of a restoration project for salmon can be reviewed by knowledgeable experts during the design phase of the project to assess the project's potential effect on Non-fish species. However, until specific details about a restoration project's design and location are known, it is difficult to assess the effects of projects on each Non-fish Species. Similar to Other Fish Species, an assessment of overall population trends, habitat preferences, and Key Habitats that should be preserved or restored is needed to ascertain the amount and location of habitat restoration needed for Non-fish Species.

One focus of restoration that has the opportunity to affect a large suite of Other Fish and Non-fish Species is off-channel habitats. This is in part because the floodplain of the main channel of the Chehalis River is particularly rich in off-channel habitats and because many of these habitats have been degraded by a combination of agricultural incursion, hydrological disconnection, and the addition of a substantial suite of non-native aquatic predators. Moreover, some of the species that would be potentially affected by such restoration are at substantial risk, including the State Sensitive Olympic mudminnow [*Novumbra hubbsi*], the State Endangered western pond turtle (*Clemmys marmorata*), and the State Endangered and Federal Candidate Oregon spotted frog [*Rana pretiosa*]).

Modeling and Scientific Uncertainty

It is important to recognize that all habitat restoration efforts (i.e., the habitat enhancements) typically occur within a backdrop of continued environmental change and degradation. Some of this environmental change was modeled in the ASEP (e.g., climate change) and some was identified as needing to be modeled in the future in the companion *Data Gaps Report* (e.g., continued removal of LWM from the stream channel and floodplain). Some background environmental changes were not incorporated into ASEP analyses at this time because they were beyond the scope of this analysis. These include, for example, changes related to human activities such as projected increases in human population in the basin and the accompanying increased in the breadth and intensity of land use. Therefore, the gains that resulted from the modeled enhancement alternatives must be considered within the context of the background losses of ecological functions, including those to aquatic systems that come with increasingly intensive human land-use practices. Ultimately, the benefits of enhancement projects will diminish over time if the progressive decline in ecological functions from human land uses is not accounted. Therefore, restoration should not be thought of as a series of individual projects but rather as an ongoing commitment, supported by the community, to reach a desired future condition that results in a net gain in aquatic species' population status due to increased ecological and habitat function and processes.

ASEP authors recognized several uncertainties of this study and identified ways to address them in the future in the companion *Data Gaps Report*. It should be noted, that quantifying the variability associated with model outputs was not possible for most ASEP analyses. Thus, the values presented throughout this report imply a certainty of outcome that is highly dependent on input parameters, many of which require further validation. The values also imply a high level of precision, when in actuality the results include a measure of uncertainty. The value of the present analysis is to synthesize available knowledge as a way to compare alternative actions and understand the implications of different assumptions and alternative future conditions. Therefore, decision makers may want a better assessment of the variability and uncertainty associated with ASEP model outputs in the future.

Many of the results presented throughout this report imply a certain level of precision, but typically lack an estimate of the variance associated with each result. Collectively, the results of the model studies conducted present the likely impacts and benefits to aquatic species given the data and analytical tools currently available. The models generally reflect a scientific understanding of processes on a qualitative level. However, quantitative components of the models and interactions of the components are subject to greater uncertainty. The companion *Data Gaps Report* was developed to identify many of these uncertainties. The *Data Gaps Report* acknowledges the need to reduce uncertainty, and for decision makers to have a better understanding of remaining uncertainties associated with model outputs in the future.

Key Findings and Data Gaps

As noted throughout this report, a great deal of work is still needed to determine where, how, and when enhancement projects would occur. The volume of enhancement measures presented in this report is extensive, between 82 miles (132 km; 50% of spring Chinook salmon habitat) and 123 miles (198 km; 75% of spring Chinook salmon habitat) of riparian restoration in non-managed forest land alone, along with continued maturation of riparian areas in managed forest lands, input of wood into the system, and removal of barriers. This level of enhancement is needed to realize the effects that are modeled in this report. Additionally, to realize the effects modeled in this report, a concerted effort by many stakeholders including landowners, tribes, and local, state, and federal agencies will be required to implement such a plan. The need for a watershed restoration planning effort that translates the broad enhancement alternatives discussed in this report into specific restoration projects selected to achieve management objectives is discussed in further detail in the companion *Data Gaps Report*. If this level of effort is not implemented successfully, salmonid species and other species in the basin will likely decline due to climate change and other factors.

The following is a list of key findings as well as data gaps of this report:

- The Chehalis River basin is the largest river basin in western Washington, and one of the few remaining systems that maintains an active connection with the floodplain, to some extent. Extensive and diverse in-channel and off-channel habitats support multiple salmonid species, an endemic species of mudminnow, the highest species richness of amphibians in Washington State, and numerous native species.
- Further reductions in aquatic habitat has the potential to affect state or federally sensitive, candidate, or listed species (e.g., the State Sensitive Olympic mudminnow [*Novumbra hubbsi*], the State Endangered western pond turtle (*Clemmys marmorata*), the State Endangered and Federally Threatened Oregon

spotted frog [*Rana pretiosa*]), and federally listed Threatened eulachon (*Thaleichthys pacificus)* and bull trout *(Salvelinus confluentu)*.

- Temperature is likely a primary limiting factor of many aquatic species in the Basin. Additional studies of temperature are needed and are discussed in the companion *Data Gaps Report*.
- Little information exists on most Other Fish and Non-fish Species to assess current abundance, habitat requirements, limiting factors, and even presence. A review of these species based on the available literature and data suggests their abundance is generally limited due to habitat degradation from multiple causes.
- Spring-run Chinook salmon appear to be at risk due to their low abundance, life history (i.e., entering the river in spring and holding during summer where they are susceptible to being exposed to high water temperatures prior to spawning), and habitat degradation. The EDT model identified temperature, habitat diversity, food abundance, and sediment load as the top four limiting factors. This run of salmon is also culturally important because these are the first salmon to enter the river each year, and are caught and used throughout the year in tribal ceremonies.
- Three primary sources of information were used to identify habitat factors that limit salmonids within the basin. These sources had a high degree of agreement on existing limiting factors. The sources included the following: Smith and Wenger (2001), the 2004 Chehalis Basin Watershed Management Plan (Chehalis Basin Partnership 2004) and the Chehalis Basin Salmon Habitat Restoration and Preservation Strategy prepared by the Grays Harbor County Lead Entity Habitat Work Group in 2011, and results of EDT analyses. The most common limiting factors identified for modeled salmonids were as follows:
  - Migration barriers
  - Riparian degradation
  - Water quantity and quality (flows and temperature)
  - Sedimentation
  - Channel complexity and stability (lack of wood)
  - Loss of floodplain habitat/connectivity
- Based on input at a habitat enhancement workshop attended by representatives from various agencies and entities (WDFW, WDNR, Ecology, WSDOT, NMFS, USFWS, USDA, Chehalis Tribe, Quinault Indian Nation, Lewis, Thurston, and Mason County Conservation Districts, Trout Unlimited, The Nature Conservancy, Wild Fish Conservancy, the ASEP Technical Committee, and the Chehalis Lead Entity) the following enhancement actions were identified to address the limiting factors. These actions were then modeled in EDT with a focus on spring-run Chinook salmon:
  - Culvert/barrier removal
  - Riparian restoration/enhancement/preservation
  - Installation of wood into the system
  - Floodplain reconnection
- Based on model studies using EDT, implementing these enhancement actions would have a positive effect on salmonids. On a percentage basis, the greatest increases were for spring-run Chinook salmon because of the focus of some actions on this species, and the effects of the actions on water temperature and other riparian attributes. This suggests that actions to moderate temperature have a larger potential to positively influence species adapted to cooler water. Also, all species of salmon benefited from the habitat enhancement actions evaluated. This suggests that if other species were targeted, these species would see responses that were greater than those reported.
- Large woody material (LWM) was a large contributing factor to the salmon responses estimated using the EDT model, primarily through future wood recruitment from increased riparian buffers.

- In general, habitat actions focused on salmon were thought to be positive or have no effect for Other Fish and Non-fish species.
- Off-channel habitat enhancement was designed primarily to address the needs of Other Fish and Non-fish species and only two projects were modeled. Consequently, off-channel habitat projects had a small effect on modeled salmonids. However, off-channel habitat is an important ecosystem component in the basin, and numerous opportunities for restoration exist in the floodplain. Data gaps that need to be addressed to fully realize the benefits and limitations of off-channel habitat enhancement are discussed in the companion *Data Gaps Report*.
- Combining habitat enhancement actions (i.e., culvert removal, in-channel and riparian buffer enhancement) resulted in cumulative benefits. The more enhancement that was completed, the greater the overall positive response in terms of modeled salmon abundance. Spring-run Chinook salmon benefited the most from these combinations because the actions targeted their spawning habitat; however, all species benefited from the combinations.
- EDT model results suggest that climate change will impact all salmon and winter-run steelhead and, under the High Climate Change scenario assumptions, spring-run Chinook salmon would be extirpated within the next 100 years. Given these results, their potential implications for salmon and steelhead as well as the fishing economy and tribal activities, more in-depth evaluations of the effects of climate change on water temperature and a climate change risk assessment are warranted. These are described further in the companion *Data Gaps Report*.

Model Assumptions

- Results from the combined model runs (climate change and habitat enhancement) suggest that the habitat enhancements modeled may have a significant ability to ameliorate the effects of climate change on salmon abundance, and in the case of spring-run Chinook salmon, their persistence. This effect, however, is dependent on the model assumptions about the effectiveness of enhancement actions and the benefits being realized now and into the future. The need for additional assessment of these assumptions is addressed in the companion *Data Gaps Report*.
- LWM is an important habitat component of many salmon species and the habitat enhancement alternatives modeled. However, LWM has been systematically removed or is currently degraded in many river systems in western Washington, including the Chehalis. If it continues to be systematically removed (by landowners, state agencies, and others), then the benefits associated with habitat enhancement alternatives that incorporate LWM will not be fully realized. The need for additional assessment of these assumptions is addressed in the companion *Data Gaps Report*.

Modeled culvert restoration benefits may underestimate the actual benefits associated with culvert removal because there are approximately 2,200 identified culverts in the basin, but the ASEP analysis estimated benefits associated with 169 culverts that were identified in previous surveys as high-priority blockages. Also, spring-run Chinook salmon were assumed to receive no benefit from culvert removal based on WDFW's observations. The validity of this assumption needs to be evaluated further. If it is an invalid assumption, there may be benefits to spring-run Chinook salmon from culvert removal that were not captured in the ASEP analyses. Conversely, the modeled culvert restoration benefits may overestimate the actual benefits associated with culvert removal. This is because all habitat upstream from a blocked culvert that was removed in the model was assumed to be available to salmon, but may not be due to other blockages further upstream that are not currently in the model. Also, a significant proportion of mapped culverts (approximately 30%) that were permitted as fish passage culverts by WDFW within 10 years and were constructed, failed, and continued to block passage (Price et al. 2010). The need for additional studies and surveys of culverts in the basin is discussed in the *Data Gaps Report*.

1 Introduction

1.1 Introduction

This *Aquatic Species Enhancement Plan* (ASEP) reflects six of the nine objectives identified by the State of Washington in the original ASEP outline. Objective 4 is to identify areas where further study is warranted (i.e., data gaps), should the project move to the next phase. A separate report has been prepared to expand on the data gaps identified in this report. Objective 8 is to identify the potential effects of alternative flood control actions on the status of habitat and fish populations in the Chehalis Basin (basin). Objective 9 is to identify potential effects of climate change on the aquatic species in the basin and flood control alternatives. Climate change effects on aquatic species are discussed in this report. A separate report, *Effects of Flood Reduction Alternatives and Climate Change on Aquatic Species*, summarizes results of studies on the potential effects of flood reduction alternatives and future climate variability on aquatic resources, and combinations of these alternatives.

This ASEP summarizes the results of previously conducted studies and additional studies conducted under the ASEP to conduct the following:

- Identify and characterize current and historic populations of Key aquatic species in the basin.
- Identify factors that are currently limiting the Key aquatic species populations in the basin.
- Identify restoration, protection, and enhancement strategies and actions to improve the status of these resources in the basin.
- Identify potential effects of climate change on key aquatic species in the basin.

This process was co-led by Anchor QEA and the Washington Department of Fish and Wildlife (WDFW); Erik Neatherlin (WDFW) and John Ferguson (Anchor QEA) co-led the study. Analyses were conducted primarily by staff from WDFW and the Anchor QEA consulting team (Anchor QEA, ICF International, Confluence Environmental, and BioAnalysts, Inc.) under the general direction of the State of Washington and the Chehalis Basin Flood Study's ASEP Technical Committee (Committee). Additional staff from the Washington State Department of Ecology (Ecology), the Chehalis Tribe, the Quinault Indian Nation, local water districts, municipalities, and natural resource agencies, also contributed to the implementation of the studies presented in this report. Their input was received during technical workshops, committee meetings, and numerous teleconferences. These workshops and meetings resulted in the approach, methods, assumptions, and alternatives used to develop the results presented in this report.

1.2 Purpose

The ASEP reflects a step-wise analytical approach where the best available scientific data and analysis are used to document the existing aquatic resources in the basin and assess factors contributing to the viability of key populations. Based on this technical foundation, future conditions are estimated assuming habitat enhancement measures are implemented and changes in the ecosystem occur as a consequence of climate change.

The purpose of ASEP is three-fold. First, it applies new scientific data collection and analysis using contemporary methods to address issues facing humans and aquatic resources dependent on habitats within the basin. Second, it provides a means for identifying and discussing priorities within the broad stakeholder community.

Third, the ASEP evaluates the effects of habitat enhancement actions and climate change on the Key Species of the basin.

1.3 Scope

The ASEP addresses potential benefits and effects to the ecosystem by focusing on key salmon, Other Fish, and Non-fish aquatic and semi-aquatic species that represent more than 70 Key Habitats and Species in the basin as identified by the WDFW, in consultation with the Anchor QEA team and partner stakeholders.

The spatial scope of the ASEP is broad. All tributaries that flow into the Chehalis River upstream from and including the Wynoochee River are included in this analysis, along with the entire mainstem Chehalis River. However, rivers west of the Wynoochee River that do not flow into the Chehalis River, but flow directly into Grays Harbor are not included (e.g., Wishkah, Hoquiam, and Humptulips) as they are unlikely to be affected by any proposed Project actions nor do they have a direct effect on the Chehalis River. Thus, most of Water Resource Inventory Area (WRIA) 22 and all of WRIA 23 are included in this ASEP.

Habitat enhancement actions for salmon species across the entire watershed from the Wynoochee River upstream have been investigated. The ASEP identified some of the current conditions of the ecosystem, and for salmon, placed this condition into an historic context using the Ecosystem Diagnosis & Treatment (EDT) model. In addition, ASEP analyzed some of the effects on the ecosystem from climate change. Other Fish and Non-fish species were evaluated using other models (e.g., Habitat Suitability Index [HSI] and PHABSIM) where sufficient data were available for use of those models and correlative models where insufficient data existed for HSI or PHABSIM analyses.

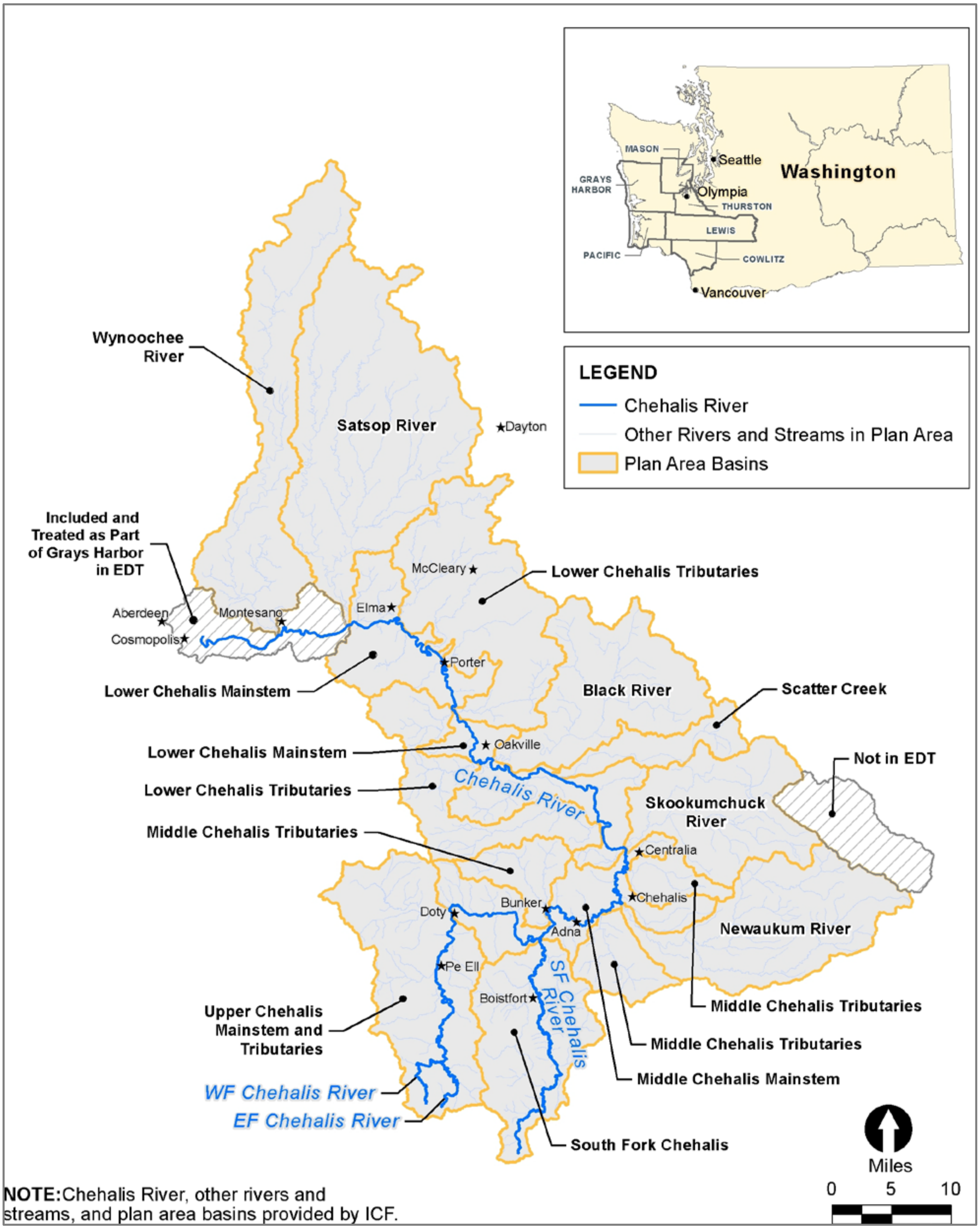
1.4 Overview of the Watershed

The basin is the largest river basin in western Washington. Except for the Columbia River Basin, it is the largest watershed in the state at 2,766 square miles (7,163 km^2). The basin extends over eight counties and encompasses large portions of Grays Harbor, Lewis, and Thurston counties, as well as smaller parts of Mason, Pacific, Cowlitz, Wahkiakum, and Jefferson counties. For purposes of water resources planning under the Washington State Watershed Planning Act of 1998, the basin was divided into two WRIAs 22 and 23.

The largest tributaries based upon average annual discharge are the Satsop River (1,968 cubic feet per second [cfs; 55.2 m^3/sec]), the Humptulips River (1,344 cfs [38.1 m^3/sec]), the Wynoochee River (1,316 cfs [37.3 m^3/sec]), the Skookumchuck River (540 cfs [15.2 m^3/sec]), the Newaukum River (506 cfs), Cloquallum Creek (375 cfs [10.6 m^3/sec]), and the Black River (330 cfs [9.3 m^3/sec]; Pickett 1992). In total, 1,391 streams with 3,353 linear stream miles (5,396 km) exist in the basin (Phinney and Bucknell 1975; Figure 1.1).

Based on WDFW spawner survey data, using the EDT model ASEP authors estimate that a total of 1,568 stream miles (2,523 km) in the basin are currently used by salmon for spawning and rearing. The Satsop River has the most stream miles available to salmon (208.2 [335.1 km]), followed by the Newaukum River (182.0 [293.0 km]), South Fork Chehalis (136.7 [220.0 km]), Wynoochee River (132.5 [213.2 km]) and Skookumchuck River (106.2 [170.9 km]). Both the Wynoochee and Skookumchuck stream miles are calculated up to existing dams on those rivers.

Figure 1.1
The Chehalis River Basin



The mainstem Chehalis River is formed by the confluence of the East Fork Chehalis River with the West Fork Chehalis River at River Mile (RM) 118.9 (RKm 191.4; Phinney and Bucknell 1975). The headwaters for the mainstem Chehalis River are in the central Willapa Hills above the town of Pe Ell. Tributaries to the Chehalis River arise from diverse sources, such as the Olympic Mountains, the Bald Hills, the Willapa Hills, the Black Hills, and a spur of the Cascade Mountain Range (Smith and Wenger 2001). The Chehalis River flows through three distinct eco-regions before emptying into Grays Harbor near Aberdeen: 1) the Cascade ecoregion, characterized by volcanic/sedimentary bedrock formations; 2) the Puget Lowland, characterized by glacial and alluvial sediment; and 3) the Coast Range (including the Olympic Mountains), characterized by volcanic/sedimentary bedrock (Chehalis Basin Partnership 2004).

Though not widely mentioned, the Chehalis River has some of the most extensive off-channel habitats (e.g., oxbows, side channels) in its main-channel floodplain of any river in the Pacific Northwest (Vadas, pers. comm. 2014). Authors have recognized the extensive side-channel habitat on the lower Chehalis floodplain (Miller 1993; Henning 2004), which appears to be roughly the vicinity of Elma downstream. By comparison, the main channel of Willamette River, which in many areas has a broader floodplain, has lost the majority of its side-channel habitat to diverse land-uses (Benner and Sedell 1997) and the reduction of processes that contribute to forming side-channel habitats (Dykaar and Wigington, Jr. 2000). As in most rivers, in the main-channel Chehalis, development of side-channel habitat is progressively more extensive downstream, and it is most developed in two areas: 1) the lower Chehalis, and 2) between the vicinity of the Black River confluence and the vicinity of the confluence with the Skookumchuck River.

The basin is bounded on the west by the Pacific Ocean, on the east by the Deschutes River Basin, on the north by the Olympic Mountains, and on the south by the Willapa Hills and Cowlitz River Basin. The upper Chehalis mainstem flows northerly and is unusual in having the combination of a confined channel with a moderate to low gradient (Weyerhaeuser 1994). The land use in this headwater area is predominately forest. As the mainstem flows through the areas of Pe Ell and Doty, the direction of flow changes to the east. As the Chehalis River approaches its confluence with the Newaukum River, the floodplain broadens and turns again to flow in a northerly direction. From Pe Ell to the City of Chehalis, land use adjacent to the mainstem is dominated by agriculture. Urban and industrial use predominates as the mainstem flows through the Centralia and Chehalis area, where the river channel has become incised. Additionally, the floodplain becomes markedly constricted just upstream of Centralia and the confluence with the Skookumchuck River prior to re-expanding into a larger floodplain downstream.

Near Scatter Creek, the mainstem flows in a westerly direction through an area of low prairie land that has experienced heavy residential growth. Downstream of Porter Satsop River, one of the largest sub-basins in the drainage, enters the mainstem Chehalis River. From Montesano to the mouth, the mainstem Chehalis River is tidally influenced with numerous sloughs and side channels (Ralph et al. 1994).

Annual precipitation varies from a minimum of 40 inches (101.6 cm) in the central portions of the basin (Chehalis/Centralia) to a high in excess of 220 inches (558.8 cm) in the headwaters of the Wynoochee and Humptulips Rivers in the Olympic Mountains. Precipitation usually falls as rain except in the higher elevations of the Olympics and in a limited area of the upper Chehalis around Boistfort (Baw Faw) Peak (at 3,113 feet [949 m], the highest point in the Willapa Hills), which seasonally receive snow. River discharge peaks between December and March. The average annual discharge of the entire basin is approximately 11,208 cfs (317.4 m^3/sec; Chehalis Basin Partnership 2004).

Existing anadromous and shellfish resources of the basin are of regional and national significance to sport, tribal, and, commercial fishing. In addition, the basin provides migratory and wintering area for waterfowl in the Pacific Flyway.

The majority of the basin (87%) is forestland. Although the basin has a high proportion of forestlands, residential and industrial development is concentrated in areas close to important basin streams and rivers; this proximity can have adverse effects on both water quantity and water quality. While only 11% of the basin as a whole is in agricultural, urban or industrial uses, this figure climbs to 42% in those areas within 1 mile of major rivers in the basin. Developed segments of these waterbodies account for almost half the length of the major rivers in the basin (Chehalis Basin Partnership 2004).

According to Watershed Geodynamics and Anchor QEA (2014), the geomorphic reaches of the mainstem Chehalis River upstream from RM 33 (RKm 53.1) range from a steeper gradient, confined reach in the headwaters to less confined, lower gradient reaches downstream. One unique feature of the Chehalis River is the extremely low gradient (0.03%) reach between RM 61.7 and 75.5 (RKm 99.3 to 121.5), near the City of Chehalis. The dominant substrate in most of the river is gravel and cobble with minor amounts of sand. Little large woody material (LWM) exists due to historic splash damming and large wood removal efforts.

The 2007 flood had a profound effect on the Chehalis River system that will persist for decades. The flood resulted in deposition of channel-filling gravels upstream of RM 104 (RKm 167.3), large log jams that caused a channel avulsion near RM 104.5 (RKm 168.1), and overbank wood and fine sediment deposits up to 6 feet (1.8 m) deep in unconfined reaches. The gravel deposits upstream of RM 104.5 (RKm 167.3) resulted in substantial fining of the substrate and currently provide excellent spawning areas for resident and anadromous fish. Through time, these deposits will be re-worked and transported downstream until the river reaches a dynamic equilibrium with the bed material, resulting in coarser substrate in much of the upper watershed, similar to conditions noted prior to the 2007 flood (Watershed Geodynamics and Anchor QEA 2014).

1.4.1 HUMAN DEVELOPMENT

Prior to European settlement, groups of Salish-speaking people lived along the Chehalis River and its tributaries. The two principal tribes in the area were the lower Chehalis and the upper Chehalis. These two tribes spoke distinct yet related Salish languages and maintained close ties through visiting, trade, and intermarriage. The lower Chehalis people relied heavily on the resources of the sea. The people of the lower Chehalis, known as the Quinault, lived on the Olympic Peninsula as members of individual family groups thousands of years before a small portion of their ancient lands became the Quinault Indian Reservation. The Quinault signed a treaty with the United States Government on July 1, 1855, which was proclaimed by the President on April 11, 1859.

The upper Chehalis people inhabited the territory from Cloquallum Creek to the upper reaches of the Chehalis River and had a strong river-based economy. The people of the upper Chehalis rejected the terms of the treaties offered by the United States Government, and Chehalis Tribe is regarded as a non-treaty tribe. The aquatic resources of the basin are extremely important to both tribes.

Today, 140,000 people live within the basin. While only 1.5% of the basin’s land-base is urbanized, more and more land is being converted to residential use as the population continues to grow. The average rate of population growth from 2000 to 2025 for sub-basins in the Chehalis watershed is projected to be 52%. The basin’s location halfway between Puget Sound and the Columbia River, the proximity of major transportation routes, a rich natural resource base, and the aesthetic beauty of the area are factors that contribute to its rapidly expanding population base (Chehalis Basin Partnership 2004).

1.4.2 FACTORS INFLUENCING AQUATIC SPECIES

This section is based primarily on the information contained in a report by Hiss and Knudsen (1993). Since the 1850s, the basin has experienced intense changes in natural resource use driven by economic and cultural development that has resulted in fluctuations in the abundance and productivity of salmon stocks.

1.4.2.1 FISHERIES

Prior to colonization by European settlers, tribal fisheries were conducted on salmon and steelhead (*Oncorhynchus mykiss*) as well as other species in the Chehalis River and tributaries (GHRPC 1992). In the 1850s and thereafter, settlers began harvesting salmon and steelhead stocks using a progression of gear types and techniques that led to competition among tribal and non-tribal harvesters as well as commercial and sport interests.

The first commercial catch of salmon was documented in 1892, and by 1934, harvest was declining. Estimated numbers of fish harvested in Grays Harbor fisheries between 1891 and 1928 based on cannery records (Cobb 1930) peaked in 1911 at approximately 275,000 coho salmon (*Oncorhynchus kisutch*) and 63,000 Chinook salmon. The number of canneries operating in Grays Harbor increased from one in 1878 to nine in 1917, and declined thereafter. During the mid-1930s, marine diesel engines became available and greatly increased the range of the fishing fleet. This led to ocean fisheries occurring outside of the basin and Grays Harbor. The ocean fisheries off Grays Harbor and elsewhere along the Pacific Coast were very productive but led to the interception of mixed stocks and reduced the ability of local managers to effectively manage returns to specific rivers. By the 1940s, charter boats began to enter the ocean fishery off of Grays Harbor and both the charter and commercial fleet continued to grow, peaking in the mid-1970s.

In the mid-1970s a number of court cases and regulatory actions reshaped harvest in the basin and elsewhere. In 1974, *United States vs. Washington* reallocated sport and commercial harvest to allow tribal treaty fishing rights to be exercised at usual and accustomed locations and tribal and non-tribal fishermen to harvest up to 50% of the harvestable salmon and steelhead. In 1976, the Magnuson Fishery Conservation and Management Act created the Pacific Fishery Management Council (PFMC) to set harvest limits and seasons for marine waters representing the exclusive economic zone (EEZ) off the Washington, Oregon, and California coasts (i.e., between 3 and 200 miles off the coasts). The PFMC consolidated the individual management interests of each state as it applies to the fish traveling through the EEZ and provided a venue to deal with complex, mixed stock harvest issues. In 1985, the Pacific Salmon Commission was formed to address additional mixed stock issues occurring between the United States and Canada. Between 1976 and the early 1990s, commercial and charter catches declined significantly and the Grays Harbor fishing fleet declined by more than 50%. Reductions in the abundance and productivity of Pacific Northwest salmon and steelhead stocks led to multiple Endangered Species Act (ESA) listings by the late 1990s; however, no ESA listings occurred for salmon or steelhead in the Chehalis River.

1.4.2.2 HABITAT

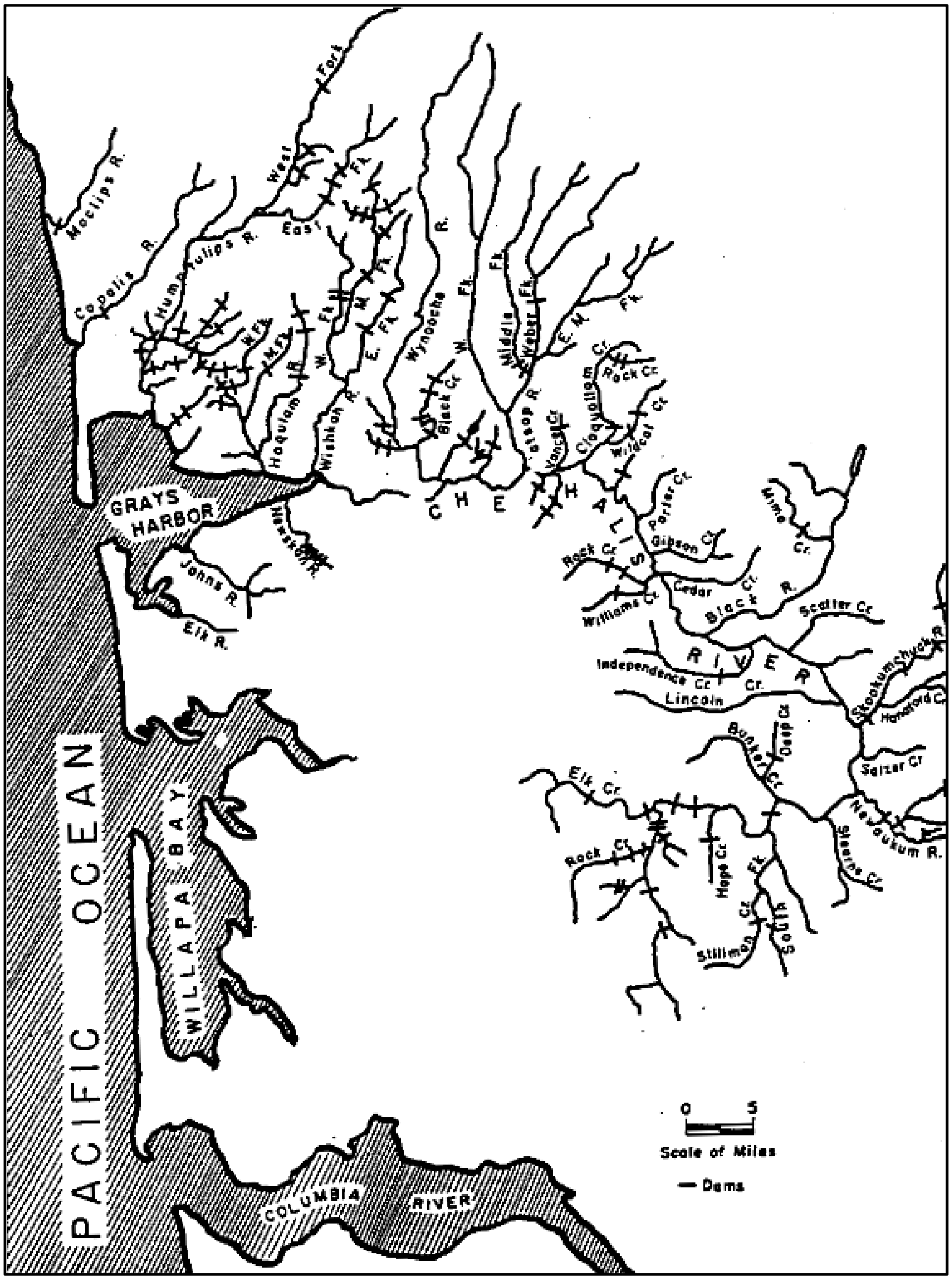
Major human-induced factors influencing salmon and steelhead habitat include agriculture, logging, gravel mining, urbanization, estuarine dredging and filling, dams, and diversions and industrial waste disposal.

Beginning in the mid-1850s, agriculture was an important contributor to the development and economy of Grays Harbor, driven in part by demands from the Fraser River gold rush. Agriculture and ranching activities shaped fish habitat in a number of negative ways including the removal of river side channels, sloughs, and ponds; straightening small streams; removing riparian vegetation and removing snags and logjams. The loss of properly functioning habitat was particularly significant along the Chehalis, Wynoochee, Satsop, and Humptulips rivers because of extensive network of dikes that were constructed by farmers during the agricultural development of the basin (GHRPC 1992).

In the 1880s, logging activities became a major industry in Grays Harbor. Demand for timber was high as a result of demand from domestic development and rebuilding efforts associated with the 1906 San Francisco fire and earthquake. Early timber harvest efforts were particularly damaging to anadromous fish habitats because of the use of splash dams to convey logs from harvest areas downstream to mills (Wendler and Deschamps 1955a). These dams created impassible barriers to fish, and direct injury or death to life history stages present during their operation that sluiced logs with large volumes of water. The sluicing damaged riparian habitats, mobilized and displaced bed load, filled in pools and riffles, increased channel instability, deposited tree bark over large areas, and reduced in-channel habitat by removing large woody material.

Splash dams were common prior to the 1930s. For example, splash dams blocked passage to 60% of the spawning and rearing habitat in Grays Harbor (Figure 1.2; Wendler and Deschamps 1955b). The average splash dam was in place for approximately 20 years. After their functional use ceased, many splash dams were left in place causing a legacy of fish barriers. During the 1950s, the Washington Department of Fisheries (WDF) conducted a successful effort to remove many splash dams that resulted in the re-colonization of reaches formerly blocked to salmon and steelhead.

Figure 1.2
Location of Splash Dams In and Around the Chehalis Basin



Note:
Source: Hiss and Knudsen, 1993, based on information contained in Wendler and Deschamps (1955a).

Lingering effects of old logging practices are evident in the recent history of the basin. However, improvements in timber harvest practices, particularly the use of transport methods other than splash dams, have lessened the effects of timber harvest on fish habitats. Additionally, scientific, policy, and regulatory changes have highlighted the relationships between timber harvest practices and habitat effects and have helped shape harvest practices.

In the early half of the 1900s, gravel from the Chehalis River and its tributaries was frequently used for road building. This practice was largely unregulated until 1945 when the WDF began requiring permits for in-stream gravel mining. In the 1950s the damage caused by in-stream gravel mining to fish habitat was recognized and WDF began conditioning permits to require mining upstream from the wetted portion of the river. Gravel mining evolved based on conservation concerns and recognition that replacement rates were lower than removal rates. By the 1970s, portions of the watershed were closed to gravel mining or modified to allow a level that would be sustainable based on estimated gravel replenishment rates.

Development and urbanization of the basin has reduced habitat complexity and function over baseline pre-European settlement conditions (e.g., Mobrand 2003). Where development has occurred, habitat losses are attributable to roads, building, culverts, levees, water withdrawals, and waste discharges. In general, urbanization has fragmented or disconnected fish habitat from its historic range and capacity.

Grays Harbor and the estuarine portion of the Chehalis River have undergone extensive historic dredging to support shipping related to log exports. As early as 1911, the Port of Grays Harbor was created, in part, to manage dredging and filling operations. As a result of this dredging, significant quantities of dredged materials were deposited in wetlands and tidelands that were important rearing habitats for juvenile salmon. These filled areas played an important role in creating land upon which the cities of Aberdeen and Hoquiam were built.

1.4.2.3 DAMS AND DIVERSIONS

The basin has two significant dams. The Skookumchuck Dam was built at RM 10 (RKm 16.1) in 1970. It inundated about 2 miles (3.2 km) of former spawning habitat and blocked access to 12 miles (19.3 km) of additional spawning habitat upstream from the reservoir. The loss of fish habitat was estimated to include that necessary to support 500 spring-run Chinook salmon, 311 fall-run Chinook salmon (*Oncorhynchus tshawytscha*), 1,800 coho salmon, and 700 winter-run steelhead spawners (Finn 1973; WDG 1970). The dam has no facilities to pass fish around the dam in either direction.

The U.S. Army Corps of Engineers built the Wynoochee Dam at RM 50 (RKm 80.5) of the Wynoochee River in 1972. Prior to construction, it was estimated that 1,500 coho salmon and 1,400 winter-run steelhead spawned at or upstream from the inundated portion of the river. In 1994, Tacoma Power added a hydroelectric power facility to the existing Wynoochee Dam. To protect the fishery, Tacoma Power shuts down the power plant for a certain period each spring to allow salmon and steelhead smolts to pass safely downstream through outlets in the dam. Tacoma Power also operates a fish collection facility 2 miles (3.2 km) downstream from Wynoochee Dam at a low barrier dam. Here, salmon and steelhead are separated from other species, and most of the collected fish are loaded into a tank truck and hauled 5 miles (8 km) upstream, past Wynoochee Lake, and released back into the Wynoochee River to spawn.

Other smaller diversions and intakes have also been constructed causing significant reductions in in-stream flows, which have resulted in decreased water quality in spawning and rearing habitats (Fraser 1986). Consumptive users include local municipalities. For example, Aberdeen draws municipal water from the Wishkah River; Centralia and Chehalis obtain water from North Fork Newaukum River; Chehalis draws water from the Chehalis River; Hoquiam obtains water from the Hoquiam River. Non-consumptive users include hatcheries throughout the basin.

1.4.2.4 INDUSTRIAL WASTE DISPOSAL

Pulp production has had a negative effect on the water quality of Grays Harbor beginning in the 1920s. The combined effect of low dissolved oxygen (DO), high temperatures, and toxic constituents of the pulp making process were believed to cause a “pollution block” in the lower portion of the river (WDF 1971) that significantly reduced the survival of salmonids. Subsequent cleanup efforts and changes to effluent treatment have improved water quality to the extent that the pollution block may have dissipated in the early 1990s (Hiss and Knudsen 1993).

1.4.2.5 WATER TEMPERATURE

Water temperature is a key environmental parameter for all aquatic species, and a key policy concern in the Basin Flood Study. In recent years, salmon mortality has been observed but little information has been collected on the impact of temperature on salmonids in the basin. Therefore, the following sources of water temperature information were summarized to help inform this topic: 1) an overview of thermal tolerances for Chinook Salmon at different life history stages based on the literature, with an emphasis on adult migrations due to observed Chinook Salmon kills in the Chehalis River in the recent past; 2) observations of species present in the Chehalis River during snorkel surveys conducted by WDFW in summer, 2013, relative to median water temperatures measured during a Forward Looking Infrared Radiometer (FLIR) flight during this timeframe; and 3) results of water quality monitoring conducted under the Project to assess effects of water retention alternatives on river temperatures.

1.4.2.5.1 Literature Review

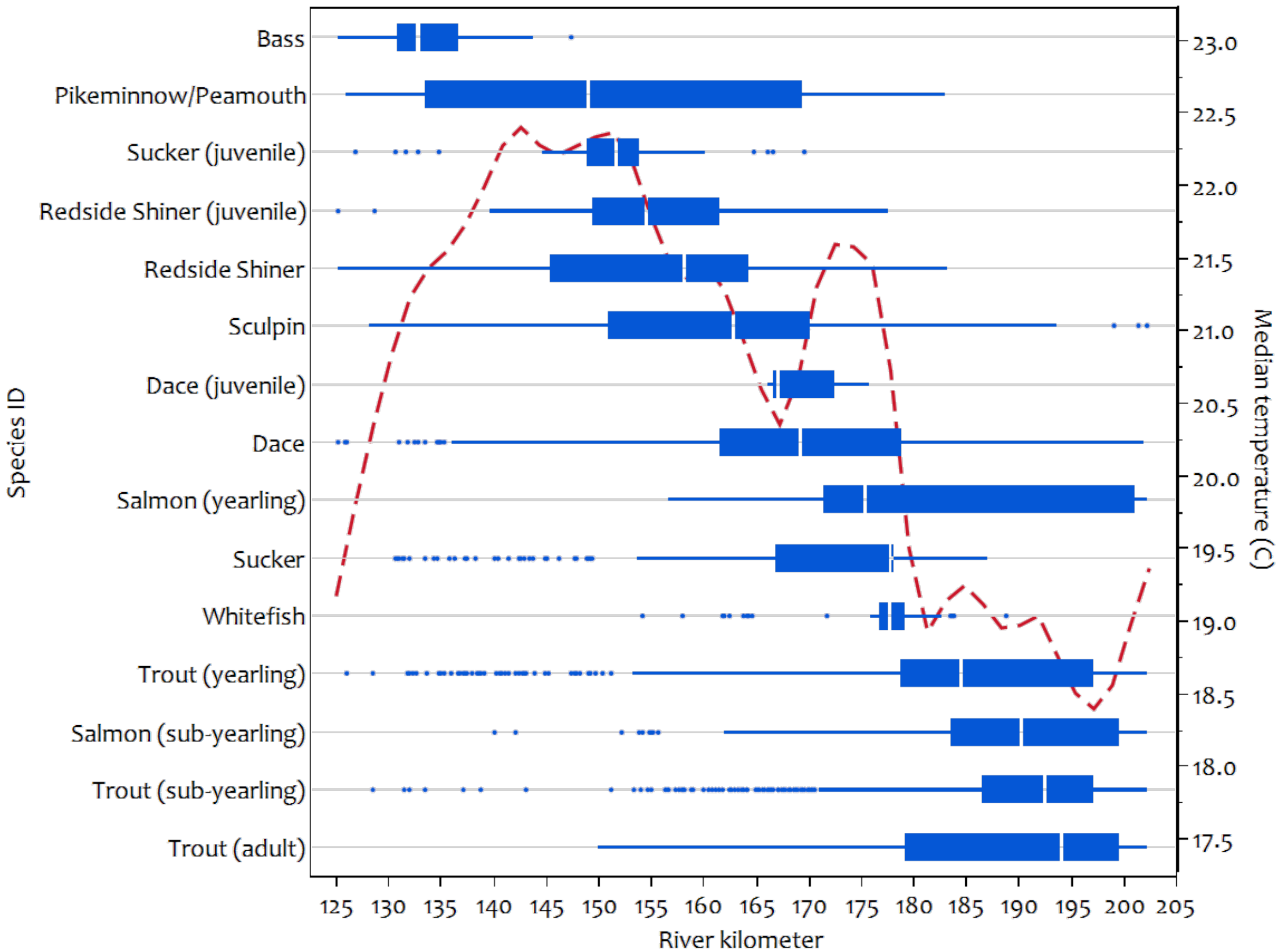
In general, adult Chinook salmon appear to experience a significant decrease in survival when water temperature reaches 21 degrees Celsius (°C; 69.8°F). The effects of temperature exceedances include: 1) direct mortality; 2) increased susceptibility to pathogens; 3) bio-energetic stress leading to decreased life-span or loss of gametes; 4) decreased fitness/loss of viable progeny; 5) delayed migration; 6) decreased competitive abilities: and 7) combinations of these.

1.4.2.5.2 Riverscape Snorkel Survey

Reach-specific data on the Chehalis River was collected by WDFW via snorkel survey, which was a continuous coverage snorkel starting at the East Fork and West Fork confluence of the Chehalis River and ending downstream from the Chehalis River confluence with the Newaukum River (at State Route 6 bridge). These snorkel surveys collected data on species composition in specific reaches of the mainstem Chehalis River from August 13 to September 12, 2013. Median temperatures were obtained from FLIR flights conducted from September 10 to 12 and on September 14, 2013, using an FLIR SC6000 infrared camera mounted to an aircraft. This temperature information was used to determine correlation between temperatures and the presence for observed species.

The results are shown in Figure 1.3. Species composition varied with distance, and ranged from a warmwater fish assemblage in lower reaches (bass, bluegill [*Lepomis macrochirus*], suckers, etc.) to a progressively colder water assemblage in upper reaches (salmon, trout, etc.). This could be due to temperature, habitat parameters, or a combination of both. For example, the lowest median temperature value where bass were observed was 19°C (66.2°F), a condition that essentially changes at approximately River Kilometer (RKm) 180 (RM 111.8). Conversely, the highest median temperature value where salmon fry were observed was 22.8°C (73.0°F), a temperature observed with decreasing frequency moving upstream. Additional modeling will be needed to make inferences on how fish communities may be affected by changing temperatures.

Figure 1.3
Observed Distributions of Common Fish Species and Correlated Median Water Temperature in the Chehalis River Basin, by River Kilometer



Note:
Box plots include first, second (median), and third quartiles, interquartile range (lines), and outliers (dots).

1.4.2.5.3 Water Quality Monitoring

Since 1983, Ecology has recorded water temperature in the mainstem Chehalis River. For the 1983 to 2012 period, median monthly water temperature collected at Dryad averaged 18.1 and 17.25°C (64.6 to 63.1°F) in July and August respectively. At Porter, median monthly water temperature was 19.8°C (67.6°F) in July and 19.45°C (67.0°F) in August.

However, because water quality (particularly water temperature) may be one of the primary foci for determining fish presence in the basin, a water quality monitoring program has been implemented to characterize temperature, DO and nutrient loads based on the following components:

- Automated continuous temperature monitoring in the mainstem Chehalis River and major tributaries
- Synoptic flow and water quality surveys during summer low-flow conditions

- Diel surveys and depth profiling of key water quality parameters conducted concurrently with the synoptic water quality survey
- Detailed characterization of the temperature and DO regime in the Centralia reach (i.e., the section of mainstem Chehalis River between the confluences with Newaukum and Skookumchuck Rivers)
- Temperature measurements in groundwater wells in the upper Chehalis River (upstream from the Newaukum River confluence)

The summary provided here focuses on the temperature measurements. Temperature probes were deployed in August 2013 throughout the basin and at numerous locations in the Mainstem Chehalis and will remain in place through summer of 2014. The probes record water temperature every 30 minutes. Temperature data were downloaded from the probe during the summer low-flow surveys and during the groundwater survey in October. The program includes three surveys, two of which were completed in August and September 2013, and a third is planned in July 2014. In addition to the continuous temperature probes, field measurements of temperature were made and will be made during the low-flow surveys. As part of the low-flow survey, at three locations (one near Pe Ell, and two in the Centralia reach) temperature measurements were made and will be made over a 24-hour period to characterize diurnal temperature changes in the Chehalis River.

Temperatures recorded by the probes at select locations through October 2013 are shown in Figure 1.4. The temperatures shown represent the 7-day average of the daily maximum (7DADmax) temperature, which is used for the regulatory thresholds established in state water quality standards for protection of biological habitat. The applicable temperature criteria are also shown in Figure 1.4 as a solid red line, over the time periods when they apply. In terms of state water quality standards, the upper reach of the mainstem Chehalis River (upstream from confluence with South Fork) is designated as core summer salmonid habitat and the rest of the river is designated as salmonid spawning, rearing and migration habitat. Figure 1.4 shows that temperatures in the upper reaches exceeded the core summer salmonid habitat criteria by a significant margin (3 to 5 °C [37.4°F to 41°F]) into mid-to-late September; in the lower reaches, temperature exceeded the salmonid spawning and rearing criteria into late September.

Spatial variation in temperature is shown for two dates (corresponding to the summer low-flow surveys completed in 2013) in Figure 1.5. The temperatures shown are instantaneous values recorded at the time of measurement. It is evident from Figure 1.5 that upper reaches of the mainstem Chehalis River were cooler than lower reaches during both surveys. As the river flowed downstream, it was progressively subjected to solar heating thereby resulting in warmer temperatures. During the August survey, the river sustained an increase of approximately 6°C (42.8°F) as it traveled from Pe Ell, Washington (near RM 110 [RKm 177.0]) to confluence of Newaukum River (approximately RM 75 [RKm 120.7]), and experienced only minor changes thereafter. A similar pattern was observed in September, but the degree of increase was lower. The tributaries generally followed a similar spatial pattern: tributaries draining into the upper reaches were cooler than those draining to the lower reaches (in Figure 1.5, the confluence with each tributary is shown by a solid vertical black line). Furthermore, during both surveys, the tributaries were consistently cooler than the mainstem Chehalis River where they entered. The temperature measurements showed that the applicable salmonid criterion identified by Ecology (shown in red in Figures 1.4 and 1.5) was exceeded over all the respective reaches where it was applicable.

Figure 1.4
7-Day Average of the Daily Maximum Temperature at Select Locations Along the Chehalis River

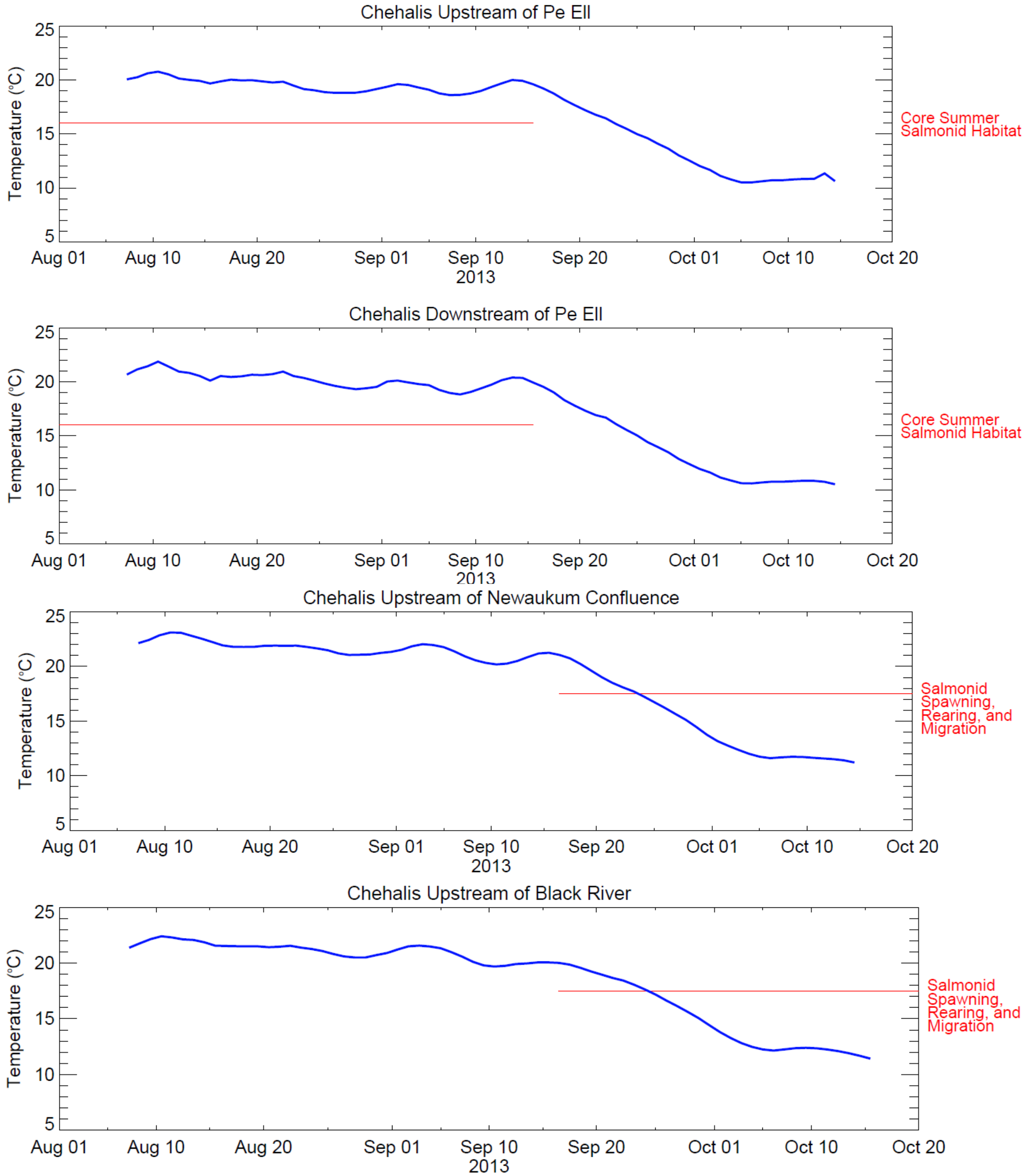
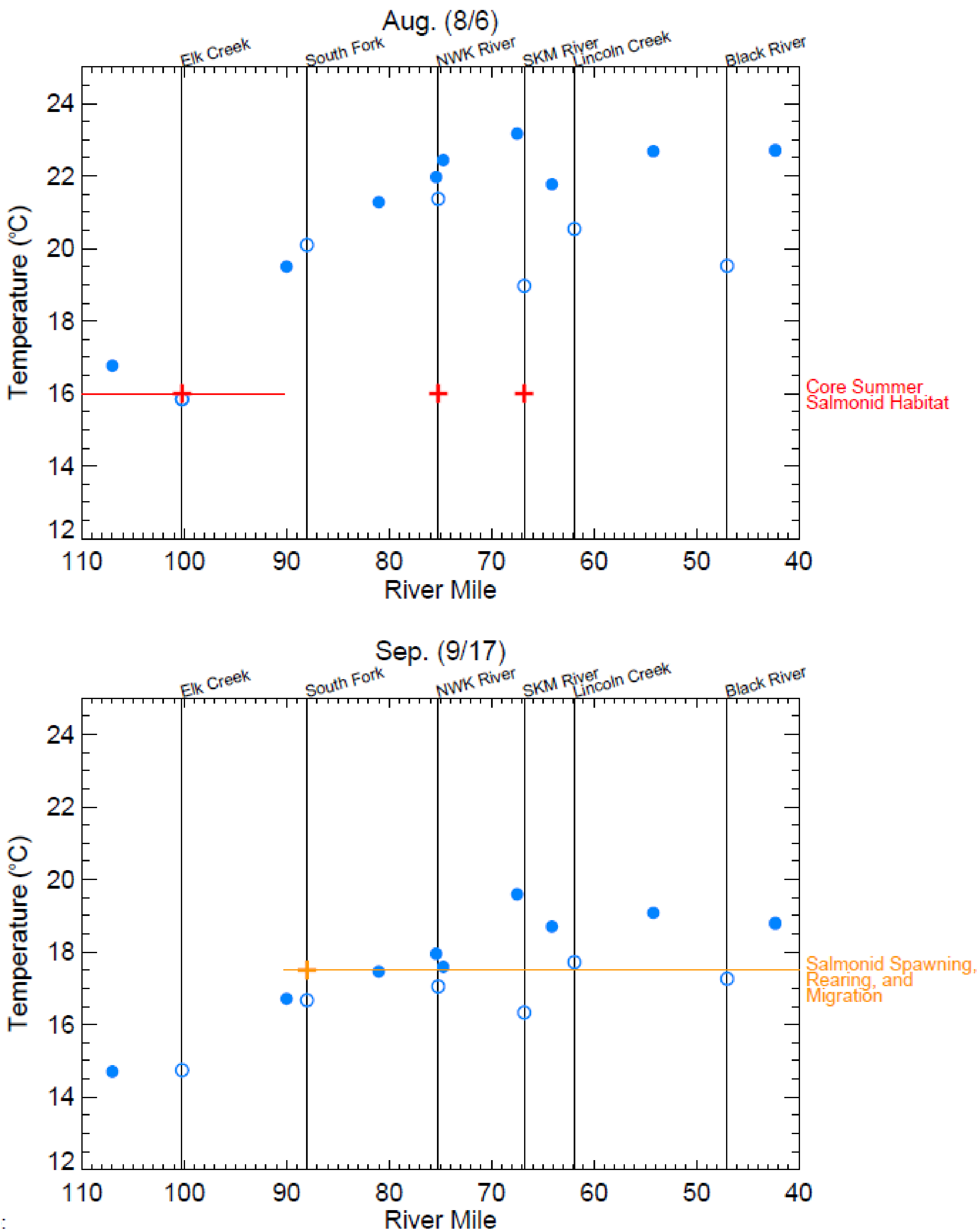


Figure 1.5
Spatial Variations in Temperature in the Chehalis River and Its Tributaries



Notes:
Open symbols represent tributaries, and filled symbols represent the mainstem Chehalis River.
Red and orange crosses represent temperature criteria for tributaries.
NWK indicates the Newaukum River and SKM indicates the Skookumchuck.

1.5 Selection of Key Species

Given this background on the watershed, one of the most important steps of the ASEP was to first determine which aquatic species should be assessed. Chehalis River spring-run and fall-run Chinook salmon, winter-run steelhead, and coho salmon were previously assessed using EDT and spring-run Chinook salmon, winter-run steelhead, and coho salmon were previously assessed using Salmon Habitat Integrated Resource Analysis (SHIRAZ), another salmon habitat-population model. Therefore, a substantial amount of information was available and these species were identified as Key Species to be analyzed using these quantitative models. Other aquatic species in the basin have less data available and were not previously analyzed using EDT or SHIRAZ; therefore, an extensive screening assessment was used to determine which additional species should be analyzed in the ASEP.

Identifying Key Species for the ASEP was a cooperative process. WDFW, in consultation with the Anchor QEA team and partner stakeholders, identified a list of Key Species (Appendix A, Table A-1) and Key Habitats (Appendix A, Table A-2) that might be affected by flood hazard reduction alternatives, habitat improvements, and climate change in the basin. The vertebrate species list was developed based on their known or probable distributions or their use of habitat in the basin. Data were drawn from the Washington State Gap Analysis Project (Cassidy et al. 1997) for Non-fish vertebrates, and the compendium on inland fishes of Washington (Wydoski and Whitney 2003) for fishes. These data were updated with more recent information from WDFW databases and fish survey data, and amphibian and other species survey data collected by WDFW and ICF (see Wildlife Technical Memorandum). A source for invertebrates at the basin scale is lacking, so Key Species of invertebrates were selected directly from WDFW's Priority and Habitat Species (PHS) List (WDFW 2008). Similarly, Key Habitats were selected from the PHS list.

Key Species were selected according to the following criteria:

- The species is of conservation, commercial, recreational, or cultural concern.
- The species is likely to be affected by the proposed flood reduction alternatives.
- The quality/quantity of data available for comparison among flood reduction alternatives.
- The species was tied directly to a Priority Habitat.

A list of Key Habitats was developed by extracting Priority Habitats or Features (Appendix A, Table A-2) from PHS (WDFW 2008) and using the approach described in Appendix A. This resulted in a final list of Key Habitats that included six macrohabitats and five habitat features or small scale-habitats that occur within those macrohabitats (Appendix A, Table A-2).

Assessing the potential effects of flood reduction alternatives on Key Species individually was impractical given available data and schedule. Also, such an approach cannot efficiently identify the groups of species that respond similarly based on their ecological requirements. For these reasons, a *coarse-filter/fine-filter* approach was developed to organize the examination of the potential effects of flood reduction alternatives on ecosystem structure and function.

The coarse-filter identifies important, relatively large-scale ecological elements (ecological community types, ecosystems, or landscapes), and then determines the status (quantity, quality, distribution, etc.) of those types so they can be compared individually or in combination against a particular standard or benchmark. In the case of the ASEP, the large-scale ecological elements termed "macrohabitats" represent the initial habitat level used to assign species into assemblages, or "macroguilds," where the benchmark is the current pre-dam condition in the basin.

