Collectively improving stormwater management

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Revised Technical Memorandum: Additional analyses of the 2015/16 SAM Mussel Monitoring Survey data

This is the revision of our first tech memo. In the first memo, we missed 12 rejected sites from Pierce County. We included them and conducted the analysis again. As a result, Option 2 sites represent smaller portion of Puget Sound nearshore UGA. Most of CDF results and patterns stay the same.

Highlights

1. This tech memo describes how the probabilistic framework is applied to the SAM status and trends studies in Puget Sound UGA nearshore areas.
2. Spatially balanced 43 sites of this study represent 1191 km (740 mi) of Puget Sound UGA nearshore area. The 36 SAM (option 1) sites alone explain 99.1% (1180 km) of the Puget Sound UGA nearshore whereas 7 Pierce County (option 2) sites represent 0.9% (11km).
3. Mussels in UGA nearshore contain significantly more organic contaminants (PAHs, PCBs, PBDEs, and DDTs) than those in least-disturbed reference sites.
4. Two least disturbed sites serves as clear reference sites by showing similar values in organic contaminants (PAHs, PCBs, PBDEs and DDTs) to initial mussel tissue contents measured at the beginning of the study.
5. Unlike organic contaminants, metals (Zn, Pb, Hg, As, Cd, and Cu) contents did not show any clear bioaccumulation pattern related to urban growth when compared to reference conditions.

Background

In this memo, Stormwater Action Monitoring (SAM) staff provide a comprehensive description of how the probabilistic framework is used for the SAM status and trends studies in Puget Sound nearshore areas. The 2015/16 SAM Mussel Monitoring survey data (Lanksbury et al. 2017) are used as an example to convey the steps of data analysis including assigning spatial weights to sites and applying the probabilistic design to a statistical analysis. This presentation and analysis focuses on mussel tissue concentrations of four organic contaminants (PAHs, PCBs, PBDEs, and DDTs) and six metals (As, Cd, Cu, Pb, Hg, and Zn). A list of abbreviations and units used in this memo is provided at the end of this report.

First, we calculated the final spatial weight for each SAM site in the study area (Result 1, Table 1). Spatial weight for each site (in this case, nearshore length) provides representative length for this study probability-based sampling design. The SAM Mussel Monitoring Survey evaluated 57 sites for sampling suitability from a total candidate list of 2,048 possible sites along the shoreline of all Puget Sound urban growth areas (UGAs). In the end, 43 sites were sampled in the Puget Sound UGA. Spatial weights are adjusted to account for the 14 candidate sites that were not sampled, (i.e., rejected due to limited access or safety reasons). Pierce County Option 2 sites were sampled per their alternative municipal stormwater permit monitoring requirements at the smaller spatial scale in the unincorporated UGAs in Pierce County. The spatial weights calculation for Pierce County Option 2 sites followed the same process but was done separately (Result 1, Table 1).

Next, we compared mussel tissue contaminant results to initial conditions (also called baseline) and least-disturbed sites. We used cumulative frequency distribution (CDF) plots to estimate the spatial extent of the contaminant results (Result 2 and 3, Figures 1-4). Contaminant levels of mussel tissue at the beginning of the study (n=6) represent initial condition (Result 2, Figures 1-2). The least-disturbed sites (n=2) were located in non-UGA areas near the Olympic National Forest, with over 90% forested land cover. These were sponsored by WDFW partner groups outside the SAM program and they provide additional information for a background condition. Pierce County Option 2 mussel tissue concentration data is included in this step.

Finally, we followed the SAM Mussels final report (Lanksbury et al., 2017) distinction of the portions of UGAs that are incorporated cities vs. unincorporated UGA. We developed CDF plots comparing these sites (Result 4, Figures 5-6). We also compared CDF plots for Pierce County Option 2 data separated from the SAM mussel data. Pierce County Option 2 sites represent a portion of spatial unincorporated shoreline of UGA (Result 5, Figures 7-8).

Results & Discussion

Result 1. Spatial weight adjustment analysis

Adjusted spatial weights were calculated for both SAM sampling sites and Pierce County Option 2 sampling sites, as both of them dropped some of the original candidate sites due to limited accessibility and safety issues. By dropping sites from the candidate list, actual sampled nearshore length became smaller than the initial study nearshore length:

- SAM sites lost 26% of the initial frame due to the 13 rejected sites out of the first 49 candidate sites

- Pierce County lost over 50% of their initial nearshore length due to their 13 rejected sites out of first 20 candidate sites in their list.

Table 1 shows the initial and final adjusted spatial weight for the SAM regional sites and Option 2 sites. Each SAM site represents 32.8 km of length and each Pierce Co site represents 1.6 km of length. The total adjusted length of shoreline that was evaluated by the total (SAM nearshore plus Pierce County) nearshore probabilistic framework was 1191 km (740 mi). The 36 SAM Mussel Monitoring Survey sites alone statistically represent 99.1% (1180 km) of the Puget Sound UGA nearshore. The 7 Pierce County Option 2 sites represent 0.9% (11km).

Table 1. Results of spatial weights calculations for SAM and Option 2 mussel monitoring sites.

Mussel Survey		SAM	Option 2	Total
Initial Design	# of candidate sites	2008	40	2048
	Initial study length (km)	1,606	32	1,638
Site information	# of sampled sites	36	7	43
	# of rejected sites	13	13	26
Adjusted length of nearshore in Puget Sound UGAs	Adjusted length (km) per site [1]	32.8	1.6	-
	Total sampled length (km) [2]	1,180	11	1,191
Contribution	Contribution to total sampled length (%)	99.1	0.9	100
	Lost contribution by rejected sites to each option length (%)	26.5	65.0	-

[1] = the total length is the sampled sites corrected lengths plus the length of the rejected sites.
[2] = the total Mussel Monitoring Survey length of nearshore sampled is the added lengths of the SAM sites and Pierce County Option 2 sites.

Result 2. Cumulative distribution of contaminants in mussel tissues along the Puget Sound nearshore UGA

We present the distribution of mussel tissues contaminant concentrations along the Puget Sound UGA using cumulative frequency distribution plots. The Y axis indicates the cumulative percentage of UGA nearshore length covered by this study design.

Among four organic contaminants, total PAHs were detected in significantly higher concentrations than other contaminants in mussel tissues (Figure 1). Spatially, 80% of the total UGA nearshore length (962 of 1,191 km) had relatively low PAH concentrations in mussel tissues. Only a few sites (3% of the nearshore length, 32 of 1,191 km) had concentrations exceeding 3,100 ng/g dw. The cumulative distribution pattern for DDTs was similar to that of PAHs. Only 4% of the UGA nearshore (34 of 1,191 km) exceeded

10 ng/g dw. This suggests a small portion of the nearshore UGA has the higher concentrations for PAHs and DDTs, perhaps from site specific sources, while the majority of the shoreline is less exposed. In contrast, the distribution of PCBs and PBDEs were less skewed toward the low concentrations, suggesting sources for these chemicals are more widely dispersed within the Puget Sound UGAs.