The fine-filter aspect of the approach was done formally for the in-stream macrohabitat, one of two macrohabitats containing most of the species for which we modeled responses to dam alternatives). More than one guild level of in-stream macrohabitat was defined because the complexity and resolution of information for that habitat allowed for this, and because it was the only macrohabitat for which the modeled species responses to dam alternatives needed to be refined. Limited data on the second focal macrohabitat, side-channel/low-flow, especially in comparison to the in-stream macrohabitat, led to the grouping of all the species or life stages of species utilizing that habitat into one macroguild. Note that guild organization is not absolute because some species (e.g., western toad [*Bufo boreas*]) or different life stages of the same species (e.g., coho salmon) can and do occur in different guilds.

1.5.1 IN-STREAM MACROHABITAT

For the in-stream macrohabitat, guild creation was fish-focused. It was first subdivided into three major types of river: mainstem, medium river, and small stream. These three major guilds were then subdivided into six lesser types, which were termed simply guilds. These guilds were characterized by differences in substrate and summer water temperatures (see Appendix A, Table A-2).

1.5.2 SIDE-CHANNEL/LOW-FLOW MACROHABITAT

The side-channel/low-flow macrohabitats consists of side-channel habitats that are not currently part of the in-stream channel. These side-channel habitats are sized proportionally to the parent river or stream channel and may or may not be intermittently connected to them. Along the mainstem and medium-sized rivers, this kind of side-channel habitat includes lateral channels, oxbow lakes, ponds, and vegetated wetlands located outside of the active river bed that were formed by past channel-forming activities (scour) of the parent river or stream.

The process of assigning species and habitat to guilds resulted in numerous associations and guild types. To further simplify this guild structure, the information was organized into the following general categories of guilds used throughout this report:

- Salmon species modeled in EDT
- Other Fish Species
- Non-fish Species

A much more detailed description of the process used to identify Key Species and guilds is provided in Appendix A. Table 1.1 identifies the Key Species selected for evaluation in the ASEP, and how they were grouped and analyzed.

Table 1.1
Key Species Analyzed in the Aquatic Species Enhancement Plan

KEY SPECIES (COMMON NAME)	SCIENTIFIC NAME	MODELING ALTERNATIVES			REPRESENTATIVE SOURCES
		EDT (E) SHIRAZ (S)	HSI	CORRELATIVE	
Salmonids					
Steelhead/resident Rainbow trout	*Oncorhynchus mykiss*	E,S			Withler 1966; Leider et al. 1986
Coho salmon	*Oncorhynchus kisutch*	E,S			Sandercock 1991; Quinn and Peterson 1996
Fall-run Chinook salmon	*Oncorhynchus tshawytscha*	E			Taylor 1990; Healey 1991; Waples et al. 2004
Spring-run Chinook salmon	*Oncorhynchus salmonncorhynchus tshawytscha*	E,S			Taylor 1990; Healey 1991; Waples et al. 2004
Other Fish Species					
Chum salmon	*Oncorhynchus keta*		X		Neave 1966; Salo 1991; Minakawa and Gara 1999
Eulachon	*Thaleichthys pacificus*			X	Mallette 2012; DFO 1999
Pacific lamprey	*Lampetra tridentata*		X		Stone and Barndt 2005; Gunckel et al. 2009
White sturgeon	*Acipenser transmontanus*		X		Parsley and Beckman 1994; Paragamian et al. 2001
Olympic mudminnow	*Novumbra hubbsi*			X	Mongillo and Hallock 1999; Henning et al. 2007
Speckled dace	*Rhinichthys osculus*			X	Batty 2010; Andrusak and Andrusak 2011
Largescale sucker	*Catostomus macrocheilus*			X	McCart and Aspinwall 1970; Dauble 1986; Scoppettone 1988
Riffle sculpin	*Cottus gulosus*			X	Baltz et al. 1982; Moyle and Baltz 1985
Reticulate sculpin	*Cottus perplexus*			X	Henning et al. 2007
Smallmouth bass	*Micropterus dolomieu*		X		Edwards et al. 1983; Sowa and Rabeni 1995
Largemouth bass	*Micropterus salmoides*		X		Stuber et al. 1982; García-Berthou 2002
Non-fish Species					
Coastal tailed frog	*Ascaphus truei*			X	Adams and Bury 2002; Hayes et al. 2006

KEY SPECIES (COMMON NAME)	SCIENTIFIC NAME	MODELING ALTERNATIVES			REPRESENTATIVE SOURCES
		EDT (E) SHIRAZ (S)	HSI	CORRELATIVE	
Western toad	*Bufo boreas*		X		Deguise and Richardson 2009; Bartelt et al. 2010
Northern red-legged frog	*Rana aurora*			X	Hayes et al. 2008; Adams et al. 2011
Oregon spotted frog	*Rana pretiosa*			X	Pearl and Hayes 2004; Cushman and Pearl 2007
Dunn's salamander	*Plethodon dunni*			X	Wilkins and Peterson 2000; Kluber et al. 2008
Van Dyke's salamander	*Plethodon vandykei*			X	Wilkins and Peterson 2000; Kluber et al. 2009
North American beaver	*Castor canadensis*			X	Naiman et al. 1988; Burns and McDonnell 1998

Notes:
EDT = Ecosystem Diagnosis & Treatment
HSI = Habitat Suitability Index
SHIRAZ = Salmon Habitat Integrated Resource Analysis

Non-native species are not PHS priorities; however, non-native species may alter habitat suitability for native species or benefit directly or indirectly from habitat changes resulting from restoration efforts in ways that impact either a guild or individual Key Species. For this reason, these were integrated into the ASEP analyses as potential stressors that could modulate the responses of either a guild or individual species resulting from the aforementioned habitat modeling. Non-native species known to occur within the Project area for which effects have been unequivocally demonstrated were addressed (Table 1.2).

Table 1.2
List of Non-native Species Evaluated in the Aquatic Species Enhancement Plan

SPECIES (COMMON NAME)	SCIENTIFIC NAME	DATA RICHNESS	AFFECTED NATIVE SPECIES	SOURCES
Fish Species				
Bluegill	*Lepomis macrochirus*	M	Northern red-legged frog	Adams et al. 2003
Smallmouth bass	*Micropterus dolomieu*	M	Northern red-legged frog	Kiesecker and Blaustein 1998
Largemouth bass	*Micropterus salmoides*	M	Olympic mudminnow, Western pond turtle	Beecher and Fernau 1982; Henning et al. 2007; Holland 1994
Amphibians				
American bullfrog	*Lithobates catesbeianus*	M	Northern red-legged frog, Western pond turtle	Holland 1994; Kiesecker and Blaustein 1997, 1998; Kiesecker et al. 2001; Adams et al. 2003; Adams and Pearl 2007
Plants				
Reed canarygrass	*Phalaris arundinacea*	M	Oregon spotted frog	Kapust et al. 2012

2 Current and Historical Population Structure of Key Aquatic Populations in the Chehalis Basin

2.1 Salmonids

2.1.1 POPULATION STRUCTURE

WDFW has delineated populations of salmon and steelhead based on life history (Appendix B), behavior, and distribution. These populations are listed in the WDFW Salmon Stock Inventory (SaSI) database. The SaSI population delineations and descriptions that have been used in ASEP analyses are provided in Table 2.1. WDFW defines three broad population groups in the basin for coho salmon, fall-run Chinook salmon, spring-run Chinook salmon, and winter-run steelhead: Wynoochee River, Satsop River, and Chehalis River populations. A separate Skookumchuck-Newaukum winter-run steelhead population is also recognized by WDFW. In other ASEP analyses, salmon and steelhead populations in the basin have been further separated into ten sub-populations for each species based on the major sub-watershed classifications of the basin.

Table 2.1
Description of WDFW-Designated Salmon and Steelhead Populations Within the Chehalis basin

STOCK NAME	STOCK ORIGIN	SPAWNING DISTRIBUTION
Chehalis spring-run Chinook	This is a native stock with wild production. Cowlitz River (lower Columbia River Basin) hatchery-origin spring-run Chinook were released into the Wynoochee River in the mid-1970s. Any significant hybridization with existing native stock is unlikely but also undocumented.	Most spawning takes place in the Skookumchuck, Newaukum, South Fork Chehalis, and the mainstem Chehalis rivers (RM 33.3 to 67.0 and RM 81.3 to 113.4 [RKm 53.6 to 107.8 and RKm 130.8 to 182.5]). Some spawning occurs in the Black River and in Elk and Stillman Creeks.
Chehalis fall-run Chinook	This is a native stock with wild production. Although various non-native hatchery fall-run Chinook stocks were introduced into the Chehalis Basin from the early 1950s through the mid-1970s, information regarding these releases is poor. Potential for hybridization between native and non-native stock did exist.	Spawning takes place throughout the Chehalis Basin upstream from the Satsop River. Major spawning areas include the mainstem Chehalis River (RM 28 to 67 and RM 88 to 108 [RKm 45.1 to 107.8 and RKm 141.6 to 173.8]), Black, Newaukum, and Skookumchuck rivers as well as Cloquallum and Porter creeks. Spawning also takes place in Cedar Creek, Stillman Creek, and the South Fork Chehalis River.

STOCK NAME	STOCK ORIGIN	SPAWNING DISTRIBUTION
Satsop fall-run Chinook	This is a native stock with composite production. Extensive releases of non-native fall hatchery Chinook including Humptulips, Willapa Bay, Puget Sound, Columbia River and Oregon coastal stocks, into the Satsop Basin have occurred since 1952, but genetic evidence from the East Fork Satsop River stock indicates a more native profile. No lingering evidence of Puget Sound Chinook genetic contribution in the East Fork Satsop River stock sampled exists. Oregon and Columbia River stock releases were minor, and no genetic evidence of their contribution has been found. Hybridization with the native stock appears insignificant.	Most spawning takes place in the mainstem Satsop River, Canyon River, and the east and west forks of the Satsop River. Spawning also occurs in Bingham, Decker, and Black creeks, as well as other unnamed tributaries.
Wynoochee fall-run Chinook	This is a native stock with wild production. Three releases of non-native hatchery fall-run Chinook have occurred into the Wynoochee Basin. Numbers of fish released were small. Potential for hybridization between introduced and native Chinook existed but was not great.	Most spawning takes place in the mainstem Wynoochee River upstream from RM 10.5 (RKm 3.2) and in Carter, Schafer, and Helm creeks. Small numbers of spawners are seen in Big and Anderson creeks.
Chehalis winter-run steelhead	This is a native stock with wild production.	Spawning takes place in more than 70 locations scattered throughout the Chehalis Basin. Most spawning takes place in the mainstem Chehalis, East and West Fork Chehalis rivers and in tributaries such as Cloquallum, Porter, Rock, Crim, Cinnabar, Hanlan, and Stillman Creeks.
Satsop winter-run steelhead	This is a native stock with wild production.	Most spawning takes place in the mainstem Satsop, West Fork Satsop, Middle Fork Satsop, East Fork Satsop and Canyon rivers, as well as Decker and Bingham creeks. Limited spawning also occurs in Dry Run, Phillips, Black, and Rabbit Creeks.
Skookumchuck-Newaukum winter-run steelhead	This is a native stock with composite production. Hybridization with hatchery adults originating from native Skookumchuck River fish has likely been occurring since 1976 due to similar timing of spawning in native and hatchery stocks in both rivers.	Most spawning takes place in the Skookumchuck, Newaukum, North, Middle and South Forks Newaukum rivers. Spawning also takes place in tributaries such as North Hanaford, Thompson, Lucas, Bernier, Mitchell, and Kearney Creeks.
Wynoochee winter-run steelhead	This is a mixed stock with composite production. This stock has been supplemented with hatchery smolts including Chambers Creek winter-run steelhead. Substantial interbreeding between hatchery and wild fish is thought to have occurred since the early 1980s.	Most spawning takes place in the mainstem Wynoochee River, upstream from and downstream from Wynoochee Lake and in Shafer and Big creeks. Spawning also occurs in tributaries such as Bitter, Helm, Carter, Anderson, and Neil Creeks.

STOCK NAME	STOCK ORIGIN	SPAWNING DISTRIBUTION
Chehalis coho salmon	This is a mixed stock with composite production. Releases of hatchery-reared coho yearlings were continuous from 1950 to 1970. In the late 1970s and through the 1980s, a large-scale fingerling release program was carried out utilizing stocks from Soos Creek, Samish, Dungeness, Satsop, Minter Creek, Sol Duc and Humptulips hatcheries. As a result of the historical movement of stocks and the size and frequency of hatchery releases, this stock is no longer considered to be native.	Most spawning takes place in over 195 mainstem rivers and tributaries scattered throughout the Chehalis Basin. Spawning takes place in accessible tributaries such as Delezene, Cloquallum, Mox-Chehalis, Mima, Waddell, Scatter, Hanaford, Lucas, Kearney, Stillman, South Fork Lincoln, Smith, and Swem Creeks. Spawning also occurs in the upper mainstem and the east fork of the Chehalis River, Skookumchuck River, and Newaukum River.
Satsop coho salmon	This is a mixed stock with composite production. Releases of hatchery-reared coho yearlings extend back to the 1930s and 1940s. In the late 1970s and through the 1980s, a large-scale fingerling release program was carried out. Stocks origins for these releases include Soos Creek, Samish, Dungeness, Minter Creek, Sol Duc, and Satsop hatcheries. As a result of the historical movement of stocks and the size and frequency of hatchery releases, this stock is no longer considered to be native.	Most spawning takes place in tributaries such as Still, Canyon, Smith, Rabbit, Decker, Dry Run, Bingham, Outlet, and Stillwater Creeks. Spawning also occurs in the mainstem and east and west forks of the Satsop River.
Wynoochee coho salmon	This is a mixed stock with composite production. Releases of hatchery-reared coho yearlings were continuous in the 1950s. In the late 1970s to 1980s a large-scale fingerling program was carried out utilizing stocks from Soos Creek, Samish, Dungeness, Satsop, Minter Creek and Sol Duc and Humptulips hatcheries. As a result of the historical movement of stocks and the size and frequency of hatchery releases, this stock is no longer considered to be native.	Most spawning takes place in tributaries such as Black, Bitter, Helm, Carter, Schafer Anderson and Big Creeks. Some spawning also occurs in the upper mainstem and west branch of the Wynoochee River.
Chehalis fall-run chum salmon	This is a native stock with wild production. Numerous releases of non-native chum, mostly from Willapa Bay and Hood Canal, have been made primarily into the Satsop River. These introductions were generally unsuccessful, and it is unlikely that significant impact to the genetic makeup of the native stock has occurred.	Most spawning takes place in the mainstem Hoquiam, Wishkah, Wynoochee, Satsop and Black Rivers. Fewer spawners are observed in Cloquallum Creek and the lower mainstem Chehalis River.

2.1.2 INTRINSIC CONDITION OF CHEHALIS BASIN SALMONID HABITAT

Prior to European settlement, the basin produced large numbers of salmon and Other Fish Species that supported indigenous peoples. Later, with European settlement, these fish species supported settlers and a thriving commercial and sport fishery in Grays Harbor and elsewhere. Fish populations and fisheries declined throughout the 20th century coincident with environmental changes associated with logging, agriculture, harvest, and urbanization.

Numeric records of pre- or early settlement salmonid population abundance in the basin are lacking. However, it is possible to get an idea of the pre-European settlement potential of the basin using the EDT model. EDT estimates the potential of habitat to support salmonid populations using the parameters of the Beverton-Holt production function: 1) *Productivity*: the measure of density independent survival measured as the adult returns per spawner—a reflection of habitat quality and 2) *Capacity*: the theoretical maximum number of adult fish that can be produced by the quantity and quality of available habitat—a measure of habitat quantity. Using these habitat-based parameters, the model also calculates *Equilibrium Abundance*, which is the density-dependent abundance at the point where the population is replacing itself and reflects both habitat quality and quantity.

The estimation of the intrinsic performance of salmonids using EDT starts from the current potential of the habitat. The intrinsic condition of the Chehalis watershed is then modeled by removing anthropogenic constraints from the current condition, such as obstructions, decreased riparian conditions, increased temperature, and so on. The EDT model estimates of the intrinsic potential of the system incorporate the inherent size, topography, and climate of the basin. This intrinsic habitat condition is used as a basis in EDT to diagnose current habitat conditions discussed in Section 4.

The estimate of intrinsic potential provided here should be regarded as a minimum estimate of the pre-settlement condition. No attempt was made to create a detailed historical account of the Chehalis habitat condition. Rather, the current depiction of the system was adjusted to remove known anthropogenic changes and habitat constraints. The estimates of intrinsic habitat potential only address changes in the Chehalis watershed upstream from the Wynoochee River; the current condition of Gray's Harbor is assumed in both the Current and Intrinsic EDT model scenarios.

The estimated Viable Salmonid Population (VSP) performance of basin salmonids in the intrinsic and current condition of the habitat based on the EDT model is provided in Table 2.2. The results in Table 2.2 for intrinsic potential only account for habitat change in the Chehalis River starting at the confluence with the Satsop River. Habitat conditions downstream from the Satsop River, in Grays Harbor and the ocean, reflect current conditions. Habitat Impairment is reduction in habitat potential between the Intrinsic and the Current habitat potential and is an indication of the amount of change in abundance that can be ascribed to modification of habitat conditions by human activities. Clearly, the Intrinsic habitat potential greatly exceeded the current habitat potential, indicating that anthropogenic actions have exerted a large constraint on salmonid habitat potential in the basin. Habitat in the basin is the most impaired for spring-run Chinook salmon and least impaired for fall-run Chinook salmon and winter-run steelhead. The detailed basis for these differences is discussed in Section 4.

Table 2.2
Estimated Habitat Potential of the Chehalis Basin Under Current and Intrinsic Conditions Using the EDT Model

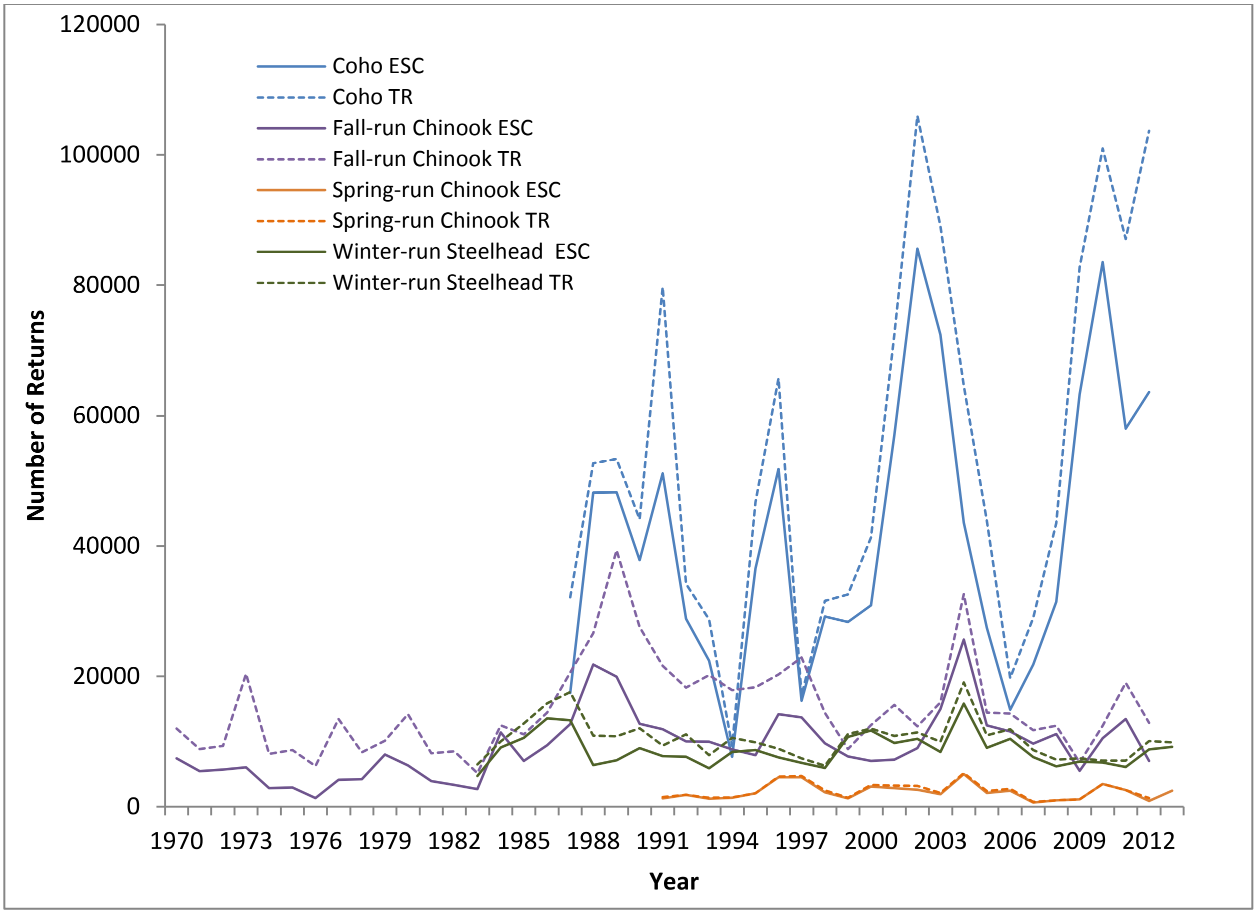
SPECIES	CURRENT	INTRINSIC	HABITAT IMPAIRMENT
Coho salmon	29,322	96,768	70%
Fall-run Chinook salmon	24,317	45,662	47%
Spring-run Chinook salmon	2,538	16,153	84%
Winter-run steelhead	4,114	8,616	52%

2.1.3 RECENT TRENDS IN ABUNDANCE OF CHEHALIS BASIN SALMONIDS

WDFW estimates escapement and total abundance of basin salmonids based on expansion of escapement and harvest surveys. This information is used to characterize the recent trend in abundance of salmonids in the basin. This discussion will be followed by a characterization of the current condition of salmonids using the VSP metrics of abundance, productivity, biological diversity, and population structure.

Summary statistics presented in this section focus on the basin-wide, total run size (pre-harvest) of wild recruits (potential spawners in a particular year) for each species or run based on data for all contributing stocks supplied by WDFW, as well as WDFW estimates of spawning escapement. Run reconstructions used to calculate these metrics include return data from the Hoquiam and Wishkah Rivers for coho salmon, fall-run Chinook, and winter-run steelhead. Escapement estimates include wild spawners of both hatchery and natural origin. Total run size is a useful metric for depicting general abundance trends because it includes estimated harvest of species whereas escapement focuses on contributions to individual populations. It is based on the sum of annual escapement and harvest estimates. Escapement estimates are based on annual redd counts and numerical and geographic expansions to identify spawner abundance. This approach relies on the visual observation and counts of redds in specified index areas that are used to extrapolate abundance to non-surveyed areas based upon weighting for distance and an estimate of the number spawners per redd. WDFW collects harvest data from treaty and non-treaty commercial and sport-fishers to estimate the number of fish harvested. All estimates of escapement and harvest rely on assumptions about the methodology and populations from which estimates are derived. When few assumptions are violated, escapement and harvest data represent good estimates of the total return. Conversely, when assumptions are not met either systematically or on an annual basis, the quality of an estimate may be lower. In the case of winter-run steelhead and spring-run Chinook salmon, WDFW staff indicated that harvest reporting might be insufficient to fully characterize the total run (Phillips, pers. comm. 2014). The annual total run and escapement for each species are summarized in Figure 2.1.

Figure 2.1
Recent Spawning Escapement and Total Run Size for Chehalis River Coho Salmon, Fall-run Chinook Salmon, Spring-run Chinook Salmon, and Winter-run Steelhead



Notes:
ESC = Spawning Escapement
TR = Total Run
The date ranges correspond to available data for each species.

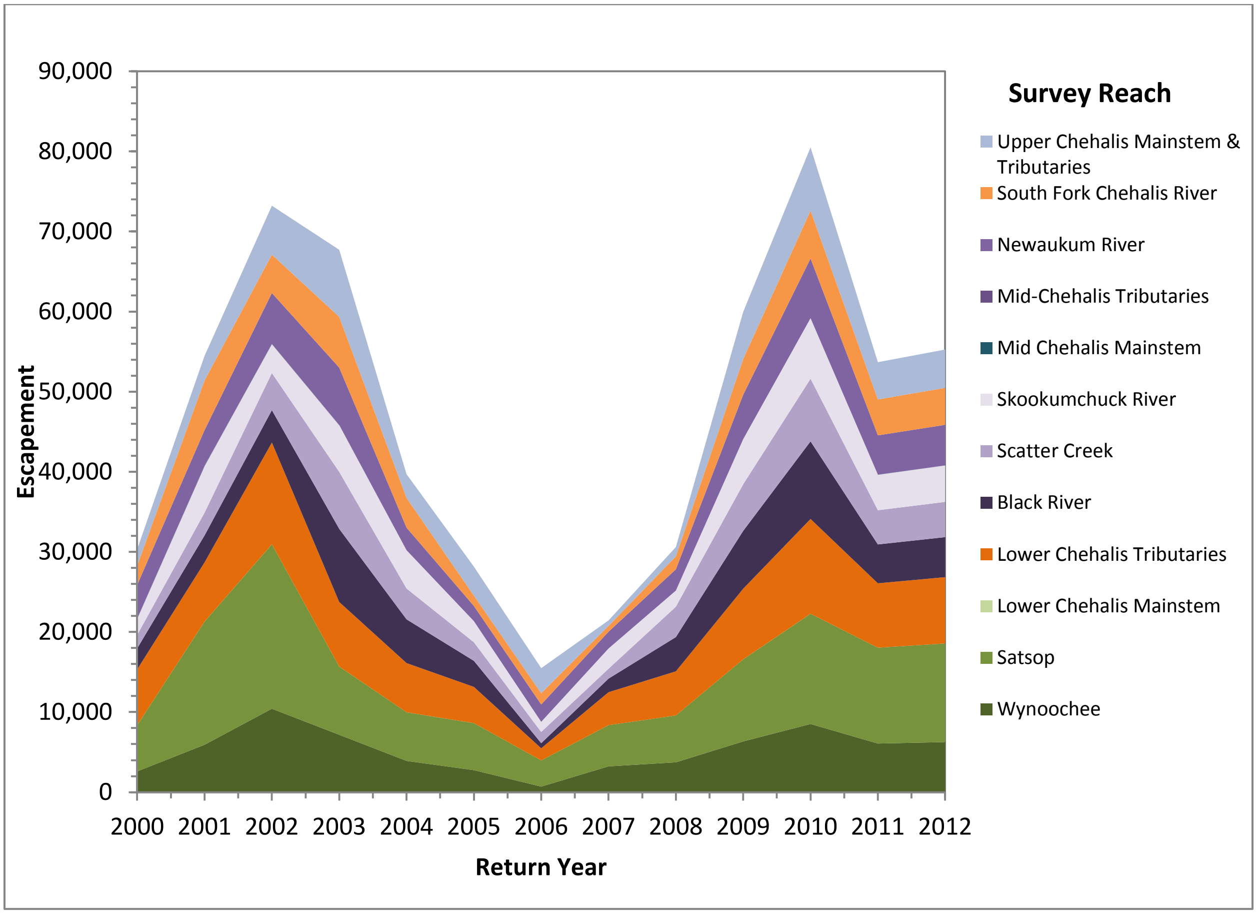
2.1.3.1 COHO SALMON

Chehalis coho salmon are found throughout the basin. Coho salmon typically emigrate to the ocean as yearling smolts and return to spawn at 3 years total age. From 1987 to 2013, the total basin-wide abundance of coho salmon (before harvest) averaged 60,000 and ranged from 111,497 in 1991 to 12,407 in 1994. Spawning Escapement of coho salmon averaged 42,594 fish. The maximum escapement over the period was 85,670 in 2002 and the lowest in 1994 when only 7,691 coho salmon returned to spawn in the basin (Figure 2.1). Basin-wide abundance and escapement estimates include Wishkah and Hoquiam River contributions.

For years in which tributary-specific escapement data were available (2000 to 2012), the highest coho salmon escapements upstream of the Wishkah River occurred in the Wynoochee River, Satsop River, and lower Chehalis tributaries (Figure 2.2).

The low abundance of coho salmon in 2006 was common to all Washington coastal coho populations and reflected low ocean survival. Coho salmon are harvested heavily in the commercial and sport fisheries accounting for the difference between total escapement and total run size. Hatchery production has contributed significantly to coho salmon returns in the basin (see Section 2.1.5).

Figure 2.2
Recent Tributary Spawning Escapement for Chehalis River Coho Salmon in Reaches Upstream of Wishkah River



Note:
Escapement estimates include wild spawning fish of natural and hatchery origin.

2.1.3.2 FALL-RUN CHINOOK SALMON

Chehalis fall-run Chinook salmon generally spawn in larger stream reaches and have a sub-yearling freshwater life history and emigrate in their first spring and typically return to spawn at 4 to 6 years total age. The majority of returning spawners are age 5 (Table 2.3).

Table 2.3
Age Composition of Returning Fall-run Chinook Salmon in the Chehalis River Basin

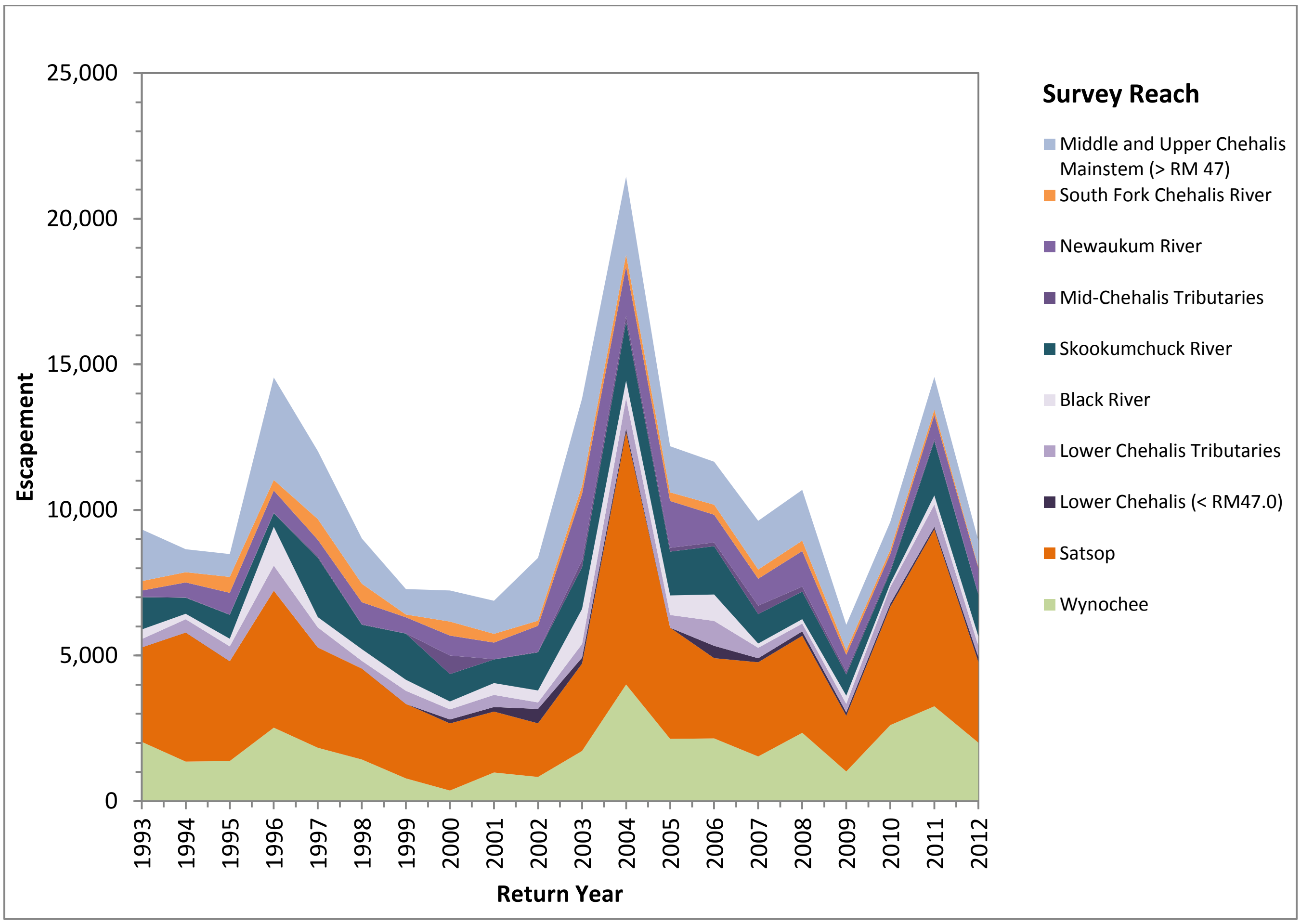
PERIOD	AGE COMPOSITION (%)				
	2	3	4	5	6
All Years (1970 to 2013)	1.5	13.7	32.6	45.4	6.5

From 1970 to 2013, total run size of fall-run Chinook salmon from the basin averaged 15,894 and ranged from a high of 39,698 in 1989 to a low run size of 5,124 in 1983 (Figure 2.1). Spawning Escapement over the period averaged 9,620 with a low escapement of 1,344 in 1976 and a maximum of 25,523 in 2004. Basin-wide abundance and escapement estimates include Wishkah and Hoquiam River contributions.

For years in which tributary-specific escapement data were available (1993 to 2012), the highest escapements upstream of the Wishkah River occurred in the Satsop and Wynoochee sub-basins (Figure 2.3). Annual escapement is highly variable, and no clear trend in production of fall-run Chinook salmon over the period is evident.

Fall-run Chinook salmon are heavily harvested in ocean fisheries, and for this reason, total abundance is appreciably larger than escapement. Hatchery production contributes to fall-run Chinook salmon returns in the basin (see Section 2.1.5).

Figure 2.3
Recent Tributary Spawning Escapement for Chehalis River Fall-run Chinook in Reaches Upstream of Wishkah River



Note:
Escapement estimates include wild spawning fish of natural and hatchery origin.

2.1.3.3 SPRING-RUN CHINOOK SALMON

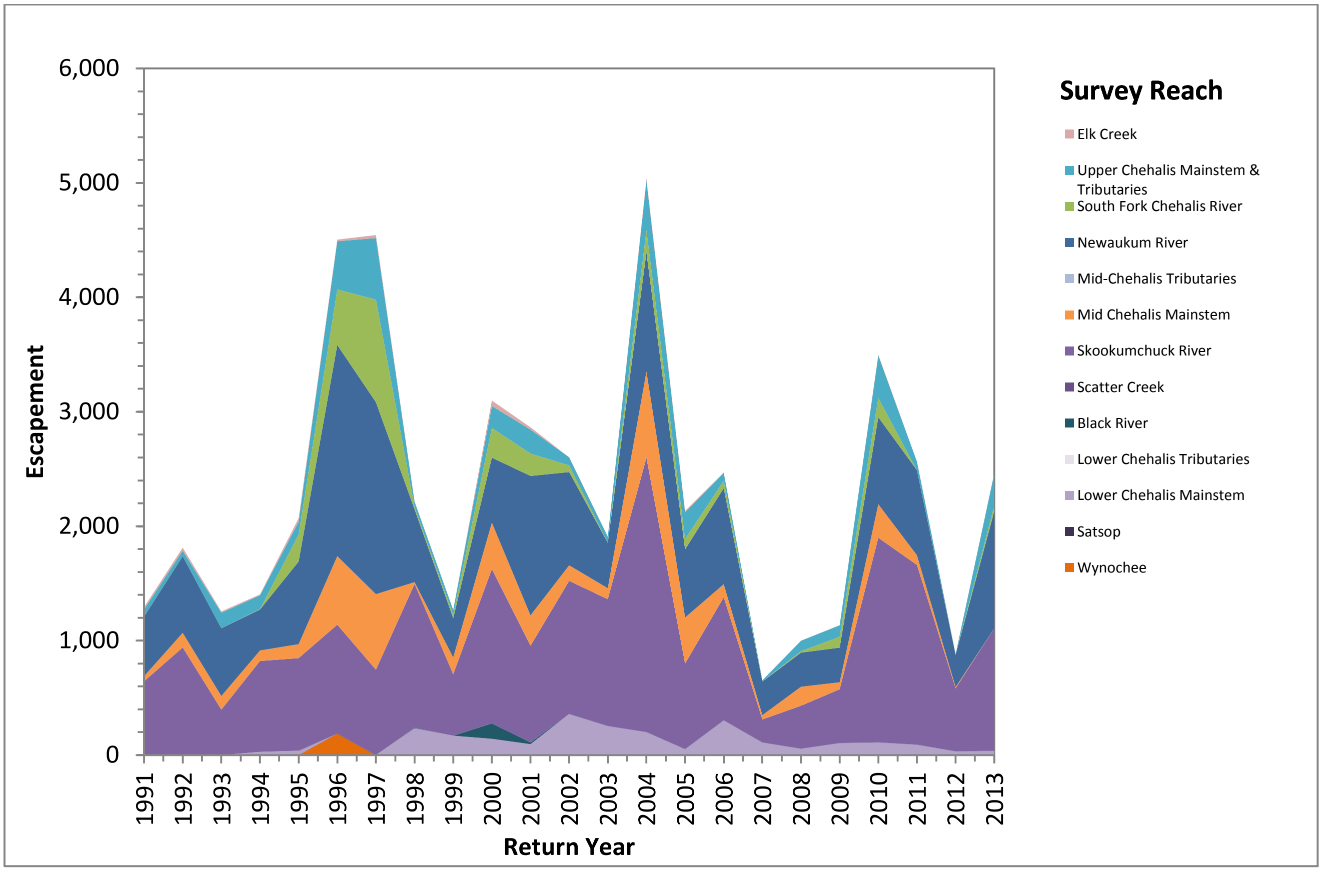
Chehalis spring-run Chinook salmon enter the river in the late winter and spring and then hold in the river during summer to spawn in the early fall, have a sub-yearling freshwater life history, and typically return to spawn at 3 to 6 years of age. The majority of returning spawners are age 4 (Table 2.4).

Table 2.4
Age Composition of Returning Spring-run Chinook Salmon in the Chehalis River Basin, Excluding Jacks

PERIOD	AGE COMPOSITION (%)				
	2	3	4	5	6
All Years (1991 to 2013)	2.1	16.6	57.3	23.7	0.3

From 1991 to 2013, total run size of spring-run Chinook salmon to the basin averaged 2,448 fish. The maximum run size was 5,153 in 2004 while the lowest run size was 724 fish in 2007 (Figure 2.1). The average escapement over the period was 2,282 adults with a range from 652 in 2007 to a high of 5,034 in 2004. Within the basin, the Newaukum and Skookumchuck rivers had the highest annual escapements (Figure 2.4). The observed differences in annual total run size and escapement are assumed to be conservative because of inadequate harvest data. Hatchery production did not contribute substantially to total spring-run Chinook salmon returns during the period. Returns of spring-run Chinook salmon are quite variable over this period and no clear trend in abundance is evident.

Figure 2.4
Recent Tributary Spawning Escapement for Chehalis River Spring-run Chinook



2.1.3.4 WINTER-RUN STEELHEAD

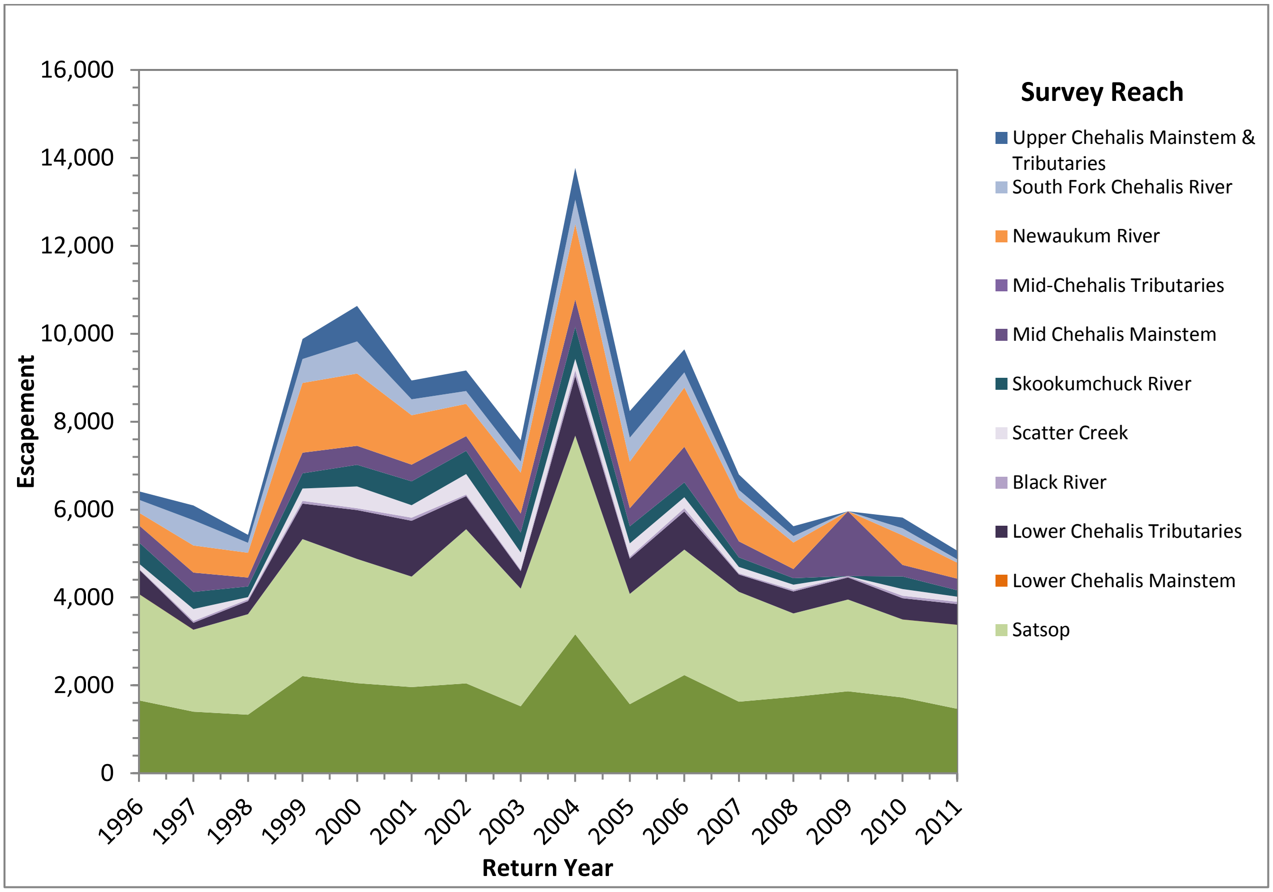
Chehalis winter-run steelhead typically emigrate after spending 2 to 3 years in the river, and then return to spawn at 3 or 4 years of age (Table 2.5).

Table 2.5
Age Composition of Returning Winter-run Steelhead in the Chehalis River Basin

PERIOD	AGE COMPOSITION (%)				
	2	3	4	5	6
All Years (1999 to 2013)	0.8	47.2	45.3	6.4	0.3

Total run size of winter-run steelhead from the basin averaged 10,417 over the period from 1983 and 2013 with a maximum run size of 19,000 in 2004 while the smallest run size was 6,298 in 1998 (Figure 2.1). Spawning Escapement of steelhead over that period averaged 8,731 and ranged from a low of 4,710 in 1983 to a maximum of 15,825 in 2004 (Figure 2.1). Basin-wide total run and escapement estimates include Wishkah and Hoquiam River contributions. The observed differences in annual total run size and escapement are assumed to be conservative because of inadequate harvest data. For years in which tributary-specific escapement data were available (1996 to 2011), the highest escapements upstream of the Wishkah River occurred in the Satsop and Wynoochee sub-basins (Figure 2.5). Hatchery production has contributed significantly to winter-run steelhead returns in the basin (see Section 2.1.5). Sport fishing is the only fishery that affects winter-run steelhead so escapement is near the total run size. No trend in escapement over the period is evident.

Figure 2.5
Recent Tributary Spawning Escapement for Chehalis River Winter-run Steelhead in Reaches Upstream of Wishkah River



Note:
Escapement estimates include wild spawning fish of natural and hatchery origin.

2.1.4 FISHERIES MANAGEMENT

WDFW manages Grays Harbor fisheries to meet the specific conservation and harvest objectives. For natural spawning Chehalis River species, the goal is to meet or exceed a spawner escapement goal of 1,400 spring-run Chinook salmon; 12,364 fall-run Chinook salmon; 8,600 winter-run steelhead; and 28,506 coho salmon. The stock specific objectives for each species are summarized in Table 2.6.

Table 2.6
Summary of Escapement Goals for Focal Salmon and Steelhead Stocks in the Chehalis River Upstream of the Wishkah River

SPECIES	STOCK	ESCAPEMENT GOAL
Spring-run Chinook salmon	Chehalis spring-run Chinook	1,400
Fall-run Chinook salmon	Chehalis fall-run Chinook	5,209
	Satsop fall-run Chinook	3,423
	Wynoochee fall-run Chinook	1,951
Winter-run steelhead	Chehalis winter-run steelhead	2,700
	Satsop winter-run steelhead	2,800
	Skookumchuck-Newaukum winter-run steelhead	1,429
	Wynoochee winter-run steelhead	1,260
Coho salmon	Chehalis coho salmon	8,134
	Satsop coho salmon	8,628
	Wynoochee coho salmon	7,168
Chum salmon	Gray's Harbor chum salmon	21,000

Note:
Source: 2003 to 2013 Region 6 forecast-escapement file supplied by WDFW.

2.1.5 HATCHERY MANAGEMENT

Most of the hatchery production in the Chehalis River occurs at tributary locations in the lower portion of the basin. In particular, the Satsop River, Wynoochee River, and Wishkah River are used as release locations for coho salmon, fall-run Chinook salmon, and winter-run steelhead. Higher in the basin, the Skookumchuck River is a release site for coho salmon and winter-run steelhead. Hatchery releases anticipated in 2014 are summarized in Table 2.7. Hatchery production levels may fluctuate over time depending on changes in program goals and operational constraints.

Table 2.7
Summary of Hatchery Facilities and Production Goals in WRIAs 22 and 23 for Spring-run Chinook Salmon, Fall-run Chinook Salmon, Steelhead, and Coho Salmon

HATCHERY	PRODUCTION GOALS BY SPECIES
Bingham Creek Hatchery	300,000 coho salmon for release in Satsop River 25,000 coho salmon for release in Quigg Lake 28,500 coho salmon for release among Still Creek, Sylvia Creek, Cook Creek 55,000 winter steelhead for release in Satsop River 200,000 fall-run Chinook for release in Satsop River 200,000 chum salmon for release in Satsop River
Humptulips Hatchery	500,000 coho salmon for release in Stevens Creek 500,000 fall-run Chinook for release in Stevens Creek 30,000 summer-run steelhead for release in Stevens Creek 125,000 winter-run steelhead for release in Stevens Creek

HATCHERY	PRODUCTION GOALS BY SPECIES
Lake Aberdeen Hatchery	30,000 coho salmon for release in Van Winkle Creek, 50,000 fall-run Chinook release in Van Winkle Creek, 170,000 winter-run steelhead for release in Wynoochee River 60,000 summer-run steelhead for release in Wynoochee River
Mayr Brothers Hatchery	300,000 coho salmon for release in the Wishkah River 200,000 fall-run chinook salmon for release in Wishkah River 100,000 Chum salmon for release in Wishkah River
Satsop Springs Hatchery	300,000 fall-run Chinook for release in Satsop River 450,000 coho salmon for release in Satsop River 200,000 chum salmon for release in Wishkah River
Skookumchuck Dam	75,000 winter-run steelhead for release in Skookumchuck River
Skookumchuck Hatchery	100,000 coho salmon for release in Skookumchuck River
Westport Net Pens	100,000 coho salmon for release in Westport boat basin

Notes:
Some of the hatchery facilities and release locations listed here are outside of the basin but represent potential sources of hatchery fish that may enter the basin.
Source: WDFW 2013.

2.1.6 VIABLE SALMON POPULATION CHARACTERISTICS

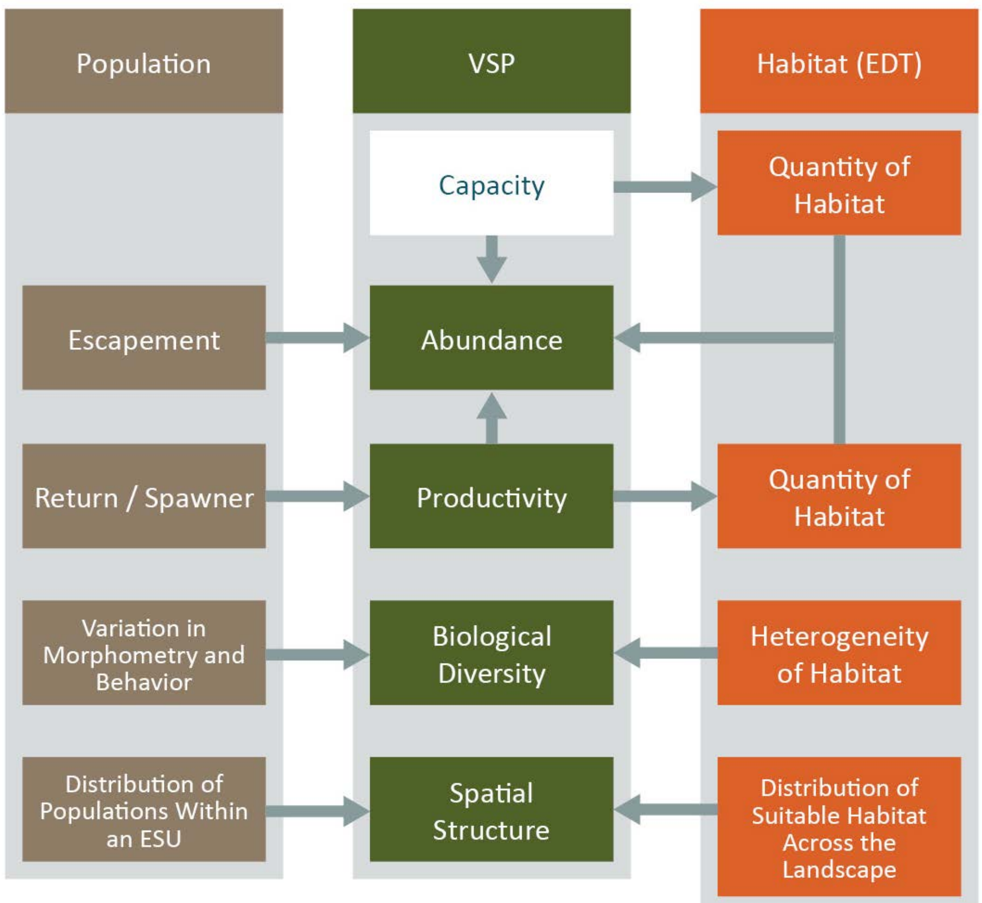
The VSP concept was introduced by the National Marine Fisheries Service (NMFS) as a means of evaluating the status of salmonids under ESA (McElhany et al. 2000). The VSP parameters reflect core population attributes that contribute to the viability of a population. To be viable, a salmonid population must have sufficient abundance to provide genetic diversity and population fecundity. They need sufficient survival (productivity or density independent survival) to withstand mortality over the life history and environmental fluctuations. A viable population must have biological diversity (e.g., life history diversity) to cope with environmental variation over time and space. Finally, a viable population needs a diverse spatial structure so that population resources are spread out over space to avoid extirpation through catastrophic events.

Within a broad conservation context, these parameters have utility because they are reasonable predictors of extinction risk, reflect important processes to populations, and are measurable (e.g., Ratner et al. 1997; Legault 2005; Thorson et al. 2013). While the same VSP parameters have been applied to numerous conservation and recovery situations, the analysis and derivation of parameter values has varied considerably among regions. Different regional approaches reflect variation in the life histories of focal species as well as data availability (Busch et al. 2008; Good et al. 2007).

Within the ASEP, the application of the VSP framework for salmonids reflects the importance of abundance, productivity, diversity, and spatial structure to the viability of populations. The VSP framework also provides a common currency for evaluating the sensitivity of populations to the range of the flood control alternatives and proposed enhancement activities.

Two approaches were used to characterize the basin in regard to VSP parameters (Figure 2.6). The first approach characterized salmonids in VSP terms based on WDFW field observations of spawner abundance in index reaches and estimated harvest. Index counts of redds and harvest have been expanded by WDFW to estimate escapement and total run size. The second approach evaluated the VSP parameters from a habitat perspective. For the habitat approach we evaluated the quantity, quality, and diversity of habitats across the basin in terms of the potential to support fish populations measured in the VSP terms. This approach was based on habitat data collected by WDFW and others evaluated using the EDT model. The goal of these analyses was to estimate VSP using both types of available data: fish returns and habitat characteristics. The fish return data reflect the current status of the populations across the watershed (coarse scale) based on spawning indices and analyses of harvest data by WDFW. The EDT used available habitat data to establish a spatial framework to evaluate habitat potential and habitat change. Using the two procedures provided an integrated approach to evaluation of fish populations and habitat (Figure 2.6). Because the two perspectives take fundamentally different approaches to estimating the VSP parameters, there is no expectation that the VSP estimates from each approach should be identical though we would expect them to result in similar conclusions regarding relative abundance and potential population viability. There are many reasons why the approaches will not yield the same number—variable ocean survival conditions, harvest rates, errors in spawner enumeration, habitat data limitations, and model assumptions for example. Integration of the two approaches instead provides a more complete understanding of fish habitat and fish abundance in the basin.

Figure 2.6
Integrated Fish Population and Fish Habitat Approach Used to Evaluate Viable Salmonid Population Parameters for Salmonids in the Chehalis Basin



2.1.7 POPULATION LEVEL VIABLE SALMONID POPULATION ESTIMATES

2.1.7.1 ABUNDANCE

Two metrics provide the coarse scale depiction of abundance: (1) total run size and (2) escapement. As previously discussed, escapement refers to the number of fish that successfully pass through fisheries and are allowed to access spawning areas. Total run size is an estimate of the number of fish that would return to Chehalis River in the absence of harvest and is derived by summing estimates of the number of fish harvested and escapement for a given year (Table 2.8). Both the average (arithmetic mean) and geometric means are reported. The geometric mean is often used to characterize population data sets and explicitly reduces the effects of annual count variability.

Table 2.8
Coarse-scale Summary of Abundance Metrics for Focal Salmonid Species Within the Chehalis River Basin

FOCAL SPECIES	ABUNDANCE
Spring-run Chinook salmon (2004 to 2013 return years)	9-year average total run = 2,267 fish 9-year geometric mean total run = 1,897 fish 10-year average escapement = 2,181 fish 10-year geometric mean escapement = 1,809 fish
Fall-run Chinook salmon (2004 to 2012 return years)	10-year average total run = 15,733 fish 10-year geometric mean total run = 14,774 fish 10-year average escapement = 12,268 fish 10-year geometric mean escapement = 11,524 fish
Coho salmon (2004 to 2013 return years)	10-year average total run = 66,505 fish 10-year geometric mean total run = 60,098 fish 10-year average escapement = 47,967 fish 10-year geometric mean escapement = 42,144 fish
Winter-run steelhead (2004 to 2013 return years)	10-year average total run = 9,963 fish 10-year geometric mean total run = 9,502 fish 10-year average escapement = 8,717 fish 10-year geometric mean escapement = 8,378 fish

Note: At the time this report was written, total run was not available for spring-run Chinook for the 2013 return year therefore, only 9 years of data were used to calculate averages. For coho salmon, fall-run Chinook salmon, and steelhead, estimates of total run and escapement include returns from the Wishkah and Hoquiam Rivers.

2.1.7.2 PRODUCTIVITY

The coarse-scale depiction of productivity is represented by recruits-per-spawner (R/S) calculated from WDFW escapement data. Because of concerns about the quality of harvest data and total run estimates, the productivity analysis evaluated spawner-to-spawner productivity rather than spawner to pre-harvest productivity. This approach provides a simple depiction of how well the spawning populations are replacing themselves after all environmental and harvest effects have been accounted for. The broader question of how production is influenced by the available quantity and quality of freshwater habitats is addressed by EDT. Note that the productivity derived from observations of fish abundance is not directly comparable to habitat derived estimates of productivity from EDT. EDT estimates the density-independent productivity parameter of a

Beverton-Holt production function. Productivity derived from fish observations incorporates density effects and would be expected to be lower than the density-independent productivity derived from EDT.

Coarse-scale productivity was calculated on a post-harvest basis as the ratio of returning spawners (R) produced by their parental spawners (S). To calculate the productivity of a spawning population, both R and S need to be determined. The value of *S* is based on the escapement of the parental population for a given year (i.e., brood year). Simply put, *S* is the number of spawners in a given brood year that will produce recruits/returns. The number of returning adults (R) that are actually produced by (S) is calculated for each brood year using age composition and run size data from subsequent return years. Because we examined the post-harvest productivity of populations, the number of returns was calculated using annual escapements rather than total run sizes. The R/S ratio was then derived from the ratio of *R* (return escapement) to *S* (parental escapement; Table 2.9). Similar to the abundance parameter, both the average (arithmetic mean) and geometric means are reported.

Table 2.9
Coarse-scale Summary of Productivity Metrics for Focal Salmonid Species Within the Chehalis River Basin

FOCAL SPECIES	PRODUCTIVITY
Spring-run Chinook salmon (1998-2007)	10-year average post-harvest R/S = 1.5 10-year post-harvest geometric mean R/S = 0.9
Fall-run Chinook salmon (1998-2007 brood years)	10-year average post-harvest R/S = 1.3 10-year post-harvest geometric mean R/S = 1.1
Coho salmon (2001-2010 brood years)	10-year average post-harvest R/S = 1.5 10-year post-harvest geometric mean R/S = 1.0
Winter-run steelhead (1999-2007 brood years)	9-year average post-harvest R/S = 0.9 9-year post-harvest geometric mean R/S = 0.8

Notes:
R/S = recruits per spawner

2.1.7.3 SPATIAL STRUCTURE

The coarse-scale depiction of spatial structure is represented by the average proportion of spawners among selected strata within the basin since 2003. The spawning strata used in the coarse scale VSP review are the same as those used for EDT (Table 2.10).

Table 2.10
Coarse-scale Summary of Spatial Structure Metrics for Focal Salmonid Species Within the Chehalis River Basin Upstream of the Wishkah River

SPATIAL STRUCTURE	SPRING-RUN CHINOOK	FALL-RUN CHINOOK	STEELHEAD	COHO SALMON
LOCATION	2003-2013	2003-2008	2003-2011	2003-2012
Wynoochee River	--	19.2%	23.7%	10.8%
Satsop River	--	33.4%	32.8%	18.3%
Lower Chehalis Mainstem	5.0%	1.3%	--	--
Lower Chehalis Tributaries	--	4.6%	8.2%	14.8%

SPATIAL STRUCTURE	SPRING-RUN CHINOOK	FALL-RUN CHINOOK	STEELHEAD	COHO SALMON
LOCATION	**2003-2013**	**2003-2008**	**2003-2011**	**2003-2012**
Black River	--	4.0%	0.6%	11.3%
Scatter Creek	--	--	3.1%	9.3%
Skookumchuck River	46.9%	11.0%	4.5%	9.1%
Mid-Chehalis Mainstem	8.8%	13.5%	6.5%	--
Mid-Chehalis Tributaries	--	1.2%	--	--
Newaukum River	28.3%	9.7%	11.7%	9.2%
South Fork Chehalis River	3.1%	2.1%	3.6%	7.6%
Upper Chehalis Mainstem and Tributaries	7.6%	--	5.3%	9.5%
Elk Creek	0.2%	--	--	--

2.1.7.4 DIVERSITY

The coarse-scale depiction of population diversity is represented by the juvenile and adult life histories of basin salmonids. These include age at juvenile outmigration and percent return by total-age (Table 2.11). This measure of diversity differs from the diversity parameter derived in EDT that reflects the heterogeneity of habitat suitability and potential life history diversity.

Table 2.11
Coarse-scale Summary of Life History Diversity Metrics for Focal Salmonid Species Within the Chehalis River Basin

DIVERSITY	SPRING-RUN CHINOOK	FALL-RUN CHINOOK	STEELHEAD	COHO
LIFE HISTORY STAGE	**2004-2013**	**2004-2013**	**2004-2013**	**ASSUMED**
Juvenile out-migration age 1 or before	100%	100%	1%	0%
Juvenile out-migration age 2	0%	0%	85%	100%
Juvenile out-migration age 3	0%	0%	3%	0%
Juvenile out-migration age 4	0%	0%	0%	0%
Adult return age 2	2.1%	1.4%	1.0%	--
Adult return age 3	20.0%	8.8%	45.5%	100.0%
Adult return age 4	57.3%	37.7%	45.5%	--
Adult return age 5	20.4%	47.4%	6.3%	--
Adult return age 6	0.1%	4.6%	0.4%	--

Note:
1. Coho salmon are assumed to be age 3 at time of return.

2.1.8 UPPER CHEHALIS RIVER SMOLT TRAP DATA

The Chehalis Tribe installed a smolt migrant trap in 2013 and has operated the trap to evaluate the composition, abundance, and timing of juvenile fish migrating downstream near the site of the flood reduction structures. On April 11, 2014, the raw data files were made available and ASEP authors conducted an initial exploration of the data. The data consisted of trap operating times, weather, flow, species, length, weight, and counts of fish collected in the trap at the end of each trapping session. A preliminary analysis of the data was made to characterize the information present in the database, produce simple plots, and suggest potential avenues for future analysis; no statistical analyses of the data were conducted.

The smolt trap was operated intermittently between February 2, 2013, and June 5, 2013, for the 2013 Water Year (WY), and beginning December 3, 2013 for the 2014 WY. The last entry in the provided database for the 2014 WY is for April 9, 2014. The trap was operated approximately 1,274 hours during 121 days of sampling in WY 2013 (43.8% of the total time), and approximately 86 of the 121 days available during WY 2014 (67.8% of the total time).

While multiple species were identified in the trap, the vast majority of fish trapped were juvenile Pacific salmon (*Oncorhynchus spp)*. In the 2013 WY, 273 winter-run steelhead, 137 Chinook salmon, and 100 coho salmon were collected. Large numbers of year-0 winter-run steelhead (380) and coho salmon (649) juveniles were also collected in the late spring of 2013 for which size information was not available. Additionally, 133 fish of Other Fish Species, including lamprey species, were collected.

In the current 2014 WY, 962 winter-run steelhead, 486 Chinook salmon, 36 coho salmon, and 16 Cutthroat trout (*O. clarkii*) were collected. Additionally, 2,911 year-0 Chinook juveniles were collected in the early spring of 2014 for which size information was not available. The remaining catch of Other Fish Species totaled 95 fish.

In general, the average size (fork length in millimeters) of winter-run steelhead and coho salmon juveniles increased with time, but for Chinook salmon in 2014, the average length of fish in March and April was much less than the average size in December through February.

A subset of fish from the three salmon species were marked with dye and released for recapture by the Chehalis Tribe. For the 2013 WY, 83 winter-run steelhead smolts were marked and 13 recaptured (15.7%), and 9 Chinook salmon smolts were marked and 6 recaptured (66.7%). For the 2014 WY, 133 winter-run steelhead smolts were marked and 24 recaptured (18%), 9 Chinook salmon smolts were marked and 4 recaptured (44.4%), and 4 coho salmon smolts were marked and 1 recaptured (25%). For future analyses, the number of fish observed could be adjusted by a mark-recapture estimator such as the Lincoln-Peterson estimator to account for imperfect catchability of fish. However, the reliability of such estimates rests on the validity of the assumptions implied by the estimators used, and careful thought would have to be given to the choice of model for obtaining smolt abundance estimates.

2.1.9 HABITAT-BASED VIABLE SALMONID POPULATION ESTIMATES USING EDT

Habitat-based estimates of VSP parameters were developed using EDT as described in Appendix C. Spatial diversity is assessed as the distribution of sub-populations across the basin. EDT calculates the capacity of the habitat based on the quantity of habitat while productivity (survival without density effects) reflects habitat quality. To be viable, a population must have sufficient abundance to maintain genetic integrity and to withstand environmental fluctuations. Mathematically, productivity must be above 1.0, meaning the population is just replacing itself, to have an equilibrium of abundance. However, to be viable, a population needs its productivity to be in excess of 1.0 to withstand environmental fluctuations and harvest. Abundance is calculated from capacity and productivity as the equilibrium abundance of a Beverton-Holt stock recruitment relationship. EDT evaluates habitat across thousands of life history trajectories that start and end at specific spawning locations. The spawning locations for each species in each watershed were provided by WDFW based on gradient and confinement criteria (Phillips, pers. comm. 2014). The productivity and capacity of the habitat varies greatly between trajectories reflecting the heterogeneity of the environment and variation within the life history strategy; some trajectories fail, meaning they have a productivity of less than 1.0. In EDT, diversity is assessed as the number of successful trajectories (productivity greater than 1.0) in the current relative to the number of successful trajectories in an intrinsic reference condition.

Habitat-based estimates of VSP parameters at the basin scale are provided in Table 2.12. Clearly, the basin provides the greatest quantity and quality of habitat for coho salmon and fall-run Chinook salmon. Spring-run Chinook salmon habitat potential is considerably less while the low diversity indicates a constriction in habitat breadth relative to the historic condition. Winter-run steelhead capacity is relatively low but the high productivity and diversity indicates that habitat in the basin is generally good for winter-run steelhead.

Table 2.12
Viable Salmonid Population Parameters Computed from Habitat Attributes Without Harvest

SPECIES	PRODUCTIVITY (RETURNS/SPAWNER)	CAPACITY (FISH)	EQUILIBRIUM ABUNDANCE (FISH)	DIVERSITY (PROPORTION OF SUCCESSFUL LIFE HISTORIES)
Coho salmon	6.0	36,321	29,322	73.6%
Fall-run Chinook salmon	5.4	31,277	24,317	90.1%
Spring-run Chinook salmon	2.7	5,443	2,538	13.8%
Winter-run steelhead	10.0	4,819	4,114	67.1%

Habitat was assessed in EDT for 14 geographic sub-regions or sub-populations. Sub-population definitions were based on WDFW observations of species presence; not all species were present in all 14 sub-regions. Fall-run Chinook salmon and coho salmon had the widest distribution within the basin while spring-run Chinook salmon the most restricted distribution. Spatial structure of habitat potential for each species across the basin is shown in Tables 2.11 through 2.14 and Figures 2.7 through 2.10. Habitat potential is dominated by the large size of the Wynoochee and Satsop watersheds. For the most part, the distribution of habitat-derived VSP parameters tracked reasonably well with the fish observation-derived estimates. An exception is the lower Chehalis mainstem populations. Based on habitat, this area has large potential capacity (due to its large expanse) but low productivity. This appears to overestimate potential fish abundance relative to WDFW observations of current fish spawning distribution.

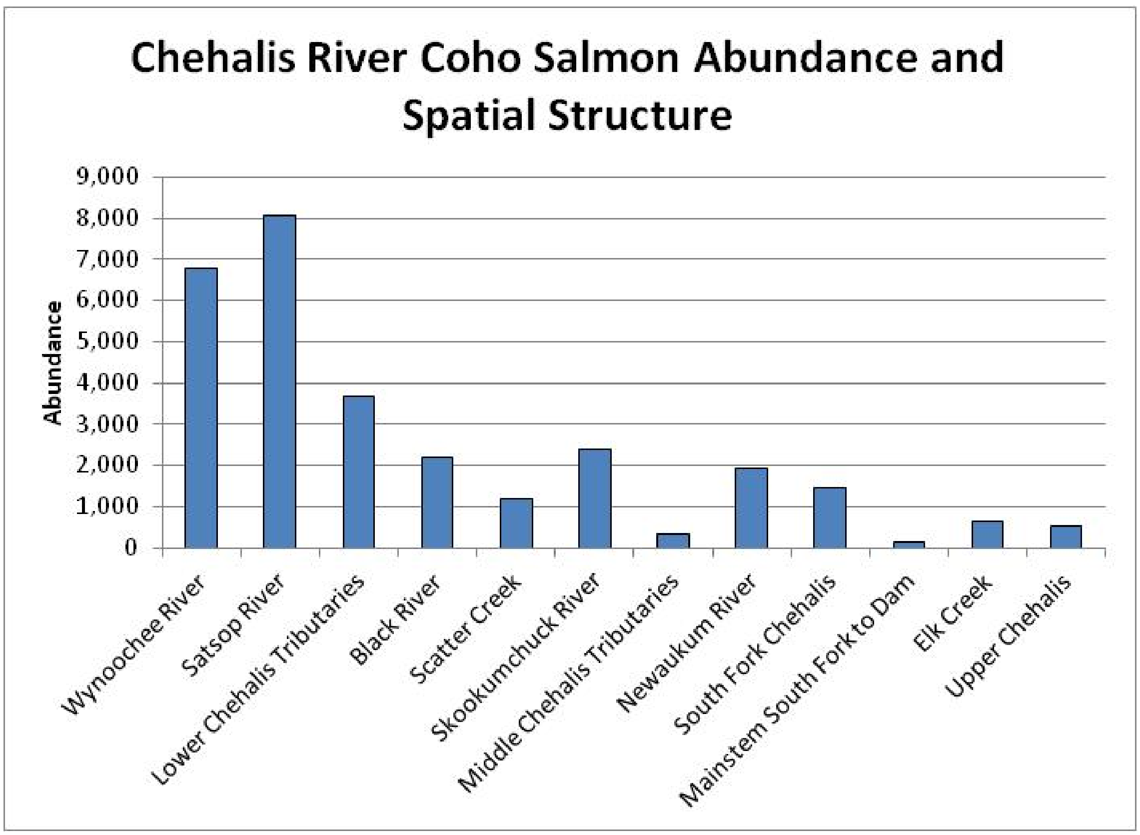
2.1.9.1 COHO SALMON

VSP indices of habitat condition for coho salmon for each sub-region are shown in Table 2.13. Coho salmon habitat is distributed throughout the basin but was skewed toward the Wynoochee and Satsop sub-basins due to their large size relative to other sub-basins. Productivity was low in mainstem reaches but higher in most of the tributaries. Similarly, diversity is highly restricted in the mainstem reaches, indicating that the breadth of suitable conditions for coho is severely constricted.

Table 2.13
Spatial Structure of Chehalis Basin Coho Salmon

SUB-BASIN	PRODUCTIVITY	CAPACITY	EQUILIBRIUM ABUNDANCE	DIVERSITY
Wynoochee River	5.7	8,213	6,773	90.7%
Satsop River	6.8	9,448	8,049	93.5%
Lower Chehalis Tributaries	5.8	4,431	3,663	77.5%
Black River	5.9	2,650	2,198	97.2%
Scatter Creek	6.8	1,379	1,176	92.4%
Skookumchuck River	5.5	2,925	2,390	66.2%
Middle Chehalis Tributaries	3.4	470	333	22.3%
Newaukum River	5.4	2,377	1,934	53.4%
South Fork Chehalis	4.5	1,879	1,463	82.2%
Mainstem South Fork to Dam	1.8	346	154	9.6%
Elk Creek	5.3	791	643	81.8%
Upper Chehalis	2.4	940	545	22.9%

Figure 2.7
Abundance and Spatial Structure of Chehalis Basin Coho Salmon



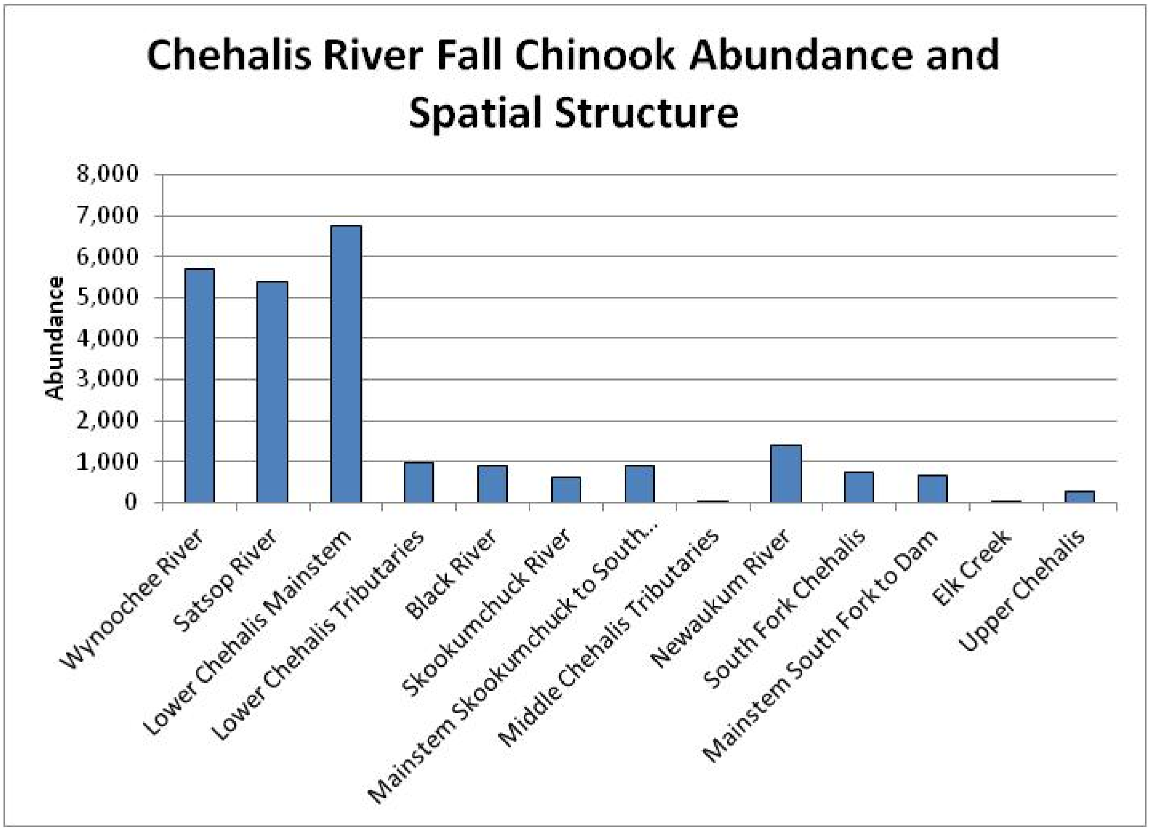
2.1.9.2 FALL-RUN CHINOOK SALMON

VSP indices of habitat condition for fall-run Chinook salmon for each sub-region are shown in Table 2.14. Fall-run Chinook salmon production is heavily skewed toward the lower Chehalis River reaches including especially the Wynoochee and Satsop sub-basins. As noted earlier, the lower Chehalis mainstem area has a high capacity based on areal extent resulting in a high potential abundance despite the relatively low productivity of the lower mainstem.

Table 2.14
Spatial Structure of Chehalis Basin Fall-run Chinook Salmon

SUB-BASIN	PRODUCTIVITY	CAPACITY	EQUILIBRIUM ABUNDANCE	DIVERSITY
Wynoochee River	5.7	6,878	5,678	91.9%
Satsop River	7.1	6,271	5,386	97.4%
Lower Chehalis Mainstem	3.9	9,076	6,765	88.2%
Lower Chehalis Tributaries	6.3	1,173	986	95.7%
Black River	5.2	1,124	908	98.4%
Skookumchuck River	3.8	817	600	100.0%
Mainstem Skookumchuck to South Fork	2.6	1,460	902	88.6%
Middle Chehalis Tributaries	3.9	27	20	50.0%
Newaukum River	3.7	1,924	1,398	85.9%
South Fork Chehalis	6.1	898	751	98.3%
Mainstem South Fork to Dam	3.0	980	650	88.7%
Elk Creek	3.5	38	27	100.0%
Upper Chehalis	2.7	395	246	75.7%

Figure 2.8
Abundance and Spatial Structure of Chehalis Basin Fall-run Chinook Salmon



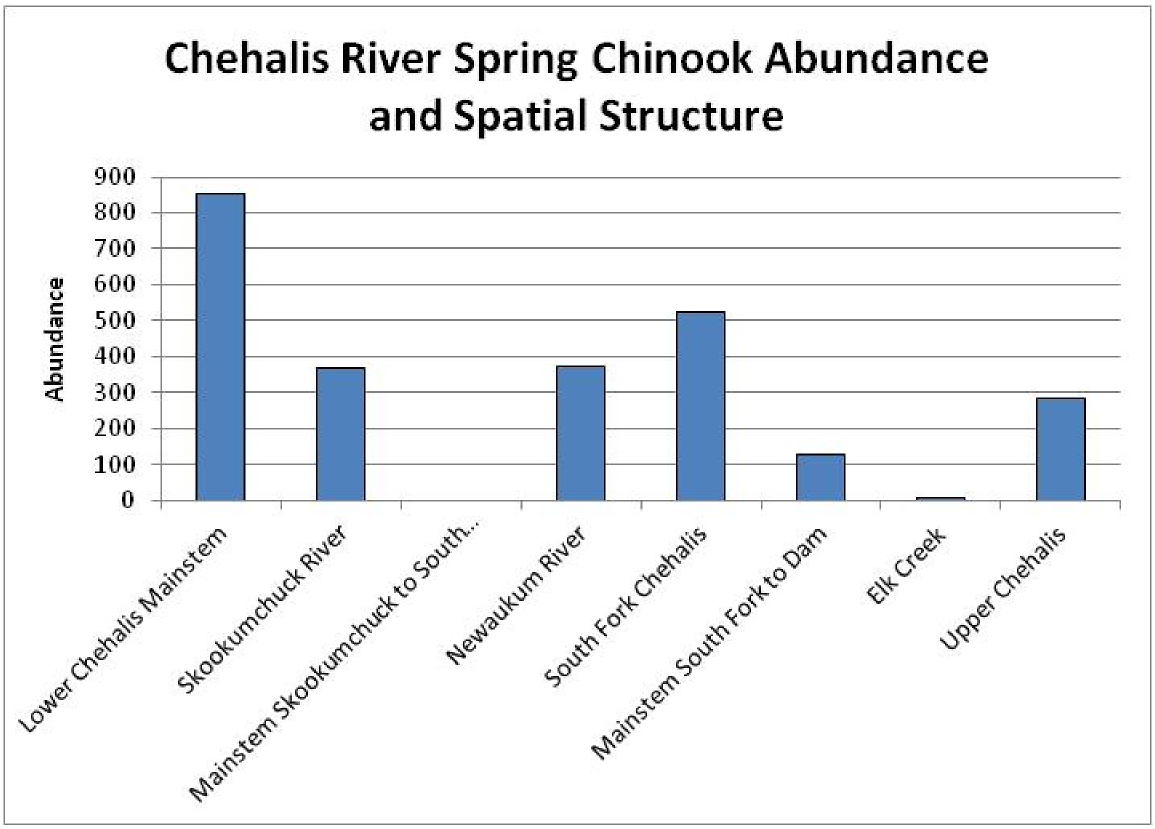
2.1.9.3 SPRING-RUN CHINOOK SALMON

VSP indices of habitat condition for spring-run Chinook salmon for each sub-region are shown in Table 2.15. Habitat potential for spring-run Chinook salmon in the basin was the most limited of all modeled salmonids. Spring-run Chinook salmon were assumed to enter the Chehalis River in the spring and then spawn in the fall. The low abundance and distribution is predicted in the model to result primarily from low pre-spawner survival due to high summer water temperatures. As was the case for fall-run Chinook salmon, the large areal extent of the lower Chehalis resulted in an estimate of large capacity for spring-run Chinook salmon, but with low productivity. Excepting this area, the Skookumchuck and Newaukum sub-basins were predicted to have the greatest habitat potential for spring-run Chinook salmon.

Table 2.15
Spatial Structure of Chehalis Basin Spring-run Chinook salmon

SUB-BASIN	PRODUCTIVITY	CAPACITY	EQUILIBRIUM ABUNDANCE	DIVERSITY
Lower Chehalis Mainstem	1.5	2,446	855	8.7%
Skookumchuck River	2.5	609	368	62.9%
Mainstem Skookumchuck to South Fork	0.0	144	0	0.0%
Newaukum River	2.1	715	373	29.2%
South Fork Chehalis	3.1	778	524	41.6%
Mainstem South Fork to Dam	1.8	281	126	1.0%
Elk Creek	1.3	39	9	66.7%
Upper Chehalis	2.9	433	282	27.9%

Figure 2.9
Abundance and Spatial Structure of Chehalis Basin Spring-run Chinook Salmon Based on Habitat



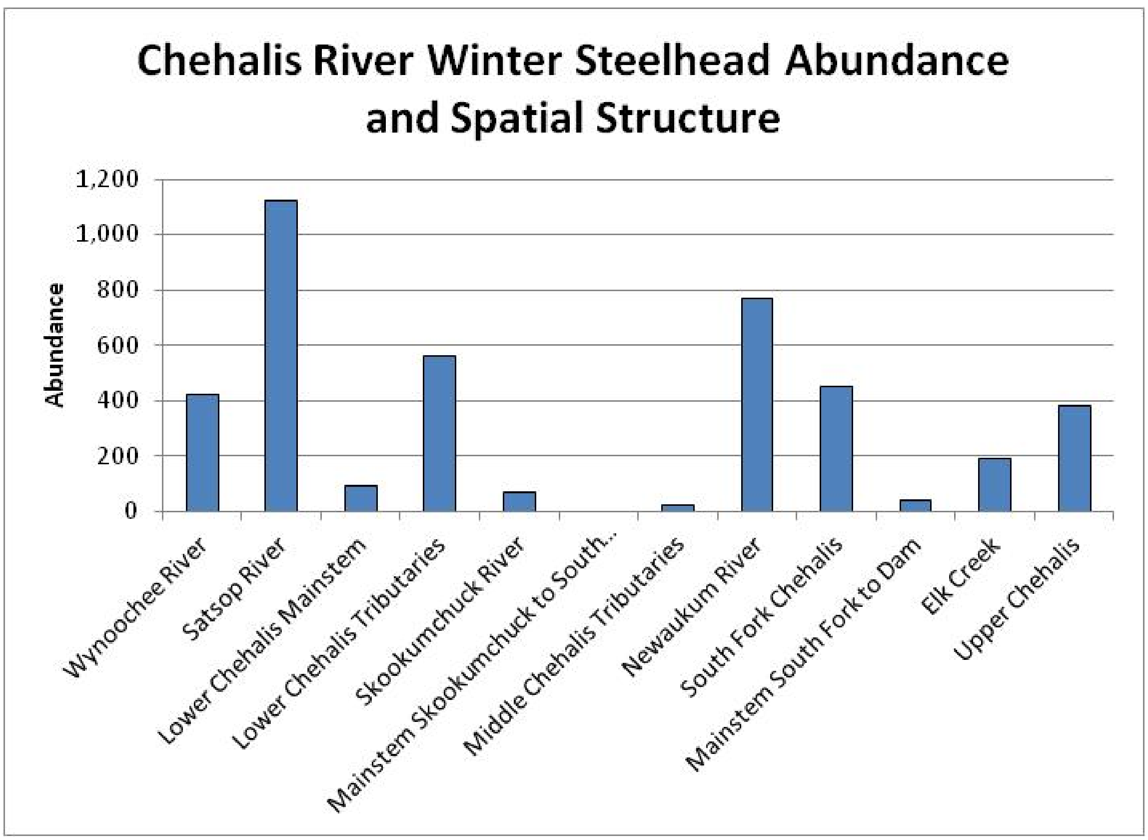
2.1.9.4 WINTER-RUN STEELHEAD

VSP indices of habitat condition for winter-run steelhead for each sub-region are shown in Table 2.16.

Table 2.16
Spatial Structure of Chehalis Basin Winter-run Steelhead

SUB-BASIN	PRODUCTIVITY	CAPACITY	EQUILIBRIUM ABUNDANCE	DIVERSITY
Wynoochee River	10.4	467	422	60.3%
Satsop River	10.1	1,244	1,120	92.0%
Lower Chehalis Mainstem	1.7	228	90	18.6%
Lower Chehalis Tributaries	8.3	638	561	53.1%
Skookumchuck River	5.7	86	71	65.4%
Mainstem Skookumchuck to South Fork	0.0	35	0	0.0%
Middle Chehalis Tributaries	6.8	26	22	46.2%
Newaukum River	11.5	844	771	65.5%
South Fork Chehalis	11.8	492	451	69.6%
Mainstem South Fork to Dam	2.1	72	38	14.9%
Elk Creek	10.1	210	189	85.1%
Upper Chehalis	6.8	444	379	54.8%

Figure 2.10
Abundance and Spatial Structure of Chehalis Basin Winter-run Steelhead Based on Habitat



2.1.10 DISCUSSION

Based on WDFW spawner index data, coho salmon are the most abundant salmon in the basin of the four salmon species and runs analyzed in terms of VSP characteristics, with a 10-year geometric mean escapement of 42,144 fish each year since 2004. The next most abundant species or run was fall-run Chinook salmon, which had a 10-year geometric mean escapement of 11,524 fish, then winter-run steelhead with a 10-year geometric mean escapement of 8,378 fish, followed by spring-run Chinook salmon with a 10-year geometric mean escapement of 1,809 fish.

WDFW spawner index data indicates that the post-harvest, 10-year geometric means of the number of recruits produced by each spawning fish (R/S) ranged from 0.8 to 1.1. Fall-run Chinook salmon had the highest geometric mean R/S (1.1), followed by coho salmon (1.0), spring-run Chinook salmon (0.9), and winter-run steelhead (0.8). As geometric means, these estimates represent a composite of data from multiple years, where the value observed for any individual contributing year may be higher or lower than the mean value reported here. That said, the geometric means calculated for the past decade suggest that spring-run Chinook salmon and winter-run steelhead population productivity has not been sufficient to maintain the population during the period of the analysis. However, ASEP authors caution that this is a complex issue, and much more analysis would be needed to fully interpret these data and determine the health and status of the populations.

In terms of spatial structure and diversity, none of these populations have been listed as threatened or endangered under ESA, and thus none have been designated as Evolutionarily Significant Units (ESUs) or main population groups under an ESU as is commonly done for species in need of recovery.

WDFW spawner index data indicates fall-run Chinook salmon and winter-run steelhead in the basin are the most dispersed salmon species of the four discussed in this report and appear to use the broadest spatial scale of habitats, followed by coho salmon and spring-run Chinook salmon. Spring-run Chinook salmon appeared to have the narrowest spatial distribution within the watershed.

Estimates of age at return in the WDFW spawner data show fall-run Chinook salmon and winter-run steelhead in the basin have the most life history diversity; for example, they can return as adults anywhere from 2 to 6 years of age. These species were followed by spring-run Chinook salmon that return as adults from 3 to 6 years of age, and coho salmon that return at age 3.

Based on the quantity, quality, and distribution of habitat, the basin currently provides the greatest habitat potential for coho salmon and fall-run Chinook salmon. These results are consistent with the WDFW spawner abundance data. Spring-run Chinook salmon habitat potential is considerably less, while the low diversity indicates a constriction in habitat breadth relative to the intrinsic condition. Again, these findings agree with the low and decreasing spawner abundance in the system based on WDFW spawner abundance data. Winter-run steelhead capacity in the EDT model is relatively low but the high productivity and diversity indicates that the quality of the steelhead habitat in the Chehalis is generally high. These results generally agree with the WDFW spawner abundance data, which showed a flat trend over time. However, one difference between the population and habitat-based data was the productivity of winter-run steelhead, which was the highest of all species evaluated based on EDT modeling but was lowest based on WDFW's spawner index data. While this could, in part, be the result of data or other modeling issues related to steelhead, a significant contributor to the difference is that the WDFW and EDT estimates of *productivity* reflect different biological parameters. WDFW data uses the R/S ratio from observed indices of fish abundance that include density effects on survival and EDT, in contrast, computes the Beaverton-Holt density independent productivity parameter. The density independent estimate of productivity should be higher than the observed R/S ratio. The difference between the two values should increase as the population approaches carrying capacity and the difference between calculated Beverton-Holt productivity and observed R/S may indicate that steelhead are closer to carrying capacity than other species. This type of difference is to expected based on methodology differences.

2.2 Other Fish Species

While ichthyologists have described fish species' distribution patterns in Washington State, population numbers and structures have generally not been studied, except for certain species that are of economic importance. Consequently, there are no population estimates for Other Fish species and the focus is on presence and distribution. From the distribution pattern descriptions, ASEP authors have distribution information on most Washington fishes.

A few species' descriptions date back to fish collected by the Lewis and Clark expedition, but more of them date from the late 19th and early 20th century and were published by Dr. David Starr Jordan, Dr. Barton Warren Evermann, and others. The Olympic mudminnow (*Novumbra hubbsi*), whose world distribution is centered in the Chehalis-Grays Harbor watershed and is not known outside Western Washington, was described in 1929 by Dr. Leonard P. Schultz's book *Keys to the Fishes of Washington, Oregon and Closely Adjoining Regions*. Because of its endemism, the Olympic mudminnow's distribution has received more detailed attention (Harris 1974; Meldrim 1968; Mongillo and Hallock 1999). Additionally, freshwater fish distributions in Washington were addressed by McPhail (1967), McPhail and Lindsey (1986), and Wydoski and Whitney (2003, originally published in 1979). These three references are most likely the most comprehensive regional listing of fish species and their distributions for Washington State. The best information on population abundance trends of Other Fishes is catch trends for white sturgeon (*Acipenser transmontanus*) and perhaps eulachon (*Thaleichthys pacificus*); although for both species, most of information is for the Columbia River, not the Chehalis River.

This information applies to native non-salmonid fishes. Several non-salmonid fishes (American shad, carp, catfishes, yellow perch, largemouth and smallmouth bass, bluegill, and other centrarchid sunfishes) have been introduced to Washington and the basin, usually for human use. These fishes have received casual attention but not intensive monitoring. In several cases, non-native fishes are suspected of adversely impacting native species, though these interactions are poorly understood.

To summarize, for Other Fish Species, we have information on distributions and relative abundance and varying amounts of life history information (see Wydoski and Whitney 2003), but no information on abundance trends or clear indications of major limiting factors.

2.2.1 CURRENT POPULATIONS OF OTHER FISH SPECIES

Similar to the amount of historical population information available for the majority of Key Other Fish Species, information on current population structures remains limited. In this section, we report currently-known distributions and highlight the lack of species-specific information available. Distribution information was drawn largely from Wydowski and Whitney (2003) as well as locality reports in the WDFW Fish Distribution Database. When available, literature and report reviews further refined distribution and life history information. Additional information was included from WDFW's riverscape survey, which was a continuous coverage snorkel starting at the East Fork and West Fork confluence of the Chehalis River and ending downstream from the Chehalis River confluence with the Newaukum River (at State Route 6 bridge). This survey took place from August to September 2013. It highlights relative abundance for select species and distribution information for those species identified. Side-channel surveys using limited survey techniques of seven Middle Chehalis oxbows (completed by WDFW in fall 2013) were referenced as well. For all surveys, lack of observations of a particular species does not indicate its absence as detectability parameters are unknown.

2.2.1.1 PACIFIC LAMPREY

Pacific lamprey (*Lampetra tridentata*) spawn and rear throughout the basin (Wydoski and Whitney 2003; WDFW Pacific lamprey spawning surveys since 2005). Juvenile Pacific lamprey usually rear from 4 to 7 years in silt and mud backwaters located in side-channel areas before migrating to the Pacific Ocean. Adults returning to spawn from April to July seek out faster water and gravel substrate. Redd survey information from 2005 to 2013 reveal Pacific lamprey spawning from the Hoquiam sub-basin to the upper Chehalis (RM 122.5 [RKm 197.1]). Additionally, Henning et al. (2007) observed Pacific lamprey in four of six wetland and oxbow locations surveyed in the lower Chehalis.

2.2.1.2 WHITE STURGEON

The low gradient mainstem of the Chehalis River does not provide preferred habitat for white sturgeon spawning and current records show no white sturgeon population spawning in the Chehalis River. However, WDFW tagging studies indicate that from 1 to 8% of Columbia River origin white sturgeon (from older-age juvenile, sub-adult, to adult fish) travel out of the Columbia River to Oregon and Washington coastal estuaries and river systems for varying periods of time. The proportion of the population that ends up in the Chehalis River is unknown, but recreational fishery catch records suggest about 1% of those residing in the lower Columbia River were caught in the Chehalis River. Approximately 95% of the sports catch occurs in the deep pools of the mainstem Chehalis River, which is in line with their known habitat preferences. More than 90% of catch records occur downstream from the confluence with the Black River. White sturgeon movement within the Chehalis System is likely blocked by the Rainbow Falls cascades, located at RM 102.1 (RKm 164.4), considerably upstream of the Black River confluence (at RM 48.8 [RKm 78.6]). Additionally, sporadic reports exist of white sturgeon catch in the Satsop and Newaukum rivers. Sturgeon likely enter the system to forage and prey may include the freshwater mussels present throughout the Chehalis River.

2.2.1.3 EULACHON

Eulachon spawn in the lower reaches of the Chehalis River including the Wynoochee and Satsop sub-basins (DFO 1999). Adults seek out sand and pea-size gravel for spawning from November to the first week in June, with peak spawning in March. Once hatched, larvae are flushed towards the estuary. Spawning locations are dependent on river conditions at the time fish enter the system. Increased eulachon spawning in the basin was reported in 1994, which coincided with poor spawning conditions in the Columbia River (DFO 1999). Eulachon were listed under the ESA in 2010 due to population declines.

2.2.1.4 OLYMPIC MUDMINNOW

Olympic mudminnow are endemic to western Washington and are found through much of the basin (Wydoski and Whitney 2003; Mongillo and Hallock 1999). They prefer slow-moving streams, wetlands, and ponds with aquatic vegetation, muddy substrate, and little or no water flow (Mongillo and Hallock 1999; Meldrim 1968). Notably, they exhibit a right-bank preference; a majority of the recorded sightings occur on the right river bank (WDFW, Fish Distribution database). Olympic mudminnow were found in one of the seven side-channel oxbows sampled by WDFW in the Middle Chehalis during the fall of 2013 and one of two side-channel oxbow from the Middle Chehalis in the summer of 2014. Although further sampling is required to confirm their presence or absence, this is in agreement with Mongillo and Hallock (1999) and Beecher and Fernau (1982) who noted that these fish were less abundant when associated with other native and non-native species, which could be due to predation. However, regardless of Other Fish presence, Henning et al (2007) found that Olympic mudminnow were more associated with low current, shallow emergent wetlands with muddy substrate and emergent vegetation.

2.2.1.5 SPECKLED DACE

Speckled dace (*Rhinichthys osculus*) are common throughout Washington, though little is known about the current population in the basin. Research from the Kettle River, British Columbia indicates juveniles prefer smaller substrate and lower velocity and depth, while adults prefer larger substrate (cobble and boulder) and faster and deeper areas (Andrusak and Andrusak 2011). During the 2013 WDFW riverscape snorkel survey, dace (not identified to species) were observed throughout the survey beginning downstream of the confluence with Big Creek; however, they were observed in higher abundance near Pe Ell. Limited catch efforts from 2013 WDFW surveys of side-channel oxbows in the middle Chehalis did not yield any speckled dace. Additionally, Henning et al. (2007) sampled four wetland and two oxbow sites in the lower Chehalis (near RM 17 and 33 [RKm 27.3 and 53.1]) and found speckled dace in one of the oxbows.

2.2.1.6 LARGESCALE SUCKER

Largescale suckers (*Catostomus macrocheilus*) are habitat generalists with spawning occurring between April and June. They are present throughout the basin with limited records indicating observations in Stearns Creek and the Satsop sub-basin (Fish Distribution Database, WDFW). Adult and juvenile suckers were observed intermittently during the 2013 WDFW riverscape snorkel surveys; however, fry and juveniles were observed in relatively higher abundance near the confluence with the South Fork Chehalis River. Juveniles were also observed in three of the 2013 WDFW side-channel surveys of oxbows.

2.2.1.7 SCULPIN

Riffle (*Cottus gulosus*) and reticulate sculpin (*Cottus perplexus*) are usually present in small streams and backwaters and are known to seek out LWM and other shelter-forming structures for spawning. Their distribution is known to include the basin (Wydoski and Whitney 2003), but population information specific to the basin is limited. Both sculpin species have been observed throughout the basin during electrofishing surveys conducted by WDFW. Henning et al. (2007) observed reticulate sculpin in 4 of 6 wetland and oxbow locations surveyed in the lower Chehalis. Additionally, sculpin (not identified to species) were captured in three of the seven WDFW side-channel surveys of oxbows in the middle Chehalis in 2013 and one of two side-channel oxbow from the Middle Chehalis in the summer of 2014.

2.2.1.8 LARGEMOUTH AND SMALLMOUTH BASS

Both Largemouth and Smallmouth Bass are not native to the basin. While they both inhabit mainstem and side-channel habitats, largemouth bass are more associated with side-channel habitat, such as oxbow lakes and side-channel marshes. Additionally, smallmouth bass prefer cooler water than largemouth bass. During the 2013 WDFW riverscape snorkel surveys, bass (not identified to species) were observed beginning downstream of the Bunker Creek confluence. Largemouth bass were also captured in three of the side-channel areas surveyed by WDFW in the Middle Chehalis region during the fall of 2013 and in both of the side-channel oxbows surveyed by WDFW in the Middle Chehalis in the summer of 2014.

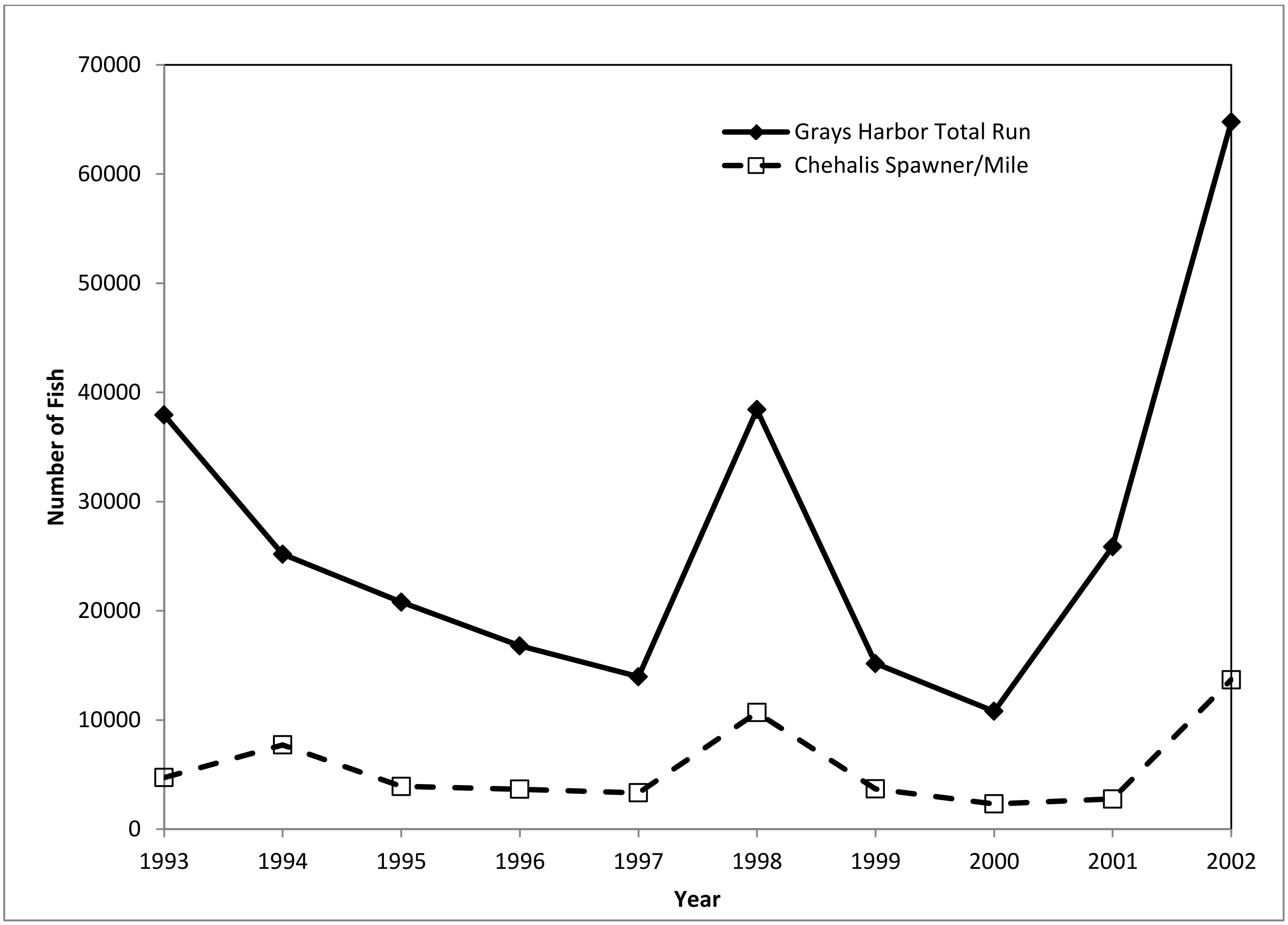
2.2.2 VIABLE SALMONID POPULATION FOR OTHER FISH SPECIES

The available data for Other Fish Species was reviewed to judge whether the data were sufficient to develop and evaluate VSP parameters for fish species other than the four salmon species and runs. As stated previously, information on Other Fish species is very limited. Consequently, other than the four salmon species previously discussed, only chum salmon (*Oncorhynchus keta*) had enough information to develop and evaluate VSP parameters.

2.2.2.1 CHUM SALMON

Unlike other species addressed in Objective 2, no escapement or total run estimates exist specifically for chum salmon in the Chehalis River. Chum salmon escapement is based on a composite estimate for all of Grays Harbor and relies on direct spawner observations at index reaches. WDFW does estimate annual relative abundance in the Chehalis River based on spawners per mile estimates from the Satsop River. These data, along with survey data from the Humptulips River are expanded to create a composite escapement estimate for all of Grays Harbor. WDFW considers the Chehalis data to have limited or poor usefulness for rating the stock's status because estimates rely on an expansion from only three index sites in the Satsop River (WDFW 2014). In the 10 years spanning 1993 and 2002, Chehalis chum salmon averaged 5,651 spawners per mile (± 3,812 standard deviation [SD]), ranging from a low of 2,313 in 2000 to a maximum of 13,695 spawners in 2002 (Figure 2.11). During the same period, total run size for wild Grays Harbor Chum salmon (prior to harvest) has averaged 29,968 recruits (±16,316 SD), ranging from a low of 10,794 in 2000 to a maximum of 64,768 in 2004 (Figure 2.11). Hatchery production contributes to chum salmon returns in the basin (see Table 2.7).

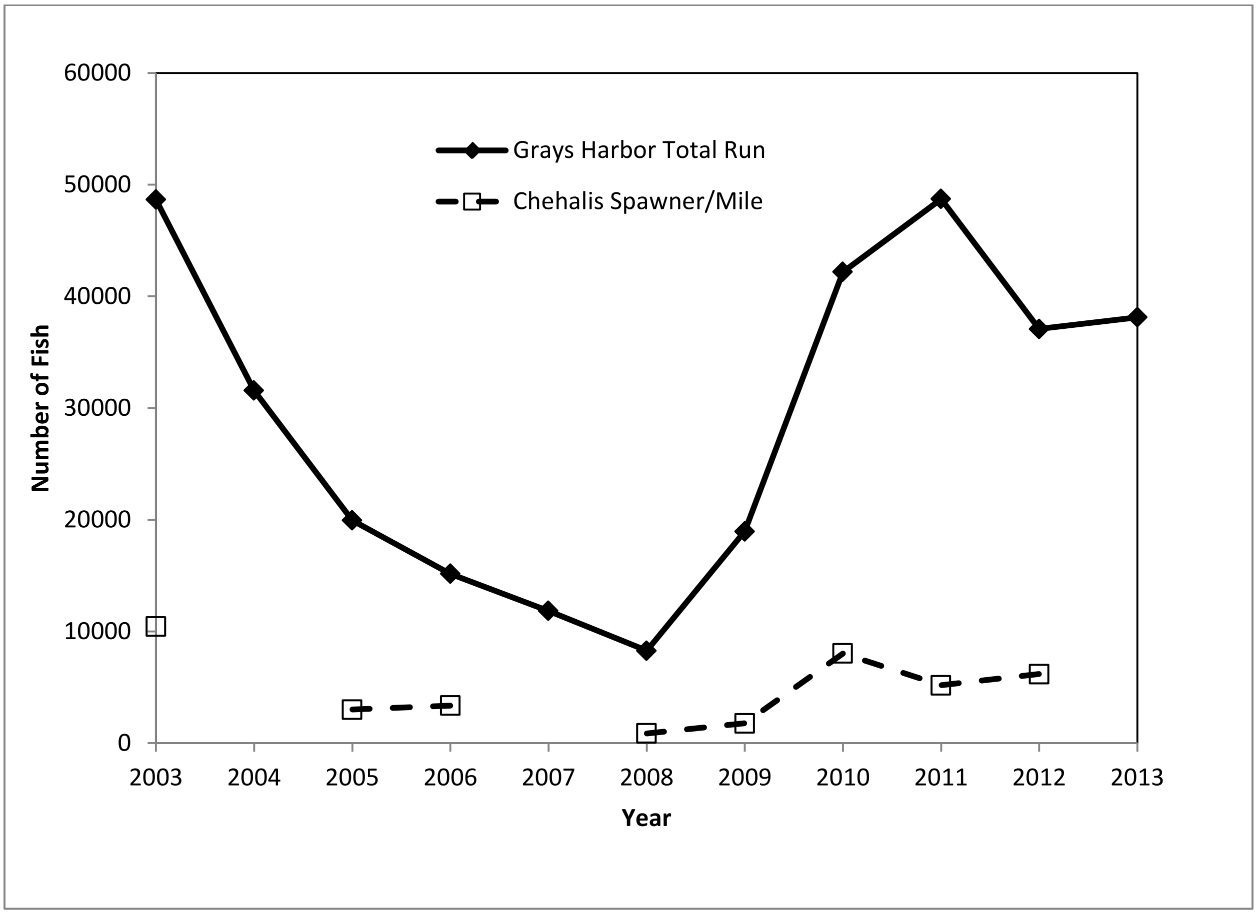
Figure 2.11
Annual Total Run Size for Grays Harbor Chum Salmon and Spawners per Mile for the Chehalis River Component, 1993 to 2002



In the period of 2003-2013, chum salmon in the basin have averaged 4,860 spawners per mile (±3,252 SD) annually, with a geometric mean of 3,791. Annual estimates of spawners/mile have ranged from a low of 880 in 2008 to a maximum of 10,438 in 2003 (Figure 2.12). The current estimates of spawner/mile for the Chehalis River are slightly lower both in terms of the average (791 fewer fish) and geometric mean (973 fewer fish), than the previous decade (i.e., 1993 to 2002).

During the same period, total run size for Grays Harbor chum salmon (prior to harvest) has averaged 29,140 natural-origin recruits (± 14,843 SD) with a geometric mean of 25,116. Total run size has ranged from a low of 8,278 in 2008, to a maximum of 48,729 in 2011 (Figure 2.12). The current run size is slightly larger both in terms of the average (2,173 more fish) and geometric mean (1,723 more fish), than the previous decade (i.e., 1993 to 2002).

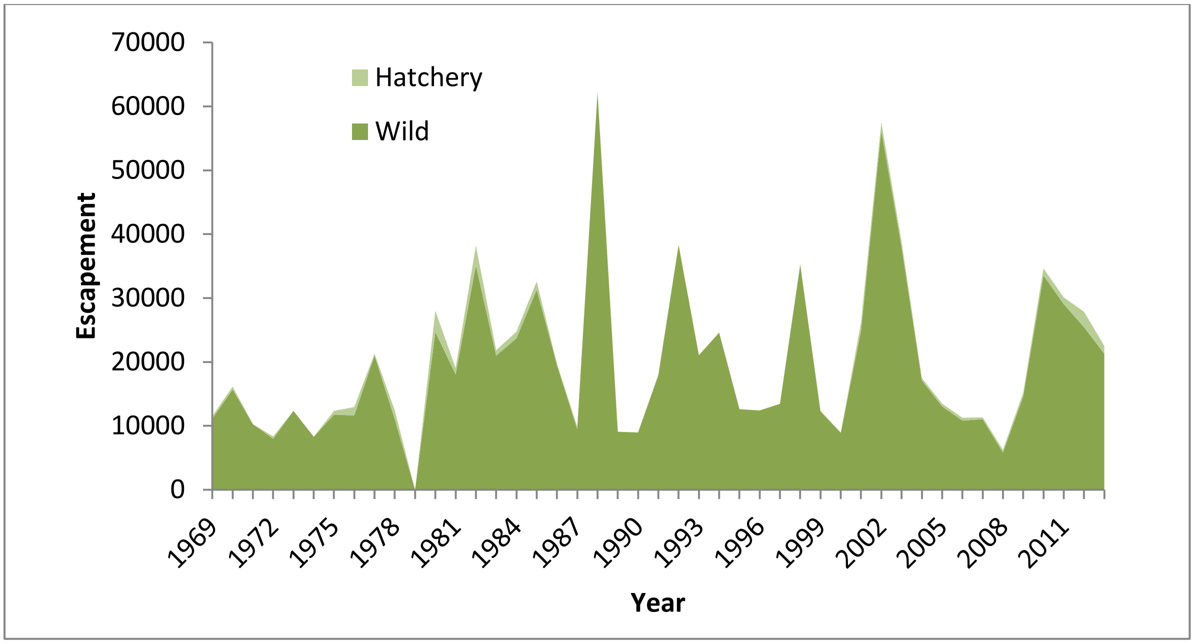
Figure 2.12
Annual Total Run Size for Grays Harbor Chum Salmon and Spawners per Mile for the Chehalis River Component, 2003 to 2013



For the entire period data were available (1969 to 2013), wild chum salmon escapement to Grays Harbor averaged 20,041 adults (±12,398 SD) with a geometric mean of 17,136. Escapement has ranged from a low of 5,826 adults in 2008 to a maximum of 62,175 adults in 1988.

During the same period, hatchery-origin returns have accounted for an average of 3% (±3% SD) of the total chum escapement to Grays Harbor. The maximum percentage contribution of hatchery fish to an annual spawning escapement was 12% in 1980; however, in 13 of the 44 return years, hatchery fish did not contribute to Grays Harbor escapements. The annual relative contribution of hatcheries to total Grays Harbor Chum escapement, since 1969, is illustrated in Figure 2.13.

Figure 2.13
Relative Contribution of Hatchery and Wild Origin Chum Salmon to Annual Grays Harbor Spawning Escapement



Note: Return data were not available for 1979.

Post-harvest productivity (R/S) of Grays Harbor chum salmon averaged 1.9 R/S (±1.8 SD) with a geometric mean of 1.1 R/S for the most recent 10 years of brood data (1999 to 2008). Over the entire range of brood years available (1969 to 2008), post-harvest productivity averaged 1.4 R/S (±1.4 SD) with a geometric mean of 0.9 R/S. The lowest productivity was observed with the 1975 brood year: 0.1 R/S, and the highest productivity was observed for the 1999 brood year: 5.3 R/S.

Chehalis chum salmon typically out-migrate as fry and the majority return to spawn at 4 years total age (Table 2.18).

Table 2.18
Age Composition of Returning Chum Salmon in the Chehalis River Basin

PERIOD	AGE COMPOSITION (%)			
	3	4	5	6
All Years (1999 to 2013)	15.5	72.4	12.0	0.1

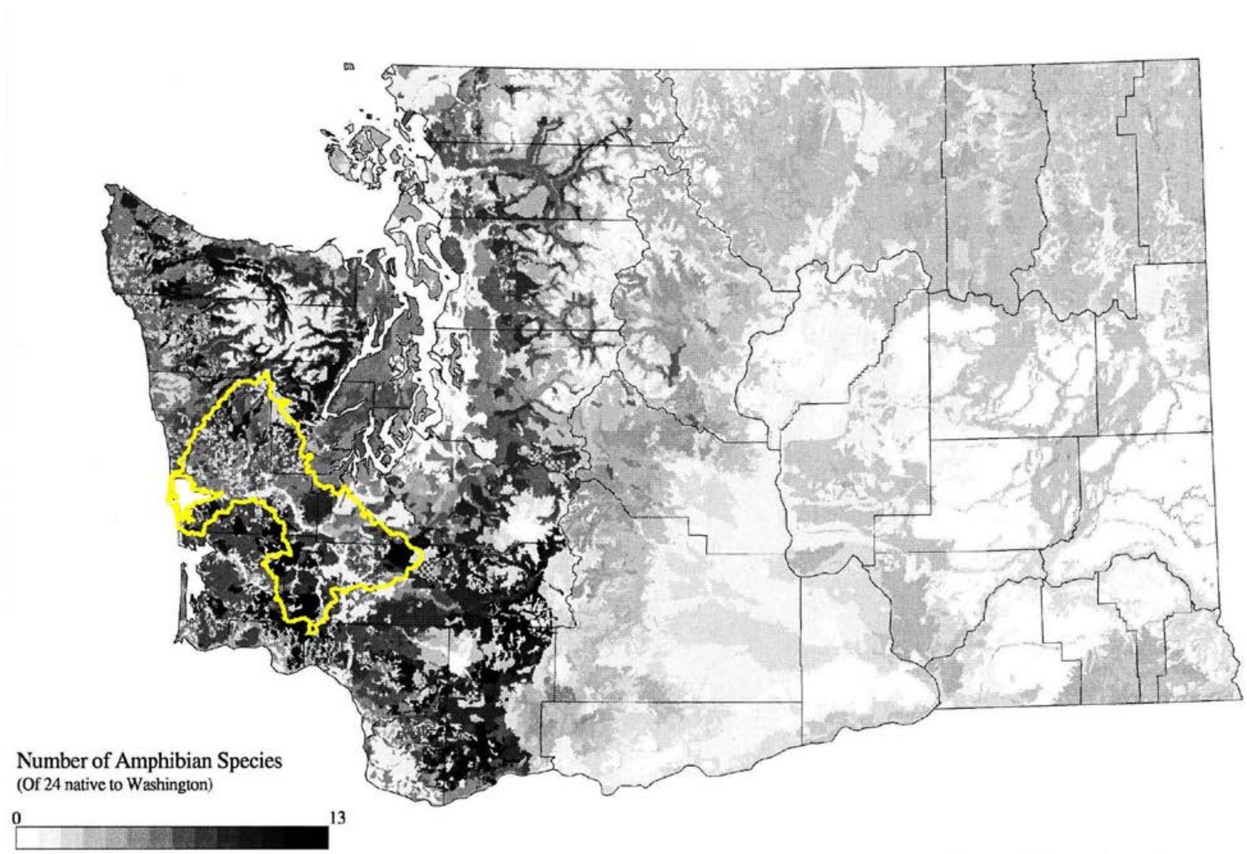
Because chum salmon are not incorporated into the EDT at this time, only coarse scale VSP parameters are depicted for this species.

2.3 Non-fish Species

2.3.1 HISTORICAL POPULATIONS OF NON-FISH SPECIES

The basin is unique in possessing the highest species richness of amphibians in Washington State. This pattern, illustrated in Gap Analysis map 10 (Cassidy et al. 1997, Volume 5; Figure 2.14), reflects the juxtaposition of headwater areas that are rich in stream-breeding (four species) and terrestrial (four species) amphibians, with a floodplain, possessing the most extensive side-channel habitats of any riverine system in Washington State that is occupied by seven different species of stillwater-breeding amphibians. The presence of the Oregon spotted frog (*Rana pretiosa*), which was listed as Threatened under the Endangered Species Act (1973) as of 28 August 2014 and occurs in only six drainage systems in the state, and Dunn's salamander (*Plethodon dunni*), which is only found in the Willapa Hills in Washington, contribute importantly to this pattern. Species richness of amphibian species that are most at risk, illustrated in Gap Analysis map 18 (Cassidy et al. 1997, Volume 5), is also highest in the basin. In-stream-breeding species such as coastal tailed frog (*Ascaphus truei*) and Cope's giant salamander (*Dicamptodon copei*), terrestrial breeding species such as very cool-adapted Van Dyke's salamander (*Plethodon vandykei*), and the increasing uncommon western toad contribute to this pattern.

Figure 2.14
Map of Native Amphibian Species Richness for Washington State



Note: Chehalis River Basin outlined in yellow.

In general, the Information on historical populations of Non-fish species in the basin is extremely sparse. Available data consist of occurrence information from Washington State Gap Analysis (Dvomich et al. 1997; Johnson and Cassidy 1997; Smith et al. 1997), the WDFW wildlife database and scattered literature sources.

2.3.1.1 NORTHERN RED-LEGGED FROG

A moderate number of historical records exist for the northern red-legged frog (*Rana aurora*) all across the basin (Dvomich et al. 1997), and both the basic predictive model for their distribution (Dvomich et al. 1997) and their relatively large typical seasonal movement scale (Hayes et al. 2008) suggests that the species was historically widespread. Because non-native aquatic predators appear to have a negative effect on this species (Kiesecker and Blaustein 1997, 1998; Kiesecker et al. 2001; Adams et al. 2003; Adams and Pearl 2007) and juxtaposition of stillwater aquatic breeding habitat to forested uplands is a basic habitat requirement of the species (Hayes et al. 2008), historic populations are likely to have been both more widespread and robust than they are today.

2.3.1.2 WESTERN TOAD

A few historical records exist for the western toad in the basin (Dvomich et al. 1997). Based on a basic predictive model for their distribution (Dvomich et al. 1997), their moderately large seasonal movements (Bartelt et al. 2010), and their ability to rapidly colonize new habitat (Crisafulli et al. 2005), it is likely this species was widespread throughout the basin historically where suitable upland (open prairie or grassland) and shallow largely unvegetated stillwater aquatic habitat were juxtaposed.

2.3.1.3 OREGON SPOTTED FROG

A few historical records exist for the Oregon spotted frog in the upper Black River system (Dvomich et al. 1997; McAllister and Leonard 1997), but only one historical record exists for the basin associated with the main channel of the Chehalis. This record, based on a specimen at the Cornell University collected in the 1940s, was found in the vicinity of Oakville, Washington, but details of the specific locality are lacking. The demonstrably negative effects of invasive reed canarygrass (*Phalaris arundinacea*) on this species (Kapust et al. 2012), the probable negative effects of non-native aquatic predators (Cushman and Pearl 2007), and its rather specialized, large warmwater marsh habitat requirement (Pearl and Hayes 2004) suggests that the species was historically more widespread when suitable aquatic habitat (open low-emergent marsh of adequate size [greater than or equal to 10 acres; 4.0 ha]) was available.

2.3.1.4 COASTAL TAILED FROG

A moderate number of historical records exists for the coastal tailed frog in the headwaters of the Chehalis above Pe Ell (Dvomich et al. 1997). Most of these data were collected during Weyerhaeuser's landscape planning efforts in the mid-1990s. Based on its relatively cool in-stream breeding habitat requirements (Hayes et al. 2006), this species was likely always restricted to the headwater landscape in the basin. Recent analyses reveal that occupancy patterns on the timber-managed landscape may not have changed significantly from the historic condition (Kroll et al. 2008); however, how populations may have changed is unknown.

2.3.1.5 VAN DYKE'S SALAMANDER

Two historical records exist for the Van Dyke's salamander in the headwaters of the Chehalis above Pe Ell (Dvomich et al. 1997). One record came from just below 1,300 feet (400 m) in elevation on the west slope of Boistfort (Baw Faw) Peak, which at 3,113 feet (949 m) is the highest point in the Willapa Hills, whereas the second came from almost exactly the same elevation roughly 2.5 miles (4 km) to the west (WDFW database). A lone record also exists from the east slope of Boistfort Peak in the adjacent Stillman Creek Basin from roughly the same elevation. The fact that Van Dyke's salamander is cool-adapted may indicate that the species was limited to somewhat higher elevations. The U.S. Forest Service's protocol for surveying for Van Dyke's salamander required that surveys should not be conducted at air temperature more than 14°C (57.2°F). However, recent efforts in the Willapa Hills have revealed Van Dyke's salamander to be more widely distributed than previously thought (WDFW unpublished data). Therefore, historic surveys may have missed the best time windows for detection and the true extent of its historic distribution is uncertain.

2.3.1.6 WESTERN POND TURTLE

Similar to Oregon spotted frog, a few historical records exist for the western pond turtle in the upper Black River system (Dvomich et al. 1997). No historical records exist for the western pond turtle for the basin associated with the main channel of the Chehalis, possibly because the main channel of the Chehalis River likely intersects a climate-limiting geographic boundary condition. This limiting condition is unstudied, but the western pond turtle lays hard-shelled eggs that appear intolerant of excessive moisture, and hence, must be laid in well-drained soils in a dry land nest that experiences a temperature high enough for proper development (Holland 1994). Therefore, the interaction between annual precipitation patterns and soil characteristics may limit western pond turtle distribution in this region.

2.3.1.7 NORTH AMERICAN BEAVER

No historical records exist for North American beaver (*Castor canadensis*) in the Project area of the basin though scattered records exist in selected major tributaries of the Chehalis (Johnson and Cassidy 1997). The basic predictive model for their distribution (Johnson and Cassidy 1997) suggests that historically they were widespread in the Project study area of the basin. However, anecdotal comments exist indicating that North American beaver had been locally trapped out (Verd 2009a) or their dams had been dynamited (Verd 2004a).

2.3.2 CURRENT POPULATIONS OF NON-FISH SPECIES

Information on current populations of Non-fish Species in the basin is sparse. Available data consist of information from: 1) 2014 amphibian surveys conducted by the WDFW Habitat Program Aquatic Research Section in the Chehalis headwaters that includes the vicinity of the dam footprint; 2) incidental data on amphibians, reptiles, and mammals recorded during the systematic in-stream fish surveys conducted by the WDFW Fish Program Science Division on the Chehalis mainstem between RM 75.8 and 125.5 (RKm 122 to 202 in 2013; 3) amphibian, reptile, and mammal data collected during the WDFW Fish Program Science Division surveys of seven side-channel oxbows in 2013; 4) incidental amphibian data from the Chehalis Tribe fish trap located at the Penasko Bridge across the Chehalis River above Pe Ell; and 5) data from the WDFW wildlife database and the scientific literature. Most available data represent occurrence records, but some population-level data exist for the lower Chehalis for selected Non-fish Species (Henning 2004; Henning and Schirato 2006).

Besides the rich natural diversity of amphibian species in the basin under historical conditions as discussed in the previous paragraphs, it is important to point out that the extensive side-channels habitats in this system (which are occupied by the largest group of native amphibians, the stillwater-breeding species) are also frequently burdened by non-native aquatic predators. These non-native species include diverse warmwater fishes (especially centrarchids and catfishes) and the American bullfrog (*Lithobates catesbeianus*). This is a complex issue because most of these fishes, such as largemouth bass, are WDFW warmwater fishery management targets. A primary reason that the federal candidate Oregon spotted frog is at high risk is its totally aquatic life history and specialization for warmwater habitats that put it in direct contact with this suite of warmwater predators year-round; this contrasts with all other stillwater-breeding amphibians, which move seasonally into adjacent uplands following breeding.

Risk to amphibians is likely not entirely a consequence of non-native aquatic predators. Less studied constraints on amphibians that utilize terrestrial habitats either seasonally (e.g., the western toad and northern red-legged frog (*Rana aurora*) or year-round (e.g., Van Dyke's salamander) may be limited by selected land uses, such as agriculture or forestry practices, in those habitats. However, a recent study of forestry practices revealed that current practices appear to have little effect on the occupancy and abundance of in-stream-breeding amphibians, further study is needed. Better understanding of how a lack of groundwater may constrain the in-stream temperature requirements of stream-breeding amphibians is needed. Furthermore, some species, such as Van Dyke's salamander, are largely unstudied with respect to forestry practices.

2.3.2.1 NORTHERN RED-LEGGED FROG

Though systematic surveys for this species have not been conducted, the northern red-legged frog appears to remain widespread in the basin based on the following. It has been incidentally recorded in forested habitat in the Chehalis headwaters in 2013 during WDFW riverscape surveys between RM 97.6 and 112.5 (RKm 157 and 181) as well as the 2014 WDFW terrestrial amphibian surveys, and the species appears to occur seasonally at high densities in side-channel wetlands in the lower Chehalis (between RM 17.0 and 37.0 [RKm 27.4 to 59.5]), which are utilized for rearing (Henning 2004; Henning and Schirato 2006). Northern red-legged frogs breed in stillwater habitats (Hayes et al. 2008), and in the Chehalis floodplain, the side-channel/low-flow habitat is probably focal for breeding because few alternative suitable (i.e., stillwater) habitats exist. Northern red-legged frogs also engage in seasonal migrations between breeding sites and forested uplands that cover more than 0.6 mile (1 km), so juxtaposition of upland forest habitat with stillwater breeding habitat is crucial to maintaining local populations (Hayes et al. 2008). In fact, recent data suggest that the area of forested upland, rather than wetland size, determines the size of local populations (WDFW unpublished data). Moreover, data from the seven oxbows sampled by WDFW during 2013 suggest that a large portion of side-channel/low-flow habitat is occupied by non-native aquatic predators, namely centrarchid fishes and American bullfrogs, which would limit northern red-legged frog use of these habitats (Kiesecker and Blaustein 1998; Adams et al. 2003). These data agree with those of Henning and Schirato (2006), who found an inverse relationship between amphibian abundance and non-native fishes in side-channel wetlands in the lower Chehalis.

2.3.2.2 WESTERN TOAD

Numerous tadpoles and metamorphosing western toads were recorded during WDFW Fish Program riverscape surveys of in-stream habitat between RM 125.5 and 95.7 (RKm 202 and 154) during late summer/early fall, indicating that western toads breed in the main channel of the Chehalis when at least quasi-isolated pools form along channel margins that can be used for breeding during the descending limb of the hydrograph in early summer. These aquatic records of toad life stages are scattered from upstream from the proposed reservoir footprint at the upstream end to well into the medium-river habitat just downstream of the confluence with the Newaukum River. In addition, substantial western toad breeding has been observed in the upper Chehalis main channel during 2014 WDFW main channel amphibian surveys and some juvenile western toads have also been observed in stream margin and forested upland habitats in the upper Chehalis system during the 2014 WDFW terrestrial amphibian surveys within and just below the footprint of the proposed dam; several of the juvenile locations are in proximity to where breeding was observed in the main channel amphibian surveys or where tadpoles were recorded during riverscape surveys. Additionally, the 2014 surveys indicate a comparatively high density of western toad breeding along the Chehalis main channel in comparison to upstream versus downstream of the proposed dam and reservoir footprint. Western toads differentially use exposed shallow (less than 12 inches [30 cm]) stillwater aquatic habitat that is typically barren of vegetation for depositing eggs, and as a consequence, are among the first colonizers of novel unvegetated aquatic habitats, such as the numerous depressional ponds created in the ash field following the 1980 Mt. St. Helens eruption (Crisafulli et al. 2005). However, no western toad life stages were recorded in stillwater habitat during the few side-channel (oxbow) surveys conducted by WDFW in 2013. Examination of the surveyed oxbow habitat indicated that it lacked the required barren shallow areas for egg deposition, and was frequently choked with the invasive, non-native reed canarygrass. Because habitat-renewing flows that set back vegetation succession is likely the process through which toad breeding habitat is created in oxbows and other side-channel/low-flow habitats, the lack of toad breeding habitat in these oxbows may reflect an interruption or limitation of this process.

2.3.2.3 OREGON SPOTTED FROG

No Oregon spotted frog life stages were observed in oxbows sampled by WDFW during 2013, and no current records of Oregon spotted frogs exist for habitats along the main channel of the Chehalis River. Like the western toad, Oregon spotted frogs require exposed shallow oviposition habitat (Pearl and Hayes 2004; Cushman and Pearl 2007), and invasive reed canarygrass, which dominates the margin of most of these oxbows, inhibits Oregon spotted frog oviposition (Kapust et al. 2012). Further, unlike the seasonally migratory northern red-legged frog, the Oregon spotted frog is not migratory. It lives year-round in aquatic habitat, making the species the most vulnerable of native amphibians to non-native aquatic predators, and especially to the combination of centrarchid fishes and the American bullfrog, some of which are resident in stillwater side-channel habitats. WDFW Fish Program surveyors detected this combination of non-native species in several of the oxbows surveyed in 2013. In addition, Oregon spotted frog occupancy appears to be limited by habitat size because all occupied sites are greater than 10 acres (4 ha) in size, an aspect that is suspected to be linked to high annual adult mortality (Hayes 1997). Lastly, as Oregon spotted frogs are a warmwater adapted species (Cushman and Pearl 2007), and a climate-limiting geographic boundary likely lies somewhere along the mainstem of the Chehalis, which, in the absence of historical data, creates uncertainty about its local distribution.

Based on information to date, the likelihood of extant Oregon spotted frog populations occurring in side-channel habitats along the main channel of the Chehalis River may be low. However, numerous unsurveyed oxbows and other side-channel habitats exist along the main channel of the Chehalis downstream from its confluence with the Newaukum River, essentially all on private lands. Additionally, no systematic surveys for amphibians have been conducted in habitats associated with the main channel of the Chehalis River between the vicinity of Elma and the Newaukum River. The extant populations of Oregon spotted frog in the Chehalis system most proximate to the Chehalis River main channel are located along the mainstem of the Black River in the vicinity of Mima Creek, Thurston County (WDFW database).

The Oregon spotted frog was listed as Threatened under the ESA on 28 August 2014 (Waterstrat 2014). A 1-month grace period (i.e., through September 28, 2014) exists for all affected parties to address required permits, if needed, to address projects where this species is known to exist or may exist (critical habitat or habitat that is potentially critical to the species). At that point, consultation will be required for any parties involved in such projects, and federal permits will be required for projects on the ground that address potential habitat within its historic range.

2.3.2.4 COASTAL TAILED FROG

Limited current data on coastal tailed frog reveals it to be distributed across the headwaters stream network from the vicinity of the proposed Project upstream. One coastal tailed frog was captured in the Chehalis Tribe Panesko Bridge fish trap in 2013 (Chehalis Tribe, unpublished data), and juvenile and adult tailed frogs have been found during the 2014 WDFW terrestrial amphibian surveys in conifer and riparian forests both within and above (higher in elevation) the footprint of proposed dam alternatives. Additionally, both WDFW riverscape and terrestrial amphibian surveys incidentally found tailed frog tadpoles within the proposed reservoir footprint and in Crim Creek.

2.3.2.5 VAN DYKE'S SALAMANDER

Current data are lacking on Van Dyke's salamander for the basin, and the WDFW-directed terrestrial amphibian surveys have found one site with Van Dyke's salamander within the area of the proposed dam footprint and a second new location somewhat upstream of the footprint. Based on sparse historic data and the fact that Van Dyke's salamander is cool-adapted, it may be confined to the coniferous forest landscape of the headwaters, which is currently managed for timber production. However, its cool-adapted characteristics necessitates sampling under cooler conditions, so the temporal pattern of 2014 WDFW terrestrial amphibian surveys likely have an incomplete understanding of its distribution in the Chehalis headwater region.

2.3.2.6 WESTERN POND TURTLE

Current data are lacking on western pond turtle for the basin and the species has not been incidentally recorded either during the WDFW riverscape or oxbow surveys. Based on information to date, the likelihood that western pond turtles exist in side-channel habitats along the main channel of the Chehalis River may be low. Yet, as with the Oregon spotted frog, many oxbows and side-channel habitats along the Chehalis main channel downstream from its confluence with the Newaukum River are unsurveyed for this turtle, essentially all of which are on private lands. Also similar to the Oregon spotted frog, the range of the western pond turtle may be limited by climate or soil conditions that change somewhere along the Chehalis main channel, which creates further uncertainty. The climate/soil limitation is linked to western pond turtle requirements for egg laying in well-drained soils that dry out for periods sufficiently long for successful incubation (Holland 1994).

2.3.2.7 NORTH AMERICAN BEAVER

Current data on North American beaver for the basin are incidental and sparse, but evidence of the beaver exists in a number of at least moderate-sized streams in much of the basin. North American beavers have been reported in oxbow side-channel habitat associated with lower mainstem, in particular, in oxbows (Henning and Schirato 2006; Henning et al. 2006). Most of these incidental data come from culvert assessment reports funded by the Washington State Salmon Recovery Funding Board. In particular, reports of North American beaver activity also exist for Delezene, Eaton, Garrard, and Independence Creeks associated with the middle mainstem Chehalis (Verd 2004a; 2009a), China, Dillenbaugh, Lincoln and Scammon Creeks, tributaries of the upper mainstem Chehalis (Verd 2004b), and Bunker and Stearns Creeks, tributaries of the middle-river Chehalis main channel (Verd 2003). Other reports have incidentally mentioned the North American beaver or its activity in the South Fork Chehalis (Verd 2009b; Verd and Wilson 2003) and Cascades slope portion of the basin (Verd and Wilson 2003). No systematic surveying specifically for the North American beaver has been conducted in the basin.

3 Habitat Factors Limiting Aquatic Species

3.1 Salmonids

Three primary sources of information were used to identify habitat factors that limit salmonids within the basin:

- The work by Smith and Wenger (2001), which identified habitat factors limiting salmonid abundance and production
- The 2004 Chehalis Basin Watershed Management Plan and the Chehalis Basin Salmon Habitat Restoration and Preservation Strategy (the latter was prepared by the Grays Harbor County Lead Entity Habitat Work Group in 2011)
- Results from EDT, which evaluated habitat used by four species of salmon in the basin

This information was reviewed by local experts and was used to help identify appropriate enhancement actions.

3.1.1 SMITH AND WENGER LIMITING FACTORS REPORT

Smith and Wenger (2001) reviewed and rated habitat conditions for salmonids within WRIAs 22 and 23. In addition, they prioritized sub-basins based upon the greatest benefits to salmonids and identified enhancement actions that would likely restore habitat conditions for salmonids. Their results are summarized in Table 40 in their report. In this section, the factors Smith and Wenger identified as limiting salmonids in the basin are described (Table 3.1).

Smith and Wenger concluded that no one factor was responsible for limiting salmonid abundance and production. They noted that salmonid habitat within the mainstem Chehalis River is affected by channel incision, sedimentation, riparian degradation, poor water quality, and reductions in stream flows. Many of these problems are translated to the mainstem from ongoing activities in tributaries. For example, debris torrents in the upper watershed have caused channel incision. In addition, increased sediment load and transport, and the lack of LWM in the channel have exacerbated channel incision within the mainstem. Tributaries contributing large volumes of fine sediments include Satsop, Wynoochee, Newaukum, South Fork Chehalis, and the upper basin. Increased peak flows because of urbanization and changes in land cover have also contributed to poor salmonid habitat conditions within the mainstem.

Smith and Wenger point out that poor water quality, including warmwater temperatures and low DO levels, affects salmonid habitat in the Chehalis River upstream from Porter. Loss of riparian vegetation, increased sediment loads, and decreased stream flows likely contribute to the poor water quality. Livestock wastes and urban stormwater drainage are the primary causes of low DO levels. These factors also limit salmonid habitat conditions within the Wynoochee, Satsop, Wildcat, Independence, Lincoln, Black, Scatter, Skookumchuck, Salzer, Dillenbaugh, Newaukum, Stearns, Bunker, South Fork Chehalis, and upper Chehalis watersheds. Loss of riparian vegetation, lack of LWM, livestock waste, sedimentation, decreased stream flows, industrial inputs, and urban runoff all contribute to the poor water quality in these tributaries.

The authors identified low stream flows and riparian habitat degradation as important factors affecting habitat conditions for salmonids in many tributaries and in the mainstem Chehalis River. Irrigation, power generation, domestic water use, and groundwater withdrawal all affect stream flows in the basin. Riparian degradation is extensive throughout the basin, especially within the Wynoochee, Satsop, Cloquallum, Garrard, Lincoln, Skookumchuck, Newaukum, Salzer, Bunker, and the South Fork Chehalis watersheds. Degradation of riparian habitat affects large wood recruitment to the channel, bank structure and stability, filtering of fine sediments and other chemicals and toxicants, nutrient input, and food for fish.

Smith and Wenger noted that excessive fine sediment delivery is a major problem throughout the basin. Landslides from roads are a major problem in several watersheds and side-cast roads supply sediment to the channels. The authors indicated that none of the watersheds within the basin are rated “good” for road density and that most are rated “poor” according to NMFS standards. The upper Chehalis and Scatter Creek have the highest road densities. Sediment recruitment from bank erosion is common in agricultural and urban areas, especially within the Wynoochee, Satsop, Newman, Porter, Gibson, Black, Skookumchuck, Newaukum, Sterns, South Fork Chehalis, upper Chehalis, Elk, Scammon, Lincoln, Rock, Williams, Workman, and Delezene watersheds. The high levels of sediment coupled with the low levels of large wood result in high fine sediment transport rates. High sediment transport rates lead to channel incision, increased width-to-depth ratios, and reduced habitat complexity.

Finally, Smith and Wenger indicated that loss of floodplain connectivity affects the quality of salmonid habitat, especially for coho salmon that rely heavily on off channels and off-channel rearing areas. Off-channel habitat is limiting in the lower Skookumchuck and Hanaford watersheds, and throughout Newaukum, Satsop, Wynoochee, Wishkah, Hoquiam, Newman, Cloquallum, China, Salzer, and Stearns watersheds. Bank protection, channelization, incision, loss of large wood, and filling and draining of wetlands from urbanization and agriculture have contributed to lost side channels and side-channel habitat. Smith and Wenger (2001) indicated that side-channel habitat is in good condition in the lower Chehalis River (RM 1 to 11 [RKm 1.6 to 17.7]) and that this area should be protected.

Smith and Wenger pointed out that the basin lacks detailed habitat data. They noted that at the time of their work, only eight watershed analyses had been completed, and of those, two were in areas upstream of most anadromous production. Nevertheless, with the help of local citizens and scientists, and available fish and habitat data, they were able to prioritize watersheds with regard to restoration efforts within the basin. The highest priority areas included the estuary, mainstem Chehalis River, Humptulips, Hoquiam, Wishkah, Wynoochee, Satsop, Black, Skookumchuck, Newaukum, and the South Fork Chehalis. Medium priority areas included Johns, Elk River, Cloquallum, Delezene, Rock/Williams, Garrard, Scatter, Lincoln, Elk Creek, and the upper Chehalis River and tributaries (upstream of Pe Ell, Washington). Low priority areas included Newman, Workman, Porter, Gibson, Cedar, Independence, Stearns, Dillenbaugh, Salzer, Bunker, and Rock Creek (near Crim Creek).

Table 3.1
List of Habitat Factors Limiting Salmonid Production Within Each Sub-basin Unit in the Chehalis River Basin

SUB-BASIN UNITS	LIMITING FACTORS	
	SMITH AND WENGER DETERMINATIONS	LEAD ENTITY'S SALMON HABITAT RESTORATION AND PRESERVATION STRATEGY
Wynoochee River	Floodplain habitat; Sediment; Riparian habitat; Stream flows; Water quality	Migration barriers*; Riparian habitat*; Floodplain habitat*; Water quality (temp); Sediment; Habitat diversity (LWM); Stream flows
Satsop River	Migration barriers; Sediment; Channel stability; Riparian habitat; Stream flows; Water quality	Floodplain habitat*; Water quality (suspended sediment)*; Riparian habitat*; Migration barriers*; Sediment*; Stream flows*; Habitat diversity (LWM)
Lower Chehalis Tributaries	Floodplain habitat; Sediment; Habitat diversity; Riparian habitat; Stream flows; Water quality	Migration barriers*; Riparian habitat*; Habitat diversity (LWM)*; Stream flows*; Sediment; Floodplain habitat; Water quality (temp)
Lower Chehalis Mainstem	Floodplain habitat; Sediment; Habitat diversity; Riparian habitat; Stream flows; Water quality	Riparian habitat*; Water quality (temp, DO, fecal coliform)*; Floodplain habitat*; Habitat diversity (LWM); Stream flows; Sediment
Black River	Migration barriers; Floodplain habitat; Sediment; Riparian habitat; Stream flows; Water quality	Water quality (temp, DO)*; Riparian habitat*; Stream flows*; Habitat diversity (LWM); Migration barriers; Floodplain habitat; Sediment
Scatter Creek	Sediment; Channel stability; Riparian habitat; Stream flows; Water quality	Riparian habitat*; Water quality (temp, fecal coliform, pH)*; Stream flows*; Sediment; Migration barriers; Floodplain habitat; Habitat diversity (LWM)
Skookumchuck River	Migration barriers; Floodplain habitat; Sediment; Channel stability; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Floodplain habitat*; Riparian habitat*; Migration barriers*; Stream flows; Water quality (temp, pH, DO, fecal coliform); Sediment; Habitat diversity (LWM)
Newaukum River	Migration barriers; Floodplain habitat; Sediment; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Riparian habitat*; Water quality (temp, turbidity, fecal coliform)*; Stream flows*; Migration barriers*; Sediment*; Floodplain habitat; Habitat diversity (LWM)
Middle Chehalis Tributaries	Migration barriers; Floodplain habitat; Sediment; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Sediment*; Riparian habitat*; Migration barriers*; Floodplain habitat*; Water quality (temp, DO, fecal coliform); Habitat diversity (LWM); Stream flows
South Fork Chehalis	Migration barriers; Sediment; Channel stability; Habitat diversity; Riparian Habitat; Stream flows; Water quality	Riparian habitat*; Sediment*; Migration barriers*; Habitat diversity (LWM); Water quality (pH, temp, DO); Stream flows; Floodplain habitat

SUB-BASIN UNITS	LIMITING FACTORS	
	SMITH AND WENGER DETERMINATIONS	LEAD ENTITY'S SALMON HABITAT RESTORATION AND PRESERVATION STRATEGY
Upper Chehalis	Migration barriers; Floodplain habitat; Sediment; Channel stability; Habitat diversity; Riparian Habitat; Stream flows	Migration barriers*; Sediment*; Riparian habitat*; Habitat diversity (LWM); Water quality (temp, DO); Stream flows; Floodplain habitat

Notes:
Limiting factors from Smith and Wenger (2001) come from their Table 40. Limiting factors from the Lead Entity's Strategy come from their Section 3 (Sub-basin Profiles).
Limiting factors with asterisks (*) are considered Tier 1 Concerns in the Lead Entity's Strategy.
DO = dissolved oxygen
LWM = large woody material

3.1.2 CHEHALIS BASIN SALMON HABITAT RESTORATION AND PRESERVATION STRATEGY

In addition to reviewing the Smith and Wenger (2001) work, the 2004 Chehalis Basin Watershed Management Plan and the Chehalis Basin Salmon Habitat Restoration and Preservation Strategy were also reviewed. The latter was prepared by the Grays Harbor County Lead Entity Habitat Work Group in 2011. This document is valuable because it provides a more recent listing of limiting factors for different sub-basins within the basin. The purpose of the strategy and the major findings within it are summarized Table 3.1 and in the following paragraphs.

The purpose of the strategy is to provide guidance to project planners and funding agencies in developing, evaluating, and implementing salmon habitat restoration and protection actions within WRIA 22 and 23. Importantly, in Section 3 in this report, the strategy identifies limiting factors within sub-basins and provides direction in determining the sequence of habitat restoration and protection projects and activities (Table 3.1). The limiting factors are listed for each sub-basin unit in WRIA 22 and 23. An asterisk (*) identifies which limiting factors are considered Tier 1 Concerns in the strategy. It is important to note that the sub-basin units in Table 3.1 are not identical to those in the Lead Entity's strategy. The strategy includes more sub-basin profiles than are shown in Table 3.1. The sub-basin units shown in Table 3.1 match those used in EDT modeling (see Section 3.1.3).

In general, the limiting factors identified in the Lead Entity's strategy are consistent with those identified in Smith and Wenger (2001; Table 3.1). In some cases, the strategy identified limiting factors that were not identified in Smith and Wenger (2001). For example, the strategy included migration barriers as an additional limiting factor in the Wynoochee and lower Chehalis Tributaries sub-basin units. The strategy also identified floodplain habitat and habitat diversity (LWM) as additional limiting factors in the Satsop River sub-basin unit, and migration barriers, floodplain habitat, and habitat diversity as additional limiting factors in the Scatter Creek sub-basin unit. Finally, the strategy included floodplain habitat as an additional limiting factor in the South Fork Chehalis sub-basin unit and habitat diversity as an additional factor in the Black River sub-basin unit.

3.1.3 ECOSYSTEM DIAGNOSIS & TREATMENT MODELING

EDT has been used to identify limiting factors and to analyze flood reduction and enhancement alternatives in the basin as part of the ASEP. The EDT model encompasses the entire basin upstream from and including the Wynoochee sub-basin (Humptulips, Hoquiam, and Wishkah sub-basins are not in the current EDT model). Conditions were described in more than 1,300 reaches including obstructions throughout the system. Conditions in the sub-basins were derived from available literature, surveys and expert knowledge and are described in a report written by Mobrand Biometrics, Inc. (2003). Conditions in the mainstem reaches were based on snorkel surveys conducted by WDFW in 2013, evaluations as part of the basin flood hazard mitigation analysis (Normandeau Associates 2012a, 2012b), and Hydrologic Engineering Center River Analysis System (HEC-RAS) modeling of flow, channel width, and temperature (Anchor QEA 2012b, Appendices A and C). Conditions in each reach were evaluated for life stages and sub-populations of coho salmon, fall-run and spring-run Chinook salmon and winter-run steelhead.

To identify limiting factors, two scenarios were evaluated in EDT: the current condition and a reference condition that is intended to capture the intrinsic characteristics of the system in the absence of anthropogenic constraints. As noted previously, EDT modeled estimates of intrinsic habitat potential assumed current survival rates in the Chehalis River downstream from the Wynoochee, Grays Harbor and the ocean. EDT was then used to conduct a “splice analysis” in which conditions for the reference condition were spliced into the current condition to record the change in model performance at a sub-population scale. Attributes were then ranked in regard to the change in sub-population abundance for each salmon species after the splice.

3.1.3.1 RESULTS: ALL SALMON SPECIES MODELED USING EDT

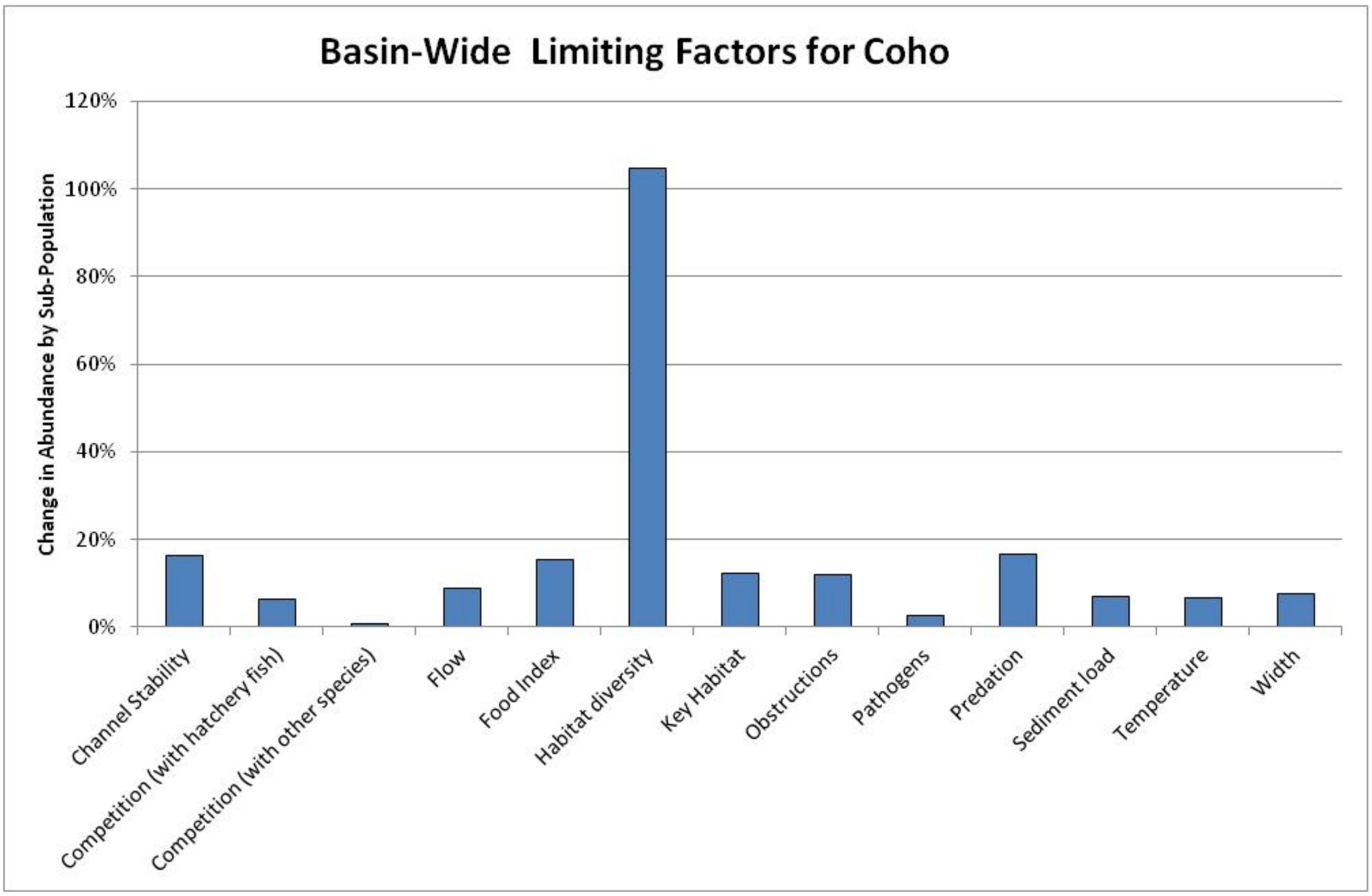
While each sub-basin in the Chehalis River had unique conditions that were evaluated for each species, commonalities exist. In general, habitat potential for upper basin sub-populations was more limited by habitat conditions compared to lower basin sub-populations. The lack of habitat diversity is a pervasive limiting factor throughout the basin. Despite the relatively recent large floods and observations of extensive movement of trees and wood throughout the system during these events, lack of LWM is a striking feature of the basin. Predation tends to be a more important factor in the lower Chehalis River because of warmer temperatures and the presence of numerous native and non-native piscivorous fish species and American bullfrogs. Warm temperatures and sedimentation are also limiting factors. Channel Stability is also frequently a top-ranked attribute for all species. This is a function of artificial confinement of the channel and bed scour (a condition that can in part be linked to the general lack of large wood in the system).

Limiting factors for each species are summarized in the following text in a basin-wide context. Limiting factors broken out by sub-basins are included in Appendix E.

3.1.3.1.1 Coho Salmon

Coho salmon limiting factors at the scale of the basin are shown in Figure 3.1. Habitat Diversity is the top-ranked limiting factor for coho salmon in all sub-basins in the Chehalis River. This attribute is tied to the amount of LWM that adds structure and diversity to stream environments. For all sub-populations, the restoration of LWM to the reference condition resulted in a substantial increase in coho salmon abundance in the model. Predation is one of the top-ranked attributes in lower Chehalis sub-populations reflecting the number of introduced species and warmwater temperatures that elevate predator activity. Channel stability, related to the amount of artificial confinement and access to floodplain habitat, is important as well especially for coho salmon that disperse downstream from the tributaries.

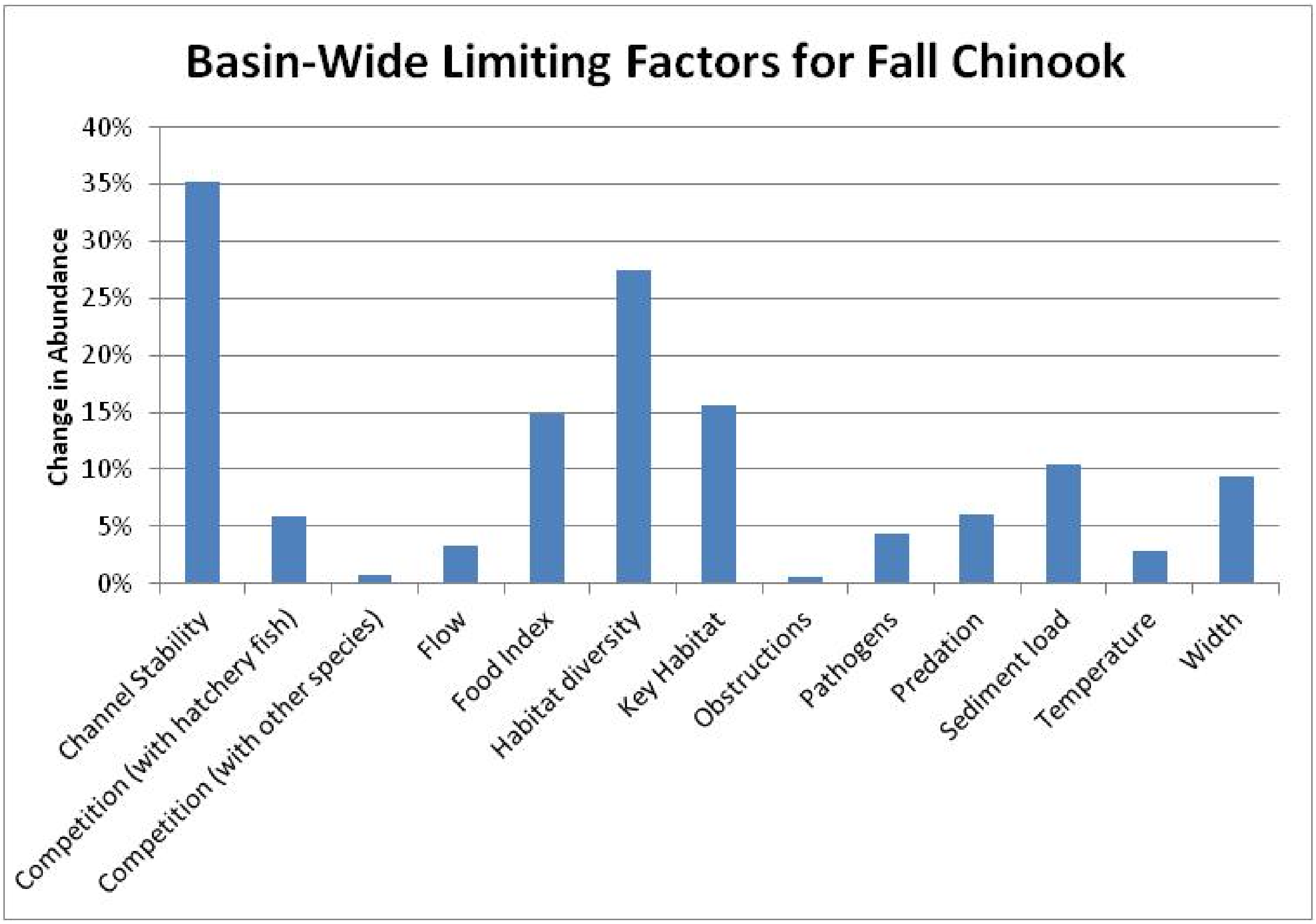
Figure 3.1
Limiting Factors for Coho Salmon Across the Chehalis Basin



3.1.3.1.3 Fall-run Chinook Salmon

Fall-run Chinook salmon sub-populations were limited by a more diverse set of attributes, although habitat diversity remains a highly ranked attribute (Figure 3.2). Channel Stability is the top-ranked limiting factor for these fish at the basin scale. This reflects the pervasive lack of floodplain access and artificial confinement in the system. The decreased importance of Habitat Diversity relative to Coho salmon reflects the shorter portion of the life history during which fall-run Chinook salmon rear in freshwater compared to a full year of freshwater rearing for Coho salmon. Similarly, Key Habitat and channel width are important limiting attributes due to the narrowing of many systems due to artificial confinement especially in the lower stream reaches favored by fall-run Chinook salmon. Obstructions were a minor limiting factor for fall-run Chinook salmon because of their distribution in lower stream reaches.

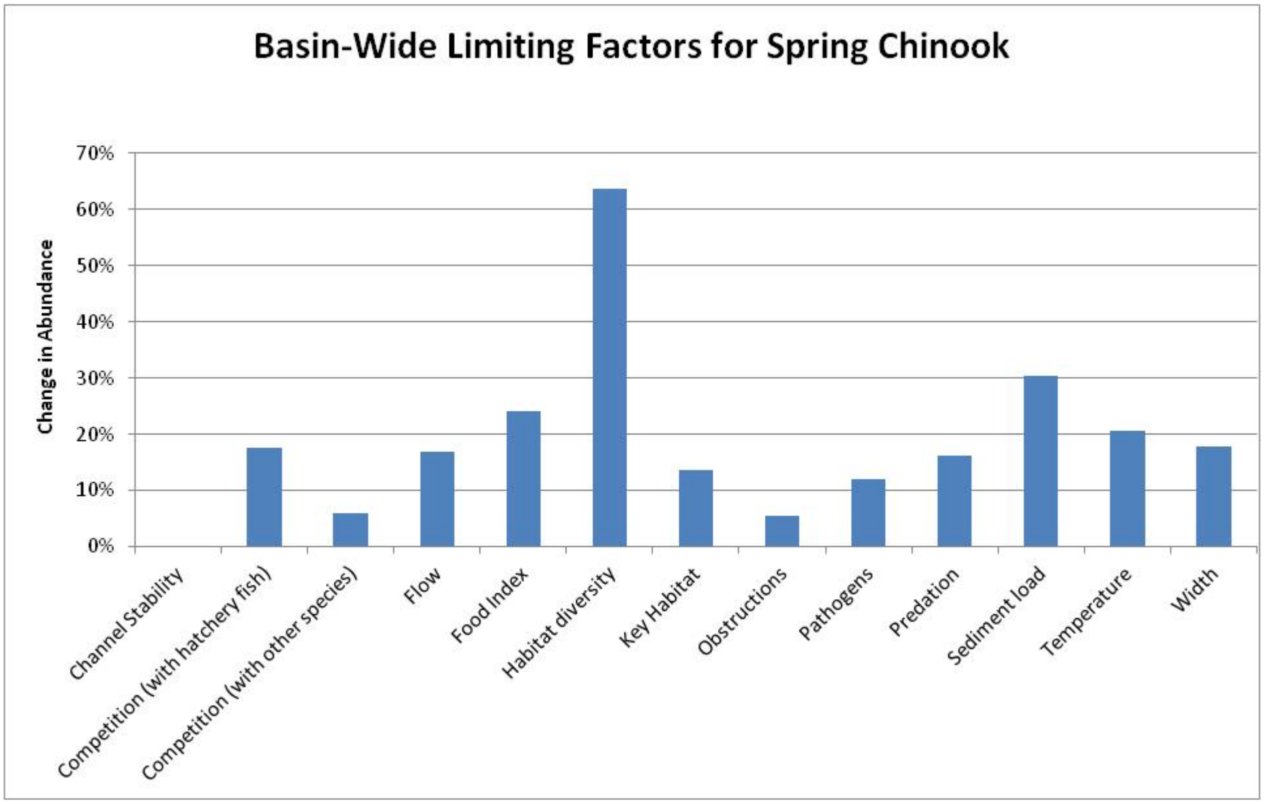
Figure 3.2
Limiting Factors for Fall-run Chinook Salmon Across the Chehalis Basin



3.1.3.1.5 Spring-run Chinook Salmon

Lack of Habitat Diversity was the top ranked limiting factors for spring-run Chinook salmon throughout the basin (Figure 3.3). Temperature was ranked higher for these fish than other species reflecting the fact that adult spring-run Chinook salmon must find areas with suitable temperatures to hold during the summer prior to spawning in the fall. Obstructions were more important for spring-run than for fall-run Chinook salmon because of their greater distribution in upper reaches of watersheds where culverts are more prevalent.

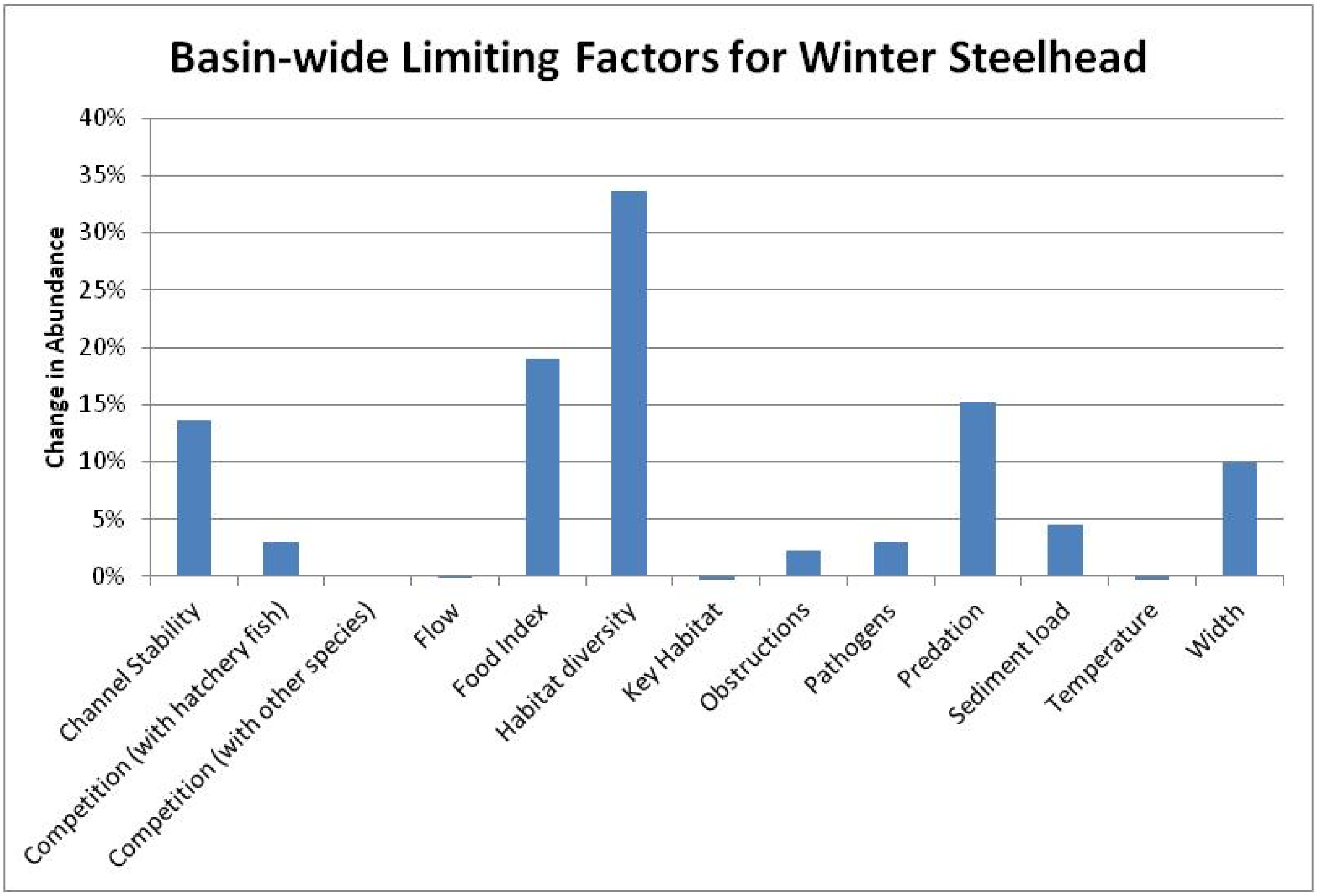
Figure 3.3
Limiting Factors for Spring-run Chinook Salmon Across the Chehalis Basin



3.1.3.1.6 Winter-run Steelhead

Habitat Diversity and Food were the top-ranked limiting factors for winter-run steelhead in the basin (Figure 3.4). In general, most attributes had lesser limiting effects on these fish compared to other species. This is a function of the wide tolerances of steelhead for habitat conditions. Predation was also a key limiting factor at the basin scale.

Figure 3.4
Limiting Factors for Winter-run Steelhead Across the Chehalis Basin



3.1.4 LIMITING FACTORS SUMMARY

Similar to Smith and Wenger (2001) and the Lead Entity work, EDT identified the following as primary limiting factors for salmonids in the basin:

- Migration barriers
- Riparian degradation
- Water quantity and quality (flows and temperature)
- Sedimentation
- Channel complexity and stability (lack of wood)
- Loss of floodplain habitat/connectivity

All three sources (Smith and Wenger report, the Lead Entity work, and the EDT model) were very similar in their findings. Pervasive as limiting factors throughout the basin are a lack of channel structure (e.g., lack of wood, channelization, loss of floodplain connectivity), water quality (e.g., temperature, flow), lack of wood in general (i.e., currently in stream and also natural recruitment via riparian input), sedimentation, and barriers.

3.2 Other Fish Species

Determining which resource requirements are limiting to a population or specific life stage requires knowledge acquired through either field surveys to establish population size and trends over time, or possibly experimentation. Determining whether a population is abundant under current or equilibrium conditions is still limited by ecological constraints requires some combination of experimental or monitoring studies where a potentially limiting factor is varied. Monitoring studies generally require several generations to see how a population responds to varied conditions, even for a single potentially limiting factor. Consequently, definitive determination of limiting factors for Other Fish Species is challenging.

For the Other Fish Species, little information is available to inform population trends and determine whether populations are being limited by ecological constraints. Much of the available information on these species is limited or anecdotal. For other species such as some culturally important salmonids, monitoring data are available. Therefore, an inventory of habitats in the basin is needed for key non-salmonid species to identify overall population trends, habitat preferences, and habitats that should be preserved.

All fish need a sufficient quantity of living space of suitable water quality, structure, and connectivity for each life history stage, as well as food and oxygen. Besides DO, other aspects of water quality include temperature, concentrations of dissolved and suspended materials and chemicals (both natural and artificial), and salinity; any aspect of water quality has a range of values that are tolerated or required by different species and these ranges differ among species. Living space structure includes volume (cubic feet or cubic meters), bed material (mud, sand, gravel, cobble, boulder, bedrock, or some combination), bed shape (including large wood accumulations, vegetation, pool and riffle forms, and bank angle and material), and current velocity. The amount of living space varies with the size and life stage of a fish; young, small fish can live in much less space than a large adult fish. *Connectivity* means the ability of a fish to go where it needs to go in order to complete its life history (including avoidance of excessive inbreeding), or access to food or life requirements that come from another waterbody. Connectivity is conditional on season and life history. Different fish species and life stages specialize on different types of food sources, thereby reducing interspecific competition and allowing several species to live together. Oxygen is generally available in Chehalis River Basin waters in sufficient concentration that it is rarely limiting, but high concentrations of decaying organic material and high temperature can reduce water's ability to hold DO and can deplete DO during the decay process, particularly when surface aeration is reduced (e.g., deep water, slow current, little wind, and low gradient).

Further adding to the difficulty of identifying limiting factors are the interactions of potential limiting factors and complex life histories of some fishes. For example, what might be an adequate food supply at one water temperature may be inadequate, and thus limiting, at a different temperature. Additionally, limiting factors are a function of both magnitude and duration of effects.

Given these caveats, available information on each of the species listed in Table 3.2 was reviewed. This information and best professional judgment were then used to identify potential limiting factors for the various species.

Table 3.2
Habitat Requirements and Possible Limiting Factors for Other Fish Species Analyzed

SPECIES	LIFE-STAGE	HABITAT REQUIREMENTS	POSSIBLE LIMITING FACTORS
Pacific lamprey	Adult spawning	Gravel substrate at pool tails and in riffles	Living space with suitable coarse, silt-free substrate—sufficient current velocity is key to maintaining silt-free substrate
Pacific lamprey	Larvae	Silty backwater along mainstem reaches and tributaries	Depositional area protected from high velocity current; these are successional habitats, but changes in sediment transport (deposition and flushing) could change rate of succession and/or change connectivity among habitats
White sturgeon	Feeding adults	Lower mainstem pools	Living space with sufficient depth, including marine access—this species is not strongly dependent on the Chehalis River Basin but is thought to move into the river from Grays Harbor to forage, possibly for freshwater mussels; no known spawning or rearing in the Chehalis Basin; migration upstream can be to upstream from the Black River.
Chum salmon	Spawning	Gravel substrate at pool tails and in riffles	Freshwater limiting factors for chum salmon are largely restricted to spawning and incubation, with flood scour and superimposition (crowding) being the two factors most likely limiting them; spatial range includes reaches up to the Black River; chum salmon can use a diversity of spawning habitat water depths and channel size
Eulachon	Spawning	Located primarily in the lower Basin and dependent on sand and pea-sized gravel for spawning	Freshwater limiting factors for eulachon are largely restricted to river conditions and spawning, with lack of appropriate substrate the most likely limiting factor; Eulachon are present in the Wynoochee and Satsop rivers; once juveniles emerge from the substrate, they are flushed out with flow
Speckled dace	Adults	Mainstem pools	Living space with suitable coarse silt-free substrate—sufficient current velocity is key to maintaining silt-free substrate; in the absence of any studies on limiting factors, living space is the most likely limiting factor
Speckled dace	Spawning	Gravel substrate at pool tails and in riffles	Living space with suitable coarse silt-free substrate—sufficient current velocity is key to maintaining silt-free substrate
Largescale sucker	Adults	Mainstem pools; there is a close association of largescale suckers and mountain whitefish	Living space with suitable coarse silt-free substrate might be a limiting factor for these long-lived fish – sufficient current velocity is key to maintaining silt-free substrate
Largescale sucker	Spawning	Pool tailouts with less specific substrate	Similar hydraulic and substratum needs to rainbow trout and other smaller-bodied salmonids
Largescale sucker	Fry	Silty backwater habitats on the mainstem and in tributaries	Require depositional areas protected from high velocity current during summer; these are successional habitats, but changes in sediment transport (deposition and flushing) could change the rate of succession and/or change connectivity

SPECIES	LIFE-STAGE	HABITAT REQUIREMENTS	POSSIBLE LIMITING FACTORS
Reticulate sculpin	All life stages	Mainstem pools	Living space with suitable coarse silt-free substrate may be a limiting factor—sufficient current velocity is key to maintaining silt-free substrate
Riffle sculpin[1]	All life stages	Silty backwater habitats on the mainstem and in tributaries	Vegetated depositional areas protected from high velocity current; these are successional habitats, but changes in sediment transport (deposition and flushing) could change rate of succession and/or change connectivity; access to cooler water temperatures could also be limiting
Olympic mudminnow	All life stages	Oxbow lakes and side-channel marshes	Maintain water level while minimizing invasion by non-native predators; potential impacts to their habitats are similar to those listed for previous habitats; non-native predators (primarily bass) are believed to be a major limiting factor
Largemouth bass (non-native predator)	All life stages	Oxbow lakes and side-channel marshes	Side-channel, low-velocity habitats with abundant food sources
Smallmouth bass (non-native predator)	All life stages	Mainstem and side-channel	Moderately low-velocity habitats with abundant food sources (somewhat colder-adapted than largemouth bass)

Note:

1. Historically, riffle sculpin habitat probably included more Olympic mudminnow, which may be rare now in the Chehalis Basin because of predation.

3.3 Non-fish Species

The following sections describe the habitat factors within the basin thought to be limiting for the seven Non-fish Species identified for this analysis. Through coordination with WDFW (Hayes 2014b), limiting factors were identified based on a review of existing information that represents a crosswalk among each species habitat requirements (information that is mostly extra-Chehalis in nature) and data that represent the best estimate of habitat conditions, albeit often at a coarse level, within the Chehalis system. As indicated in the companion *Data Gaps Report*, data within the Chehalis system on the distribution of Non-fish Species, particularly in the side-channel habitats associated with the floodplain of this river's main channel, is the largest data gap. This gap needs to be addressed to understand what is actually limiting these species (and a number of Other Fish Species) in this system and structure meaningful enhancement objectives and effective enhancement plans. That said, the descriptions here are based on the available data. A summary of putative habitat limiting factors per species and the sources of additional information for the analysis are presented in Appendix E, Table E-5.

3.3.1 NORTHERN RED-LEGGED FROG

The primary habitat limiting factors in the basin for northern red-legged frog appear to be the presence of warmwater non-native species that prey on northern red-legged life stages in their side-channel aquatic breeding habitat and lack of sufficient area of upland forest adjacent to suitable aquatic breeding and rearing habitat. The former is based on the data from a handful of oxbows and side-channel habitats from WDFW surveys in 2013 and work in the lower Chehalis (Henning 2004; Henning and Schirato 2006) indicating that these are often rich in warmwater non-native species, and field and experimental work elsewhere indicating these non-native species may have negative effects (Kiesecker and Blaustein 1997, 1998; Kiesecker et al. 2001; Adams et al. 2003; Adams and Pearl 2007; Adams et al. 2011). In the Chehalis, non-native species that have been identified as potential predators of northern red-legged frog include bluegill (*Lepomis macrochirus*), yellow perch (*Perca flavescens*), smallmouth bass (*Micropterus dolomieu*), brown bullhead (*Ictalurus nebulosus*), and American bullfrog (*Lithobates catesbeianus*). The importance of upland forested habitat being close to aquatic breeding habitat is based on the combination of recent work demonstrating the area of forested uplands adjacent to aquatic breeding habitat appears to be an important control on northern red-legged frog population size (WDFW, unpublished data) and that adult northern red-legged frogs spend most of each year in upland forested habitat within the seasonal migration distance (up to several kilometers) of the aquatic breeding habitat (Hayes et al. 2008). Land use in the basin appears to have undergone conversion from upland forest to other uses, particularly agriculture, especially within seasonally migration areas adjacent to breeding habitat that adult northern red-legged frogs typically utilize. As indicated in the *Data Gaps Report*, examination of historical aerial photography is needed to verify the basis of this limitation.

3.3.2 WESTERN TOAD

The primary habitat limiting factors in the basin for western toad appear to be lack of suitable side-channel low-flow habitat (suitable meaning shallow and open [typically unvegetated] areas for breeding and rearing), which results in part from the presence of non-native vegetation such as reed canarygrass in aquatic habitats (reed canarygrass forms dense monocultures that eliminate suitable breeding and rearing habitat for the species), and lack of upland prairie habitat adjacent to aquatic habitat.

In the Chehalis floodplain, suitable breeding habitat for western toad may be limited to the in-stream main channel, where open shallow stillwater habitat appears seasonally during the declining hydrograph. This supposition is based on the observation that the few side-channel habitats examined in 2013 during WDFW fish surveys revealed no western toads and very little suitable breeding habitat, and western toad reproduction was exclusively recorded in-stream in the main river channel. In addition, though the western toad tadpoles are generally regarded as unpalatable (Peterson and Blaustein 1991), evaluation of unpalatability has only addressed a small portion of the potential predators (Gunzberger and Travis 2005). Hence, as riverscape surveys have demonstrated that the downstream main channel of the Chehalis is predator rich, western toads could also be limited to upstream portions of the mainstem by the aquatic predator suite. Additionally, breeding habitat reliability is important for western toad because the species displays high breeding site fidelity, that is, they deposit eggs in in the same general location every year.

Similar to the northern red-legged frog, habitat complementarity between western toad breeding habitat and their upland non-breeding season habitat is critical except that in the case of the toad, the uplands need to be an open terrestrial habitat, such as prairie. Western toads disperse from their breeding habitat into their upland habitat at distances from 500 meters to more than 2 kilometers. Agricultural land use can provide the equivalent open conditions (lacking tree and shrub vegetation) found in prairie, but many agricultural fields have regular seasonally disturbance that may limit western toad use. In the Chehalis system, patterns in prairie habitat mapped imply that that habitat has become historically restricted by agriculture; this restriction and its magnitude would need verification using historical aerial photographs.

3.3.3 OREGON SPOTTED FROG

The primary habitat factors limiting Oregon spotted frogs in the basin includes the presence of non-native warmwater predators that prey on Oregon spotted frog life stages, the presence of non-native invasive vegetation, and in selected situations, the lack of open canopy adjacent to aquatic habitat that provides excessive shading.

Oregon spotted frog is identified as more vulnerable to non-native warmwater non-native predators introduced to the West, such as American bullfrog and various fish species (sunfishes, yellow perch, basses, and bullhead catfishes). This is because, as a species, with an entirely aquatic life cycle, its life stages have much more opportunity for contact with these predators. As mentioned previously, side-channel habitats in the Chehalis floodplain appear to be warmwater non-native predator rich and are the only stillwater habitats large enough to have Oregon spotted frog potentially present. Non-native, invasive vegetation, especially reed canarygrass that can locally form monocultures in habitat suitable for Oregon spotted frogs, can limit breeding for this species (Kapust et al. 2012). Observations at the few oxbows examined in the Chehalis floodplain during WDFW fish surveys of these habitats revealed that reed canarygrass dominates the shallow margins of those habitats, and may reflect a widespread condition in this system.

3.3.4 COASTAL TAILED FROG

The primary habitat limiting factor in the basin for coastal tailed frog appears to be lack of in-stream LWM, which largely reflects lack of older seral stages of upland coniferous forest across the headwaters of this basin. Observations along much of the main channel Chehalis indicate a wood-limited condition, so it is assumed that this condition translates to the headwater areas of this system as well; however, fieldwork to verify the reality of this condition has not been conducted. LWM that is key in forming stable step-pool habitat in medium to small streams can be important feature to maintaining breeding and rearing habitat for coastal tailed frog (Jackson et al. 2007), but the magnitude of its importance in Chehalis headwaters is not known as coarse inorganic substrates may also be key for step-pool formation in such habitat.

Higher water temperature, sediment loading, and the quality of adjacent upland habitat conditions for over-wintering may also limit coastal tailed frog, although these factors are poorly understood and research is needed to draw firm conclusions. Despite the potential negative effects of forestry practices, this species frequently occurs in many young forests that have been harvested one or more times in the past. Sensitivity to timber harvest may depend on its interaction with surface geology and local hydrology, and research will be needed to disentangle the basis of any limitation.

3.3.5 VAN DYKE'S SALAMANDER

The primary habitat limiting factors in the basin for Van Dyke's salamander may be lack of stream-proximate riparian habitat with limited disturbance and lack of LWM in large diameter classes. Van Dyke's salamanders appear to occur very close to stream channels. Unpublished research indicates that up to 90% of Van Dyke's salamanders remain within about 13 feet (4 meters) of wetted stream edges. As a consequence, alterations to riparian habitats proximate to streams have the potential to harm Van Dyke's salamander, but this remains unstudied.

Habitat requirements for Van Dyke's salamander also probably includes the need for LWM in larger size classes, that is, 50 centimeters (19.7 inches) in diameter or larger, as most of the few nests of this species that have been found were in LWM of these size classes (e.g., Blessing et al. 1999). Moreover, LWM in intermediate decaying classes is most closely associated with the species, likely not only for the nesting habitat it provides, but for foraging and refuge habitat as well. As a consequence, LWM in various stages of decay should be maintained near stream systems, which reflects a need for older seral stage coniferous forests that provide the sources of LWM in the appropriate size classes.

Van Dyke's salamanders, which are stenotherms (i.e., organisms which tolerate a narrow range of temperature), are only active near-surface during the cooler times of the year, may also benefit when the habitat of stream corridors and riparian areas have enough shade to maintain relatively low, stable substrate temperatures.

Unaltered riparian corridors along streams, especially in headwater areas along first- to third-order streams where this species is anticipated in Chehalis headwater areas, should be maintained. Stream-edge upland buffers would likely benefit this species, which as a cool-adapted stenotherm may also be more vulnerable to the temperature effects of climate change than other species.

3.3.6 WESTERN POND TURTLE

The primary factors likely to limit habitat for western pond turtle in the basin include warmwater non-native predators in the focal stillwater habitats they use, limited upland nesting habitat because existing prairie habitat is degraded by presence of non-native, invasive vegetation or disturbed by agricultural activities, and lack of basking habitat in the focal stillwater habitats they use due to limited LWM. Currently, impediment to understanding potential limiting factors for western pond turtle is lack of data on side-channel habitats along the main channel of the Chehalis River within the basin, a pattern previously described for other side-channel habitat utilizing species. Moreover, whether western pond turtles are still present in side-channel habitats along the main channel of the Chehalis River is unknown.

Western pond turtle hatchlings are vulnerable to non-native warmwater predators, but especially American bullfrogs and largemouth bass (Holland 1994). Research also suggests that hatchling turtles are more vulnerable to bullfrogs than other warmwater predators (Holland 1994). Based on WDFW surveys of a handful of side-channel habitats along the middle Chehalis River main channel, both American bullfrogs and warmwater non-native fishes appear to be common in those habitats.

Western pond turtles nest in open terrestrial habitat, and typically nest and travel within 1312 feet (400 meters) of stream or open stillwater habitat used for rearing (Holland 1994). Marginal riparian vegetation must also not be so dense that it impedes movement between those habitats (Holland 1994). Depending on location in the basin, open prairie habitat adjacent to stream or stillwater habitat that might be used for rearing appears to be either lacking or degraded due to the presence of non-native invasive vegetation, such as Scotch broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus armeniacus*) or agricultural activities that deter nesting. This perspective is based entirely on coupled cursory observations from aerial photography and ground-truthing.

Basking sites for western pond turtles may also be limiting in side-channel habitat or shallow open water habitat. The supposition is based on the limitation of LWM in the Chehalis system, not on data showing that LWM is sparse in side-channel habitat potentially used by turtles. Basking sites typically comprise LWM of sufficient size, so riparian forest of sufficient maturity is needed to generate LWM of the appropriate size range to create basking sites.

3.3.7 NORTH AMERICAN BEAVER

As indicated earlier, existing information on North American beaver within the basin is limited to anecdotal records in streams and side-channel habitats. Data are entirely lacking about the factors that may be limiting to the North American beaver. In general, factors limiting the North American beaver elsewhere typically include the quality of riparian habitat, notably the presence of trees, especially selected deciduous trees and shrubs, within the riparian habitat (Allen 1983). North American beavers frequently prefer deciduous trees, such as cottonwoods (*Populus* spp.) and willow (*Salix* spp.), over alternative food sources (Allen 1983). Gathering basic information both on where beavers exist and on habitat parameters important to the North American beaver within the basin would provide the perspective on potential limiting factors for the species needed to direct potential enhancements for the North American beaver in this system.

3.4 Discussion

For salmonids and most Other Fish Species, each sub-basin in the Chehalis system has unique conditions that create different combinations of limiting factors for each species, but commonalities exist. Additionally, while information about many of the Other Key Fish Species' specific individual limiting factors is minimal, some general observations regarding limiting factors probably apply to all Key Fish Species.

Barriers are probably a limiting factor to many fish species as they limit the available area for life functions. In general, the upper basins were more limited by habitat conditions compared to lower basins. The lack of habitat diversity in river channels is a pervasive limiting factor throughout the basin. Lack of LWM is a frequent condition throughout the basin due to the widespread lack of riparian buffers of the age (size) and species for LWM recruitment. Predation, a notable limiting factor for native fish species, tends to be more important in-stream in the lower Chehalis because of warmer temperatures and the presence of numerous non-native, and native, piscivorous fish species. Whether a similar pattern exists for native fish species in side-channel habitats is suspected, but unexamined. Channel stability is also frequently a limiting factor for all fish species, along with sedimentation. These latter limiting factors largely reflect artificial confinement of the channel and the lack of connectivity to floodplains.

For Non-fish Species, limiting factors are less known, but some similarities also appear to exist. Lack of suitable riparian habitat appears to be limiting for all Non-fish Key Species. Predation due to non-native species is a limiting factor in common for several Key native Non-fish Species, notably the stillwater-breeding amphibians and the turtle utilizing side-channel habitat. However, predation by non-native species may also limit selected native fish and western toads in in-stream main channel of the Chehalis River. Lack of complementary habitats also appears to be limiting factor for the stillwater-breeding amphibians and the turtle. However, the species needs of complementary habitats differ.

Lastly, wood limitation in the Chehalis system may have important secondary and long-term effects. Large wood is critical to channel-forming processes (Watershed Geodynamics and Anchor QEA 2014), so the existing limitation of large wood may be limiting the processes that create side-channel habitat. If that is the case, the current off-habitat landscape may already be on a declining trajectory, which would affect the entire suite of side-channel dwelling species. An understanding of where the system exists on this trajectory will be necessary to inform how much positive effect specific restoration projects can provide under differing circumstances.

4 Ecosystem Model and Analytical Framework

4.1 Introduction

A premise of the ASEP is that actions affect the physical environment that forms habitat for species and creates the emergent properties of the ecosystem. Therefore, the primary focus of the analytical framework and its component models is habitat—how it is used by species, how it is created and maintained in the Chehalis River system, and how enhancement actions and climate may affect it in the future.

The ASEP analytical framework is depicted in Figure 4.1. Questions about how enhancement actions (and other factors analyzed in ASEP) may affect aquatic species that are identified. Action hypotheses about how these actions may affect species are developed, and translated into potential changes in physical conditions and processes. Drawn from published scientific information, action hypotheses are conceptual models of how actions are expected to change the physical environment. The action hypotheses point to attributes affected by actions and the amount of physical change expected from those actions.

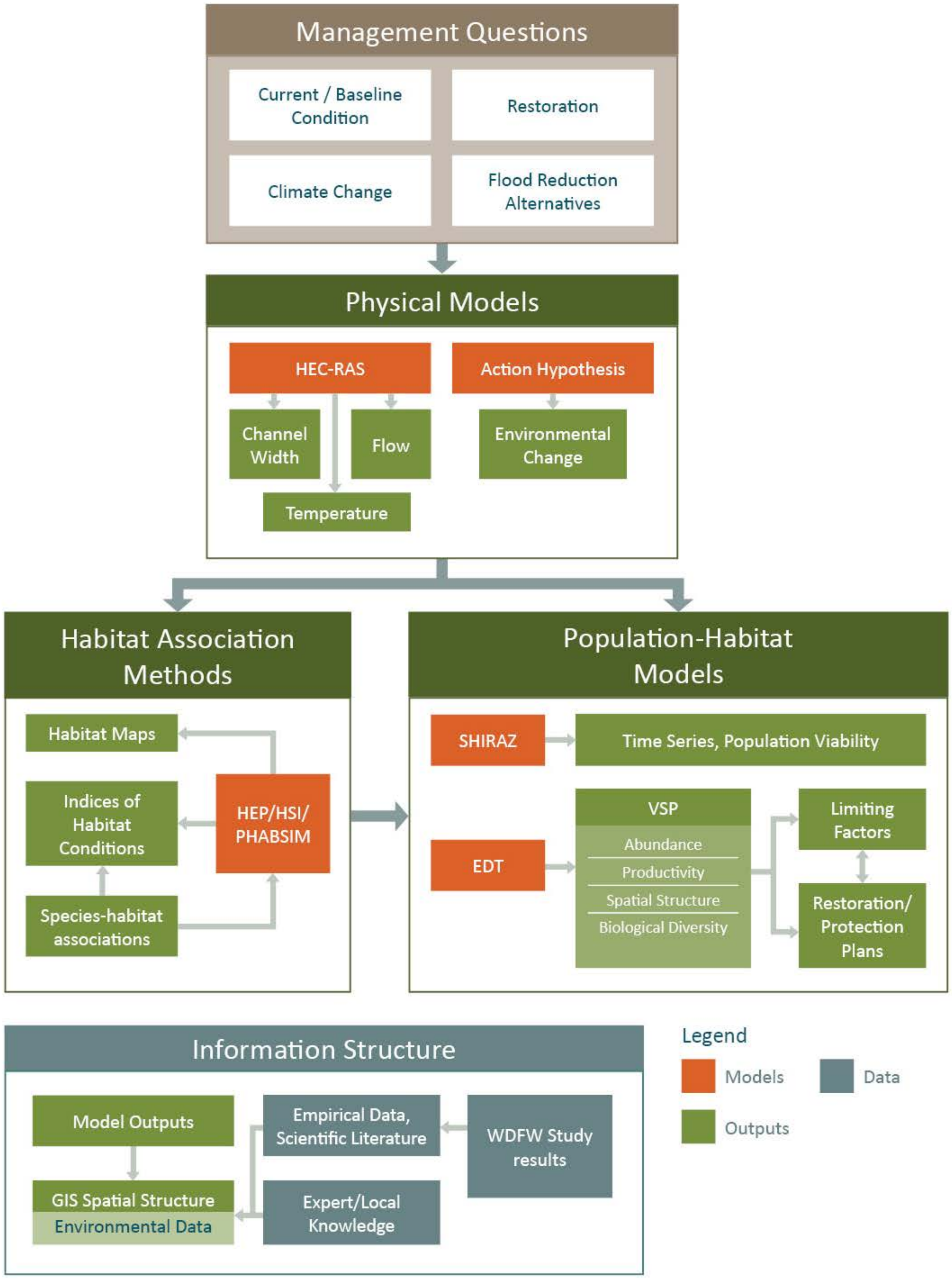
Changes in physical process are then evaluated for their potential effect on aquatic species and guilds through a series of habitat-association and population models. Outputs include changes in habitat, population parameters such as abundance and productivity, and factors limiting the productivity of habitat to support aquatic species. The result of the analytical framework is insight into how the Chehalis watershed operates as a biological and physical system and the ecological outcomes that can be expected from various management actions.

The biological effects of these environmental changes were evaluated using the best available information for each Key Species analyzed to represent a guild. This evaluation resulted in both quantitative and qualitative models being used to relate habitat characteristics to species distribution, occurrence, or abundance. The following three categories of models were used:

- Salmon habitat-population models:
  - EDT: Spring- and fall-run Chinook salmon, coho salmon, and winter-run steelhead
  - SHIRAZ: Spring-run Chinook salmon, coho salmon, and winter-run steelhead
- HSIs, which provide the structure needed to model in PHABSIM:
  - Chum salmon, Pacific lamprey, white sturgeon, smallmouth bass, largemouth bass, and western toad
- Correlative models:
  - Eulachon, Olympic mudminnow, speckled dace, largescale sucker, riffle sculpin (*Cottus gulosus*), reticulate sculpin, Dunn's salamander, Van Dyke's salamander, coastal tailed frog, northern red-legged frog, Oregon spotted frog, and North American beaver

Thus, habitat enhancement actions and climate change scenarios were assessed across a wide array of species, environments, and ecological processes.

Figure 4.1
The ASEP Analytical Framework for the Chehalis River



Notes:
EDT = Ecosystem Diagnosis & Treatment
HEP = Habitat Evaluation Procedure
HSI = Habitat Suitability Index
PHABSIM = Physical Habitat Simulation
VSP = Viable Salmonid Population

All model-based studies require assumptions about the starting condition of the attributes being modeled (e.g., habitat, population dynamics, and migration characteristics). Each of the assumptions can influence model outcomes in ways that can lead to over- or under-estimating the actual condition of the response being modeled. As pointed out by Hilborn and Mangel (1997), models are descriptions of nature, and there can never be a “correct” model, but there may be a “best” model. Also, a great deal of science is based on inductive inference, where conclusions about the past are extrapolated into the future to forecast or predict how a population might respond to changing conditions (Anderson 2008).

The ASEP modeling studies, therefore, were acts of inference. For example, in applying the EDT model to the basin, ASEP modelers developed conceptual models or hypothesis about how the system functions and parameterized the EDT model using available data and in a manner consistent with the conceptual model. The modelers then tested how the system may respond to various alternatives (i.e., habitat enhancement and future climate scenarios) using the parameterized model.

When interpreting ASEP model results, it is important for decision makers to understand how assumptions made about how salmon will respond to changes in habitat conditions in the basin may affect model outcomes. The companion report titled *Effects of Flood Reduction Alternatives and Climate Change on Aquatic Species* summarizes assumptions made on the potential effects of flood reduction alternatives and future climate variability on aquatic resources, and combinations of these alternatives. Assumptions made for the ASEP are identified in the text of the report.

4.2 Modeling Biological Effects

The biological effects of the changes captured in the physical models were evaluated using the three categories of biological models described previously. These ranged from quantitative models that predict a population’s response to changes in habitat conditions, to species-habitat associations models, and finally to simple correlations (e.g., presence/absence information).

Population-habitat models relate habitat conditions to a quantitative measure of species performance such as fish abundance. To make quantitative conclusions, population habitat models require physical data (empirical, derived from other models or expert knowledge) and biological knowledge of species-habitat relationships, life history, and population structure. Two different population-habitat models developed for the basin system were used in ASEP analyses: EDT and SHIRAZ. Use of two models allows some comparison and more confidence in the conclusions of the models when both models project similar outcomes. However, only EDT was used in the ASEP. SHIRAZ was used in the companion report *Effects of Flood Reduction Alternatives and Climate Change on Aquatic Species*.

The EDT model is a habitat model for salmonids that has been used in many systems throughout the Pacific Northwest, including the basin. It evaluates habitat at a stream reach scale; the basin EDT model encompasses the entire basin upstream of the Wynoochee River.

The EDT model uses a mathematical basis (the disaggregated Beverton-Holt stock recruitment relationship) and various relationships to relate habitat to fish performance. EDT provides a detailed analysis of habitat limitations at various life stages and reach scales for each species, as well as sub-population in the Chehalis. EDT captures the variability in habitat conditions across the basin and was used in this manner to identify habitat limiting factors (see Section 3) and the effects of actions taken to address these factors (see Section 5).

Species-habitat associations used included simple, qualitative, depictions of associations between species and their habitats. The HSI models are more formal representations of habitat associations that compute an index of suitability of modeled conditions for species. These can range from models based on detailed experiment to models based on best professional judgment; in the Chehalis they were used for species for which data were limited and were employed as input to Physical Habitat Simulation (PHABSIM) models to evaluate probable influence of hydrological changes to some of the less studied aquatic species. These models have fewer data requirements than quantitative population-habitat models and are available for a number of species. SI is a flexible approach allowing a wide range of certainty and uncertainty in data and knowledge. HSI is not always independent of life history and can be highly quantitative though in most applications HSI models rate habitat for a life stage or a species. n these analyses, HSI models were used for key aquatic and terrestrial species with more limited biological information available to use to evaluate action hypotheses. In some cases they compute an index of suitability without reference to species life history, in which cases the results of HSI models cannot be related to VSP parameters, limiting factors or population management goals. In the ASEP, HSI models were used for key aquatic and terrestrial species with limited biological information to evaluate the action hypotheses.

The final types of models used were correlative models, which relate the observed presences of a species to values of environmental variables at sites. Many Key Species in the Other Fish and Non-fish Species groups have too little information available regarding their distribution and life histories to allow for a detailed description of their use of the basin. To begin to address this poorly known information, indices describing differences in the amount of floodplain inundated under different peak flows were developed. These provided a qualitative measurement of the magnitude and direction (positive, negative, or no change) of response for macrohabitat guilds and species associated with those guilds.

Development of the analytical framework resulted in a range of qualitative and quantitative models that are now available for use beyond the present Project.

5 Identifying Actions to Address Habitat Limiting Factors

5.1 Introduction

A key task of the ASEP is to identify actions that address the limiting factors identified in Section 3 and to estimate the benefits of the actions on Key Species. The focus of the effort is on salmonids because of the abundance of data for salmon species, coupled with the lack of data for many of the Other Fish and Non-fish Species and because of the cultural and economic importance of salmon.

Two steps were undertaken to develop the habitat enhancement actions modeled under the ASEP. First, a list of proposed enhancement projects for the basin was compiled from the Project Information System (PRISM) database maintained by the Washington State Recreation and Conservation Office and the Habitat Work Schedule. The Habitat Work Schedule is a habitat restoration project mapping and tracking database for Washington State's Salmon Recovery Lead Entities and their partners (Appendix D). This list was used to identify the specific off-channel projects discussed later in this chapter, and more generally to assist in identifying the types of enhancement projects that habitat restoration experts believe are needed in the basin and their locations. Second, in addition to the background research completed and summarized previously, detailed knowledge of the basin and input on salmon enhancement actions was obtained from local experts familiar with each sub-basin during a three-day salmon restoration workshop. The workshop was held in late March 2014 to identify the types and locations of restoration projects that would best address limiting factors for salmon. Invitations to the workshop were sent to representatives from state and federal agencies (WDFW, Washington Department of Natural Resources, Ecology, Washington State Department of Transportation [WSDOT], NMFS, USFWS, U.S. Department of Agriculture), tribes (Chehalis and Quinault), local conservation agencies (Lewis, Thurston, and Mason County Conservation Districts), conservation organizations (Trout Unlimited, The Nature Conservancy, Wild Fish Conservancy), the ASEP technical committee, and various representatives from the Chehalis Lead Entity organization. The workshop was organized by sub-basin, as evaluated in EDT, to allow for experts to attend those sub-basins for which they had the most expertise.

For each sub-basin, results from the EDT analysis and direct discussions during the workshop about the locations and types of actions with the most effect on Key salmon species were used to identify the primary limiting factors. In the EDT model, the basin is divided into 1,378 separate reaches. The characteristics of the in-channel habitat for salmon attributed to each EDT reach were used to identify the limiting factors for each sub-basin (see Section 3).

Some enhancement actions were basin-wide actions, such as barrier removal. Others were discussed in general terms, but in terms of specific reaches of a sub-basin where they were needed. These include riparian buffers, placement of structures in the channel, and floodplain reconnection. The notes from the 3-day workshop are included in Appendix F. The following were the most common habitat enhancement actions identified in the workshop:

- Remove or improve barriers to fish passage (culverts)
- Riparian enhancement, restoration, and preservation

- In upper areas where forestry practices are dominant
  - Reduce sediment delivery/proper road abandonment
  - Longer cut rotations, than the current 35 years
- In lower areas where agriculture and development are affecting the rivers
  - Purchase farms
  - Plant riparian areas
  - Add in-water wood structure: site specific depending on geomorphology and need
  - Install sediment trapping structures
  - LWM placement
  - Install in-stream log cribs
  - Floodplain re-connection
  - Potentially reconnect oxbows in specific areas that will not exacerbate invasive predator issues
  - Remove levees
  - Allow river to move within the floodplain
- Education of the benefits of enhancement actions to select agencies and the public

Subsequent to the 3-day workshop, a two-day workshop was held with additional WDFW staff to further refine the types of enhancement actions and locations of the actions to be modeled. During this meeting, it was decided that enhancement actions should focus on the lower reaches and in spring-run Chinook salmon habitat, since the habitat of this species is the most impaired, and this species is the least abundant salmon species in the basin. This species is also highly important to the Chehalis Tribe, who fish on the species and celebrate the arrival of this, the first salmon adults to enter the river each year (Secena, pers. comm. 2014). At the two-day meeting it was decided that additional actions should focus on increasing channel complexity and introducing more wood into the system. Subsequent conversations resulted in the specific actions of restoring, enhancing, and/or preserving riparian areas in spring-run Chinook salmon habitat, placing LWM within spring-run Chinook salmon habitat, and identifying the location of two areas to re-connect side-channel habitat with a focus on Other Fish and Non-fish Species.

The results of these workshops were also compared to the enhancement actions identified by the Lead Entity for the basin. The Lead Entity adopted seven strategies, all equal in value, for addressing the most pressing limiting factors identified within the sub-basins of WRIAs 22 and 23. Salmon habitat projects and activities must meet one or more of these strategies for inclusion on the Habitat Project List for Salmon Recovery Funding Board consideration. These guiding strategies are as follows:

- Attain a healthy and diverse population of wild salmonids.
- Restore, enhance, and protect the Grays Harbor Estuary.
- Restore and preserve properly functioning riparian areas.
- Restore habitat access.
- Restore properly functioning hydrology.
- Restore floodplain and stream channel function.
- Prioritize habitat projects and activities within sub-basins that provide the highest benefit to priority stocks.

In Section 3 of the strategy, the Lead Entity describes a conceptual model for sub-basin profiles (Grays Harbor Lead Entity 2011). The goal of the conceptual model is to identify short- and long-term voluntary restoration and protection actions that improve or protect natural processes within sub-basins that create healthy habitat for salmonids. In Table 2 in the strategy, the Lead Entity identifies the different kinds of limiting factors in WRIAs 22 and 23 and describes their effects on physical processes and salmon. In addition, for each sub-basin profile, they assign each limiting factor to one of three tier concerns. Tier 1 Concerns represent the most pressing limiting factors affecting the viable salmonid population parameters of abundance, productivity, diversity, and spatial structure. The preference of the Lead Entity is that Tier 1 Concerns would be first in line for implementation, because of their potential effect in providing the greatest benefit to fish. Tiers 2 and 3 follow in the same vein, although decreasingly reduced in priority because of their lesser benefit to fish. The strategy notes that, even though Tier 1 Concerns will scientifically render the greatest benefit to fish, community values may not always endorse them as a priority. In some sub-basins or along certain reaches, it may be possible only to implement Tier 2 and 3 general recovery actions. The results of the workshops and the Lead Entity's results and focus are very similar in their desire to focus on the limiting factors most pressing viable salmonid populations.

To the extent possible, the enhancement actions identified in the salmon habitat workshop were also evaluated for their potential effect on Other Fish and Non-fish Species. Because far less is known about these species, the qualitative assessment that was completed to identify any potential effect of the salmon enhancement actions represents the best interim effort, and one that should be improved after more comprehensive data are obtained on these species, especially in side-channel habitats. In many cases where data are particularly limited, the best professional judgment of WDFW experts was used.

It should also be noted that besides restoring habitat, reestablishing chum salmon populations could result in productivity benefits to multiple species through the delivery of marine-derived nutrients to aquatic ecosystems.

More detail regarding how the enhancement actions were modeled, where they were modeled, and the assumptions used is presented in the following sections under each enhancement action.

5.2 Salmonid Enhancement Actions

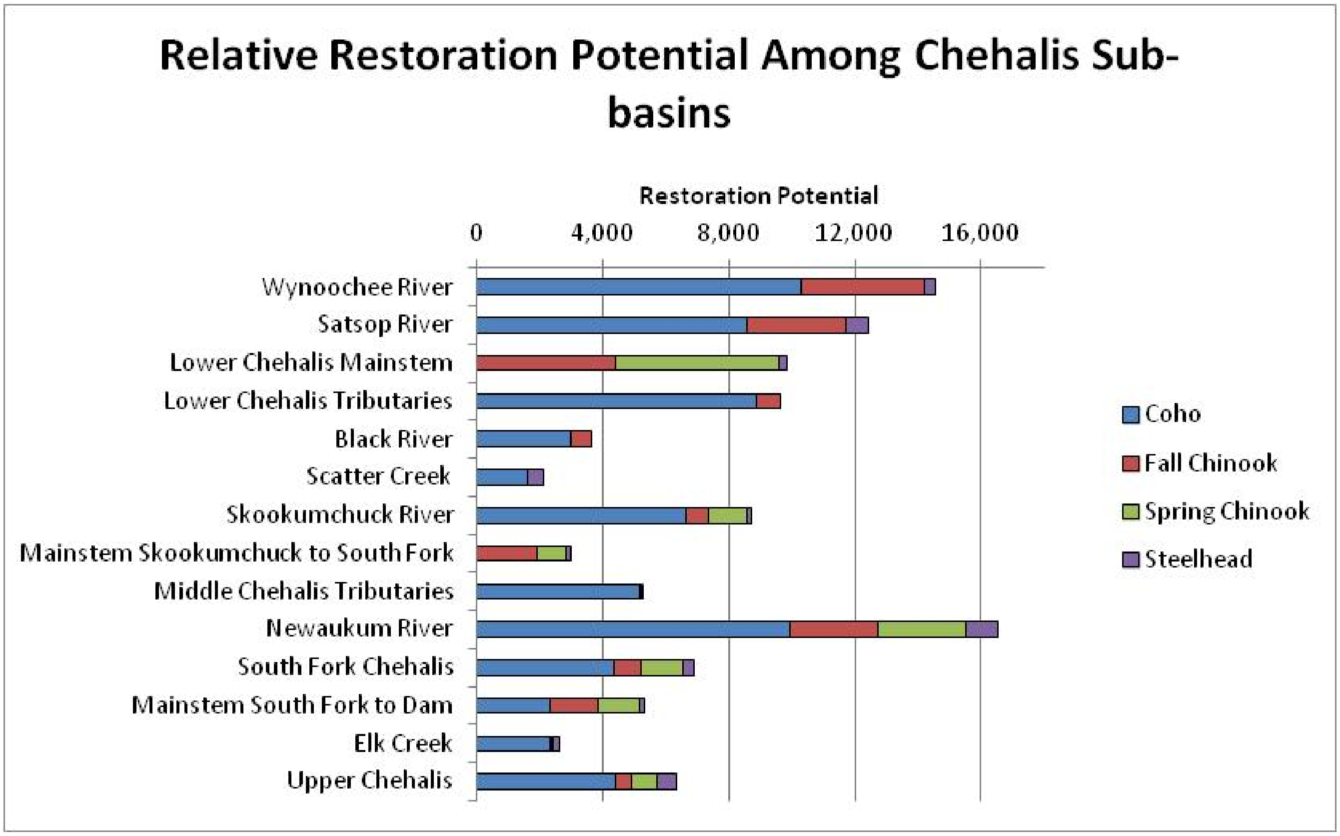
Three general types of enhancement actions for salmon were evaluated using the EDT model: culvert removal, maturation of riparian areas in managed forests (MFs), and other actions in the non-managed forest (NMF) lands. The other primary actions taken in the NMF lands were riparian establishment (i.e., planting riparian buffers, land acquisition, conservation easements), installing LWM within the channel, and floodplain reconnections.

5.2.1 RESTORATION POTENTIAL

Restoration potential refers to the difference between the current potential of the habitat to support a species in a sub-basin and the potential of the habitat for the species in its intrinsic condition as modeled in EDT. Restoration potential is a re-casting of the habitat impairment results presented in Section 3 in a way that focuses on relative restoration priorities across sub-basins. Restoration potential is influenced by the size of the sub-basin, the intrinsic potential of the habitat for the species, and the degree of impairment of the current habitat condition. Comparison of the restoration potential between species and sub-basins across the basin provides a road map for restoration activities based on the underlying environmental condition and species biological needs. The analysis asks the question *Where does restoration have the greatest potential to benefit species in the Chehalis basin?* A similar question could be asked for each sub-basin to compare restoration at a reach-scale, though that has not been done in this analysis.

A comparison of restoration potential for all four modeled salmonids across the fourteen Chehalis sub-regions in the EDT model is shown in Figure 5.1. Overall, the Newaukum sub-basin had the greatest cumulative restoration potential. The Newaukum has relatively high potential for all four species and has important habitat impairment that could respond to habitat restoration activities. The Skookumchuck sub-basin also emerged as a sub-basin with high restoration potential across all four species. The Wynoochee and Satsop sub-basins have high restoration potential primarily due to their large potential capacity for coho salmon. Note that the restoration prioritization in Figure 5.1 assumes a base condition similar to the current condition of the watershed. A shift in future climate conditions due to climate change could affect these results.

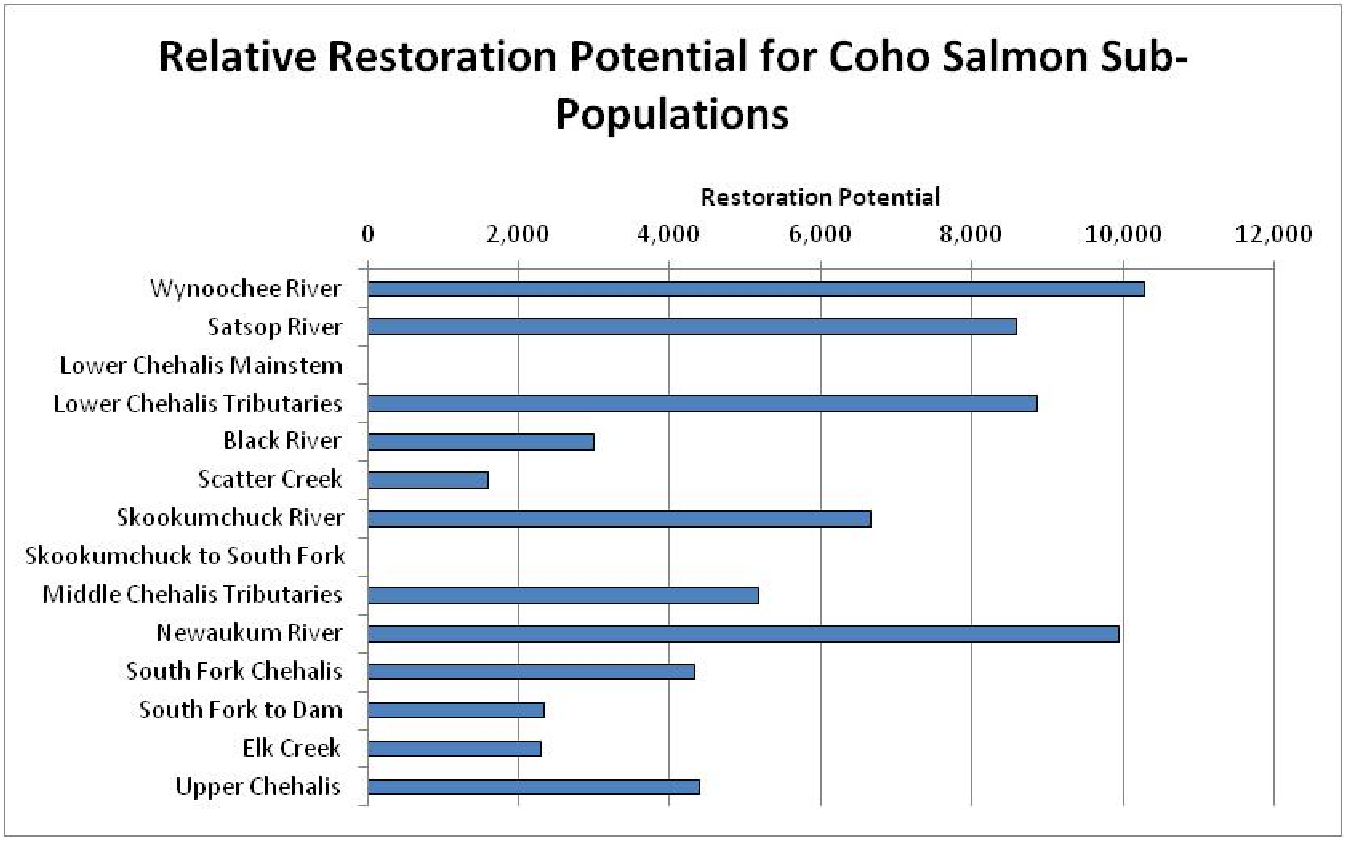
Figure 5.1
Restoration Potential by Sub-basin



Note: Restoration potential is measured in number of fish individuals.

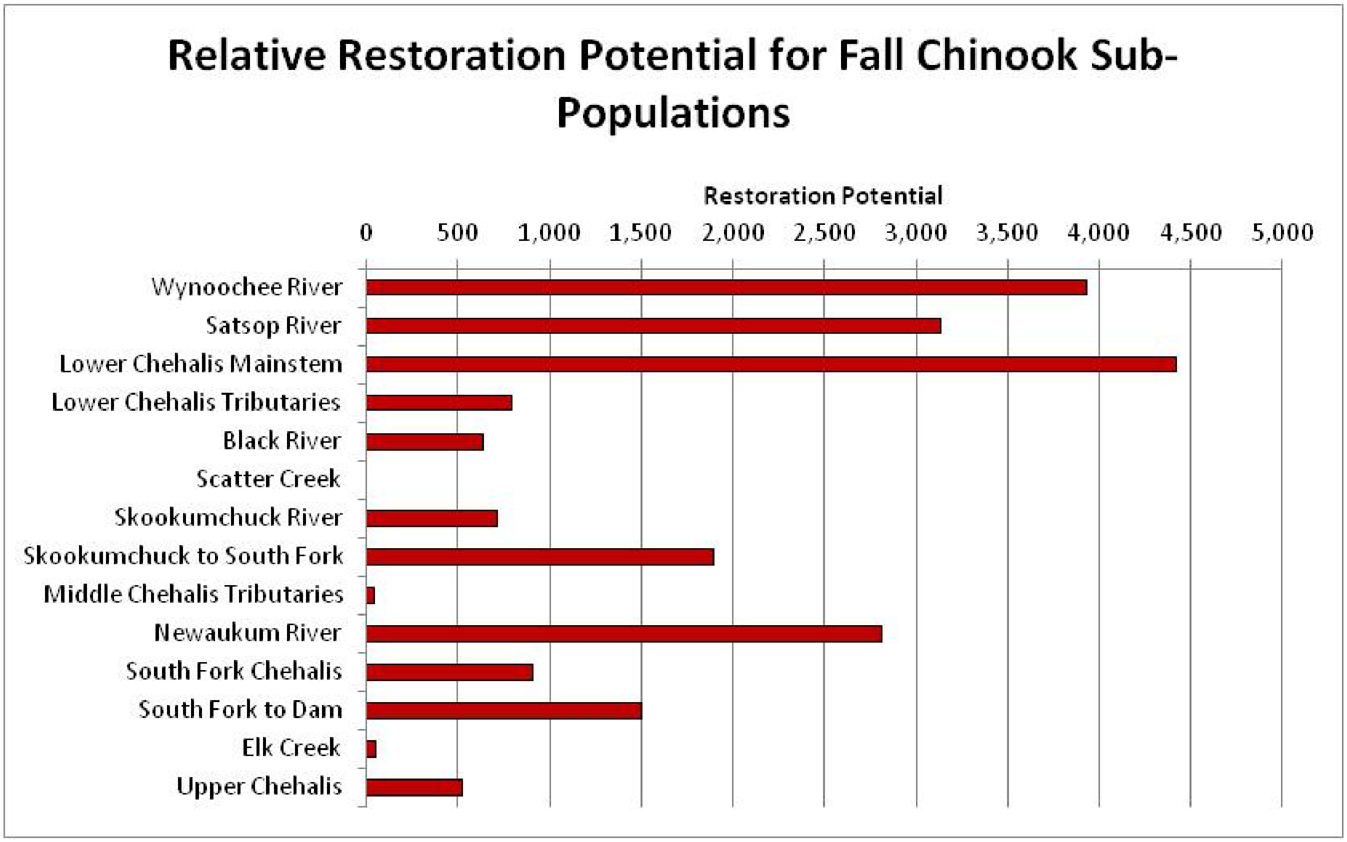
Figure 5.2 illustrates the restoration potential of each basin for Coho. Similarly, Figures 5.3, 5.4, and 5.5 illustrate the restoration potential for each basin for fall-run Chinook, spring-run Chinook, and steelhead, respectively. These figures identify which basins have the highest restoration potential for each species. As shown in Figure 5.2, enhancement actions taken in most sub-basins, other than the lower Chehalis mainstem and Chehalis mainstem from Skookumchuck to the South Fork would have a positive effect on coho salmon. This is likely a reflection of the fact that coho are prevalent throughout the basin. The sub-basins with the greatest restoration potential for fall-run Chinook are the Wynoochee, Satsop, lower Chehalis Tributaries, Skookumchuck and Newaukum (Figure 5.3). The lower Chehalis mainstem and Newaukum are also the sub-basins with the highest restoration potential for spring-run Chinook (Figure 5.4). This is a reflection of these species being present primarily lower in these sub-basins. The lower Chehalis mainstem and Newaukum also have high restoration potential for steelhead (Figure 5.5).

Figure 5.2
Restoration Potential for Coho Salmon by Sub-basin



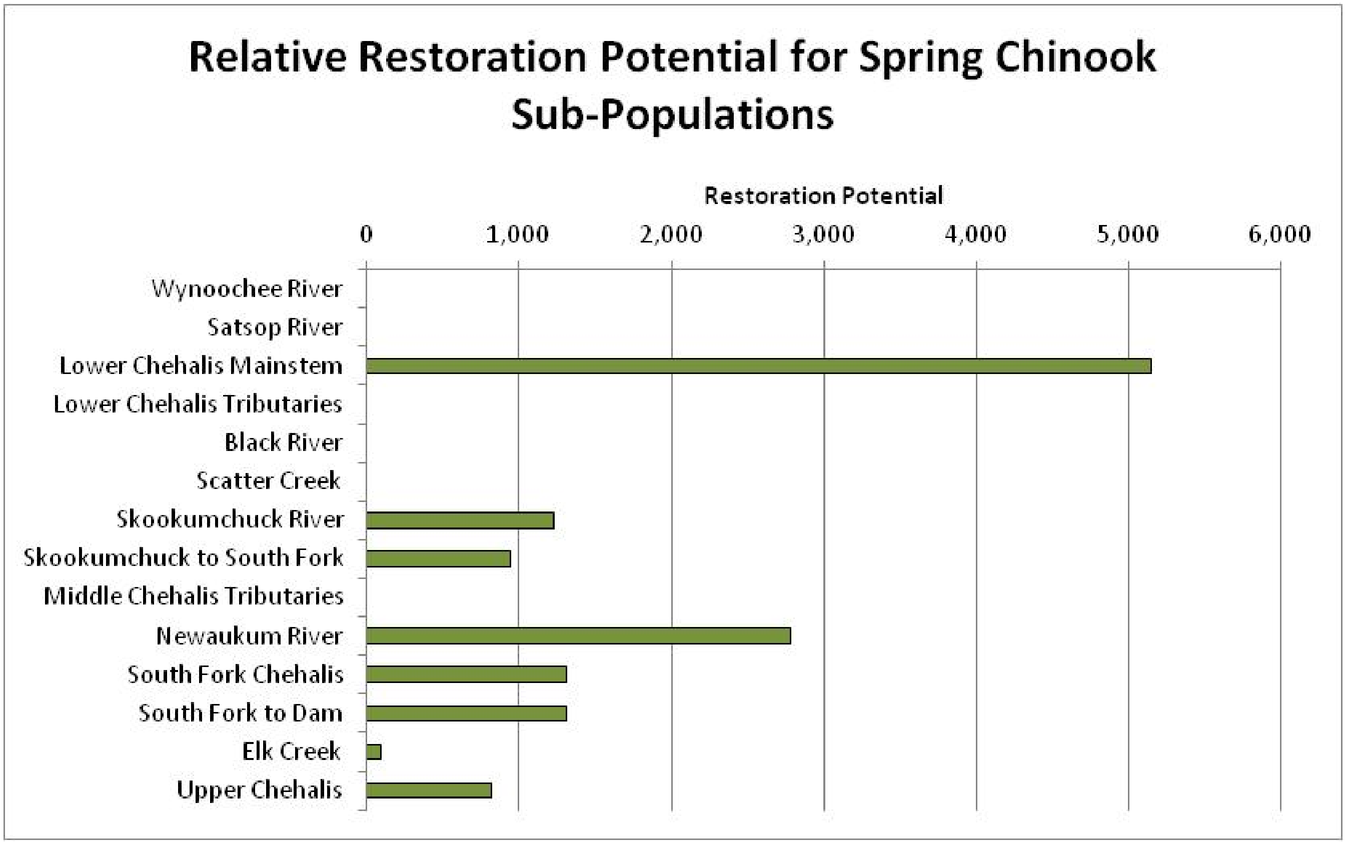
Note: Restoration potential is measured in number of fish individuals.

Figure 5.3
Restoration Potential for Fall-run Chinook Salmon by Sub-basin



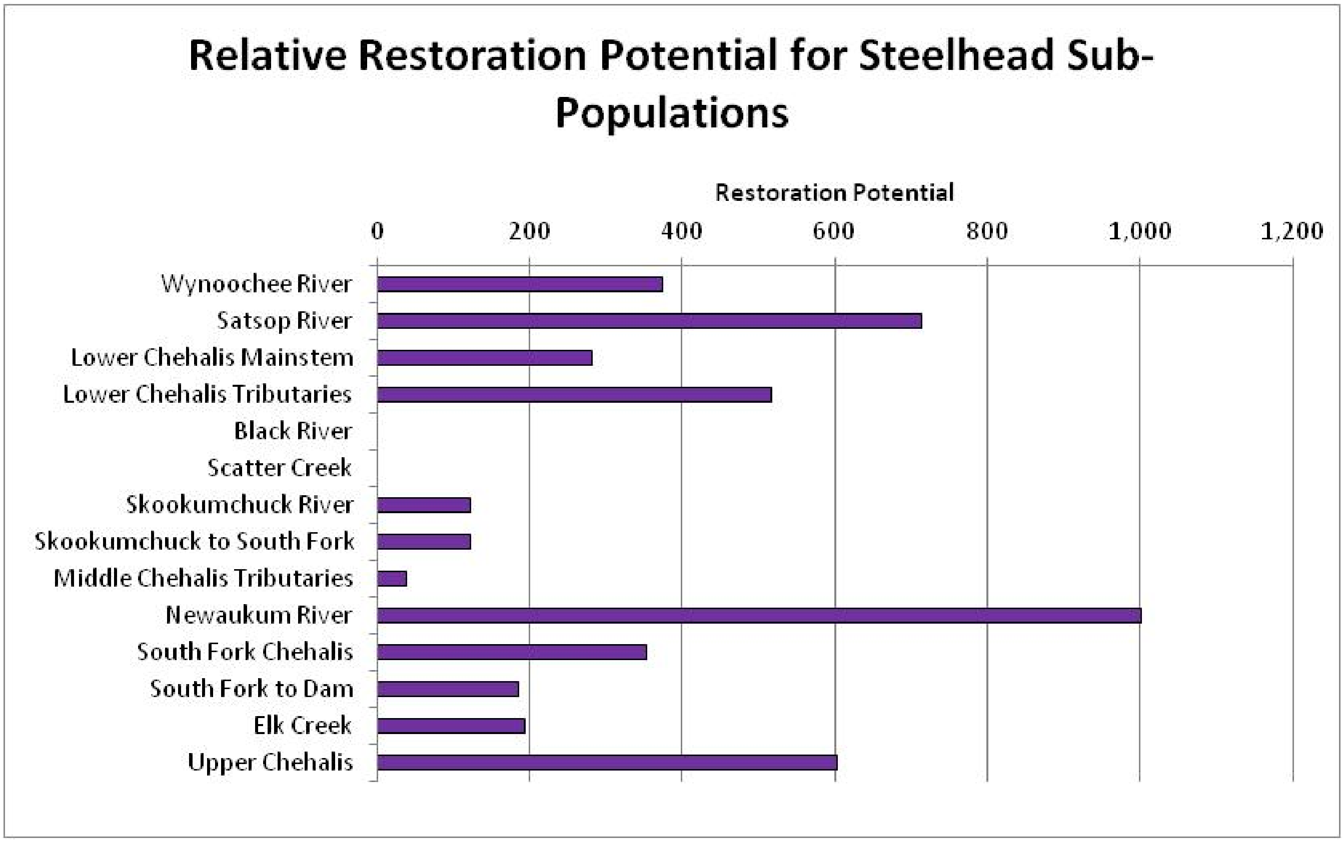
Note: Restoration potential is measured in number of fish individuals.

Figure 5.4
Restoration Potential for Spring-run Chinook Salmon by Sub-basin



Note: Restoration potential is measured in number of fish individuals.

Figure 5.5
Restoration Potential for Steelhead by Sub-basin

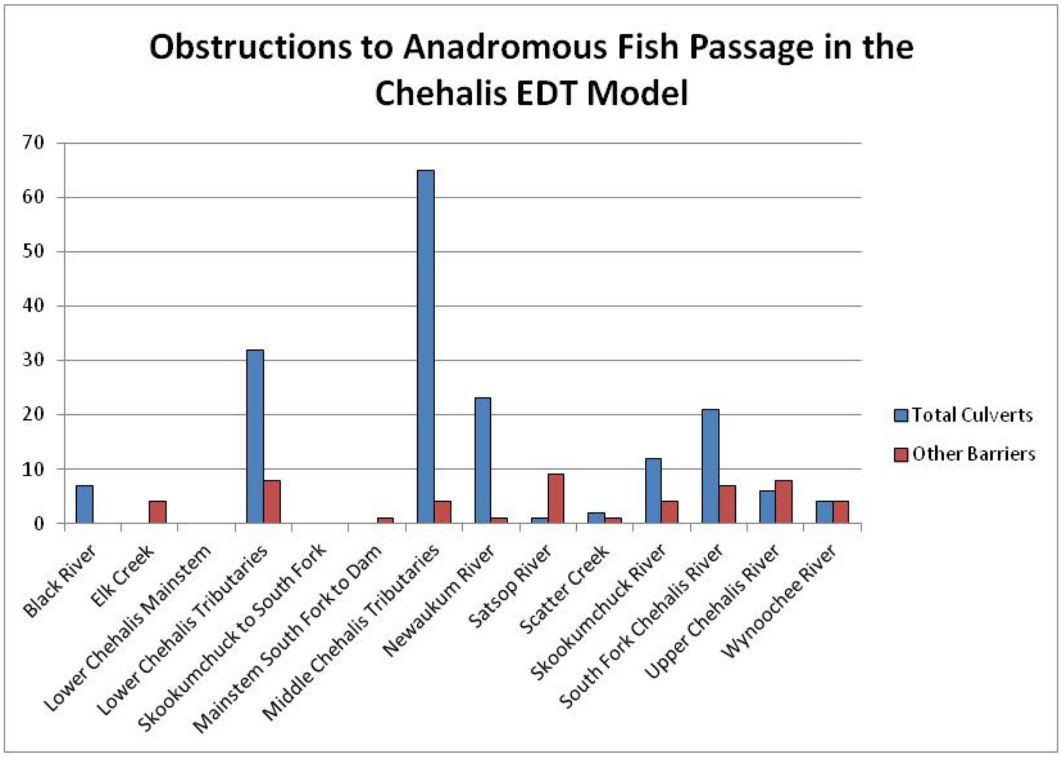


Note: Restoration potential is measured in number of fish individuals.

5.2.2 CULVERT REMOVAL

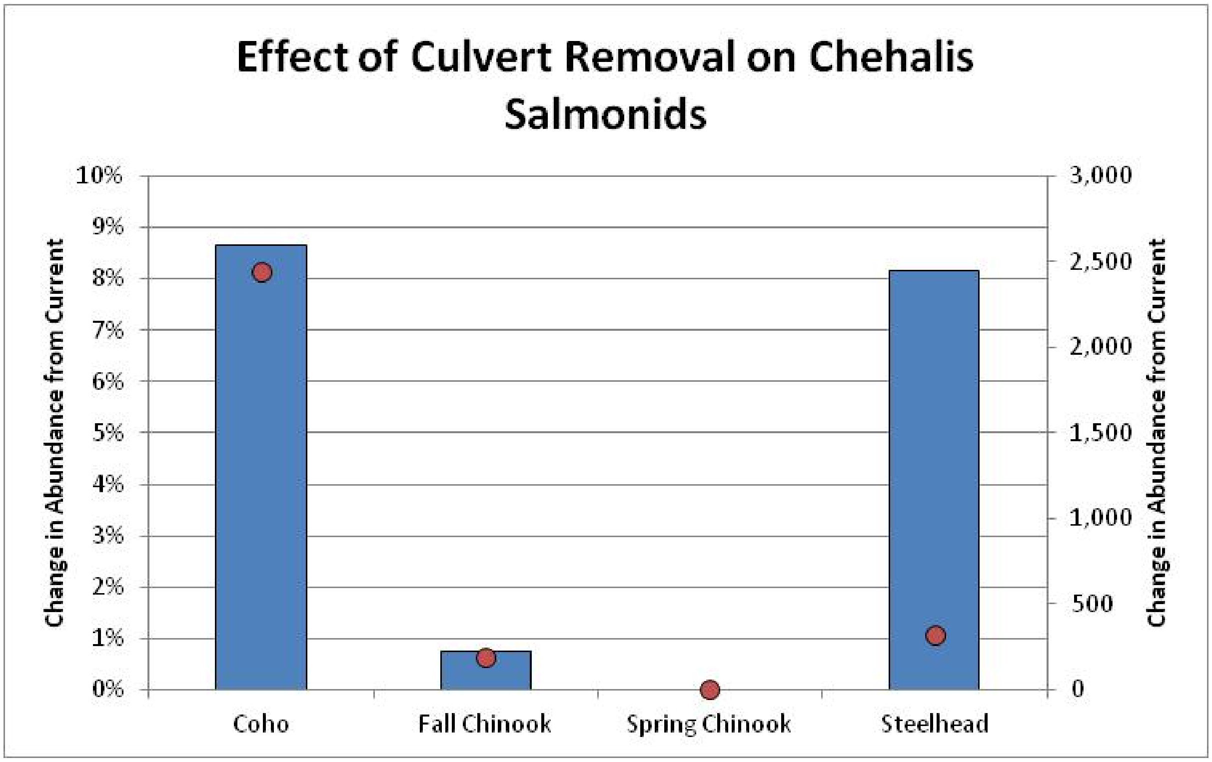
The effect of culverts and other human-caused impediments to adult and juvenile salmonid passage was examined both as a limiting factor and as an enhancement strategy because obstructions are pervasive throughout the basin. The EDT analysis of culvert effects focused on 169 culverts ranked as high priority (Anchor QEA 2012a), and WDFW indicated that adult salmonids, with the exception of spring-run Chinook, either do currently or could potentially spawn upstream from these culverts (Figure 5.6). There are numerous additional natural barriers in the EDT model, as well as other artificial barriers such as screens or dams resulting in a total of 224 obstructions to fish migration in the Chehalis EDT model. These additional barriers affected overall model performance but were not removed in the No Culverts Alternative. The culverts incorporated into the Chehalis EDT model are a subset of a much larger set of culverts, and as such, the results should be regarded as a minimal estimate of the effects of culverts throughout the basin. It is important to consider that the model only evaluates obstructions that have at least one spawning reach upstream from the obstruction. The distribution of spawning reaches and obstructions in the model had an important effect on the estimated effect of removing the obstructions.

Figure 5.6
Obstructions and Barriers Incorporated into the Chehalis EDT Model



The effect of obstructions on salmonids can be examined on a basin-wide-by-species scale and at a sub-population scale by species. At the basin-wide-by-species scale, the effect of removing all culverts in the system within the designated spawning zone was greatest for coho salmon and winter-run steelhead and least for spring-run Chinook salmon (Figure 5.7). Removal of all obstructions in the model had no effect on spring-run Chinook salmon because WDFW concluded that there was no potential habitat for spring-run Chinook salmon upstream from existing culverts, and that therefore, their distribution would not expand if existing blocking culverts were removed. This assumption was based on WDFW's observations of where spring-run Chinook salmon spawn, the proximity of key barriers to these spawning locations, and the professional opinion of WDFW biologists that spring-run Chinook salmon would not move upstream of the barriers to spawn or rear once the barriers had been removed. If this assumption is incorrect, spring-run Chinook salmon in the basin may benefit from culvert removal, but the level of benefit was not estimated in this stage of ASEP feasibility analysis. Changes in fall-run Chinook salmon abundance was low because this species is generally distributed in lower stream reaches downstream from many of the culverts that occur in upper stream reaches. Removing all culverts in the EDT model increased habitat potential across the entire basin by 8.5% for coho salmon, 8.2% for winter-run steelhead, and approximately 1% for fall-run Chinook salmon.

Figure 5.7
Effect of Removal of Culverts in the EDT Model on Habitat Potential (Potential Abundance) of Salmonids in the Chehalis Basin



Note: Bars represent percent change and dots represent numeric change in abundance relative to current condition.

The cost of removing these culverts was estimated for the 169 culverts evaluated in the EDT model. Table 5.1 summarizes the costs and breaks them down by sub-basin. Additionally, there is a pending lawsuit requiring culverts on State-owned lands that are barriers to fish to be repaired by 2016 for State agencies, with the exception of WSDOT, which must complete repairs by 2030. As the cost of those culverts would be handled though State funds, they are identified separately in Table 5.1. Assumptions used for estimating these costs are in Appendix G.

Table 5.1
Culvert Project Cost Summary

EDT SUB POPULATION	NUMBER OF PROJECTS	LOW RANGE	MEDIUM RANGE	HIGH RANGE
Upstream from Elk Creek	3	$330,000	$500,000	$690,000
State-owned	*1*	*$70,000*	*$100,000*	*$140,000*
Other Ownership	*2*	*$260,000*	*$390,000*	*$550,000*
Black River	7	$2,570,000	$3,730,000	$5,110,000
State-owned	*1*	*$70,000*	*$100,000*	*$140,000*
Other Ownership	*6*	*$2,500,000*	*$3,630,000*	*$4,970,000*
Lower Chehalis Tributaries	32	$3,150,000	$4,650,000	$6,430,000
State-owned	*1*	*$30,000*	*$40,000*	*$60,000*

EDT SUB POPULATION	NUMBER OF PROJECTS	LOW RANGE	MEDIUM RANGE	HIGH RANGE
Other Ownership	*31*	*$3,130,000*	*$4,610,000*	*$6,380,000*
Middle Chehalis Tributaries	*65*	$9,690,000	$14,110,000	$19,350,000
State-owned	*7*	*$2,170,000*	*$3,140,000*	*$4,290,000*
Other Ownership	*58*	*$7,510,000*	*$10,960,000*	*$15,060,000*
Newaukum River	23	$3,560,000	$5,240,000	$7,240,000
Scatter Creek	2	$120,000	$180,000	$250,000
South Fork Chehalis	21	$2,940,000	$4,290,000	$5,900,000
State-owned	*1*	*$70,000*	*$100,000*	*$140,000*
Other Ownership	*20*	*$2,870,000*	*$4,190,000*	*$5,760,000*
Satsop River	1	$70,000	$100,000	$140,000
Wynoochee River	4	$280,000	$420,000	$570,000
Skookumchuck River	11	$1,240,000	$1,810,000	$2,500,000
All	**169**	**$23,950,000**	**$35,030,000**	**$48,180,000**
State-owned	**11**	***$2,410,000***	***$3,480,000***	***$4,770,000***
Other Ownership	**158**	***$21,540,000***	***$31,550,000***	***$43,410,000***
	Avg. per Project	**$150,000**	**$210,000**	**$290,000**

Notes:
Totals and averages have been rounded up to the nearest $10,000.
Culvert points located within 50 feet (15.2 m) of state-owned land were assumed to have state ownership, unless otherwise noted.
State-owned lands included WSDOT right-of-way, and WDNR major public lands, and WDNR parcels.
If culvert data specifically identified the ownership type, those data were used rather than the alignment with parcels.

The ASEP results may under or overestimate the actual benefits to some degree. For example, the model may underestimate the actual benefits associated with culvert removal because there are approximately 2,200 identified culverts in the basin, but the ASEP analysis estimated benefits associated with 169 culverts that were identified in previous surveys as high-priority blockages. The ASEP *Data Gaps Report* identifies additional culvert surveys as being needed. Also, the culverts modeled were not selected with any particular species or sub-basin of the watershed in mind. Actions targeted on specific habitats and species may produce enhanced responses for the targeted species.

Conversely, results of ASEP model studies of culvert removal may also overestimate the actual benefits associated with culvert removal because few (if any) river systems have current and comprehensive culvert surveys that identify all barriers. In addition, a significant proportion of mapped culverts (approximately 30%) that were permitted as fish passage culverts by WDFW within 10 years and constructed, actually failed and continued to block passage (Price et al. 2010). Because culvert surveys are not commonly done through time, these failures can go undetected (Price et al. 2010). Hence, the model may overestimate the positive contribution of barrier corrections, and to be effective, barrier enhancement actions need to be completed in a manner that adheres to the permit specifications to ensure the projects work as planned.

5.2.2.1.1 Coho Salmon

Distribution of coho salmon spawning and culverts used in the EDT model are shown in Figure 5.8. Coho salmon have the broadest distribution of spawning across the basin among the four salmon species analyzed, and therefore, were most affected by obstruction removals. The greatest contribution to overall coho salmon abundance occurred when culverts were removed in the Satsop River (Figure 5.9). However, this largely reflects the size of the Satsop sub-basin and the potential for large numeric changes in abundance due to its size. At a sub-population level, the greatest percent increase in abundance occurred in the middle Chehalis tributaries where abundance was doubled, albeit with a small increase in total abundance (Figure 5.9). The middle Chehalis tributaries have the largest number of culverts that blocked or impeded passage of coho salmon in the Chehalis EDT model.

Figure 5.8
Distribution of Coho Salmon Spawning Reaches and Obstructions in the EDT Model

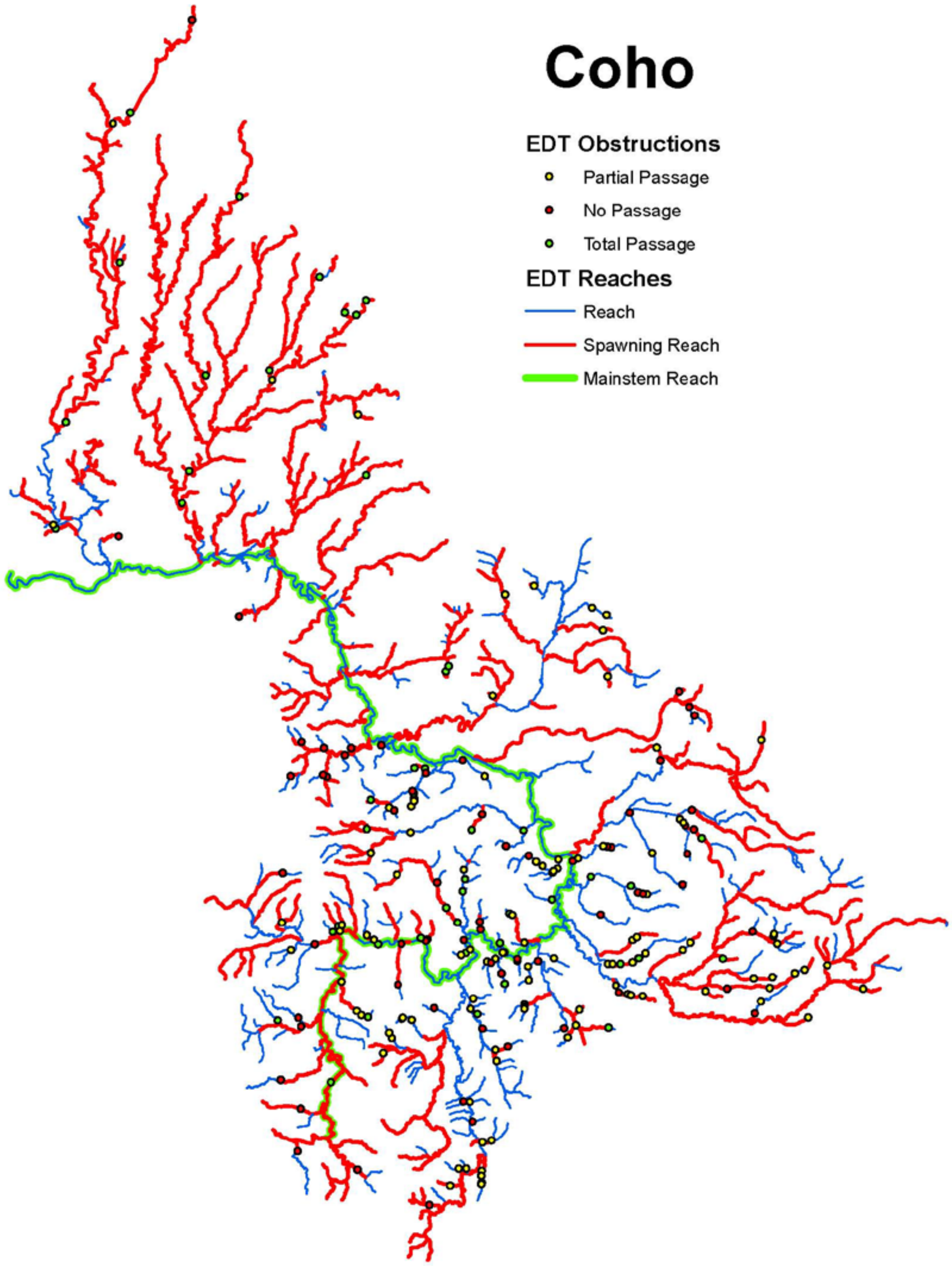
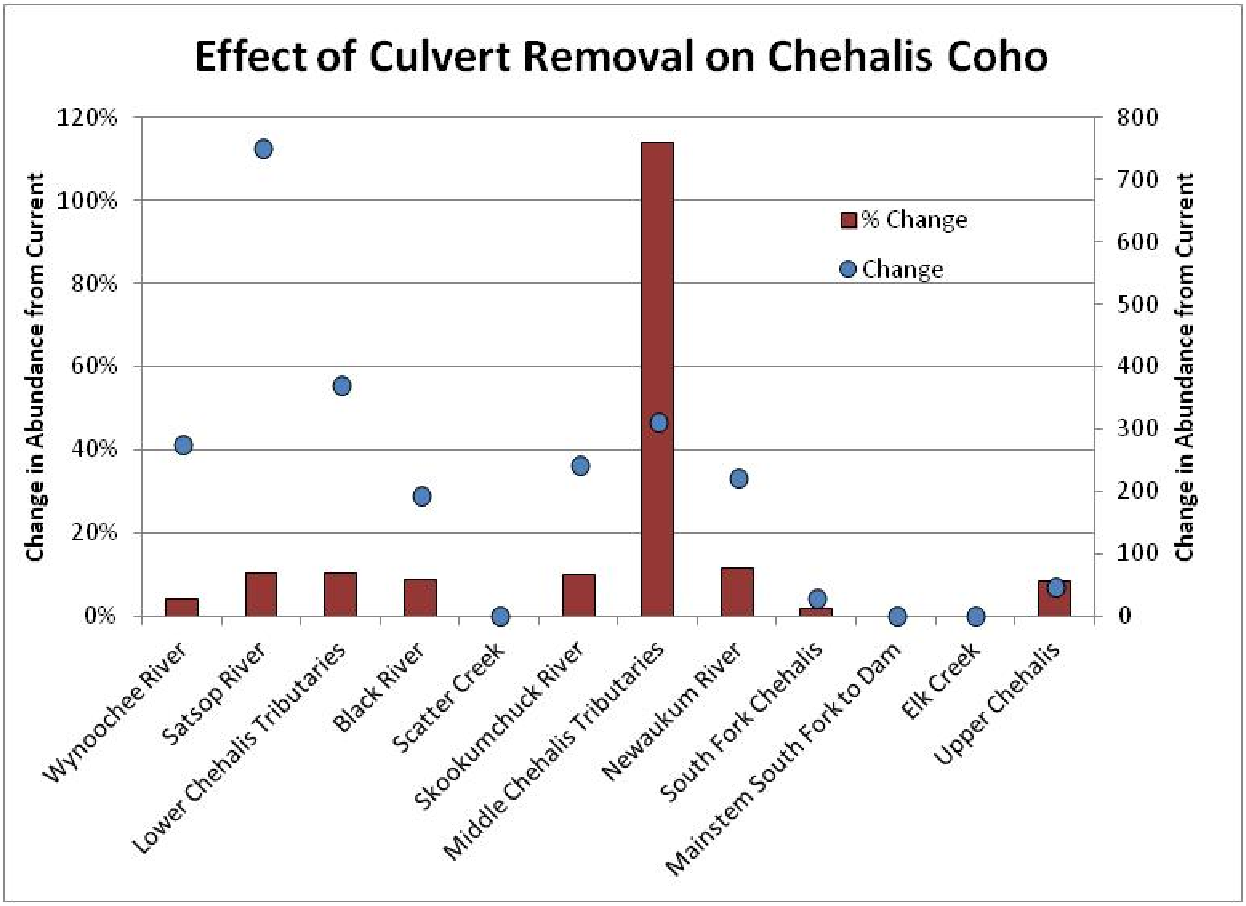


Figure 5.9
Effect of Removal of Culverts in the EDT Model on Abundance of Coho Salmon Sub-populations



Note: Bars represent percent change and dots represent numeric change in abundance relative to current condition.

5.2.2.1.2 Fall-run Chinook Salmon

Fall-run Chinook salmon spawning distribution was more restricted than coho salmon and was generally located lower in the system (Figure 5.10). Because most culverts were in smaller reaches higher in the system, there was a relatively small effect on fall-run Chinook salmon in the model by removing culverts (Figure 5.11). Benefits of culvert removal for fall-run Chinook salmon were restricted to the Wynoochee and Newaukum basins (Figure 5.11) resulting in an overall lower effect of barrier removal compared to coho salmon or winter-run steelhead. The greatest percent change in abundance at the sub-basin scale was in the Newaukum system. Removal of culverts in other sub-basins had little or no effect on fall-run Chinook salmon abundance.

Figure 5.10
Distribution of Fall-run Chinook Salmon Spawning and Obstructions in the EDT Model

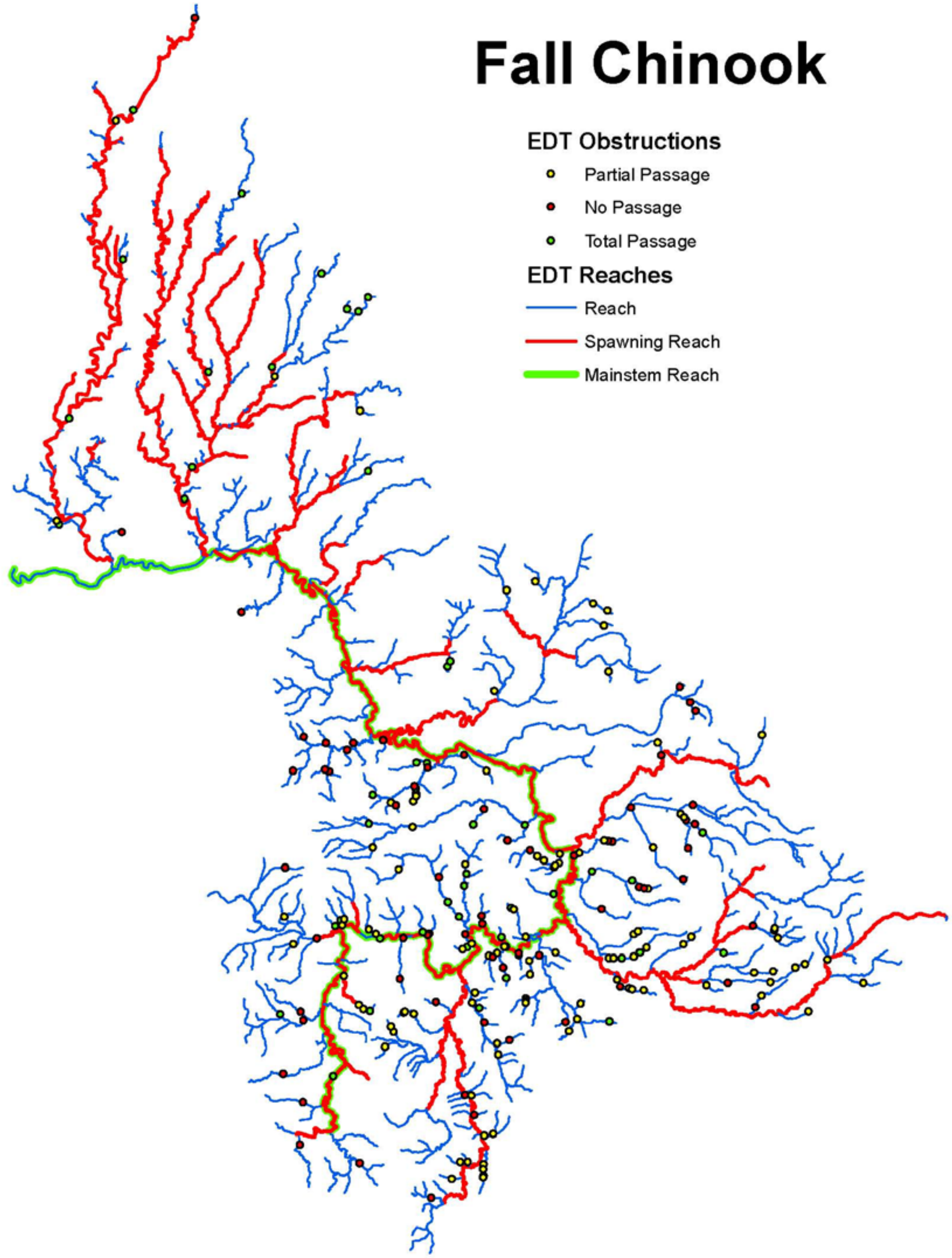
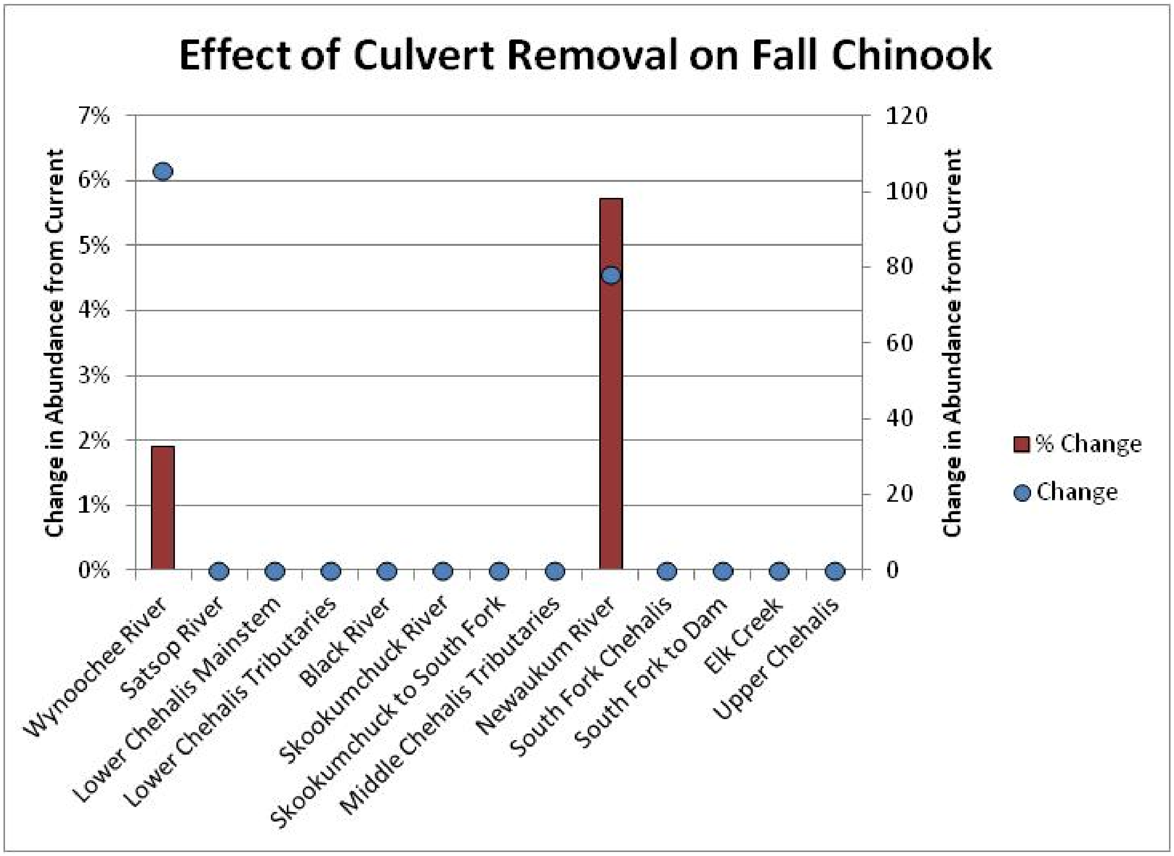


Figure 5.11
Effect of Removal of Culverts in the EDT Model on Abundance of Fall-run Chinook Salmon Sub-populations

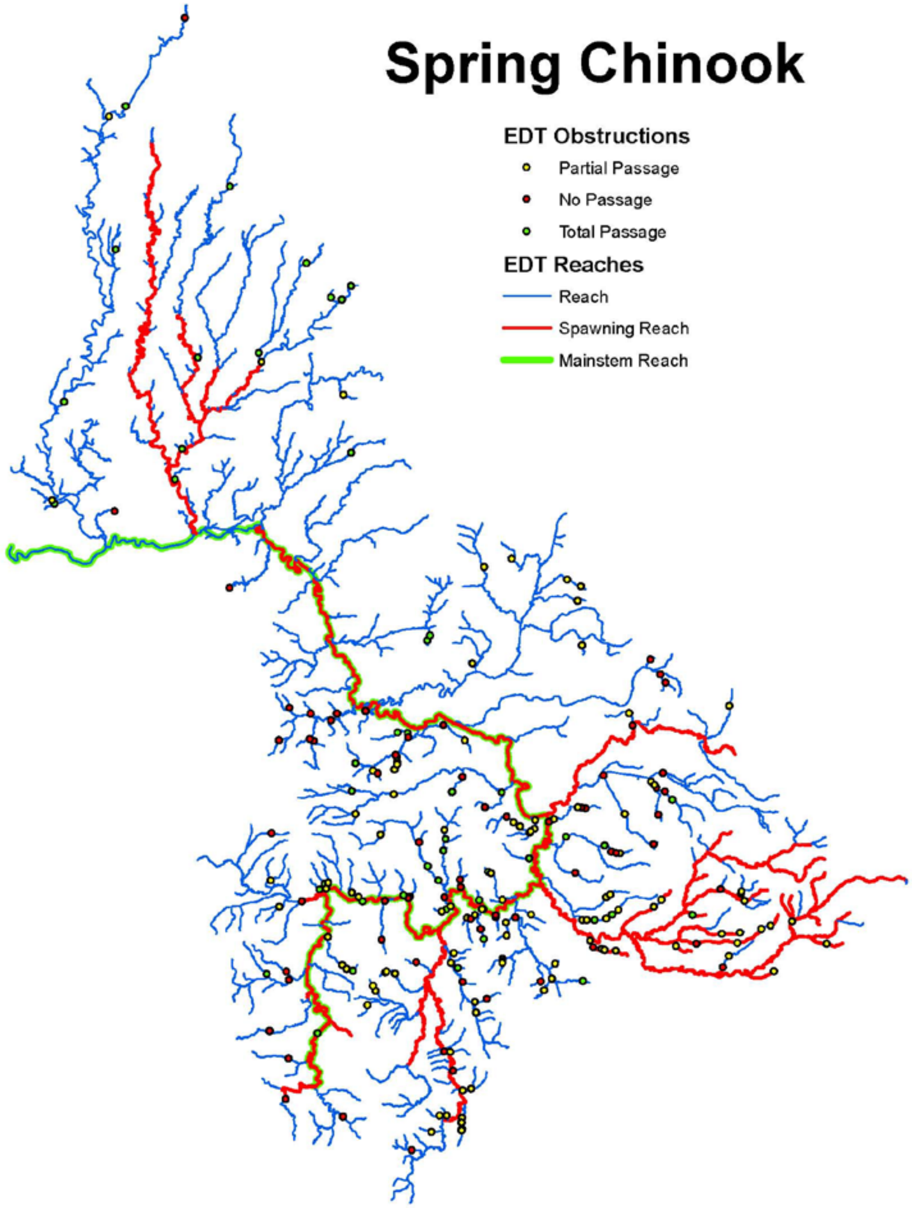


Note: Bars represent percent change and dots represent numeric change in abundance relative to current condition.

5.2.2.1.3 Spring-run Chinook salmon

Because of the assumed distribution of spring-run Chinook salmon spawning in the basin that was downstream from all blocking culverts (Figure 5.12), removal of culverts in the model had no effect on spring-run Chinook salmon abundance. Results of EDT modeling indicated that no benefits would accrue to spring-run Chinook salmon associated with the culvert alternative where 169 high-priority culverts in the basin were removed. This assumption was based on WDFW's observations of where spring-run Chinook salmon spawn, the proximity of key barriers to these spawning locations, and the professional opinion of WDFW biologists that this run of Chinook salmon would not move upstream of the barriers to spawn or rear once the barriers had been removed. If this assumption is incorrect, spring-run Chinook salmon in the basin may benefit from culvert removal, but the level of benefit was not estimated in this stage of ASEP feasibility analysis.

Figure 5.12
Distribution of Spring-run Chinook Salmon Spawning and Obstructions in the EDT Model



5.2.2.1.4 Winter-run Steelhead

Winter-run steelhead are assumed to have a rather broad spawning distribution within the basin. However, many of the obstructions in the model were in lower-gradient small streams in the lower and middle Chehalis that were not included in the WDFW list of winter-run steelhead spawning reaches (Figure 5.13). Given the distribution of spawning and obstructions in Figure 5.13, it is not surprising that the effect of removing culverts on winter-run steelhead sub-populations was highest in the upper sub-basins (Figure 5.14). Removing obstructions in the Newaukum River and upper Chehalis had the greatest effect on sub-population abundance.

Figure 5.13
Distribution of Winter-run Steelhead Spawning and Obstructions in the EDT Model

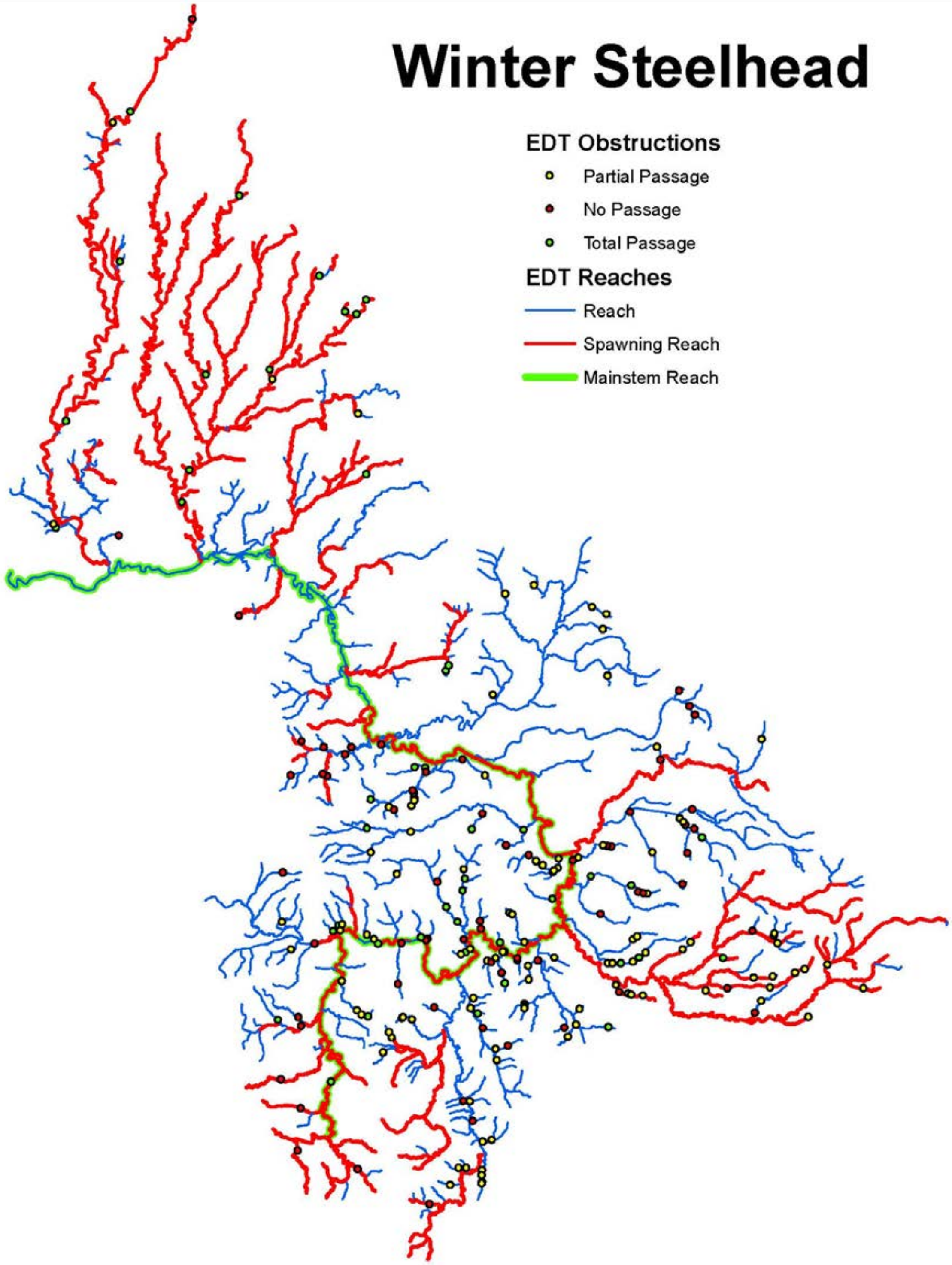
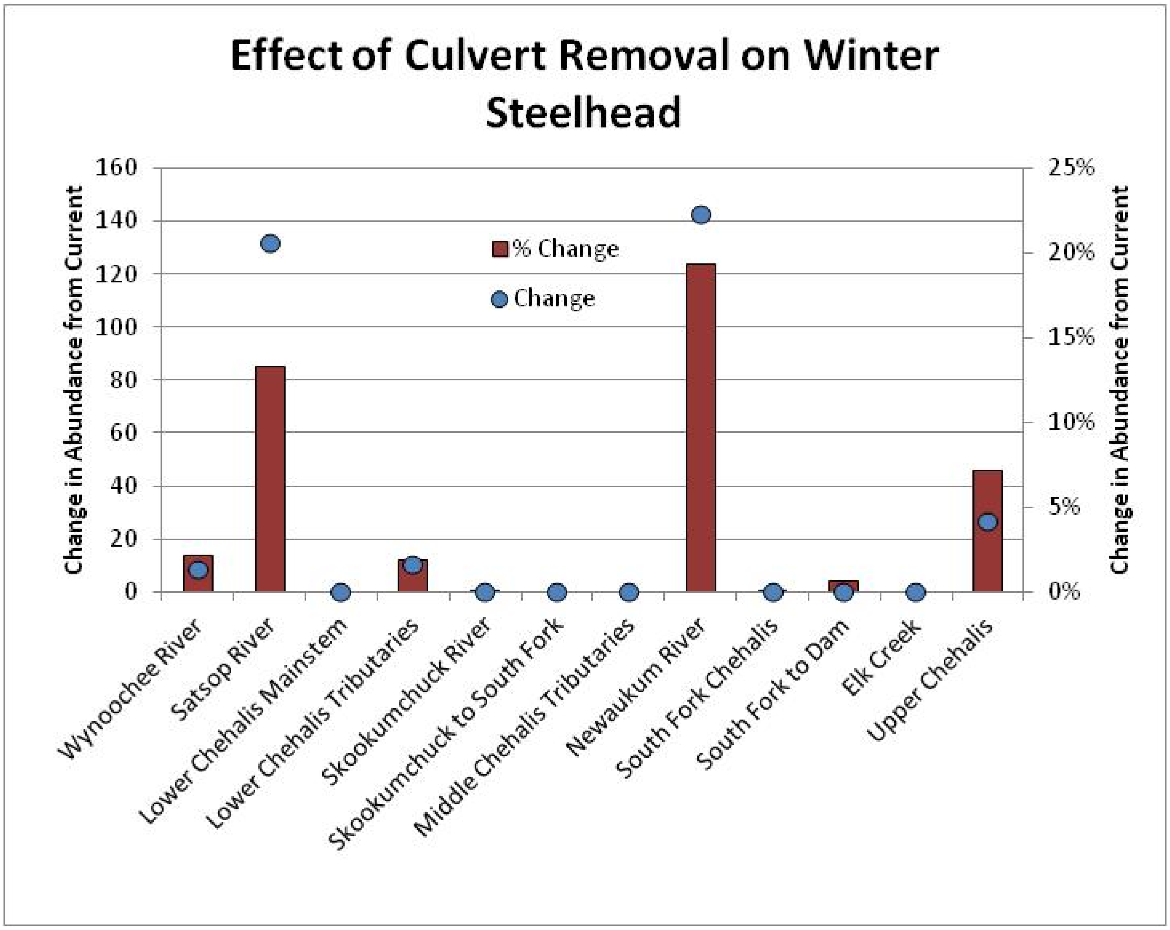


Figure 5.14
Effect of Removal of Culverts in the EDT Model on Abundance of Winter-run Steelhead Sub-populations



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

5.2.3 RIPARIAN ENHANCEMENT

The basin-wide assessment of enhancement opportunities for salmonids includes enhancement of riparian areas in two areas of the basin: 1) public and privately MF, most of which fall under the Washington Forest Practices Act (WFPA), and 2) areas outside of MFs, most of which lie downstream from the public and privately managed forest lands. The premise of the analysis is that riparian conditions in these areas can be improved substantially with potential benefits to aquatic environments and performance of anadromous salmonids. Within MFs, the mechanism for achieving riparian improvements is primarily the WFPA, which mandates riparian buffers of varying widths. The modeled actions in MFs evaluate the maturation of these riparian buffers and hypothesized changes to aquatic environments. For areas outside MFs, conditions could improve due to enhancement actions, land acquisition, or other measures. Though the means to accomplish these changes may differ between the two areas, the underlying riparian model that describes the function of the riparian zone and how it can be incorporated into the EDT model are the same in both areas. A summary of the methods used to determine the riparian effects is in Appendix H.

5.2.3.1 RIPARIAN MODEL

5.2.3.1.1 Application of the Model to Managed Forest Lands

Much of the basin is represented by public and private MFs (Figure 5.15). MF lands predominate in the Satsop and Wynoochee sub-basins and the upper Chehalis and South Fork sub-basins. Most of the lowland areas have other land uses, mainly agricultural. Changes to the riparian and aquatic conditions discussed previously were made to the EDT reaches that were predominantly within the MF designations in Figure 5.15. About 48% of the reaches in the EDT model were affected by the improvements to riparian conditions in MFs.

The functions of the riparian zone were assumed to be recruitment of wood into the stream, addition of food (insects and detritus) into the stream, shading of the stream channel, condition of surface and groundwater entering the stream and stabilization of the stream channel. Changes in these functions due to modification of riparian conditions were incorporated into the EDT model through changes in 1) LWM, 2) food, 3) temperature, 4) water quality, 5) sediment, 6) channel form, and 7) riparian function. To model the effect of maturing riparian areas, the restoration potential of these functions was increased from existing levels as described in the following sections. A more thorough summary of the methods used to determine the riparian effects is in Appendix H.

For this analysis, two alternative scenarios were analyzed to capture the uncertainty in the possible effects of riparian restoration in MF areas on aquatic environments (Table 5.2). These two scenarios increased the estimated restoration potential of riparian areas in MFs by 20% or 60% from the current value used in EDT. It is important to note that increasing restoration potential of riparian areas by percentages based on this hypothesis is non-linear. For example, a 60% increase in the shade function for MFs landscapes that are already providing approximately 50% level of shade results in a level of approximately 95% of maximum value for shade and a 20% increase would result in a value of approximately 70% . An example of how these changes were applied to the LWM attribute in EDT is shown in Figure 5.16. These changes were applied to 100% of the EDT stream reaches encompassed by MFs (green areas in Figure 5.15).

Table 5.2
Scenarios Modeled in EDT for Managed Forests

SCENARIO	REACHES APPLIED	CHANGE TO RIPARIAN ATTRIBUTES
MF60	100% of reaches in MFs	60% increase of restoration potential from current condition
MF20	100% of reaches in MFs	20% increase of restoration potential from current condition

Note: MF = managed forest

Figure 5.15
Publicly and Privately Managed Forests in the Chehalis Basin

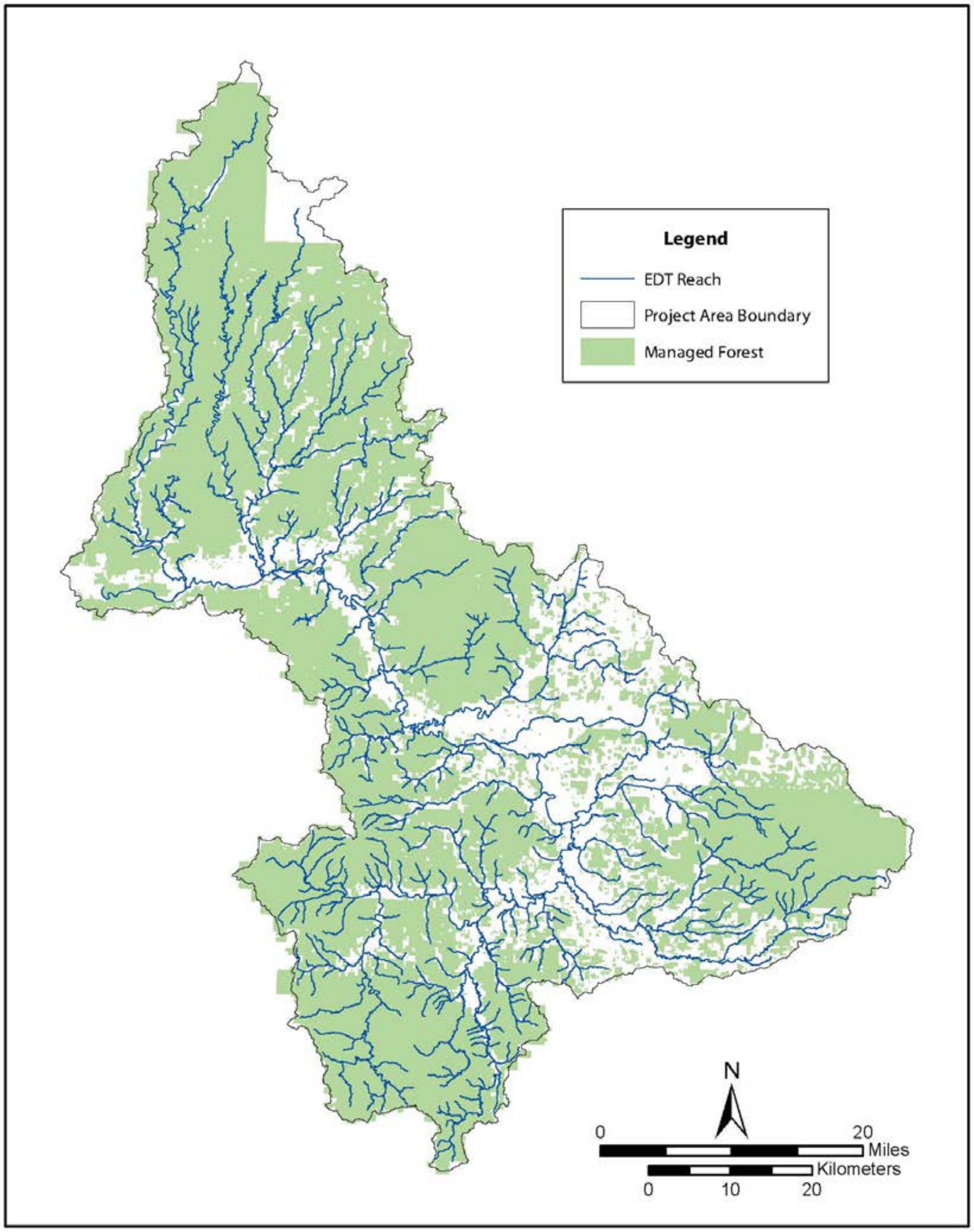
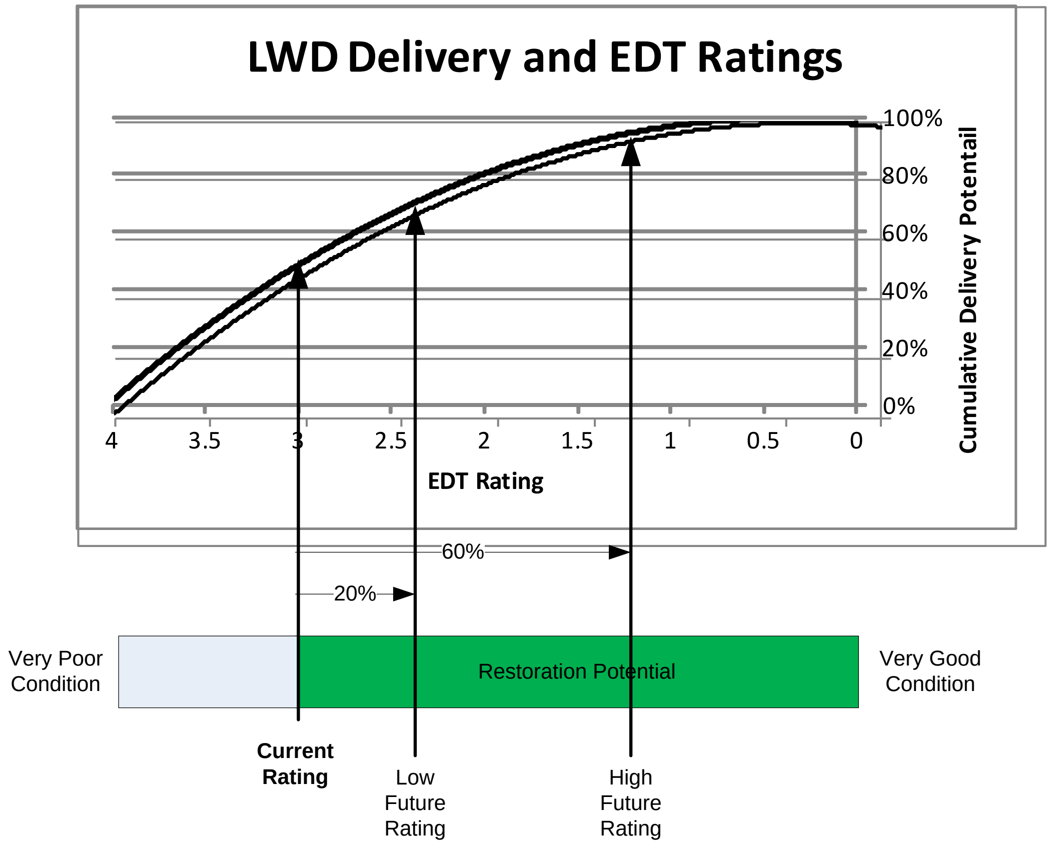


Figure 5.16
Proposed Relationship Between EDT Ratings for LWM and LWM Delivery Potential



ASEP model studies of riparian buffer restoration in MFs assumed two different levels of functional response. However, to realize these responses, LWM that develops in MF riparian buffers needs to be available to recruit into the stream channel and stay in the channel once recruited. ASEP model studies assumed this was the case. However, if this woody material is not available for recruitment or retained, modeled outputs would overestimate the restoration benefits associated with riparian buffer maturation in MFs. LWM, an important habitat component of many salmon species, has been systematically removed or is currently degraded in many river systems in Western Washington, including the Chehalis. In fact, most large wood has been removed following important wood recruitment events, such as the 2007 flood. The addition of large wood via maturation of riparian areas was modeled with EDT with resultant benefits to multiple salmon species. However, large wood removal is a systematic and ongoing process. If removal continues (by landowners, state agencies and others who view large wood as posing risks to farm lands, bridges, culverts, roads and boaters on the river), the modeled benefits to salmon from riparian buffer maturation would be overestimated. In other words, the benefits from LWM recruiting into the stream channel from riparian buffers can only be realized if the material stays in channel or on the floodplain.

5.2.3.1.2 Application of the Model to Non-managed Forest Areas

Areas of the basin outside NMFs (the white areas in Figure 5.15) have no over-arching mechanism to regulate riparian conditions, as the WFPA does in MF areas. As a result, a broader set of scenarios was analyzed to address alternative hypotheses about the type of potential riparian enhancement action, the spatial application of riparian improvements, and the intensity of application of the actions (Table 5.3).

Type of Actions. Two types of restoration were evaluated. The first type of enhancement action was applied only to the LWM attributes in EDT. These scenarios assumed that wood would be increased in designated stream reaches through placement of engineered log jams (ELJs) or other structures. This was considered a short-term action to provide benefits pending the natural increase in large wood through maturation of riparian forests.

The second type of restoration was restoration of all riparian attributes due to maturation and restoration of riparian forests. These scenarios made the same changes to riparian attributes described previously for the MF reaches but applied them only in modeled reaches for the scenarios as described in Table 5.3.

Reaches Applied. Spatial distribution of riparian improvements in modeled scenarios was based on a premise that riparian restoration for this analysis would focus on restoration for spring-run Chinook salmon in the basin. Thus the first criteria for restoring riparian conditions in areas outside MFs was that changes would only be applied to reaches with spring-run Chinook spawning habitat in the model as shown in Figure 5.12. Because there is overlap in spatial distribution of the four salmonid species the changes, affected them all but did limit the coverage of riparian improvements. For example, no changes were made in areas outside MFs in the Wynoochee or Satsop sub-basins because these areas did not have spawning for spring-run Chinook in the model.

The second criteria for spatial distribution of riparian improvements hypothesized different levels of application of the actions. Actions were applied to either 50% or 75% of the spring-run Chinook spawning reaches outside MFs. Reaches were chosen systematically. For the 50% alternatives, actions were applied to every other reach with spring-run Chinook spawning habitat. For the 75% alternatives, actions were also applied to every other reach that did not receive the treatment under the 50% alternatives.

Intensity of Change in Riparian Attributes. LWM scenarios assumed that 50% of the restoration potential for LWM would be provided in the modeled reaches. The riparian restoration scenarios assumed the same changes to attributes described previously for the MFs. This involved restoration of 20% and 60% of the restoration potential for the riparian attributes in EDT.

Table 5.3
Description of Modeled Riparian Enhancement Scenarios in Non-managed Forest Lands

SCENARIO: INTENSITY OF CHANGE/SPATIAL APPLICATION	TYPE OF ACTION	REACHES APPLIED	CHANGE IN RIPARIAN ATTRIBUTE
NMF-LWM50/50	Add large wood structures	50% of NMF reaches having spring-run Chinook spawning	50% of restoration potential of LWM attribute
NMF-LWM50/75	Add large wood structures	75% of NMF reaches having spring-run Chinook spawning	50% of restoration potential of LWM attribute
NMF-Riparian20/50	General riparian improvement	50% of NMF reaches having spring-run Chinook spawning	20% increase of restoration potential from current of all riparian attributes
NMF-Riparian20/75	General riparian improvement	75% of NMF reaches having spring-run Chinook spawning	20% increase of restoration potential from current of all riparian attributes
NMF-Riparian60/50	General riparian improvement	50% of NMF reaches having spring-run Chinook spawning	60% increase of restoration potential from current of all riparian attributes

SCENARIO: INTENSITY OF CHANGE/SPATIAL APPLICATION	TYPE OF ACTION	REACHES APPLIED	CHANGE IN RIPARIAN ATTRIBUTE
NMF-Riparian60/75	General riparian improvement	75% of NMF reaches having spring-run Chinook spawning	60% increase of restoration potential from current of all riparian attributes

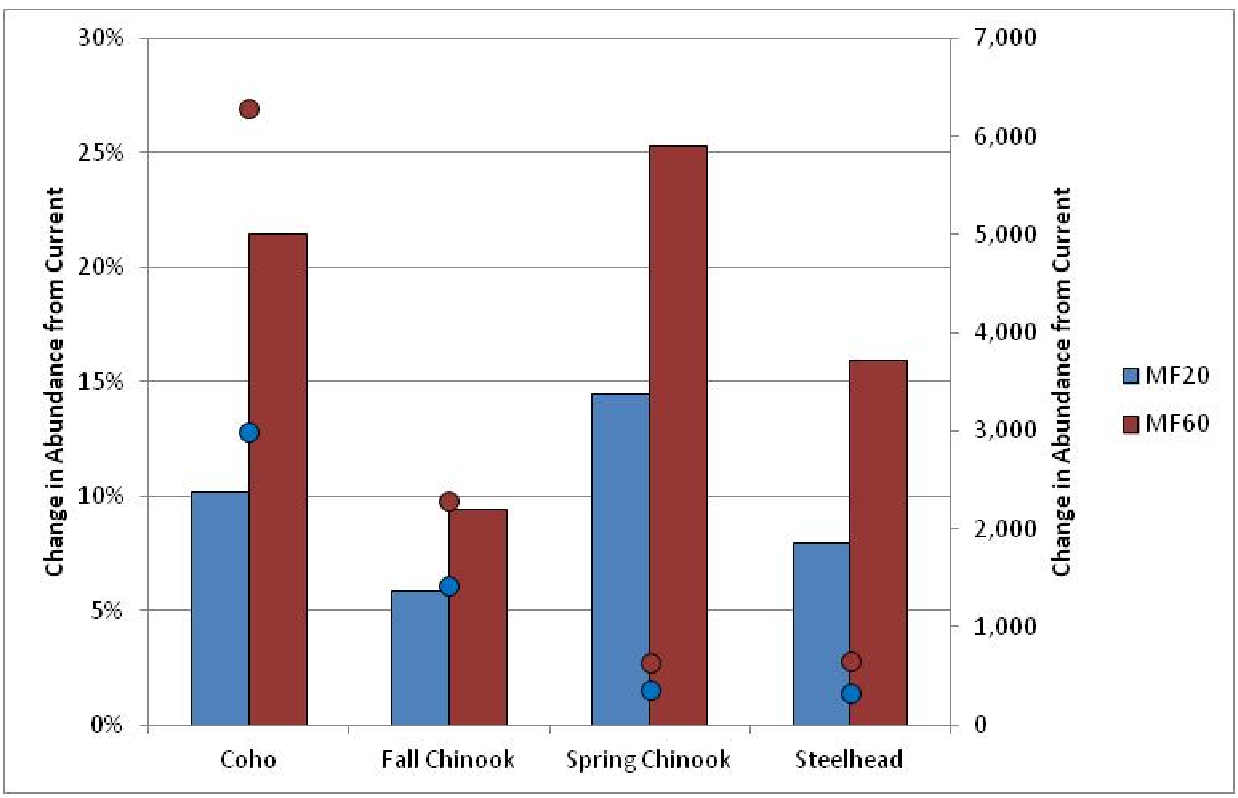
Note:
LWM = large woody material
NMF = non-managed forest

5.2.3.2 RESULTS

5.2.3.2.1 Effect of Riparian Changes in Managed Forest Reaches

Species Level. On a percentage increase, spring-run Chinook salmon benefited the most from riparian changes in MFs followed by coho salmon, steelhead and fall-run Chinook (Figure 5.17). These differences largely reflect the intersection of modeled spawning reaches for each species and the application of the MF riparian changes. Fall-run Chinook salmon were distributed lower in the Chehalis system and less so in the MF reaches compared to the other species, and they received relatively small benefit from changes in MF compared to other species.

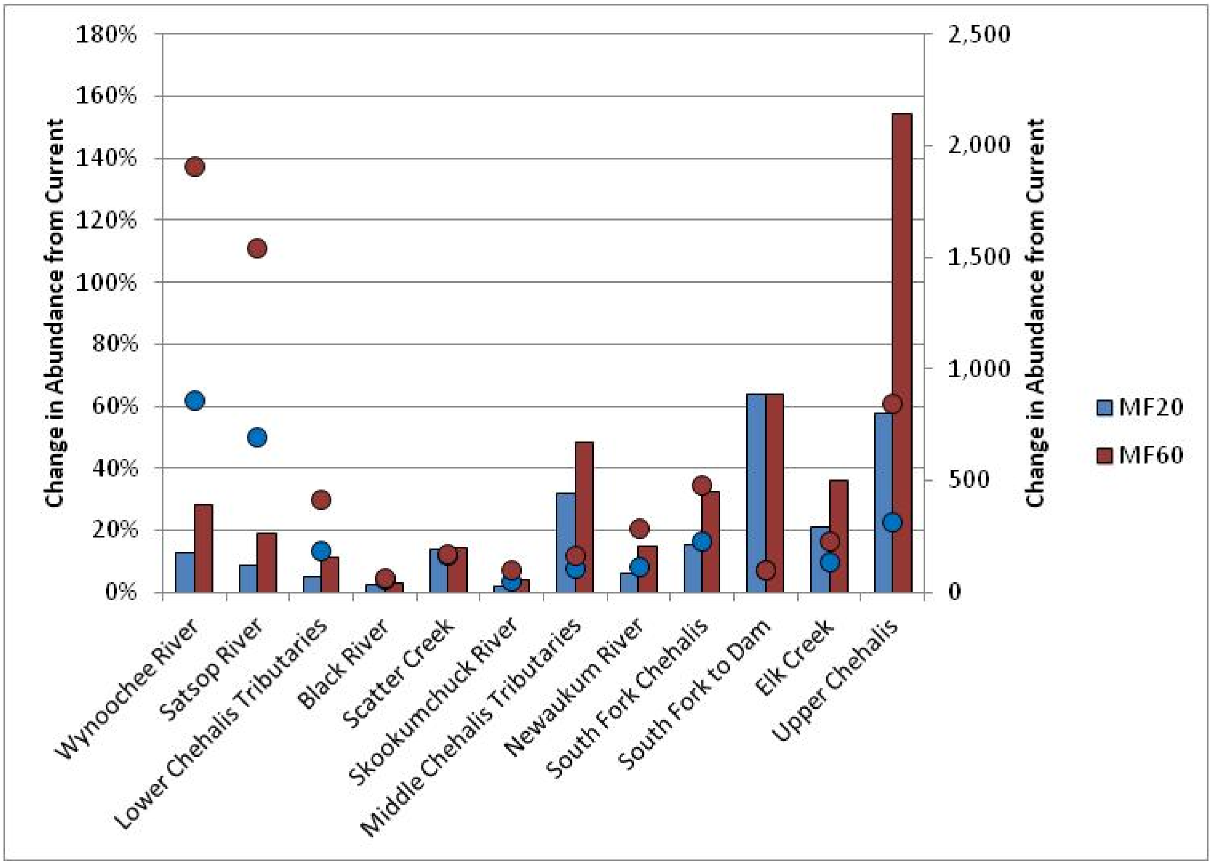
Figure 5.17
Changes in Abundance of Chehalis Basin Salmonids with Riparian Changes in Managed Forest Lands



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Coho Salmon Populations. The greatest gain in abundance for coho salmon populations, due to riparian improvements in MF reaches, was in the upper Chehalis River reach (Figure 5.18). This area is almost entirely within MFs and also had coho spawning throughout. Riparian changes also benefited coho salmon in the South Fork to Dam area, Elk Creek, and Middle Chehalis Tributaries. Areas with smaller amounts of MF, mostly in the lower basin, had relatively smaller changes from enhancement.

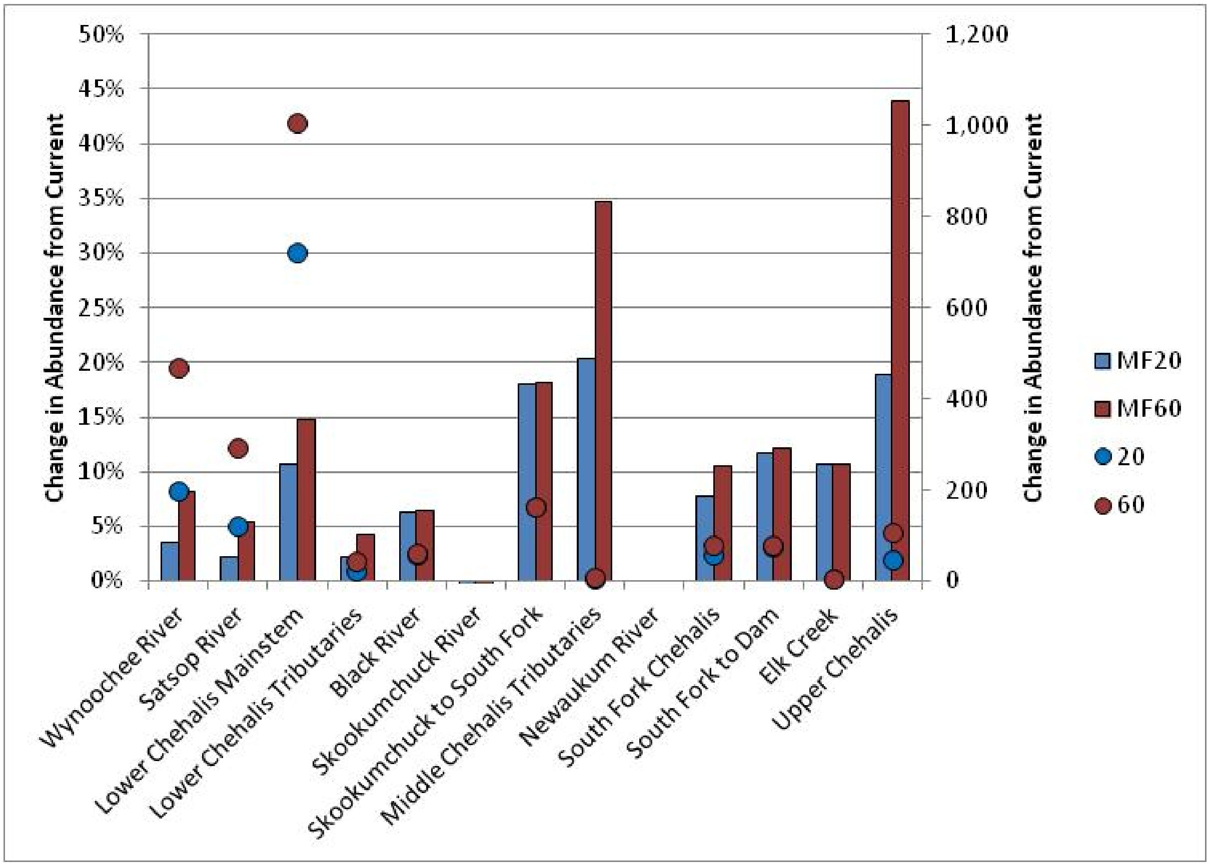
Figure 5.18
Total Projected Habitat Potential for Coho Salmon by Sub-population with Improved Riparian Conditions



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Fall-run Chinook Salmon Populations. Fall-run Chinook salmon are distributed lower in the system than other species and outside MF areas, to a large degree. As a result, the overall effects of MF enhancements were much smaller than for other species (Figure 5.19). The greatest change in abundance due to riparian changes in MFs was in the upper Chehalis area that is almost entirely within MF. This is a small population compared to lower river fall-run Chinook populations, and the numeric changes due to the riparian enhancements in the upper Chehalis were relatively small. Fall-run Chinook salmon were assumed to be blocked by the falls near the mouth of Elk Creek and were not modeled in the upper reaches where MF predominates.

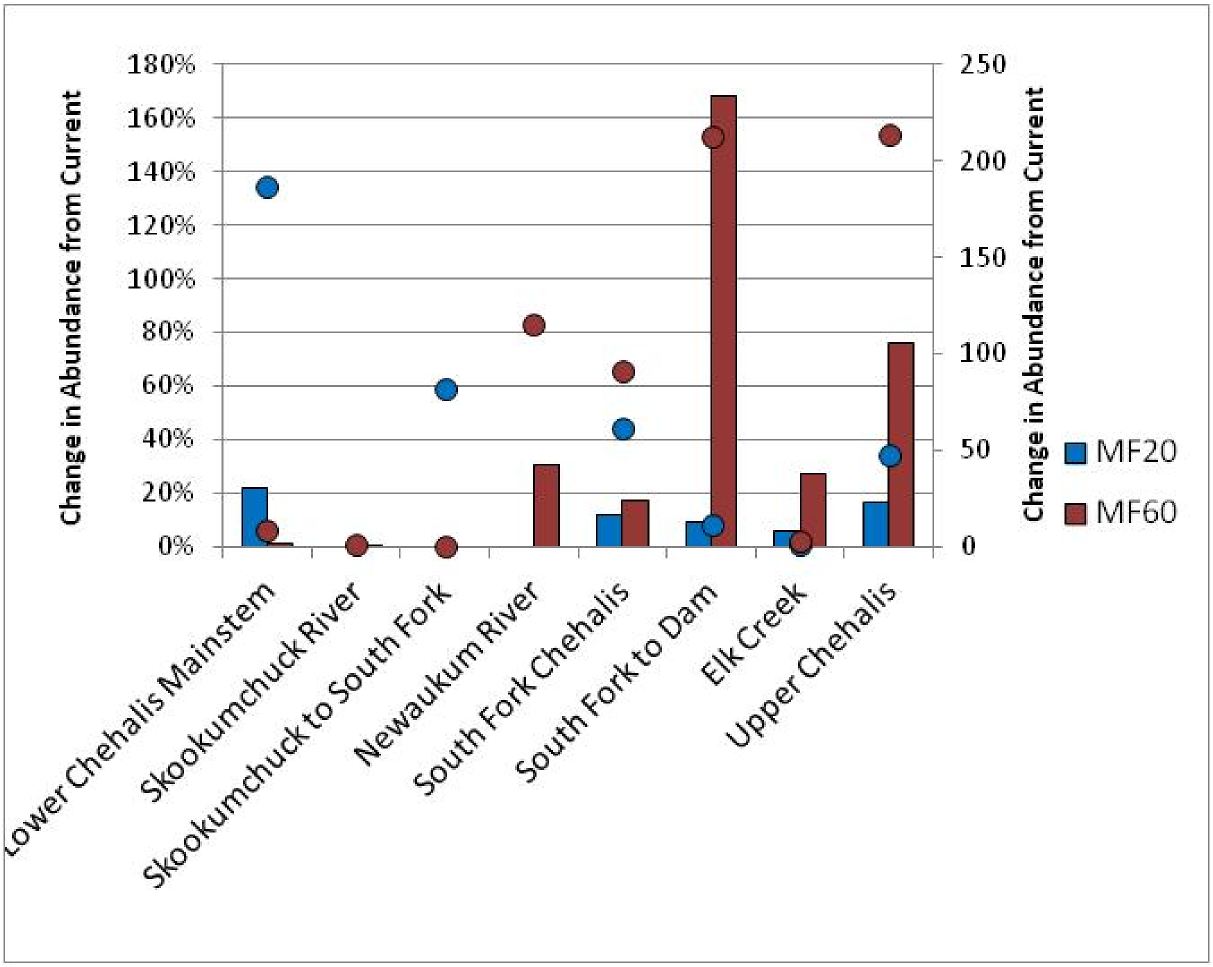
Figure 5.19
Total Projected Habitat Potential for Fall-run Chinook Salmon by Sub-population with Improved Riparian Conditions



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Spring-run Chinook Salmon Populations. Spring-run Chinook salmon benefited from changes in riparian conditions, primarily in the South Fork to Dam segment and the upper Chehalis River (Figure 5.20). In the model, the South Fork to Dam spring-run Chinook population is especially sensitive to temperature changes during the summer and fall. Even though this area does not have a lot of MF, the changes did reduce temperatures and improve abundance, although the change represents very few fish due to the overall low abundance of the population. The large changes in the upper Chehalis reflect the large amount of MF in this area. Spring-run Chinook spawning in Elk Creek was limited to the short reach downstream from the falls at RM 1.1 (RKm 1.8), and, as a result, riparian actions in the MF areas, most of which are upstream from the falls, provided almost no benefit to spring-run Chinook.

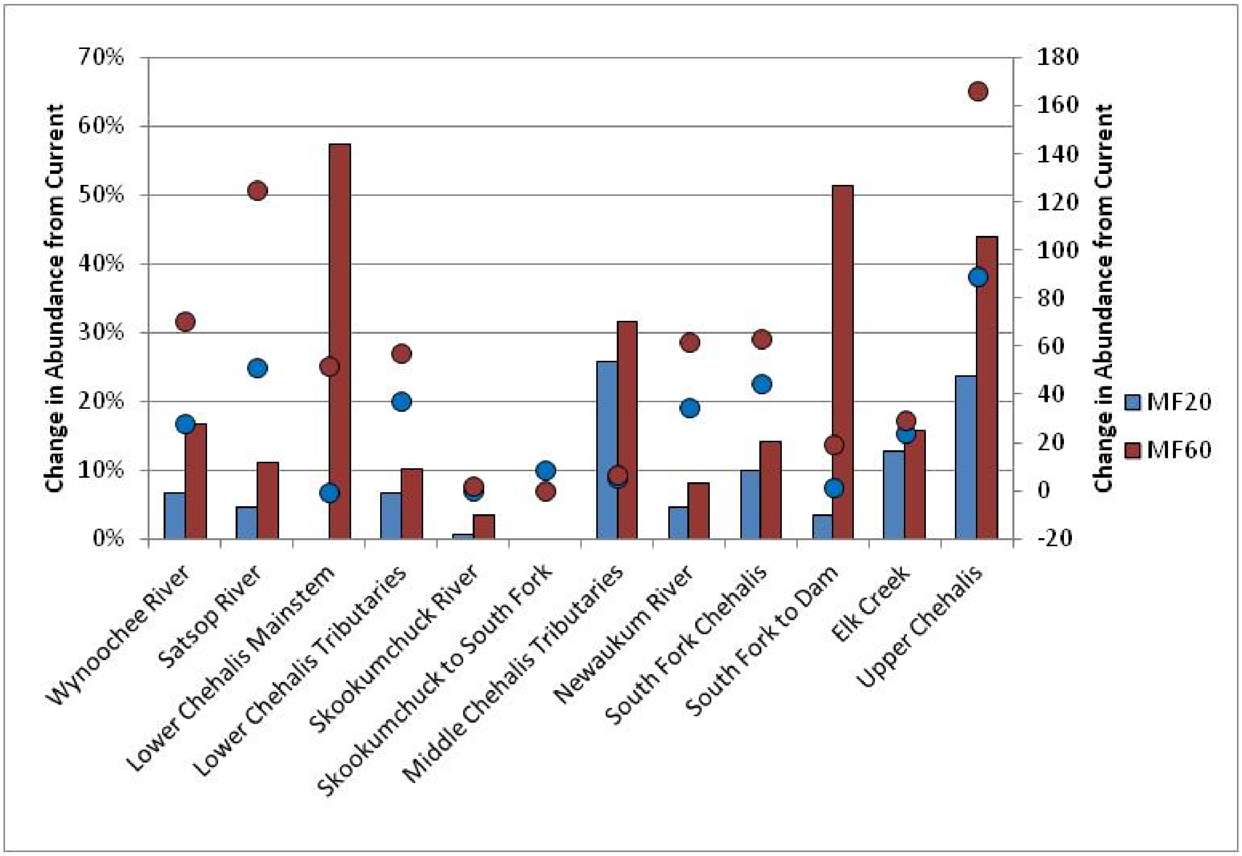
Figure 5.20
Total Projected Habitat Potential for Spring-run Chinook Salmon by Sub-population with Improved Riparian Conditions



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Winter-run Steelhead Populations. Benefits of riparian changes in MFs for steelhead were distributed across most sub-basins (Figure 5.21), reflecting their broad distribution in the basin, especially in upper stream reaches where MFs predominate. The greatest changes were in the upper Chehalis area, the South Fork to Dam, and the lower Chehalis mainstem populations. The large change in the upper Chehalis population reflects the predominance of MF in that area, while the large change in South Fork to Dam population reflects the reduced water temperature during the juvenile life stage. A similar effect of temperature decrease resulting from the MF60 riparian enhancement benefited the lower Chehalis mainstem population. Benefits of riparian changes in Elk Creek were greater than those for spring-run Chinook because steelhead were assumed to be able to access the sub-basin upstream from the falls, much of which is in MF.

Figure 5.21
Total Projected Habitat Potential for Winter-run Steelhead by Sub-population with Improved Riparian Conditions



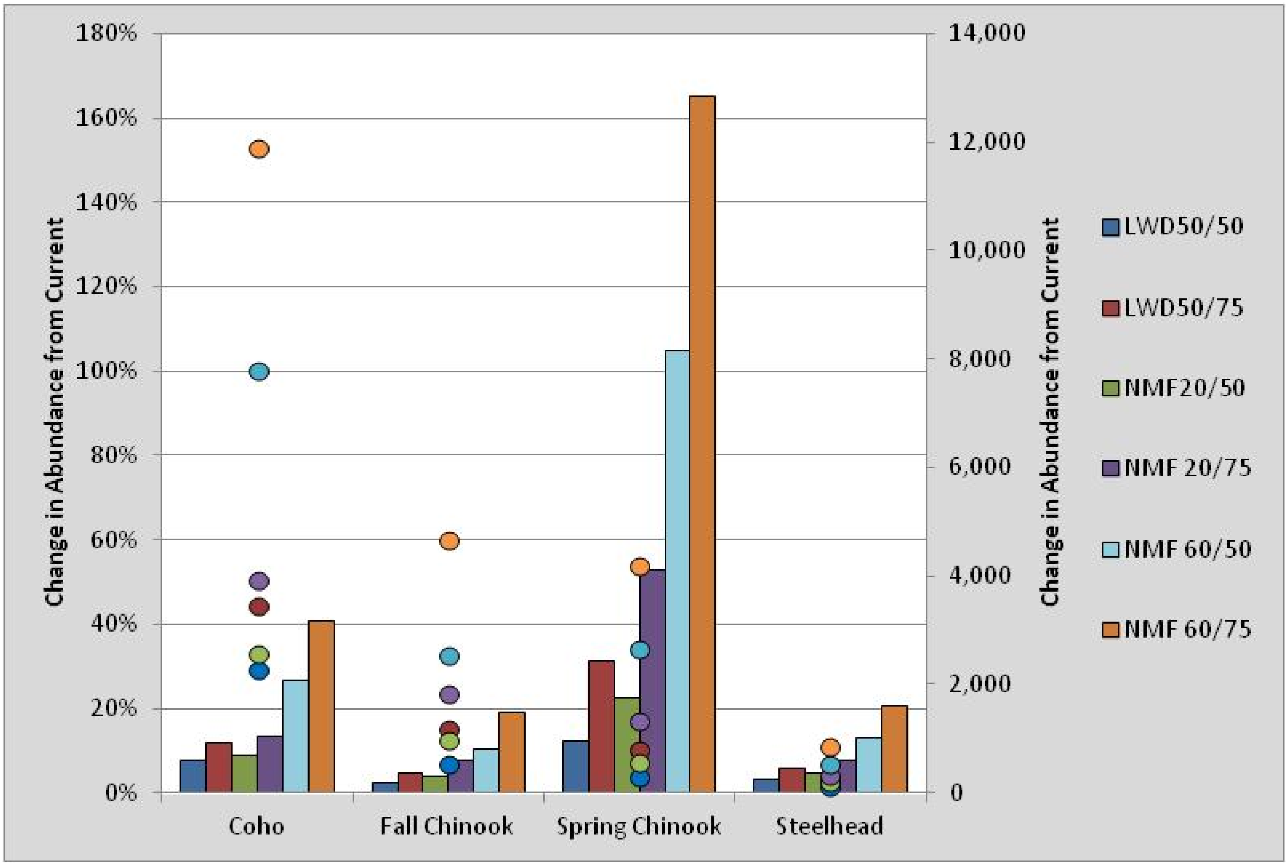
Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

5.2.3.2.2 Effect of Riparian Changes in Non-managed Forest Reaches

Areas of the basin outside MFs are generally lower in the system, including most mainstem reaches (the white areas in Figure 5.15). Note that riparian changes in NMF were applied only to reaches with spring-run Chinook spawning in the model, which excluded the Wynoochee and Satsop sub-basins.

Species Level. The benefits of riparian changes in NMFs were greatest for spring-run Chinook, followed by coho. Relatively small benefits were seen for fall-run Chinook and steelhead (Figure 5.22). This was partially because of the focus of the action on spring-run Chinook spawning reaches, but also because the broad riparian actions added shading and were assumed to reduce temperature, which generally had a beneficial effect for spring-run Chinook throughout the analysis. For the most part, the several riparian alternatives in NMFs form a progression reflecting intensity of treatment and spatial distribution of application of the treatment in the model (Figure 5.22).

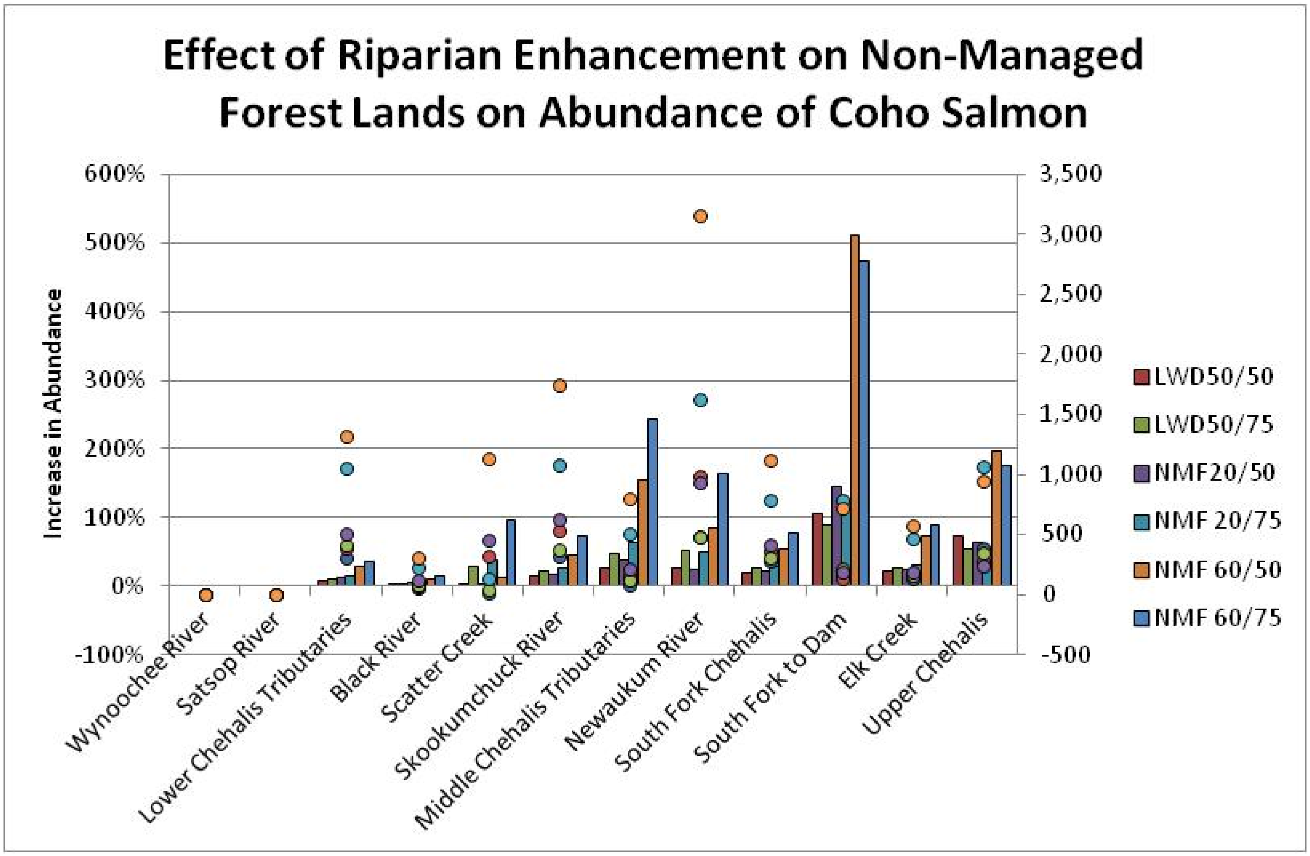
Figure 5.22
Species-level Effects of Riparian Changes in Non-managed Forest Lands on Chehalis Basin Salmonids



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Coho Salmon Populations. The riparian changes in NMF areas had substantial proportional benefits for individual coho salmon populations and sub-basins (Figure 5.23). The high intensity riparian alternatives (NMF 60/50 and NMFS 60/75) resulted in large proportional increases in coho abundance in the mainstem from the South Fork to the proposed dam site, Newaukum River, the upper Chehalis, and the Middle Chehalis tributaries. The Middle Chehalis tributaries were mostly outside MF areas and generally represented coho salmon spawning in the model, resulting in substantial benefits to coho salmon in this small population.

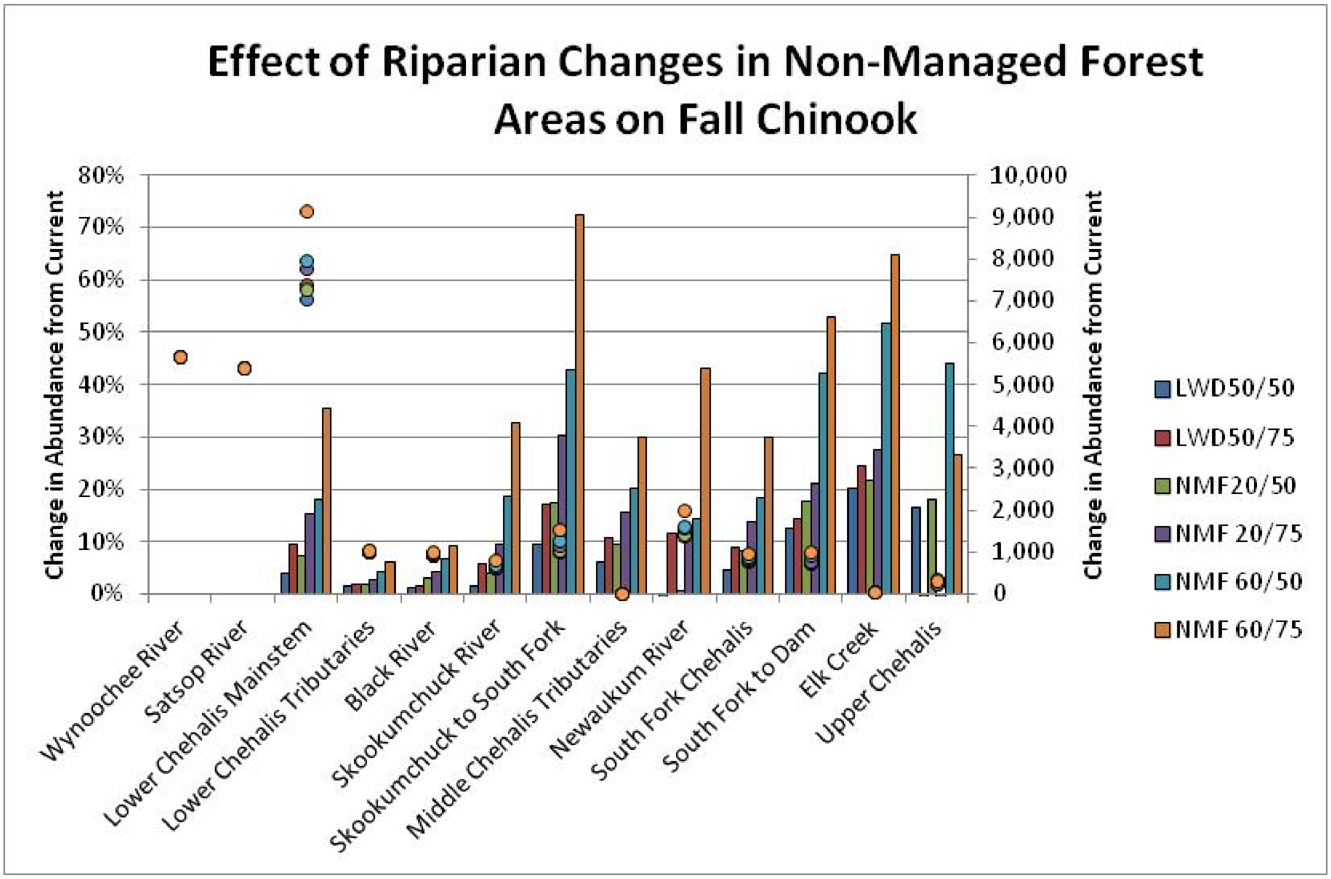
Figure 5.23
Effect of Riparian Changes in Non-managed Forest Reaches on Coho Salmon Populations



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Fall-run Chinook Salmon Populations. Riparian change in NMFs provided smaller proportional benefit for fall-run Chinook salmon compared to other species, though the changes could still be characterized as substantial (Figure 5.24). The greatest proportional benefit from riparian actions was seen in the mainstem section from the Skookumchuck to the South Fork. The Elk Creek population responded to the riparian enhancements, although the changes represent a very small number of fish, as this population is confined to the RM 1.1 (RKm 1.8) section downstream from the falls.

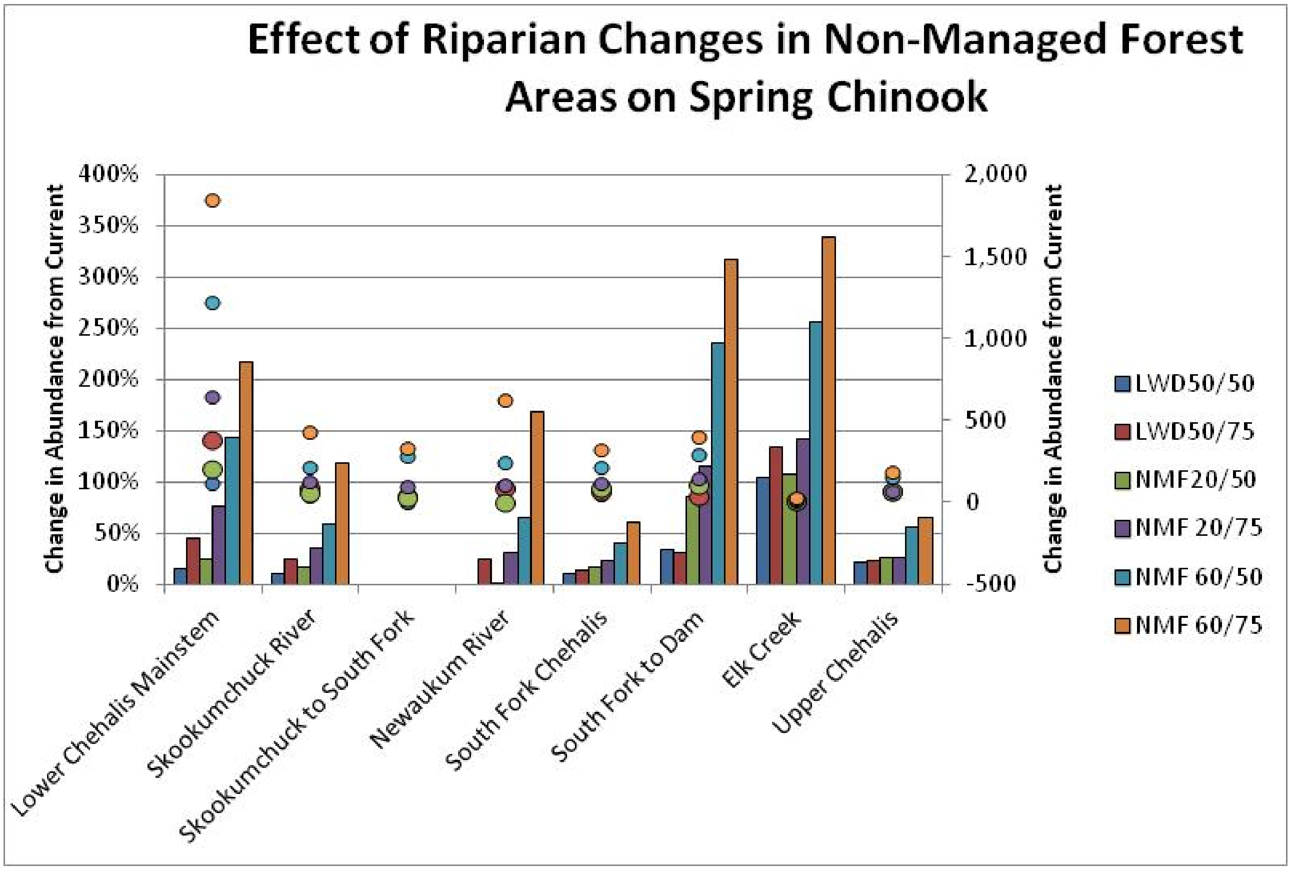
Figure 5.24
Effect of Riparian Changes in Non-managed Forest Lands on Fall-run Chinook Salmon



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Spring-run Chinook Salmon Populations. Riparian measures in NMF reaches had substantial proportional benefits for spring-run Chinook populations (Figure 5.25). The greatest benefits were seen in the South Fork to Dam and Elk Creek populations. The South Fork to the dam spring-run Chinook population responded favorably to temperature moderation provided by the riparian enhancements. Riparian change in Elk Creek had a substantial proportional change in spring-run Chinook abundance, but it was only in the short reach downstream from the falls because spring-run Chinook were assumed to not pass the falls on Elk Creek. The Newaukum sub-basin has a larger area of NMF compared to the South Fork or upper Chehalis areas, resulting in a high benefit from riparian enhancement in the NMF areas.

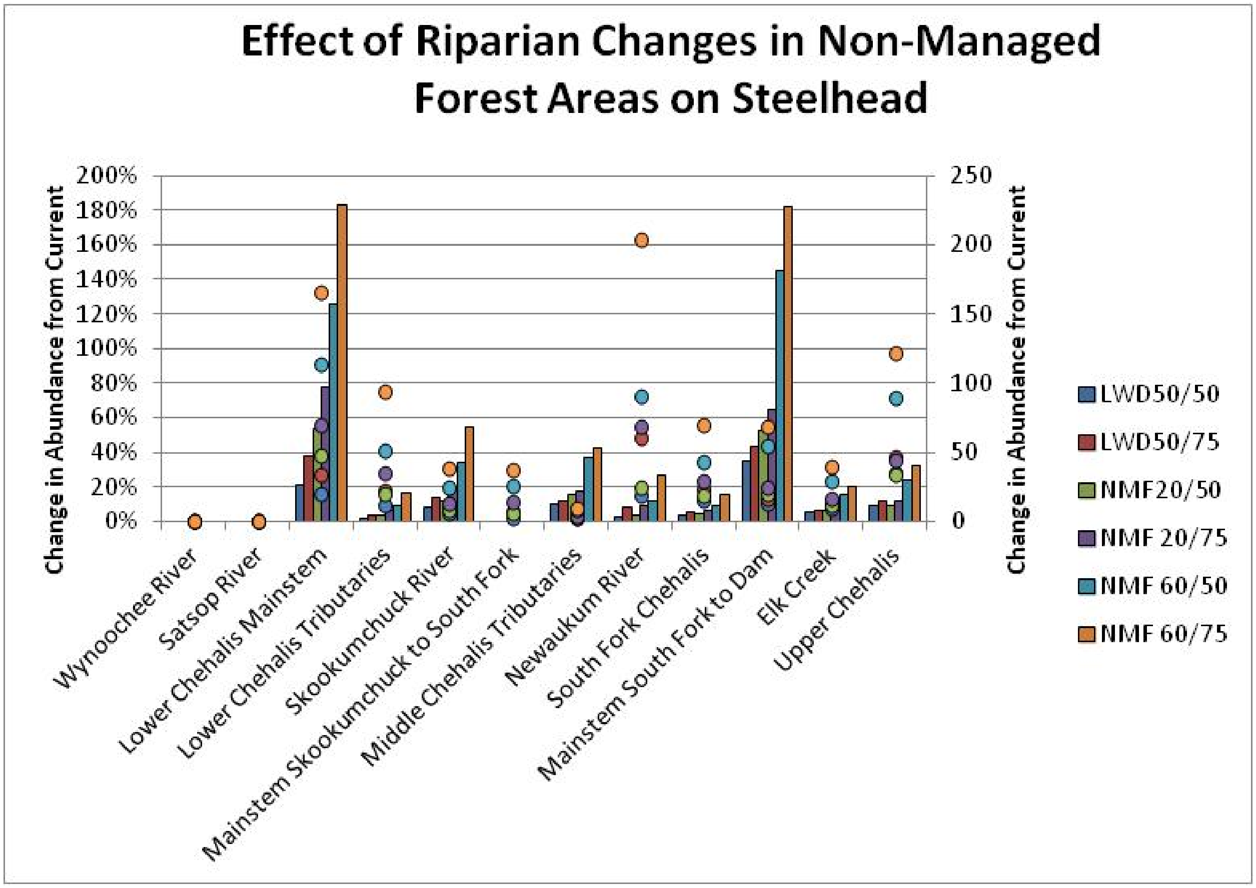
Figure 5.25
Effect of Riparian Measures on Spring-run Chinook Salmon Populations



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Winter-run Steelhead Populations. Benefits of riparian actions in NMFs on steelhead occurred primarily in mainstem reaches in the lower Chehalis River and from the South Fork to the proposed dam site (Figure 5.26). These changes resulted from moderation of summer temperature because of improved riparian conditions. Steelhead spend 2 years in the Chehalis River as juveniles and high summer water temperature limits steelhead abundance in the mainstem.

Figure 5.26
Effect of Riparian Actions in Non-managed Forest Areas on Steelhead



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

5.2.4 COSTS

The costs of implementing the NMF actions are summarized in Table 5.4, and assumptions are included in the footnotes. Additional assumptions used for estimating these costs are in Appendix G.

Table 5.4
Basin-wide Spring-run Chinook Salmon-focused Restoration Totals

ENHANCEMENT ACTION	LOW RANGE	MEDIUM RANGE	HIGH RANGE
50% Action Area			
Riparian Treatments	$ 26,800,000	$ 45,400,000	$ 66,300,000
Acres Treated	*1,241*	*1,241*	*1,241*
Cost Per Acre	*$ 30,000*	*$ 40,000*	*$ 60,000*
Cost Per River Mile	*$ 330,000*	*$ 560,000*	*$ 810,000*
LWM Placements	$ 12,900,000	$ 18,500,000	$ 25,100,000
Cost Per River Mile	*$ 160,000*	*$ 230,000*	*$ 310,000*
Restoration Total	$ 39,700,000	$ 63,900,000	$ 91,400,000
75% Action Area			

ENHANCEMENT ACTION	LOW RANGE	MEDIUM RANGE	HIGH RANGE
Riparian Treatments	$ 40,200,000	$ 68,100,000	$ 99,500,000
Acres Treated	*1,862*	*1,862*	*1,862*
Cost Per Acre	*$ 30,000*	*$ 40,000*	*$ 60,000*
Cost Per River Mile	*$ 330,000*	*$ 560,000*	*$ 810,000*
LWM Placements	$ 19,400,000	$ 27,800,000	$ 37,700,000
Cost Per River Mile	*$ 160,000*	*$ 230,000*	*$ 310,000*
Restoration Total	$ 59,600,000	$ 95,900,000	$ 137,200,000

Notes:

1. Totals have been rounded up to the nearest $100,000.
2. Total miles of treated channel are 82 for 50% and 123 for 75%. Length data was taken from GIS on May 13, 2014. EDT data were provided by IFC on May 13, 2014.
3. Areas identified for spring-run Chinook salmon spawning are per WDFW and do not include areas of land more than 80 acres (32.4 ha).
4. Riparian treatments are applied only to a portion of the reaches identified for spring-run Chinook Spawning. Assumptions include the following:
   a. 50% and 75% of the spawning channels will be restored outside the WFPA areas.
   b. A proposed riparian buffer width of 250 feet (76.2 m) on each side of the stream.
   c. A 50/50 spilt between revegetation and preservation was assumed for the riparian areas to be treated.
   d. Easements required for 25% of the riparian planting areas.
   e. Purchase required for 25% of the riparian planting areas.
5. LWM placements are a combination of ELJs and smaller LWM structures placed at a net average rate of 124 pieces of LWM per mile.

ELJ = engineered log jam
LWM = large woody material

5.2.5 OFF CHANNEL

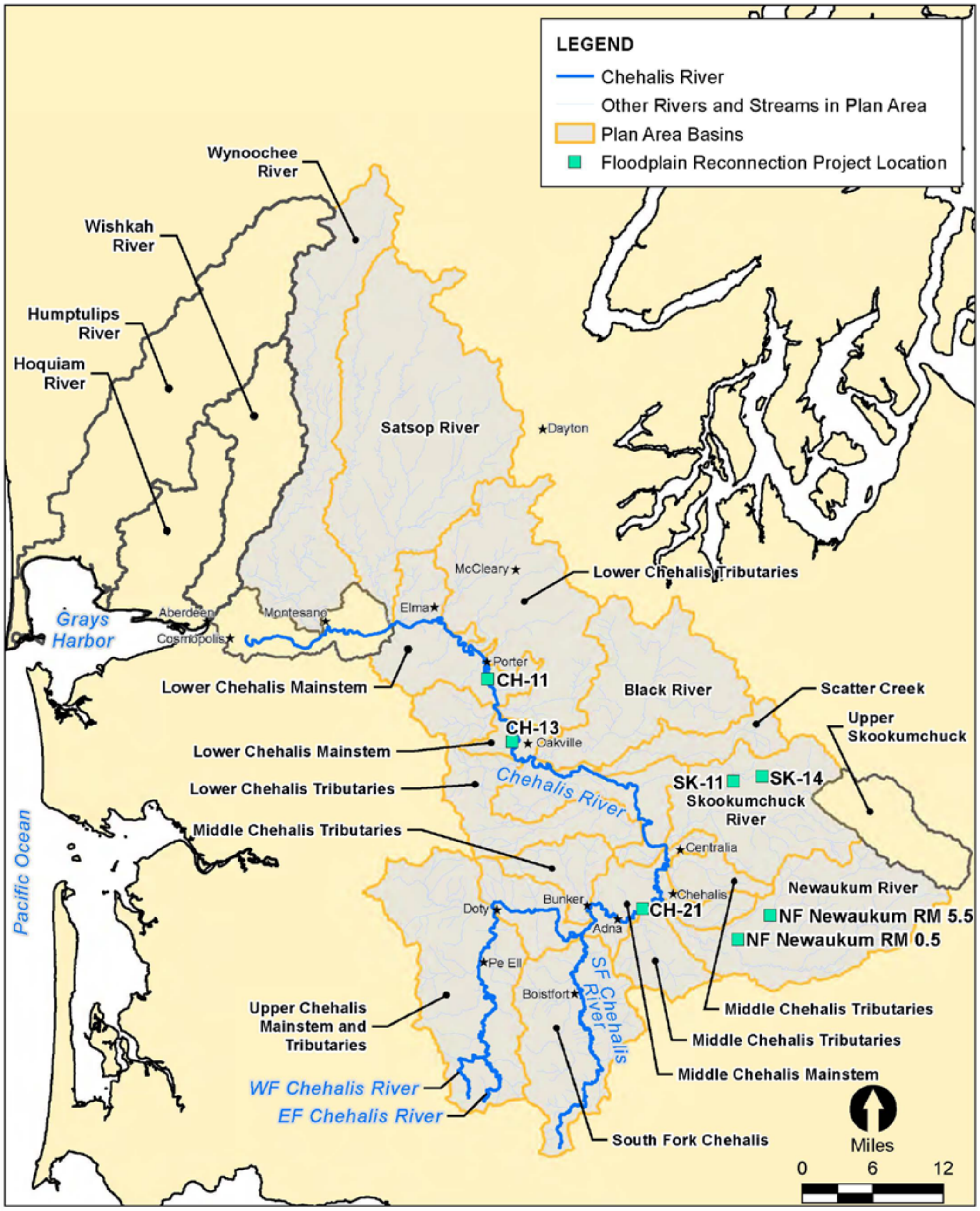
Six potential project locations were evaluated within spring-run Chinook spawning reaches: two on the mainstem Chehalis, two on the Newaukum, and two on the Skookumchuck. Two of these off-channel restoration projects were selected in coordination with WDFW and evaluated for their effects on Chehalis salmon populations (Figure 5.27; Table 5.5). Assumptions used for estimating these costs are in Appendix G. Additional information regarding these projects is included in Appendix I.

The locations of the projects chosen took into account the desire to target Other Fish and Non-fish Species. The two chosen locations, CH-13 and SK-14, are thought to have excellent potential as trial off-channel connection projects, based upon the assumption that they would have existing populations of Key Other Fish and Non-fish Species. Project CH-13 on the mainstem Chehalis River is located near Porter, Washington at RM 43 (RKm 69.2). Project SK-14 is on the Skookumchuck River at RM 15 (RKm 24.1).

Table 5.5
Selected Off-channel Restoration Projects in Spring-run Chinook Salmon Spawning Reaches

RIVER	SELECTED PROJECT	RM	2014 ASEP COST EST.	PROJECT DESCRIPTION	LIMITING FACTORS ADDRESSED
Mainstem Chehalis	CH-13	43	$5,900,000	Reconnect oxbow with mainstem Chehalis. Enhance low elevation areas, off channels, and floodplain habitat with vegetated benches and LWM.	Floodplain Conditions, LWM, Riparian Conditions
Skookumchuck	SK-14	15	$550,000	Off channel/floodplain enhancement. Includes removing invasive species/planting native forest trees and understory.	Floodplain Conditions, Riparian Conditions, LWM

Figure 5.27
Floodplain Reconnection Project Locations

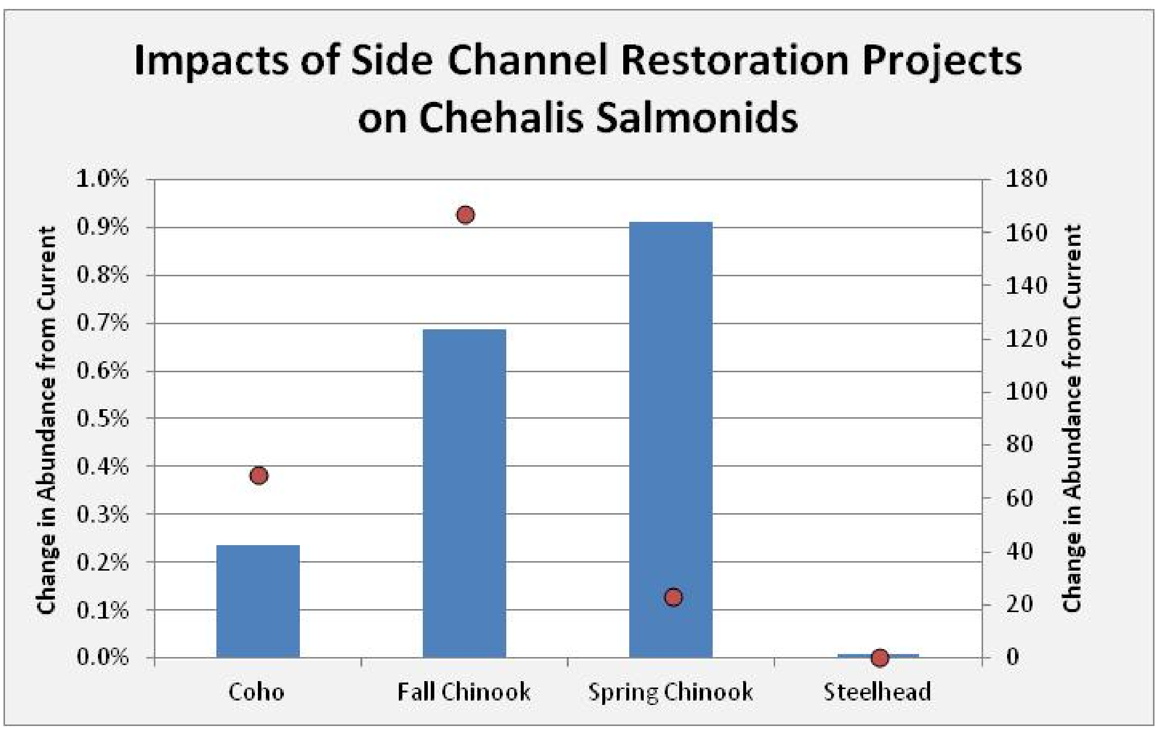


The projects were modeled in EDT to assess effects from these projects on the four species of salmon modeled in EDT. At a species scale, the selected off-channel restoration projects had very small effects on overall abundance, ranging from 0.025% for coho salmon to 0.90% for spring-run Chinook salmon (Figure 5.28). The greatest proportional benefits were to spring-run Chinook, followed by fall-run Chinook and coho salmon. Steelhead in the model were assumed to not utilize off-channel habitats, and so the projects provided no benefit to steelhead. Overall, the projects contributed small numbers of coho salmon, fall-run Chinook, and spring-run Chinook to the basin.

The Skookumchuck off-channel project would only benefit fish from the Skookumchuck sub-basin, and the project on the mainstem Chehalis would mainly benefit nearby populations and provide less benefit to upper Chehalis River populations. For these reasons, a more relevant analysis is at the population level (Figure 5.29). The changes in abundance of coho salmon, fall-run Chinook, and spring-run Chinook were greatest for the mainstem Chehalis River, Black River, and Skookumchuck populations. Effects to other populations were minimal to zero. The mainstem Chehalis River and Black River populations benefited from the mainstem Chehalis off-channel project (CH-13), while the Skookumchuck project (SK-14) benefited Skookumchuck populations. Skookumchuck populations could also receive some benefit from the mainstem Chehalis off-channel restoration.

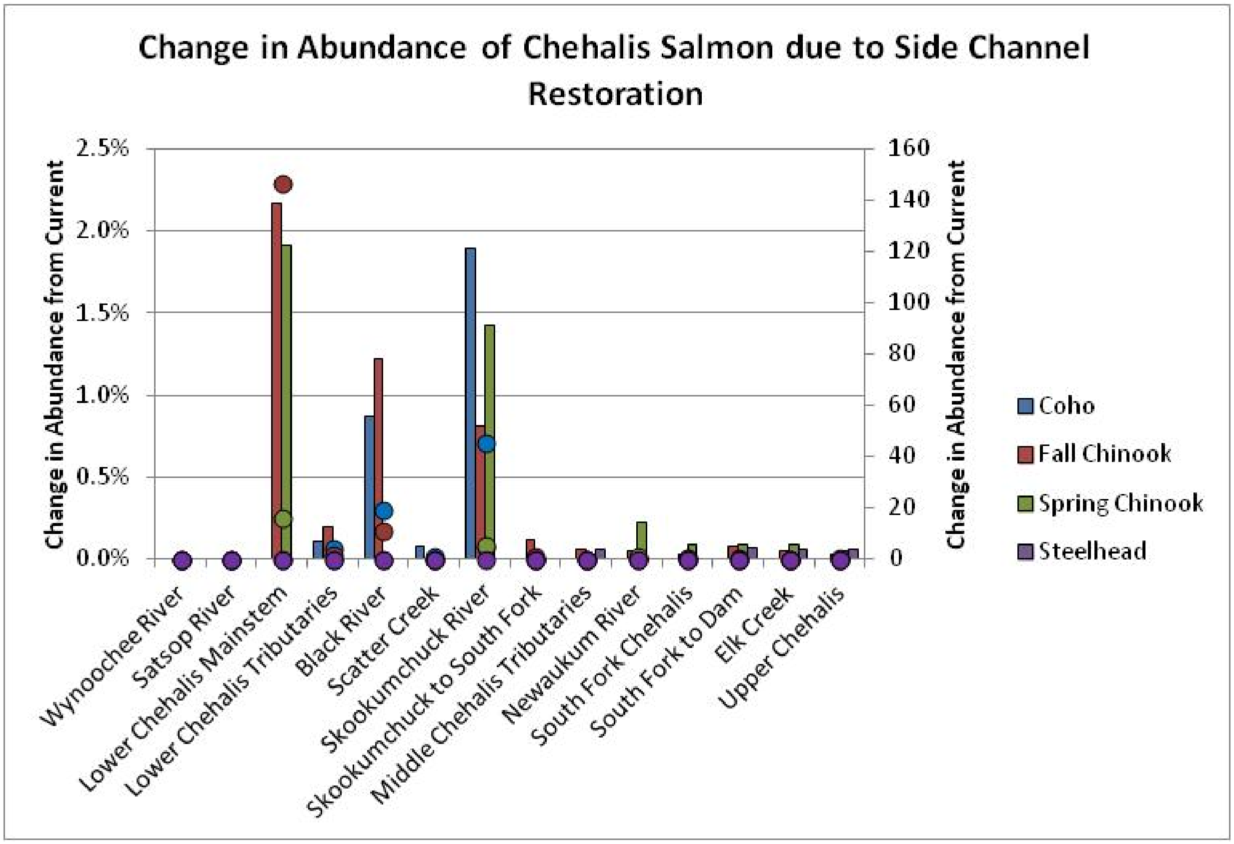
Due to the lack of information on Other Fish and Non-fish Species, off-channel restoration projects should be further analyzed prior to implementation. Once a site is selected, monitoring to determine the population levels of existing species should be conducted. Monitoring during and after construction of these projects should also be conducted to determine what effects these projects may have on target species population levels, and also if they are creating habitat for non-native predators. At the onset of a restoration program, control areas should also be established to monitor existing target and non-native predators and determine which direction these populations are trending. This information can be used to compare with the restoration projects and determine the effect of the restoration projects in comparison with existing population trends.

Figure 5.28
Changes in Abundance of Chehalis Salmonids Due to Off-channel Restoration Projects



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Figure 5.29
Changes to Individual Populations of Chehalis Salmonids Due to Off-channel Restoration Projects



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

The low gradient, poorly confined geomorphology of the basin is characterized by a diverse and complex network of off-channel aquatic areas that provide critical habitat for a suite of fish (including juvenile salmonids), amphibians and aquatic reptiles (including the western pond turtle). In river systems such as the Chehalis, off-channel habitats are inherently dynamic and undergo a physical and vegetation process of succession over time. This process relies on both the creation of newly connected off-channel areas during freshets (flood events) and maintenance of existing connectivity between the main stem and off-channel areas. Land use practices that straighten or confine the river channel or dewater or eliminate off-channel areas can negatively influence the quantity and quality of habitat for this suite of species. Moreover, altered connectivity between off-channel areas and the main river channel could hinder the ability of many of these species to re-colonize or seasonally access off-channel habitats. As such, restored connectivity has high potential to benefit aquatic species in the portions of the basin with well developed off-channel habitats. However, a key uncertainty associated with this potential benefit is whether and how the presence of non-native species (e.g., largemouth bass and American bullfrogs) may effect (and perhaps detract from) the benefits that off-channel habitats and their ecosystem dynamics accrue for native species (e.g., juvenile coho salmon, Olympic mudminnow, northern red-legged frog, Oregon spotted frog). Hence, the distributions of off-channel habitat-dependent species and their interactions with both seasonal changes in habitat and the non-native predators occupying those habitats need to be better understood prior to providing confident technical guidance on the benefits of connecting and creating off-channel habitats in the basin.

When identifying locations for off-channel projects, adjacent upland components should be taken into consideration. Several non-fish species require extensive adjacent riparian and upland habitats to complete their life cycles. n discussions with WDFW (Hayes pers. comm. 2014a), it was estimated that for planning purposes, establishing a 1,500-foot-wide (457-meter-wide) upland segment, at least on one side, of off-channel projects would provide adequate habitat for those species that require uplands adjacent to off-channel habitats for their seasonal life history needs, such as the northern red-legged frog. The distance along the off-channel habitat that this increased width of uplands would extend would vary with the size of project. For smaller projects, in the range of 1,000 linear feet (304.8 m) or less of aquatic off-channel habitat, an upland segment over a distance of 50% of the aquatic habitat length was estimated as adequate as a first cut to evaluate the effects of these projects on target species. This distance could be reduced on larger projects, but would depend on the project site and existing adjacent habitats. The experimental nature of these projects would require monitoring to verify the effectiveness of these estimates.

Because of the high value of these ecosystems to salmonids, other fish, and non-fish, off-channel restoration projects should be a part of the overall restoration strategy for the basin. They need to be approached with caution to ensure they provide the intended benefits and not increase habitat for non-native invasive species. To address these issues, control sites should be established in appropriate areas in the basin to determine what species are present in existing off-channel areas and how prevalent they are. The specifics of these control projects are detailed more fully in the companion *Data Gaps Report*.

After the control projects determine presence and abundance of species, this information should be used to inform where off-channel projects should be implemented. Until results from the control projects are available, the exact location of off channel projects should not be determined. However, once preliminary data is collected from the control projects, implementing two large and four smaller projects would be an advisable approach for these types of projects. This approach will provide valuable information on the effects of implementing these projects and aid in determining which projects provide the greatest benefit for target species. Using the two projects that were had cost estimates completed for the ASEP as a guideline, the figure $15 million should be considered to be included in the overall restoration package to implement two large projects and four smaller off-channel projects.

5.2.6 COMBINATION SCENARIOS

The previous sections discussed changes to the abundance of the four salmonid species with habitat enhancements considered individually. This section discusses the results of considering the actions in combination. In analyzing combinations of actions, important synergies can occur. Synergisms can be positive, meaning that the change resulting from the combination of actions is greater than the sum of the change from each individual actions, or synergies can be negative in which case the combination of actions results in a smaller change than the sum of the change from the individual actions (though the effect will generally be greater than the change for any one action by itself). Positive synergies occur for example when removal of a blocking culvert is combined with habitat enhancement such as the addition of large wood downstream and upstream from the culvert. Removing the culvert by itself increases capacity by opening new habitat, but that habitat is of poor quality because it lacks wood. On the other hand, adding the wood without removing the culvert only results in a change to fish abundance from improving habitat quality downstream from the blocking culvert. Removing the culvert and then adding wood upstream and downstream from the culvert increases capacity (more habitat) and productivity (greater habitat complexity due to wood), resulting in an overall change in abundance that is greater than the sum of doing either action by itself. Negative synergies occur when the effect of actions are limited by the total habitat capacity and the restoration potential for the habitat. Consider three actions, each of which restore 50% of the habitat restoration potential when executed in isolation. When executed in combination, the first action may restore 50% of the potential, but the second can only restore 50%

of the remaining potential, while the third action can only restore 50% of the potential remaining after the second action. In this case, the total result of implementing all three actions is less than the sum of implementing each in isolation though greater than the effect of any of the three actions in isolation. Negative synergies can be counter-intuitive but reflect reality: it is not possible to restore more than the total potential of the habitat (it might be possible to enhance habitat conditions beyond their intrinsic conditions but these types of actions are not considered). Negative synergism especially occurs when analyzing wide-spread actions that mainly improve habitat quality (productivity) rather than habitat quantity (capacity). In combining the actions previously discussed, negative synergies occur and affect the interpretation of results.

Combination scenarios combined riparian and culvert enhancements into two scenarios intended to bracket the enhancement actions (Table 5.6). Low and High Enhancement Alternatives were created by combining the low Enhancement Alternatives for NMF areas and for MF, and the High Enhancement Alternatives for NMF and MF, respectively. Culvert removal was added to both Enhancement Alternatives.

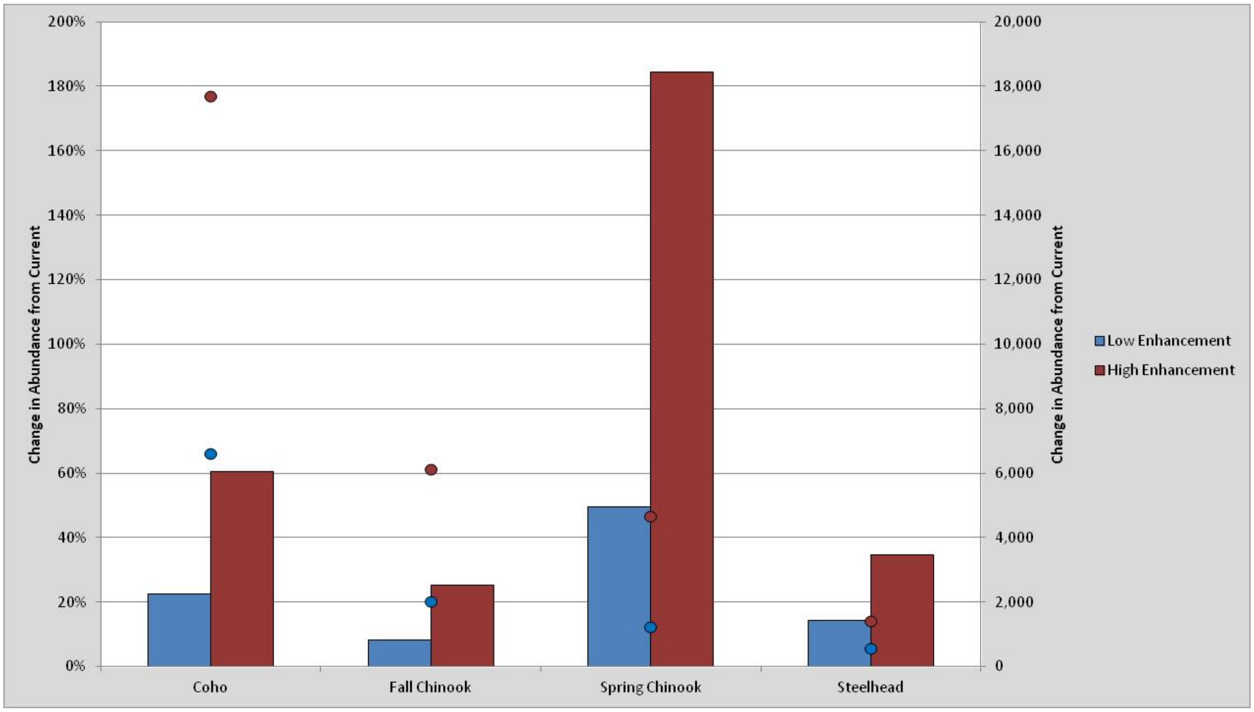
Table 5.6
Description of Combination Scenarios Analyzed for Chehalis Basin Salmonids

SCENARIO	DESCRIPTION
Low Enhancement	NMF 20/50 + MF 20 + Culvert removal
High Enhancement	NMF 60/75 + MF 60 + Culvert removal

Notes: MF = managed forest
NMF = non-managed forest

Species Level. Results of the enhancement combination scenarios are shown in Figure 5.30. Proportional change in abundance measures the benefit of the actions on the species, while numeric changes show the overall effect of the actions on Chehalis salmonids. The change in abundance from current habitat to the low and high enhanced habitat was greater than the change from any of the actions by themselves but less than the sum of each action indicating a negative synergism. As a proportion of the population, the enhancement measures primarily benefited spring-run Chinook, which were the target of the NMF alternatives that affected conditions in the mainstem reaches. Spring-run Chinook in the model responded positively to reductions in temperature that are realized from the enhancement alternatives. In addition, actions in NMF targeted spring-run Chinook spawning reaches. The enhancement measures had the greatest numeric change for coho salmon that are the most abundant species in the Chehalis model. As discussed previously for individual measures, fall-run Chinook had a relatively small benefit from the enhancement measures despite their high overall abundance. This had to do with the distribution of enhancement actions relative to the distribution of fall-run Chinook in the basin as discussed previously in connection to Figure 5.10.

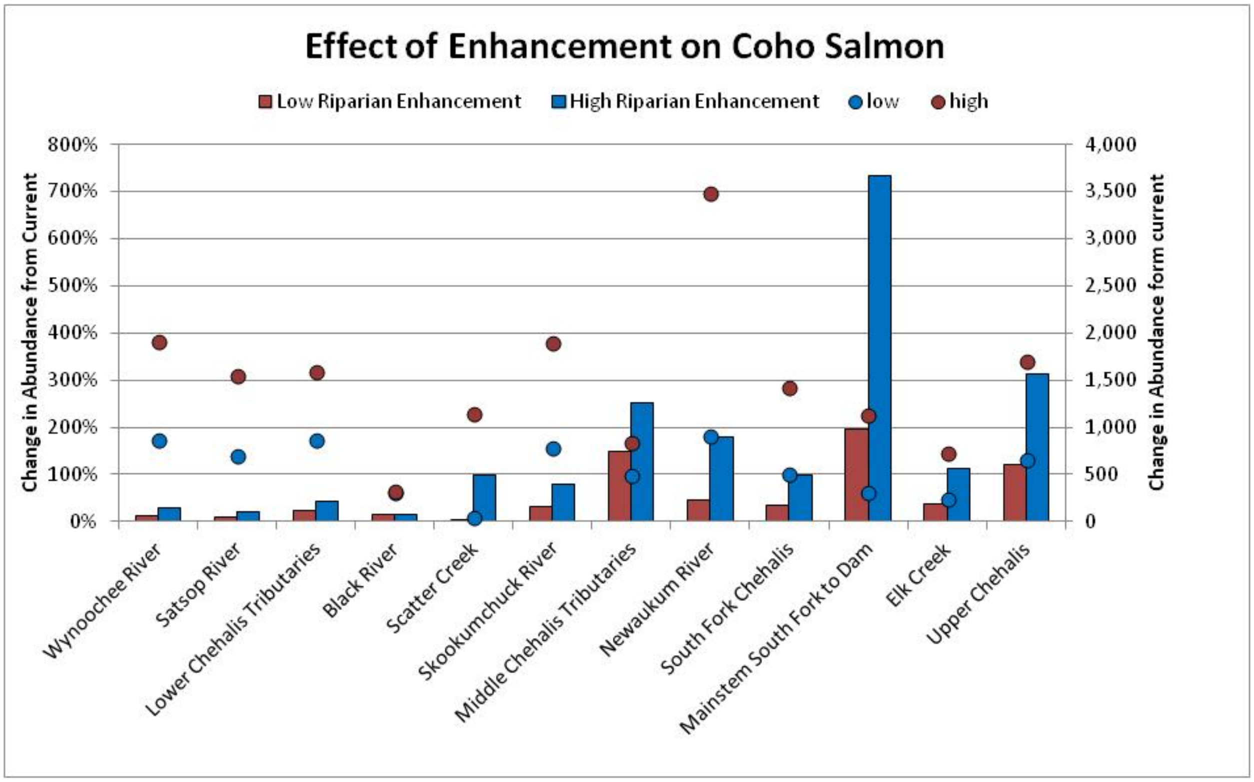
Figure 5.30
Changes in Chehalis Basin Salmonids from Current Abundance Due to Riparian Enhancements, Culvert Removal



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Coho Salmon. The effect of the enhancement combination scenarios on coho salmon populations is shown in Figure 5.31. The enhancement scenarios had their greatest proportional effect on coho salmon in mainstem South Fork to Dam segment. This is a potentially productive area of the river for coho salmon that benefited from the addition of large wood and a reduction in temperature. The enhancement scenarios also had benefited coho salmon in the Newaukum River and the upper Chehalis River.

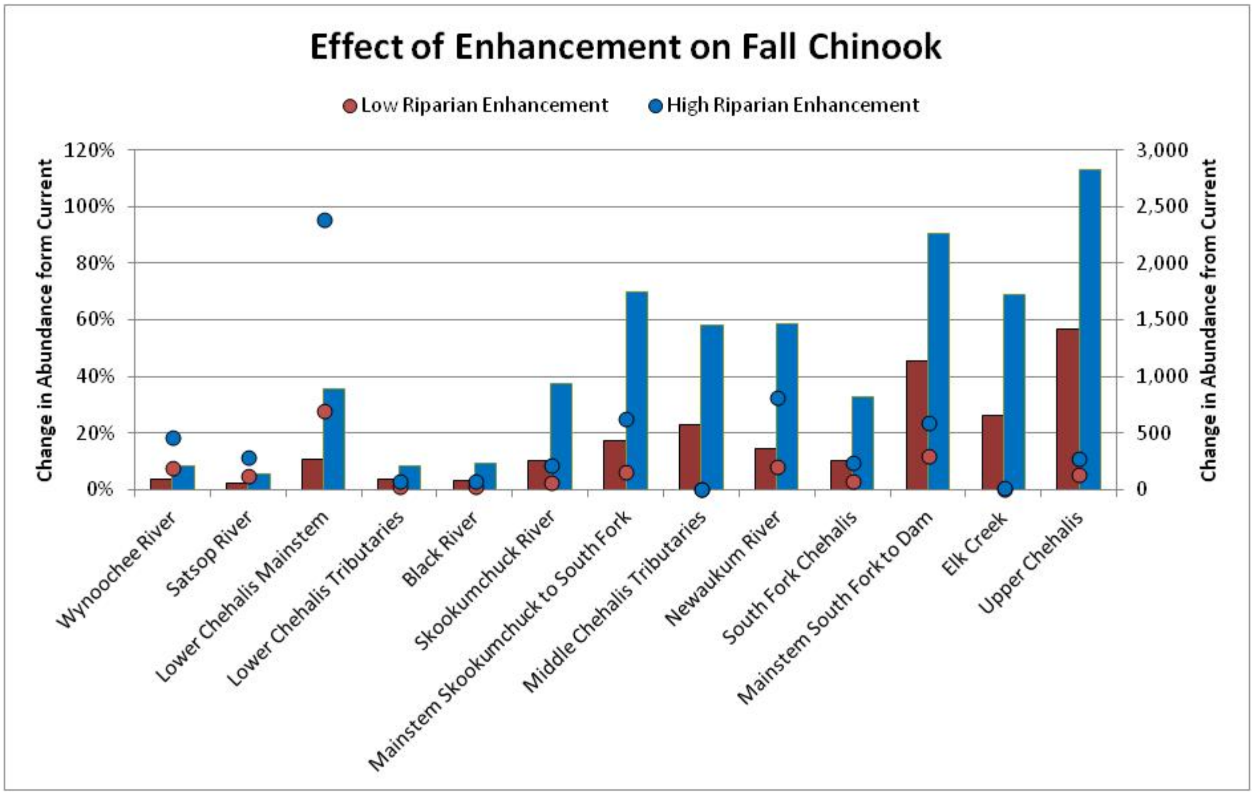
Figure 5.31
Effect of Combination Scenarios on Chehalis Coho Salmon Populations



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Fall-run Chinook salmon. The overall effect of the enhancement measures on fall-run Chinook was less than that seen for other species. As discussed previously, this had to do with the juxtaposition of the enhancement measures and fall-run Chinook distribution in the model. The proportional change to individual fall-run Chinook populations increased from downstream to upstream, with the greatest effects to the upper Chehalis River populations (Figure 5.32). These fall-run Chinook populations have relatively low abundance relative to lower Chehalis River populations. Nonetheless, the enhancement measures had a high proportional benefit.

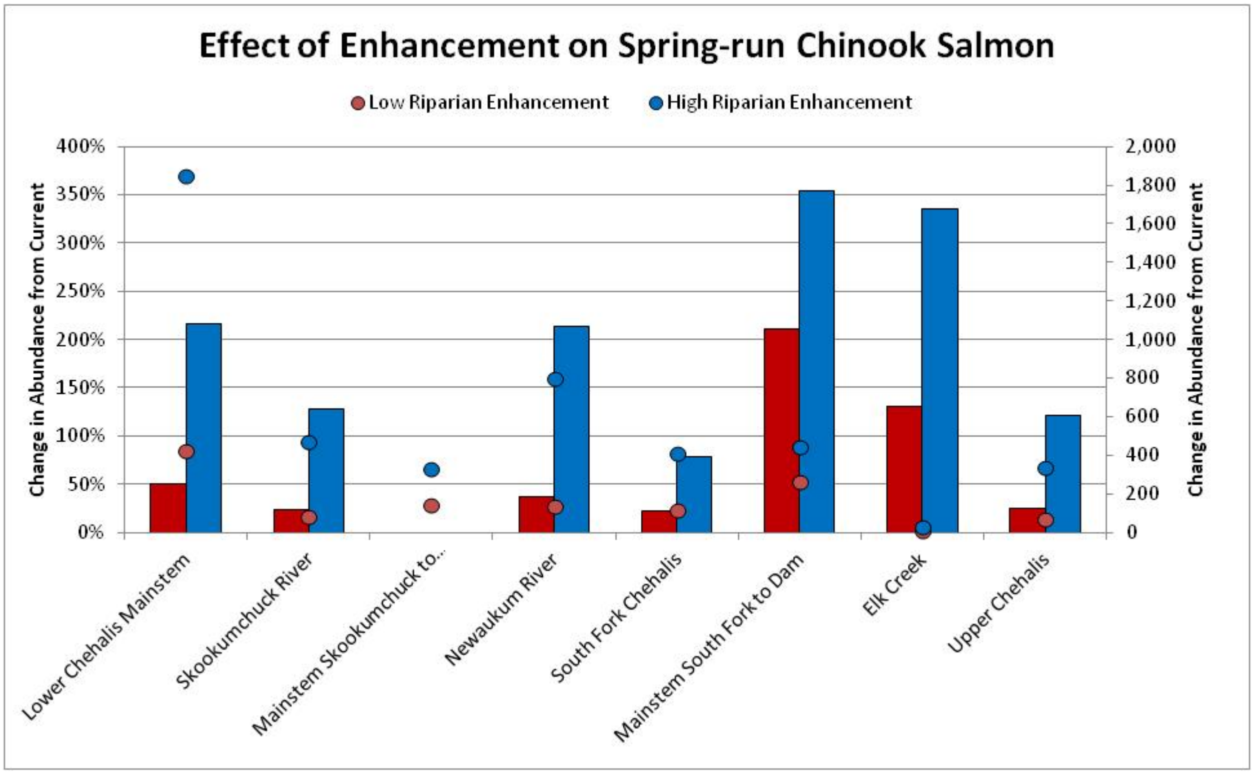
Figure 5.32
Effect of Combination Scenarios on Chehalis Fall-run Chinook Salmon Populations



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Spring-run Chinook. The low and high riparian enhancement measures had their greatest benefit for spring-run Chinook in the mainstem Chehalis River population between the South Fork and the dam (Figure 5.33). Spring-run Chinook in this segment showed a positive response to actions that decreased water temperature during the summer adult holding period and fall spawning. Temperature reduction due to the enhancement measures also had a positive effect on spring-run Chinook in the lower Chehalis mainstem. Enhancement measures in the Newaukum River benefited spring-run Chinook due to the combination of temperature change and addition of large wood.

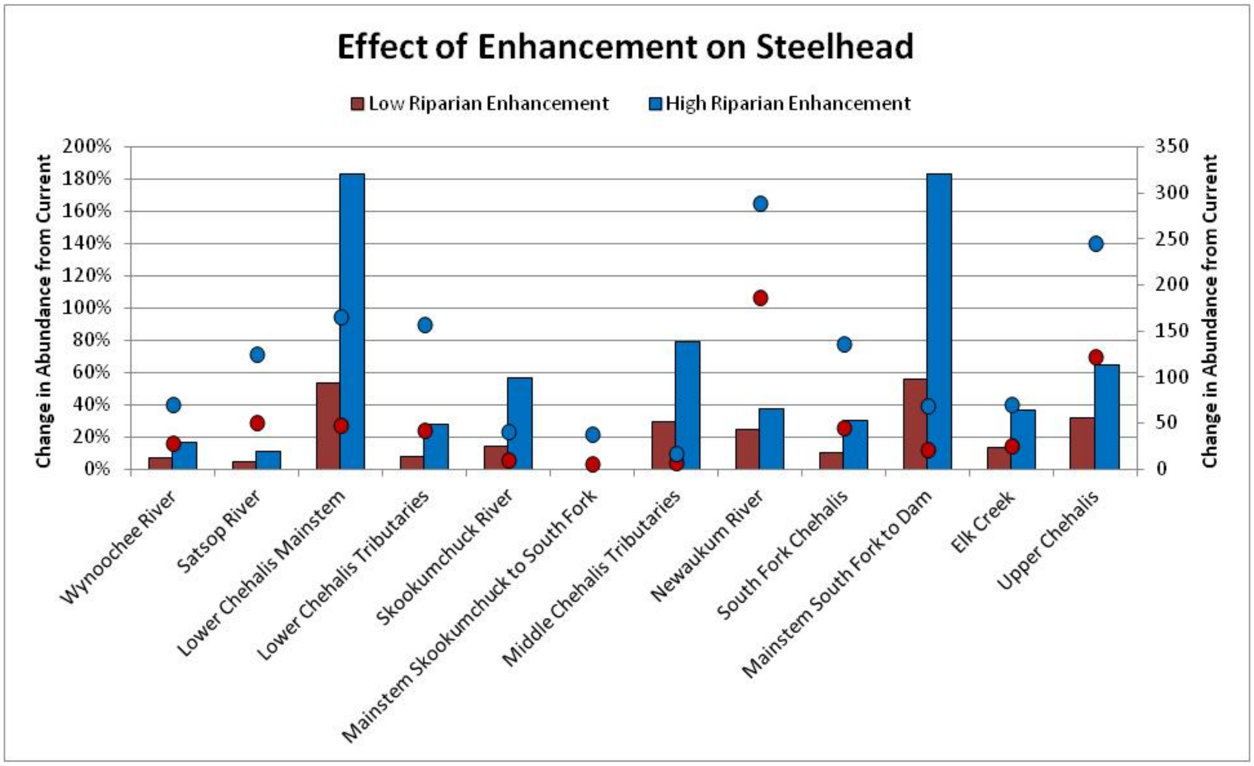
Figure 5.33
Effect of Combination Scenarios on Chehalis Spring-run Chinook Salmon Populations



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

Steelhead. The pattern of benefits to steelhead from the enhancement measures followed a similar pattern to that of spring-run Chinook (Figure 5.34). The greatest proportional change was to the small population in the mainstem from the South Fork to the Dam. However, in contrast to spring-run Chinook that benefited from cooler water during the adult life stages, the enhancement measures benefited steelhead during the juvenile periods. Winter-run steelhead were assumed to spend two years in freshwater, and the cooler summer temperatures benefited the juvenile rearing life stage. A similar mechanism was behind the large proportional change in steelhead in the lower Chehalis River.

Figure 5.34
Effect of Combination Scenarios on Chehalis Steelhead Populations



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

5.3 Other Fish Species Enhancement Actions

In Section 3 of this report, descriptions of the habitat requirements of the Other Fish Species and factors that may be limiting different life stages are provided in general terms, along with a list of potential enhancement actions that could be used to address the limiting factors. In this section, the discussion is further expanded by focusing on the types of enhancement actions needed to address the limiting factors.

Eleven fish species exist in this grouping: Pacific lamprey, white sturgeon, chum salmon, eulachon, speckled dace, largescale sucker, reticulate sculpin, riffle sculpin, Olympic mudminnow, largemouth bass, and smallmouth bass. Of the three broad groups of organisms being evaluated in ASEP (salmonids, Non-fishes, and Other Fishes), the Other Fish groups have the least amount of information on their life history and habitat requirements. As pointed out in Table 4.2, in many cases, the factors limiting a population and the types of enhancement actions required are unknown.

The types of enhancement actions discussed previously for Other Fish can be organized into the following categories:

- **Salmon restoration projects would be positive to neutral for Other Fish species:** For species with life stage requirements similar to salmon, projects that improve salmon habitats would be neutral or perhaps positive for some other species as well. For example, speckled dace spawn in gravel substrate at the tail-outs of pools and in riffles. Enhancement actions for salmon that reduce silt loading and increase in-channel habitat complexity will benefit speckled dace spawning as well. Speckled dace adults reside in mainstem pools. Enhancement actions for salmon to increase in-channel habitat complexity will benefit adult speckled dace as well. This could include placement of LWM, ELJs, boulders, etc. Largescale sucker fry and Pacific lamprey larvae occupy silty backwater habitats on the mainstem and in tributaries. They require depositional areas protected from high velocity current during summer. These are successional habitats, where changes in sediment transport (deposition and flushing) could change the rate of succession and connectivity. Projects that construct or maintain backwater-rearing habitats for salmon will benefit largescale sucker fry and Pacific lamprey larvae rearing.

- **Restoration projects for some species would be similar to salmon projects:** Restoration projects that benefit other species of salmon and steelhead will likely benefit chum salmon as well, with the exception of projects aimed at rearing of juvenile salmon. Limiting factors for chum salmon are largely restricted to spawning and incubation, with flood scour and superimposition (crowding of redds) being the two factors most likely to limit them. Restoration projects that address scour such as controlling flooding and in-channel structures, and projects that reduce superimposition of redds by expanding access to or constructing additional spawning habitat will benefit chum salmon.
- **Restoration projects that maintain the current frequency and duration of flows to reduce fine sediment accumulations and maintain the current mosaic of habitat types**: Projects that address these attributes could potentially benefit a number of species and life stages. This includes adult Pacific lamprey and speckled dace that require appropriately sized and clean gravel substrate at pool tail outs and in riffles, and adult large scale suckers that reside in pool habitat.
- **Restoration projects that provide off channel habitat and connectivity to these habitats:** Largescale sucker fry, speckled dace, and Pacific lamprey larvae occupy silty backwater habitats on the mainstem and in tributaries. They require depositional areas protected from high velocity current during summer. These are successional habitats, where changes in sediment transport (deposition and flushing) could change the rate of succession and connectivity. Projects that construct or maintain backwater-rearing habitats will benefit large scale sucker fry, speckled dace, and Pacific lamprey larvae rearing.
- **Restoration projects that maintain access to mainstem foraging areas:** Adult white sturgeon are thought to move into the lower mainstem Chehalis River from Grays Harbor to forage. Catch records indicate that the majority of their distribution is below the Black River with less than 10% of the recorded catches coming from above. For these foraging migrations to be successful, the fish need access to main channel reaches and self-sustaining populations of key food resources. They are not spawning in the river and can enter the river in any season. Therefore, projects that maintain water quality in the mainstem and access to upstream mainstem reaches should benefit white sturgeon.
- **Restoration projects that maintain access to spawning habitat:** This is a generic requirement for all species, but in this context it refers specifically to chum salmon. As with other salmon species, chum salmon are able to spawn in shallow water and diverse channel habitats. Enhancement actions that will benefit chum salmon include improving access to spawning areas through barrier removal, improving the quality of spawning habitat, maintaining flows over redds sufficient for flushing and oxygenating gravels, and enhancing riparian vegetation to maintain bank stability and decrease sloughing of banks and siltation.
- **Restoration projects that maintain adequate quantity of spawning habitat and substrate type:** Freshwater limiting factors for eulachon are largely restricted to river conditions and spawning, with a lack of appropriate sand and pea-sized gravel substrate being the most likely limiting factor. Eulachon are present in the mainstem Chehalis River, as well as the Wynoochee and Satsop rivers. Once juveniles emerge from the substrate, they are flushed out of the natal reach with river flow. Enhancement actions that maintain an adequate quantity of sand and pea-sized gravel areas for spawning will benefit eulachon.

- **Restoration projects that involve control of non-native predators through targeted removals:** For Olympic mudminnow, removal of non-native predators, such as largemouth and smallmouth bass, from oxbow lakes and off-channel habitats, will benefit the species. This might be accomplished by targeted harvest of predator species through changes in harvest regulations (season length and daily catch limits), fishing derbies and reward programs, and selected trapping. However, the effectiveness of these approaches on Olympic mudminnow is untested, and responses to their application are uncertain. Hence, any attempts at their application should involve monitoring that can adaptively track the results and provide direction to improve any future attempts at applications. A large part of this uncertainty is based on whether the locations targeted for restoration are associated with the in-stream main channel Chehalis that is non-native dominated, and whether off-channel reconnection is also part of the restoration. If the in-stream main channel Chehalis is not non-native-dominated, then non-native removal would likely be a success if off-channel reconnection is also part of the restoration. If the in-stream main channel Chehalis is non-native-dominated, then the success of non-native removal would be uncertain if off-channel reconnection is part of the restoration. In the latter instance, it would be critically important to adaptively monitor the results of the enhancement action. The creation of preferred habitats for species will reduce the potential for further contractions of their distribution and range.

Based on existing information, our ability to quantify the potential benefits of these actions to most Other Fish Species is limited, as restoration science has focused on culturally and economically important fish species, such as salmon. As pointed out in Section 5, available information on the species discussed here is too sparse to inform population trends or, in many cases, to identify their ecological constraints. Therefore, a critical and necessary precursor to enhancement actions on most Other Fish species is inventory of aquatic habitats to understand where they occur in the basin and the status of their populations. Even after habitats, sites, or projects for potential enhancement actions are identified, it is crucial that their application be monitored, because of the uncertainty associated with responses, especially for Other Fish species that occupy off-channel habitats, where almost no data exist. This will ensure that attempted restorations can contribute meaningfully to future efforts, should they not succeed.

5.4 Non-fish Species Enhancement Actions

To an even greater degree than for Other Fish Species, available information on Non-fish Species is too sparse to precisely direct restoration activities that will positively benefit them, particularly because the balance of the Non-fish Species occur in the most ignored macrohabitat of the floodplain, the off-channel/low-flow habitats. The critical first step in attempting to apply any enhancement actions on these species is a distributional inventory to identify where they still occur in the basin, as uncertainty exists as to whether some Non-fish Species are still present. For example, uncertainty exists about whether Oregon spotted frog and western pond turtle occur in off-channel habitats associated with the main channel Chehalis River. As off-channel habitat in which the Non-fish Species may be present is almost entirely (more than 97%) on private lands, conducting such an inventory will require a private landowner liaison who is particularly effective in facilitating partnerships. Further, the inventory should not only be able to identify where Non-fish Species may be present, but the status of their populations and their likely limiting factors (non-natives or habitat conditions). Once these have begun to be identified, focused habitat-, species-, and project-specific enhancement actions can begin to be designed and implemented. The following sections provide a description of potential habitat restoration activities that could begin to be addressed for Non-fish Species once the aforementioned inventory has begun to identify sites and conditions appropriate for these activities. As with Olympic mudminnow and other Non-fish Species that occupy off-channel habitats, the effectiveness of a number of these restoration approaches is poorly tested on Non-fish Species, so responses to their application are uncertain. Hence, any attempts at their application should incorporate monitoring that can adaptively track the results and provide direction to improve any future restoration attempts. Potential restoration activities were identified based on a review of existing information and coordination with WDFW (Hayes pers. comm. 2014b). A summary of potential restoration activities per species and the sources of information for the analysis are presented in Table 6.2, following the species-specific sections.

Additionally, restoration projects that benefit juvenile coho salmon in off-channel habitat are likely to benefit the entire suite of Key Non-fish Species that occur in off-channel habitats (namely, northern red-legged frog, Oregon spotted frog, western pond turtle, North American beaver, and, if present, western toad). Juvenile coho salmon co-evolved with these species, and limited information reveals that they can be abundant there where coho are present (Henning 2004; Henning and Schirato 2006). Nonetheless, the Non-fish Species' responses to restoration approaches of any kind carry uncertainty because their responses have been so rarely tracked. For this reason, it will be crucial to track the response of Non-fish Species in restoration projects involving juvenile coho salmon in off-channel habitats so that the results can adaptively modify future restoration efforts, when needed.

5.4.1 NORTHERN RED-LEGGED FROG

Potential restoration activities in the basin for northern red-legged frog includes preserving existing suitable upland forest habitat adjacent to aquatic habitat, restoring degraded upland forest habitat, and removing or suppressing warmwater non-native species that prey on northern red-legged frogs.

Preserving existing quality upland forest habitat adjacent to aquatic habitats used by northern red legged frogs would be a beneficial restoration activity for this species, as research indicates the quality of terrestrial habitat (specifically as a function of area) has a greater effect on the northern red-legged frog populations than the aquatic habitat (WDFW unpublished data). Restoring degraded upland forest habitat by removing non-native invasive vegetation, allowing woody debris to accumulate by promoting a multi-age tree canopy that can mature, and promoting a dense understory vegetation of native species (especially with sword fern [*Polystichum munitum*] and/or snowberry [*Symphiocarpus albus*] that shelter northern red-legged frog invertebrate food resources; Hayes 2008; WDFW unpublished data). Acquisitions to allow riparian forest maturation may help in restoring degraded forest, but an active restoration schedule will be needed to remove aggressive forest canopy and understory non-native shrubs and vines ranging from sweet (or bird) cherry (*Prunus avium*) to English holly (*Ilex aquifolium*) and English ivy (*Hedera helix*). Moreover, if nearby sources of these aggressively invasive non-natives exist, a long-term cost will include a vigilance program to eliminate them if they begin to reappear, as long as nearby sources exist.

Removal of non-native fish species, especially centrarchid fishes (basses and sunfishes) and ictalurid catfishes (bullheads) that prey on northern red-legged frogs would also be a beneficial restoration activity based on their known negative effects (Kiesecker and Blaustein 1998; Adams et al. 2003). However, this activity does present a management conflict, because these non-native fish species are recreational game species managed by WDFW. This restoration option would require a policy decision by state government agencies about the management approach, and cooperation from the warmwater fish program within WDFW. Assuming that the management conflict can be resolved, methods do exist, such as rotenone application, to eliminate fish from a circumscribed body of water. Implementing such applications would have to occur during the seasonal interval when the off-channel habitat is disconnected, and at locations where few or no native non-target species would be affected. Additionally, reappearance of these undesirable non-native fishes during seasonal intervals where the off-channel habitat becomes reconnected to the stream would have to be considered in the context of reinvading potentially proximate sources. If elimination of non-native fish is not an option, habitat modification to disfavor the target non-native fish species could be considered, with actions tailored to the habitat requirements of the target non-native species being addressed. Whether actions are implemented will also depend on the risks of these alterations to native Fish and Non-fish Species.

Removing American bullfrogs from northern red-legged frog habitat does not present the management conflict that the removal of non-native fish species presents, but bullfrog removal does present several challenges, such as efficiency of removal methods and costs associated with committing to the long-term management and monitoring that would be necessary to confirm its effectiveness (Adams and Pearl 2007). Bullfrog removal has the potential to be effective in small circumscribed wetlands, but vigilance against recolonization is a perpetual cost if proximate sources exist (Adams and Pearl 2007). However, northern red-legged frog species are less vulnerable to bullfrog predation than other frog species because they spend less time in aquatic habitats, where adult bullfrogs typically inhabit, compared to terrestrial habitats. As a consequence, management of American bullfrogs would be a lesser priority than management of non-native fishes, as far as the northern red-legged frog is concerned.

5.4.2 WESTERN TOAD

Potential restoration activities in the basin for western toad include preserving existing off-channel habitat, with western toad breeding habitat features such as shallow depths, low-flows, and open water conditions; removal of nonnative, invasive vegetation that form dense emergent thickets; eliminating open water habitat; and preserving or restoring upland prairie habitat adjacent to suitable aquatic breeding habitat.

Suitable stillwater breeding habitat for western toad, which is open and typically unvegetated, appears to be limited within the basin, and may be restricted to the seasonal appearance of such habitat in the in-stream main channel Chehalis River. Limited data suggest that the lack of such suitable habitat in off-channel areas associated with the river's main channel largely reflects the establishment of dense stands of invasive reed, which often creates dense monocultures that eliminate open water habitat. Removal of invasive vegetation from aquatic habitats that provide known or potential western toad habitat would restore or create habitat conditions for the species. Several vegetation management options for reed canarygrass removal exist (Hayes et al. 2013). These include livestock grazing, herbicide application, mulching, and solarization. All these options must be well planned, as improper implementation can create conditions that would be detrimental to western toad or other aquatic species. Appropriate permits are also often required for activities within or near aquatic habitat. Proper herbicide application in aquatic habitats, under the jurisdiction of Ecology, requires following strict permit requirements for the type of herbicide, time of year applied, and quantities used. Livestock can over-graze, compact soils and degrade water quality with waste, so grazing intensity and frequency has to be adjusted to levels appropriate to the habitat addressed. Solarization involves the placement of shade cloth over areas where reed canarygrass needs elimination. Less problematic ecologically than either grazing or herbicide application, solarization has dimension (implementation limits the size of treated unit[s] potentially treatable), timing (warm-season requirement for effectiveness at Pacific Northwest latitudes), and land use considerations (land use cannot have interfering [disturbance] conditions) that would limit its application.

Because loss of the processes that create off-channel habitat is not certain (see Section 4.2), projects that create new off-channel habitat could provide breeding and rearing habitat for western toad. Such projects are likely to be successful within the movement range of any local western toad populations because western toad is known to be able to rapidly colonize such novel habitats (Crisafulli et al. 2005). However, given that the processes for maintaining the novel habitat at the new locations may not exist, maintaining these habitats at an early stage of succession will be a long-term cost associated with their creation if they are expected to function as western toad breeding and rearing habitat.

For western toad, enhancement actions focused exclusively on breeding habitat may be insufficient to guarantee success, because of the western toad requirement for juxtaposed suitable (open) upland non-breeding habitat. This juxtaposition must also involve an upland habitat piece of sufficient size, because toads generally move between 1,640 feet to 1.2 miles (500 m to 2 km) into uplands from their aquatic breeding habitat. Hence, enhancement actions that addressed breeding habitat must also consider whether suitable upland non-breeding habitat that has a patch size that encompasses the aforementioned upland dispersal size range exists, and if not, the proximate upland habitat will require restoration to some level of suitability. Restoration of unsuitable habitat that is covered by dense forest, shrub, or graminoid will require vegetation removal and implementation of some process to maintain the habitat in an early graminoid-dominated successional stage. Vegetation removal methods are diverse, but selection of the method should be compatible with the faunal assemblage that co-exists with western toads.

5.4.3 OREGON SPOTTED FROG

Potential restoration activities in the basin for Oregon spotted frog includes removal of warmwater non-native species that prey on Oregon spotted frogs, removal of non-native invasive vegetation that degrades or eliminates aquatic habitat, and preserving or restoring open canopy conditions adjacent to aquatic habitats that provide known or potential breeding habitat for Oregon spotted frog.

Removal of non-native warmwater predators to assist Oregon spotted frogs presents the same problems described for northern red-legged frogs (see Section 5.4.1). However, removal of these species is much more important for Oregon spotted frogs because their entirely aquatic habitat places them in contact with this suite of predators year-round. Though untested, habitat manipulation to create conditions that simply disfavor non-native warmwater predators is unlikely to be successful in maintaining populations of Oregon spotted frogs that may exist in the basin. Moreover, USFWS will view such habitat manipulation as too great a risk to take with any Oregon spotted frogs that may remain in the Chehalis system.

In Washington State, invasive reed canarygrass often develops dense monocultures, which alters, degrades or eliminates breeding habitat for Oregon spotted frog (Kapust et al. 2012). Reed canarygrass vegetation management in Oregon spotted frog habitat has been used successfully to enhance breeding habitat (Kapust et al. 2012; WDFW unpublished data), so some kind of vegetation management scheme could be applied to reed canarygrass. Vegetation management options are discussed in Section 5.4.2 addressing western toad.

Preserving or restoring open canopy conditions adjacent to aquatic habitats that Oregon spotted frog inhabit may also be important. The Oregon spotted frog is a warmwater marsh specialist, so shading may reduce habitat quality. This is important in the context of potential conflicts with certain categories of salmonid restoration efforts in which tree and shrub plantings have occurred in seasonal or permanent wetlands with the intent of shading water to promote cooling. Hence, this kind of potential conflict between Oregon spotted frog and salmonid restoration efforts will have to be considered on a case-by-case basis, but it is likely that policy will favor enhancement actions for the federally listed Oregon spotted frog over salmonids.

5.4.4 COASTAL TAILED FROG

Identifying potential restoration activities in the basin for coastal tailed frog is limited by data gaps in existing literature on the species habitat needs, particularly within the basin. Preservation of second growth to mature upland coniferous forest adjacent to stream channels as a source of LWM appears to be the most likely beneficial restoration activity. Less understood are the potential benefits to coastal tailed frog for restoration activities influencing stream temperature and the quality of forest habitat adjacent to stream systems.

Additional research is necessary to accurately identify the benefits to coastal tailed frog from potential restoration activities.

Allowing second-growth coniferous forest to mature in uplands adjacent to medium to small streams would provide an ongoing source of LWM that would contribute to formation of step-pool habitat, an important habitat feature for coastal tailed frog (Jackson et al. 2007). This approach would likely only be effective for coastal tailed frogs in the headwaters portion of the basin as they appear to be absent from lower elevations. Moreover, its contribution is likely to be much more significant in Non-fish-bearing streams, because those streams possess a 50-foot (17-m), two-sided riparian buffer on as little as 50% of that portion of the stream network, based on current forestry practices rules under the state Forests and Fish Habitat Conservation Plan. More specifically, its contribution is likely to be more significant in non-fish-bearing streams that are temperature labile because they have intrinsically low-flow volumes and groundwater inputs do not modulate their temperatures. Additionally, preservation of suitable forested habitat in the upper reaches of stream systems would likely benefit several in-stream and riparian-dwelling amphibian species, as well as a variety of other wildlife species utilizing those habitats. Allowing second-growth coniferous forest to mature would either require acquisition (purchase) of private forest lands for this purpose or negotiation with private landowners to exclude target areas from harvest. The latter is unlikely to occur if ownership remains private.

5.4.5 VAN DYKE'S SALAMANDER

Potential restoration activities in the basin for Van Dyke's salamander include preservation of quality riparian habitat that includes conditions for LWM recruitment that maintains a stream of LWM over time sufficient to ensure enough LWM in an intermediate stage of decay appropriate for utilization by Van Dyke's salamander.

Van Dyke's salamander is a riparian specialist (Jones 1999) that is relatively sedentary and appears to have a low upper temperature tolerance (Blessing et al. 1999; Jones 1999) that may limit its ability to survive in or colonize disturbed habitats. Similar to coastal tailed frog, allowing second-growth coniferous forest to mature in uplands adjacent to medium- to small-sized streams would provide riparian habitat that Van Dyke's salamander would be able to utilize, and would be an ongoing source of LWM that may be important for its nesting (Blessing et al. 1999). Approaches to allowing second-growth coniferous forest to mature were discussed under coastal tailed frog (see Section 5.4.4). Though not experimentally examined, retaining dead and downed woody debris may also contribute to providing both nesting and moist refuge micro-habitats, an effect that likely translated to other terrestrial salamander species as well.

5.4.6 WESTERN POND TURTLE

Potential restoration activities in the basin for western pond turtle includes removal of warmwater non-native species that prey on western pond turtle hatchlings, preservation of prairie habitat, restoration of prairie habitat by removing nonnative invasive vegetation, and LWM placement in off channel or shallow open water habitat. As no information currently exists regarding the presence of western pond turtle within the floodplain of the main channel Chehalis River, confirming presence of this species is an important precursor in targeting restoration activities.

If western pond turtles are found in off-channel habitats containing non-native warmwater predators, removal of non-native species that prey on western pond turtle would present an important restoration activity. As with Oregon spotted frog, habitat manipulation to create conditions that simply disfavor non-native warmwater predators is unlikely to allow western pond turtle hatchlings to survive because of their highly aquatic habit and shallow-water habitat needs that would place them in frequent contact with some of these aquatic non-native predators. Approaches to and issues with removing different non-native aquatic predators were discussed under northern red-legged frog (see Section 5.4.1).

Similar to western toad, enhancement actions for western pond turtle that focused exclusively on the aquatic habitat may not suffice to guarantee success, because of the western pond turtle requirement for juxtaposed suitable (open) upland habitat for nesting. Western pond turtles require well-insulated upland habitat (that is, open and largely unvegetated) large enough to encompass typical movement distances (up to 1,312 feet [400 m]) from the aquatic habitat. Hence, enhancement actions that address the non-breeding aquatic habitat must also consider whether suitable upland breeding habitat exists that has a patch size large enough to accommodate the nesting movement range, and if no patches of sufficient size exist, then the upland habitat would require restoration to some level of suitability. Approaches to restoring open terrestrial habitat were discussed under western toad (see Section 5.4.2). Western pond turtles also have the added requirement of a suitable nesting substrate, which is a well-drained soil in which to excavate the nest (Holland 1994). Hence, if restoration of open terrestrial habitat is needed in upland landscapes where soil types are a mosaic over relatively small scales, evaluating the suitability of the soil where restoration is occurring may be needed.

The frequently limited availability of LWM in the basin is likely to translate to limited availability of LWM in some off-channel habitats. At the latitude of the Chehalis system, presence of aquatic LWM in off-channel habitats may be critically important to the western pond turtles to enable them to adequately raise their body temperatures (Holland 1994). This is especially important for digestion, adequate growth in juveniles, and proper yolking of eggs in adult females (Holland 1994). Hence, in LWM-limited off-channel habitats, LWM placement would provide basking habitat for western pond turtles that would properly support these biological functions. Moreover, encouraging forest to mature adjacent to these western pond turtle aquatic habitats would provide a continued source of LWM.

5.4.7 NORTH AMERICAN BEAVER

Identifying potential restoration activities in the basin for North American beaver is limited by data gaps in existing literature on the species presence within the basin. Additional research is necessary to accurately identify the benefits to North American beaver from potential restoration activities. In general, preserving quality riparian habitat with deciduous trees, especially cottonwoods and willows (which are a preferred food resource for the beaver), or restoring degraded riparian habitat would benefit beaver, as well as several of the aforementioned amphibian species and other wildlife. However, as North American beaver is off-channel habitat-focused, some of the previous suggestions for enhancement of other Non-fish Species in off-channel habitats will favor beaver even where beaver is not necessarily targeted. In particular, those that involve enhancement of deciduous riparian forest, which would affect food resources where cottonwoods, willows, and selected riparian shrubs (such as red osier dogwood) are involved, and would affect dam building resources where most woody riparian species are involved.

Table 5.7 qualitatively summarizes the anticipated effects of enhancement actions on Other Fish and Non-fish Species in the basin.

Table 5.7
Qualitative Effects of Enhancement Actions on Other Fish and Non-fish Species in the Basin

KEY SPECIES	SALMON ENHANCEMENT ACTIONS				OTHER ENHANCEMENT ACTIONS		NOTES
	BARRIER REMOVAL	RIPARIAN ENHANCEMENT	IN WATER WOOD STRUCTURE	FLOODPLAIN RECONNECTION	INVASIVE PREDATOR MANAGEMENT	INVASIVE VEGETATION MANAGEMENT	
Chum salmon	+	+	+	+	+	+	Chum salmon would benefit from all salmon restoration projects (except perhaps those aimed primarily at juvenile salmonids).
Eulachon	*u*	+	+	*u*	*u*	*u*	
Pacific lamprey	+	+	+	+	*u*	*u*	
White sturgeon	+	+	*u*	*u*	*u*	*u*	
Olympic mudminnow	*u*	*u*	*u*	+	+	*u*	Barrier removal and reconnection to off channel habitat would be positive as long as they do not introduce invasive predators.
Speckled dace	+	+	+	+	*u*	*u*	
Largescale sucker	+	+	+	+	*u*	*u*	
Riffle sculpin	*u*	*u*	*u*	*u*	*u*	*u*	
Reticulate sculpin	*u*	*u*	*u*	*u*	*u*	*u*	
Smallmouth bass	+	*u*	+	+	*u*	*u*	
Largemouth bass	+	*u*	+	+	*u*	*u*	
Northern red-legged frog	+/-	++	*n*	+/-	++	+/-	Barrier removal and reconnection to off-channel habitat would be positive as long as they do not introduce invasive predators.
Western toad	+/-	-	*n*	*n*	+	+	Barrier removal would be positive as long as they do not introduce invasive predators.
Oregon spotted frog	*n*	-	*u*	*u/-*	+	+	Reconnection to off channel habitat would be unknown as long as they do not introduce invasive predators. If predators are introduced, it would be negative.
Coastal tailed frog	+	+	++	*n*	*n*	*n*	

KEY SPECIES	SALMON ENHANCEMENT ACTIONS				OTHER ENHANCEMENT ACTIONS		NOTES
	BARRIER REMOVAL	RIPARIAN ENHANCEMENT	IN WATER WOOD STRUCTURE	FLOODPLAIN RECONNECTION	INVASIVE PREDATOR MANAGEMENT	INVASIVE VEGETATION MANAGEMENT	
Van Dyke's salamander	+	++	*n*	*n*	*n*	*u*	
Western pond turtle	+	-	++/*n*	+	+	+	Basking sites would be very beneficial if they are lacking and would be neutral if not lacking.
North American beaver	+	++	*u*	+	*n*	*n*	

Notes:
Enhancement ratings: + = beneficial effect; ++ = very beneficial effect; - = negative effect; -- = very negative effect
n = not applicable, meaning the condition is not in the Chehalis River system or habitat that the species occupies
u = unknown

6 Climate Change

6.1 Introduction

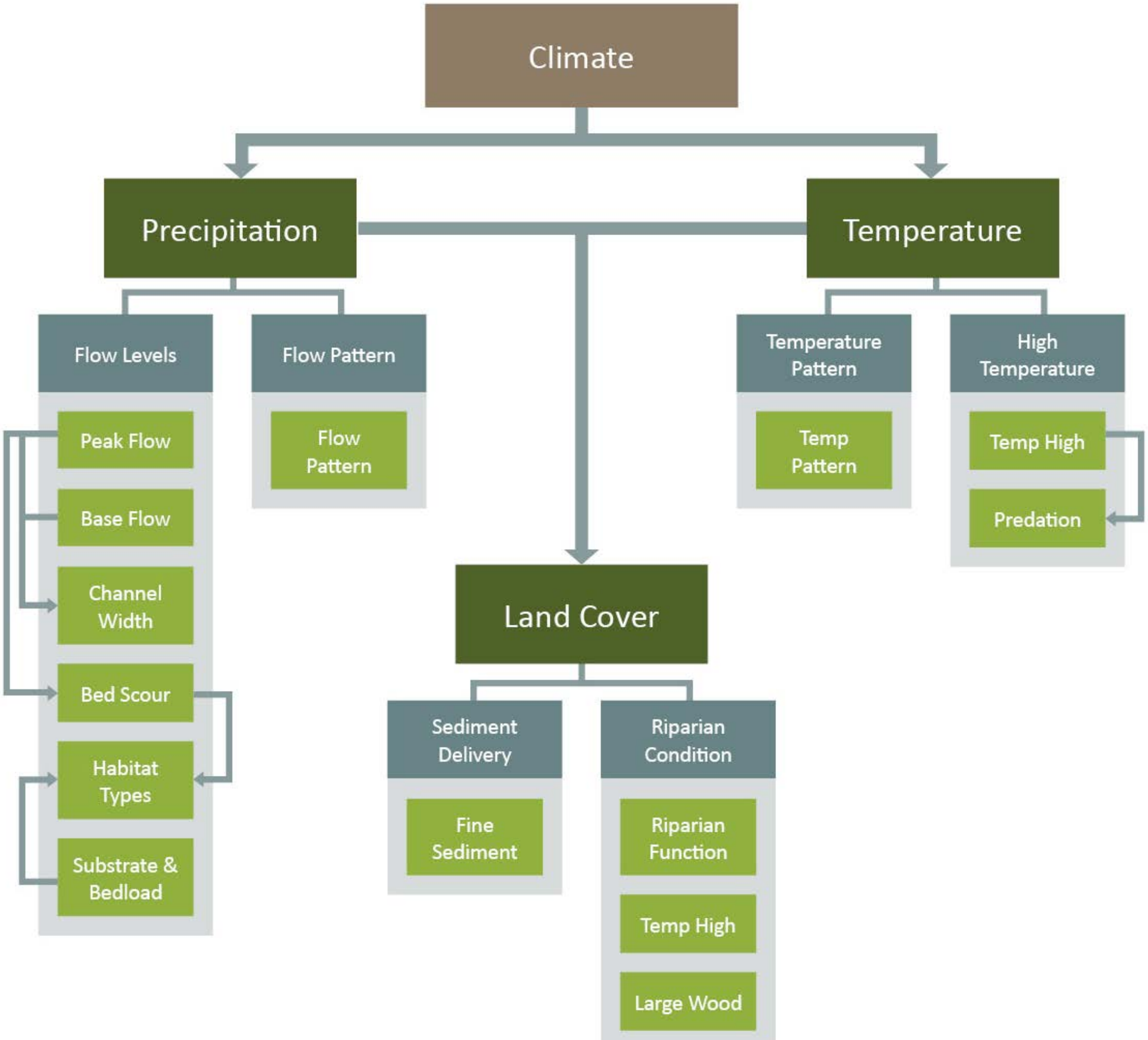
Changes to a basin associated with climate variability are important considerations for any long-term planning effort. This is because the changes can have major implications for species and habitat conditions (e.g., Mantua et al. 2009; Crozier and Zabel 2006). Changes in the ecosystem from climate could alter—positively or negatively—the availability and quality of suitable habitats for aquatic and semi-aquatic species and could affect population responses to flood hazard reduction or habitat enhancement activities. The purpose of the ASEP climate change analysis was to provide decision makers with information on how projected changes associated with climate may affect the modeled salmon species and how it may affect the enhancement actions being modeled in EDT. A more comprehensive analysis of the methods used and the effects from climate change is included in the companion report *Effects of Flood Reduction Alternatives and Climate Change on Aquatic Species Report*.

6.1.1 ECOSYSTEM DIAGNOSIS & TREATMENT

Assumptions regarding alternative future environmental conditions were incorporated to the entire stream network in the Chehalis basin. EDT evaluates potential salmonid production for a given environmental condition that can be compared to potential production in another condition, including alternative future climates. Salmonid production under current environmental conditions was compared to the estimated production under alternative conditions that are consistent with the available scientific information on regional climate change effects. The alternative climate scenarios were not intended to represent conditions in any particular year, nor the downscaling of a specific regional climate model. The intent of the analysis was to conduct a sensitivity analysis, and estimate fish production under alternative future conditions given the available scientific information on climate change.

A simple conceptual model of how climate change could affect aquatic conditions in the Basin is shown in Figure 6.1. Climate controls conditions in aquatic systems in the Chehalis system through two primary processes: precipitation and temperature (Edmonds et al. 2003). Climate determines the amount, pattern, and form (snow or rain) of precipitation in a basin. Air temperature, resulting from solar radiation, wind, and weather, is a large determinant of water temperature and the annual pattern of water temperature. Precipitation and temperature also affect land cover as a result of their effect on fire frequency and vegetation patterns, which may lead to higher erosion and sediment delivery and loss of riparian cover (Dale et al. 2001).

Figure 6.1
Conceptual Model of Climate Controls on Aquatic Environments



Note:
Green boxes indicate attributes in EDT that can be manipulated to capture alternative future environmental conditions.

Groundwater interaction may also play an important role in climate change, but was not addressed in this assessment.

The expected changes in climate can be expected to alter environmental conditions in the Chehalis River and produce significant changes in species distribution and abundance, through changes in ecological functions and services. Figure 6.1 shows attributes in the Chehalis EDT model that are expected to change and the direction of change as a result of climate scenarios modeled, which were used to estimate effects on populations of coho salmon, fall-run and spring-run Chinook salmon, and winter-run steelhead.

6.1.1.1 CLIMATE CHANGE ALTERNATIVES MODELED USING EDT

Although the broad outlines of climate change are relatively well defined at global and regional scales (Independent Scientific Advisory Board 2007), they are less defined at watershed scales. At finer scales of resolution, variability and uncertainty in downscaled model predictions increases. Even the direction of change in precipitation, stream flow and other attributes differs between downscaled model data at finer scales. The University of Washington Climate Impacts Group (Snover et al. 2013) summarized climate modeling results for Washington State and found that model results are "mixed, but most models predict an increase in annual stream flow" but that "models disagree on the direction of change." Regarding winter flow, most models project an increase in winter stream flow for Washington State on an average ranging from 25% to 34% by year 2080. The models predict a decrease in summer stream flow from 44% to 34% by the 2080s. Stream temperatures are expected to increase in most future climate projections with changes to summer water temperature likely to be significant in terms of salmonid production (Mantua et al. 2010). Snover et al. (2013) summarized modeling results for stream temperature and concluded that locations in western Washington State that will experience temperatures that are stressful to salmonids (more than 67^{o}F (19.4^{o}C) will increase by 16%, and many locations will exceed 70^{o}F (21^{o}C) for the entire summer by year 2080, a situation that would be lethal for most salmonids.

Based on these analyses, it was hypothesized that under future climate conditions, winter flow in the Chehalis is likely to increase, summer flows should decrease, and summer water temperatures are likely to increase. However, the specific changes in these attributes in the basin are uncertain and cannot be predicted with available analytical tools.

To capture a range in these predicted trends, two alternative future conditions were developed and assessed using EDT, based on the attribute changes in the conceptual model in Figure 6.1. These two alternative futures are characterized as "Low Climate Change" and "High Climate Change" Alternatives (Table 6.1). These alternatives are based on the flow record from 1989 to 2012, where each WY was analyzed and placed into one of five categories: Wet, Normal Wet, Normal, Normal Dry, and Dry, based upon historical data. HEC-RAS model outputs of WY selected to represent each category provided quantitative estimates of the flow and channel width changes expected in each WY. All EDT analysis other than the climate change analysis described in this report are based on a HEC-RAS depiction of flow and channel width in the mainstem Chehalis River for the Normal WY condition. Therefore, the Low Climate Change scenario was constructed by combining the HEC-RAS analyses of Normal Wet and Normal Dry WY conditions, consistent with the assumption of wetter winter and drier summers. The High Climate Change scenario was constructed by combining the HEC-RAS analyses of Wet and Dry WY conditions, consistent with the assumption of much wetter winter and drier summers. Under both scenarios, no changes to the flood reduction alternatives were assumed in regard to operations or conditions within the reservoir footprint.

In addition to the change in channel width, a second key effect of increased winter flow is a possible increase in bed scour. Bed scour is an important attribute in EDT because of its potential impact on the survival of salmonid eggs deposited in redds. While it seems reasonable to expect that the depth and frequency of bed scour would increase with increases in winter flow, there is no way to quantitatively estimate the change. To capture the effect in the two climate futures alternatives, it was hypothesized that: 1) bed scour would increase in proportion to the increase in peak flow, and 2) the increase in bed scour would be greatest in higher gradient stream reaches. Specifically, bed scour in the EDT model was assumed to increase in proportion to the change in peak flow in reaches with a gradient greater than 0.4%. The result is that bed scour was increased in most reaches upstream of the South Fork Chehalis River but not in most of the lower gradient reaches downstream. Temperature changes in the Low Climate Change and High Climate Change scenarios were consistent with projections of change from Snover et al. (2013) for years 2020 and 2080, respectively (Table 6.2), and applied to the modeled temperatures in EDT.

As a result of data availability, all quantitative modeling of flow and width (HEC-RAS) and temperature in EDT related to flood reduction alternatives has focused on the mainstem reaches downstream from the proposed dam site. For conditions in the tributaries, HEC-RAS model output was not available. Conditions in these systems were based on available habitat surveys and the expert opinions of WDFW biologists. Because climate change will affect the entire basin, it was necessary to include changes to tributary conditions. In the absence of any means to quantitatively project flow, channel width, temperature, and other factors in the tributaries under the alternative future conditions, the assumption was made that the proportional changes to attributes in the mainstem that are based on quantitative analysis applied to the tributary reaches as well. As a result, both future alternative conditions assume changes in the tributary stream reaches in addition to changes in the mainstem Chehalis River.

Table 6.1
Summary of Changes Related to Alternative Future Conditions Modeled in EDT

ATTRIBUTE	AREA	LOW CLIMATE CHANGE	HIGH CLIMATE CHANGE	SOURCE
High Flow	Mainstem downstream from dam site	Increase	Increase	HEC-RAS
Low Flow	Mainstem downstream from dam site	Decrease	Decrease	HEC-RAS
Winter Channel width	Mainstem downstream from dam site	Increase	Increase	HEC-RAS
Summer Channel width	Mainstem downstream from dam site	Decrease	Decrease	HEC-RAS
Temperature Max winter	Mainstem downstream from dam site	Increase based on Snover et al., See Table 2		Snover et al. 2013
Temperature Max summer	Mainstem downstream from dam site			
Bed Sour	Mainstem downstream from dam site	If gradient >0.004 then increase rating by proportion Flow High increases, otherwise no change	If gradient >0.004 then increase rating by proportion Flow High increases, otherwise no change	Hypothesis
High Flow	Tributaries	Increase	Increase	
Low Flow	Tributaries	Decrease	Decrease	
Winter Channel width	Tributaries	Increase	Increase	
Summer Channel width	Tributaries	Decrease	Decrease	
TempMax winter	Tributaries	See Table 2; apply same proportions to tributaries		
TempMax summer	Tributaries			
Bed Scour	Tributaries	If gradient>0.004 then increase rating by proportion FloHigh increases, otherwise no change	If gradient>0.004 then increase rating by proportion FloHigh increases, otherwise no change	

Note:
EDT = Ecosystem Diagnosis & Treatment
HEC-RAS = Hydrologic Engineering Center River Analysis System

Table 6.2
Assumed Changes in Water Temperature in the Chehalis Based Under the Alternative Futures Scenarios

MONTH	LOW CLIMATE CHANGE		HIGH CLIMATE CHANGE	
	UPPER	LOWER	UPPER	LOWER
10	9%	8%	32%	28%
11	11%	10%	36%	34%
12	13%	15%	44%	49%
1	15%	14%	48%	46%
2	19%	18%	50%	46%
3	14%	11%	43%	33%
4	9%	8%	28%	23%
5	6%	6%	20%	17%
6	8%	7%	24%	22%
7	8%	7%	23%	21%
8	9%	8%	26%	23%
9	8%	7%	27%	25%

6.1.1.2 EDT RESULTS FOR CLIMATE CHANGE AND ENHANCEMENT

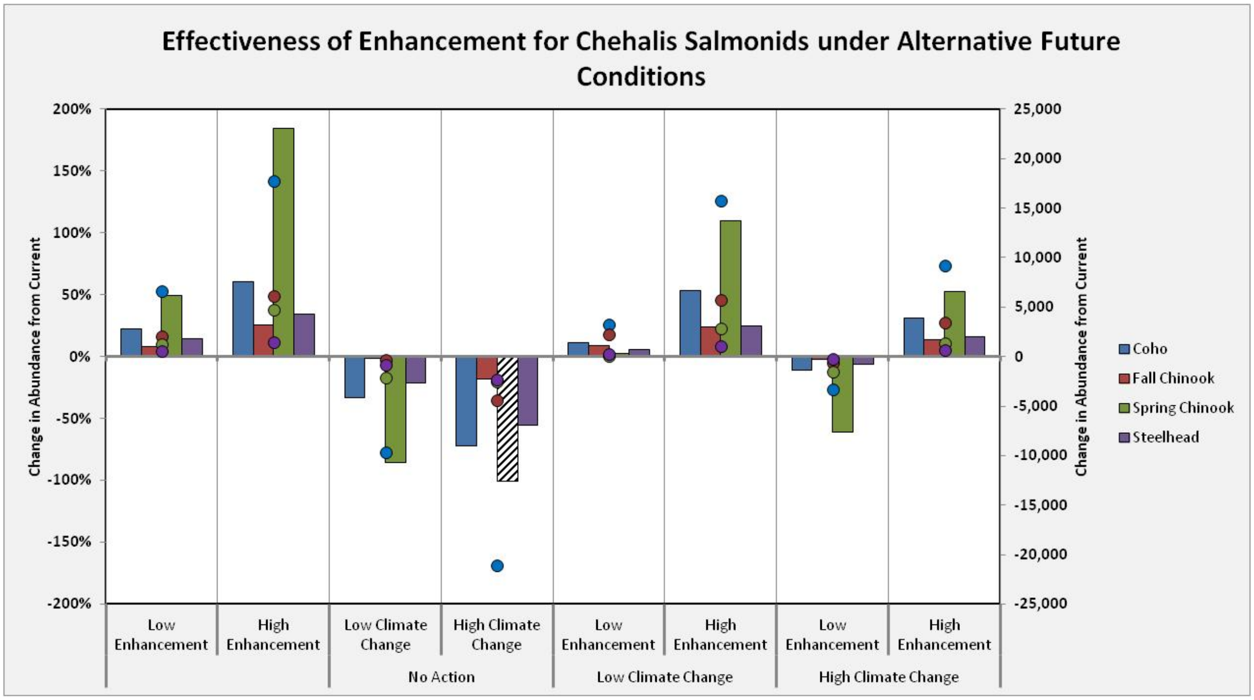
The effects of the composite riparian enhancement on Chehalis salmonids were also examined under alternative future conditions that are consistent with regional projections of climate change in the Pacific Northwest. Evaluating the actions under alternative future conditions evaluates the sensitivity of the enhancement actions to the base condition and provides insights into the possible effects of future climate conditions.

Climate change effects were examined for the low and high riparian enhancement conditions under low and high climate change conditions (Table 5.6). Low riparian enhancement scenario combined the lowest riparian restoration in NMF lands (NMF 20/50) and the lowest level of restoration in the MF lands (MF20). High riparian enhancement included the NMF 60/75 condition in NMF lands and the MF 60 condition in MF lands. Both the low and high enhancement scenarios included the removal of all culverts.

At a species level, enhancement and climate change had their biggest effect on spring-run Chinook (Figure 6.2). As stated previously, enhancement affected spring-run Chinook the most because the enhancement actions in NMF focused on spring-run Chinook spawning reaches. Climate change affected spring-run Chinook strongly because of the sensitivity of this species to temperature changes, primarily because of the effect of temperature on the pre-spawning and spawning life stages. Enhancement and climate change had the smallest effect on fall-run Chinook. These fish spend the least time in the Chehalis system of all the salmonids, and so they benefited the least from enhancement and suffered the least from the climate change scenarios modeled for the basin.

Although climate change considerably reduced the effectiveness of both enhancement strategies, low and high enhancement moderated the effect of climate change compared to the effect of climate change without enhancement. Under high climate change conditions, the low enhancement scenario reduced abundance relative to the current condition, especially for spring-run Chinook. However, without the enhancement, spring-run Chinook were extirpated from the Chehalis system. The high enhancement scenario increased abundance of all four species relative to the current condition for both climate change scenarios (Figure 6.2).

Figure 6.2
Overview of Chehalis Basin Salmonid Enhancement and Climate Change

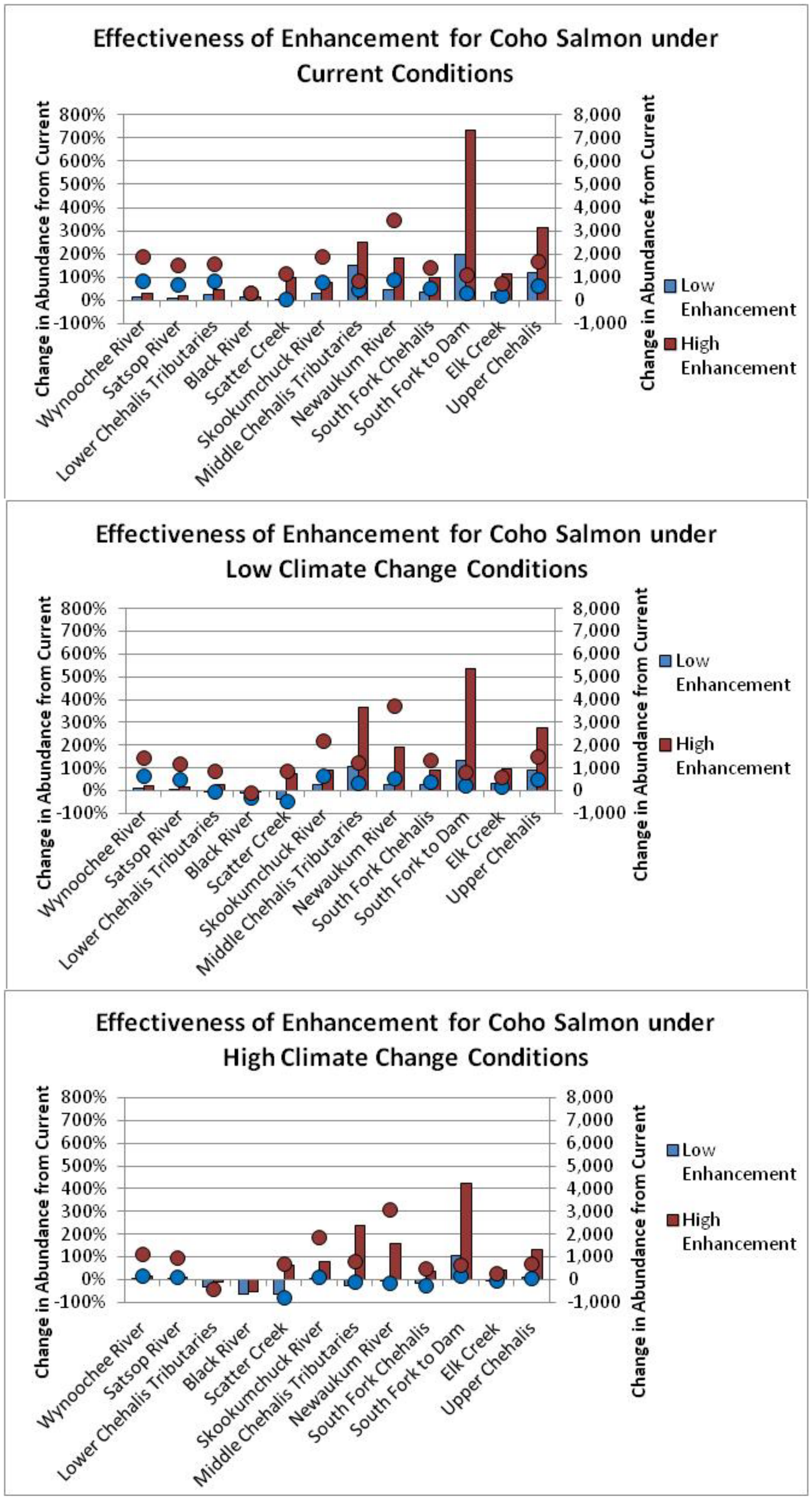


Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

6.1.1.2.1 Coho Salmon

Climate change considerably reduced the benefits of MF enhancement on coho salmon (Figure 6.3). Many of the lower river populations declined in abundance despite the enhancements, although not nearly so much as they declined under the alternative future conditions without the enhancements. Both low and high enhancement strategies had their biggest effects on the upper Chehalis coho populations. While the effectiveness of restoration decreased with climate change conditions for the upper Chehalis populations, abundance was still increased relative to the current condition. On the other hand, several lower river populations decreased in abundance relative to the current condition.

Figure 6.3
Climate Change and Enhancement Effects on Coho Salmon

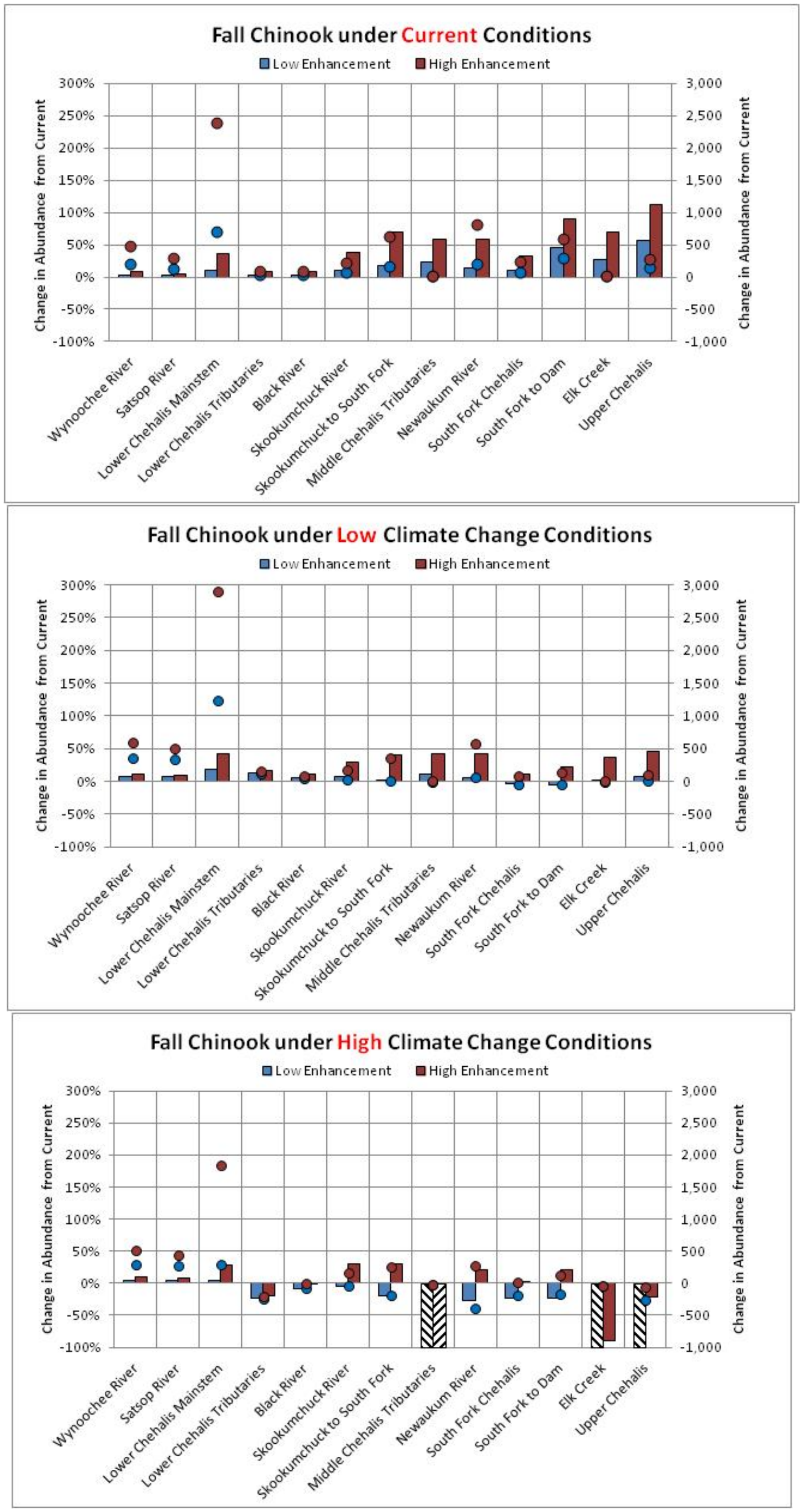


Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

6.1.1.2.2 Fall-run Chinook

As discussed previously, fall-run Chinook benefited the least from enhancement (Figure 6.4). Adult fall-run Chinook enter the river in the fall with a short adult pre-spawn holding period, and juveniles leave the following spring. However, marginal populations suffered under climate change. Fall-run Chinook in the middle Chehalis tributaries were extirpated under high climate change under both the low and high enhancement scenarios. Similarly, the Elk Creek population was extirpated under high climate change with low enhancement and nearly so under high enhancement. Both the middle Chehalis tributaries and Elk Creek fall-run Chinook populations had very low abundance in the model, and the extirpation of these populations had little effect on total abundance, though it did reduce spatial structure of the species in the basin.

Figure 6.4
Climate Change and Enhancement Effects on Fall-run Chinook

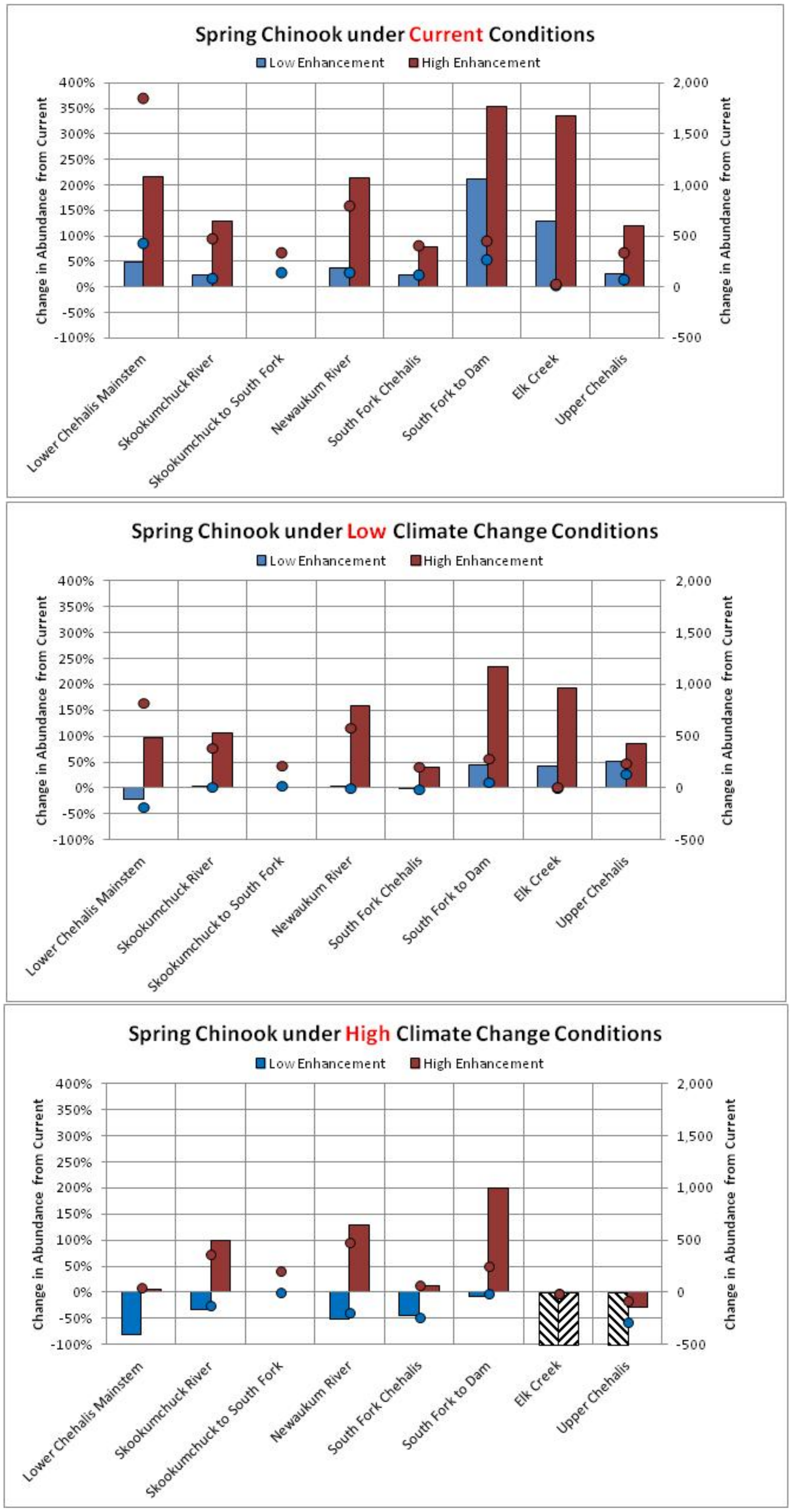


Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

6.1.1.2.3 Spring-run Chinook

Spring-run Chinook suffered the most under climate change and were extirpated from the Chehalis system under the high climate change condition with no enhancement. However, enhancement considerably moderated the effects of climate change on spring-run Chinook in the model (Figure 6.5). While the benefits of enhancements to spring-run Chinook were considerably reduced with climate change conditions relative to their benefits under current conditions, spring-run Chinook were not extirpated from the system under climate change in combination with the enhancement scenarios. Spring-run Chinook were extirpated from Elk Creek under the high climate change condition regardless of enhancement scenarios. However, spring-run Chinook in Elk Creek were confined to the lower 1.1-mile (1.8 km) reach downstream from the falls and represented a very small component of the overall spring-run Chinook population in the basin. The low enhancement measures were unable to compensate for the high climate change condition in the upper basin, resulting in extirpation of this population under high climate change conditions.

Figure 6.5
Climate Change and Enhancement Effects on Spring-run Chinook

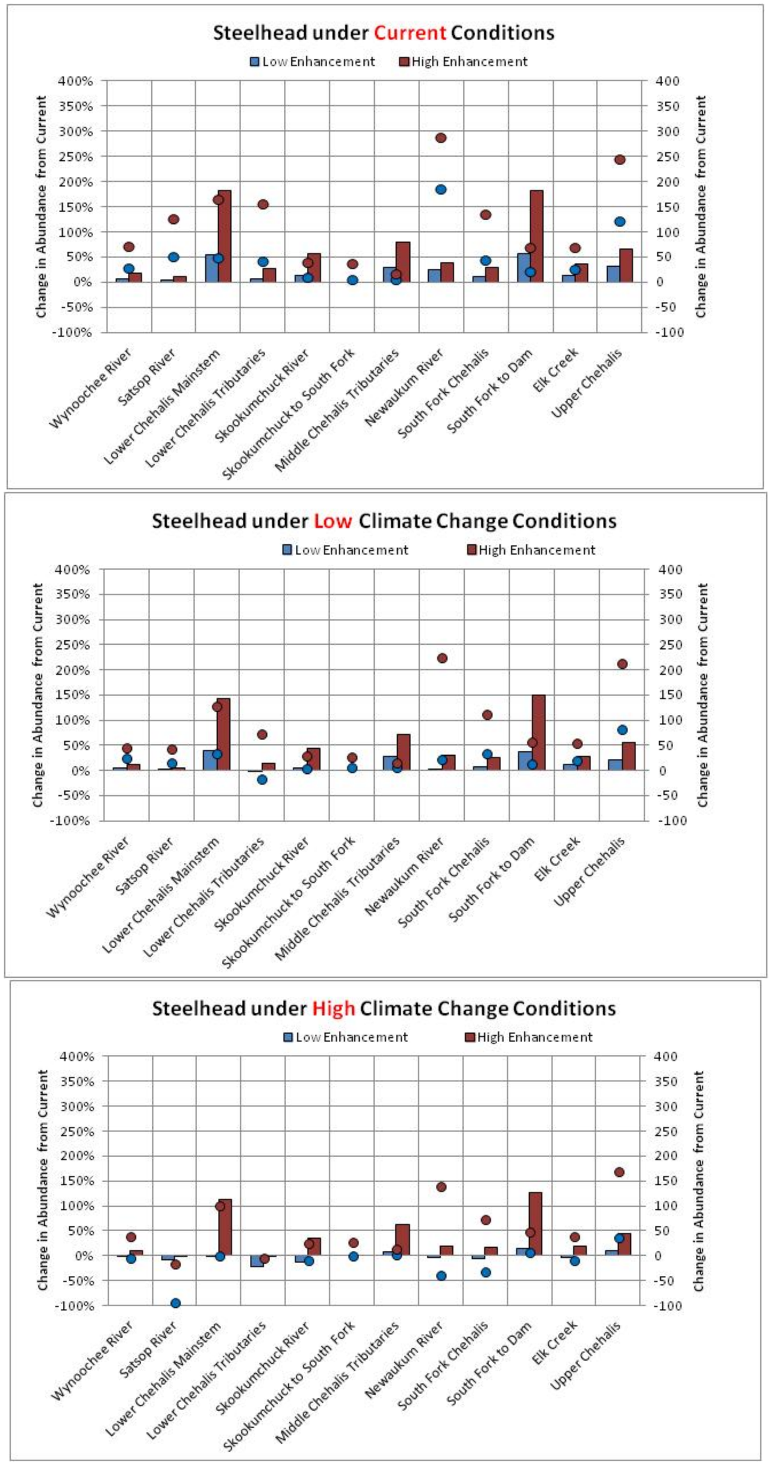


Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

6.1.1.2.4 Winter-run Steelhead

Winter-run steelhead displayed a similar response to enhancement and climate change as the other species (Figure 6.6). The benefits of enhancement were considerably reduced relative to benefits without consideration of climate change. However, several populations that were extirpated under climate change alone increased in abundance with the enhancement measures.

Figure 6.6
Climate Change and Enhancement Effects on Steelhead



Note:
Bars represent percent change and dots represent numeric change in abundance relative to current condition.

6.1.2 QUALITATIVE ASSESSMENT OF THE EFFECTS OF HABITAT RESTORATION ACTIONS IN RELATION TO CLIMATE CHANGE

The following sections assess the types of effects that could be seen from enhancement actions in relation to climate change. While ASEP authors have modeled restoration scenarios in EDT indicating the potential effects that climate change may have on enhancement actions, this assessment is intended to add context to the modelled scenarios and additional effects that could be seen in future conditions based on how enhancement actions can alleviate the potential effects of climate change.

6.1.2.1 BARRIER REMOVAL

In the basin, barriers such as dams, diversions, and road crossings (culverts) block fish passage and the transport of flows, sediment, and organic matter, including wood. Removing barriers or providing fish passage at barriers reestablishes upstream and downstream migration pathways and restores natural stream flow, sediment, and organic matter transport. This is especially critical if important upstream cool-water habitats are disconnected from warmer downstream habitats. For example, access to Scatter Creek, a cool-water tributary within the basin, may be important to salmonids. Providing access to cool-water streams will increase habitat and life-history diversity. Barrier removal addresses factors such as stream flows and temperature, and may affect nutrient limitations and sediment issues.

6.1.2.2 FLOODPLAIN RECONNECTION

Flood control measures such as dikes, levees, and bank armoring (riprap) have disconnected floodplains from their rivers/streams throughout the basin. These structures reduce the ability of the river to create and sustain diverse habitats and to allow migration of fish into those habitats. Reestablishing floodplain connectivity restores floodplain dynamics that create habitat for diverse fish assemblages. Enhancement actions include reconnection or creation of off channels and sloughs, removal or set-back of levees and dikes, and re-meandering of straightened channels. These actions can ameliorate temperature increases by increasing hyporheic flow paths beneath the floodplain, which cools water during the summer. Floodplain reconnection projects address factors such as high flow refugia, temperature, cover, nutrients, and food. Floodplain reconnection will benefit salmonids, Olympic mudminnows, and several other species within the basin.

6.1.2.3 RESTORATION OF INCISED CHANNELS

Alterations in sediment transport, stream flows, and riparian structure and function have increased the incision and scour of stream channels in the basin. This tends to reduce the connection between surface and sub-surface flows, decrease late summer stream flows, increase stream temperatures during summer and decrease them during winter, and reduce floodplain connectivity. Enhancement actions that aggrade incised or scour channels restore floodplain aquifer storage, increase summer base flow, decrease summer stream temperatures, and increase habitat diversity and productivity. Hence, restoration of incised channels addresses factors such as stream flows and temperature, and factors associated with floodplain reconnection.

Stream Flow Restoration: Within the basin, several factors have affected stream flows, including water diversions, dams, urbanization, logging, roads, and grazing. For example, logging, roads, and impervious surfaces in urban areas increase flood flows and decrease summer base flows. In addition, low stream flows are often reduced because of water withdrawal from streams for irrigation or consumptive uses, and both peak and low-flows can be reduced by water storage structures. Under extreme flow regulation, peak flows can be reduced to the point that many geomorphological and ecological functions of streams are lost. Actions that restore or improve environmental flow regimes can ameliorate not only low stream flows, but can also increase habitat diversity and other ecological functions. Actions that restore flow regimes address factors such as stream flows, temperature, habitat diversity and complexity, and water quality. Any actions taken to restore flow regimes should have safeguards on the water such that any additional flows cannot be appropriated for other purposes.

6.1.2.4 RIPARIAN RESTORATION

A host of land-use activities contributed to the loss of riparian habitat throughout the basin, including urbanization, roads, logging, and agriculture. Loss of riparian vegetation reduces stream shading, root reinforcement of banks, supply of large wood and organic matter, and nutrient filtration and sediment trapping. Actions that restore or protect riparian functions tend to cool streams, increase wood supply, which increases habitat diversity and complexity, increase nutrients and food for fish, and reduce fine sediment recruitment. Although restored riparian functions do not directly ameliorate stream flow changes, they do mitigate stream temperature increases via increased shading, or increased wood recruitment and sediment storage in headwater channels that have been scoured to bedrock. Riparian enhancement actions address factors such as temperature, fine sediment, cover/shelter, nutrients, and food.

According to the local experts, the actions should address many of the factors limiting salmonids within the basin and are resilient to climate change, especially projected shifts in temperature regimes. Other enhancement actions, which are not as resilient to climate change but nevertheless address limiting factors in the basin, include reducing erosion and sediment delivery and in-stream rehabilitation. The following paragraphs describe these two categories of enhancement actions and the limiting factors that they address.

6.1.2.5 REDUCING EROSION AND SEDIMENT DELIVERY

Sediment supply to stream channels in the basin is increased through surface erosion from areas cleared of vegetation (e.g., unpaved roads, logged areas, agricultural areas, etc.). In forested areas, such as the headwaters of the basin, unpaved roads and landsliding from roads or clear cuts contribute large volumes of sediment to the channel. Actions that reduce fine sediment recruitment include riparian restoration, reforestation, removing or abandoning roads, resurfacing roads (or adding cross drains or water bars to prevent delivery of sediments to streams), rebuilding stream crossings to avoid fill failures, landslide hazard reduction, and removal of livestock from key areas (e.g., stream banks and riparian areas). Implementation of these actions will improve stream habitat by decreasing fine sediments in the channel, increasing pools depth, and narrowing widened channels.

6.1.2.6 IN-STREAM REHABILITATION

In many cases, land-use activities within the basin have simplified and straightened stream channels, resulting in reduced habitat capacity and productivity. Enhancement actions that improve in-stream habitat conditions include addition of woody debris, boulders, and spawning gravels to improve habitat structure, and reconstructing channel characteristics (e.g., re-meandering). These actions are considered short-term actions because they are susceptible to failure and often require frequent maintenance. In addition, they do not address the underlying disrupted processes (e.g., large wood delivery). Nevertheless, in some of the headwater streams of the Chehalis River where the channels have been scoured to bedrock and there is little in-stream habitat structure, the addition of wood and boulder structures may improve sediment storage and increase habitat complexity for fish. These actions should be considered in concert with actions that address the underlying disrupted processes. In-stream rehabilitation actions address factors such as habitat diversity and complexity, fine sediment, and cover/shelter.

7 Data Gaps

7.1 Introduction

One component of the ASEP is to identify data gaps that need to be filled should the Project proceed into the next phase of implementation. A draft report identifying data gaps that became apparent as the ASEP was implemented has been developed as part of this process. The report presents data gaps in four categories (Key Species and Habitats, Flood Reduction Alternative modeling, climate change, and watershed restoration planning). The reader is referred to the companion *Data Gaps Report* for a more thorough discussion of these data gaps.

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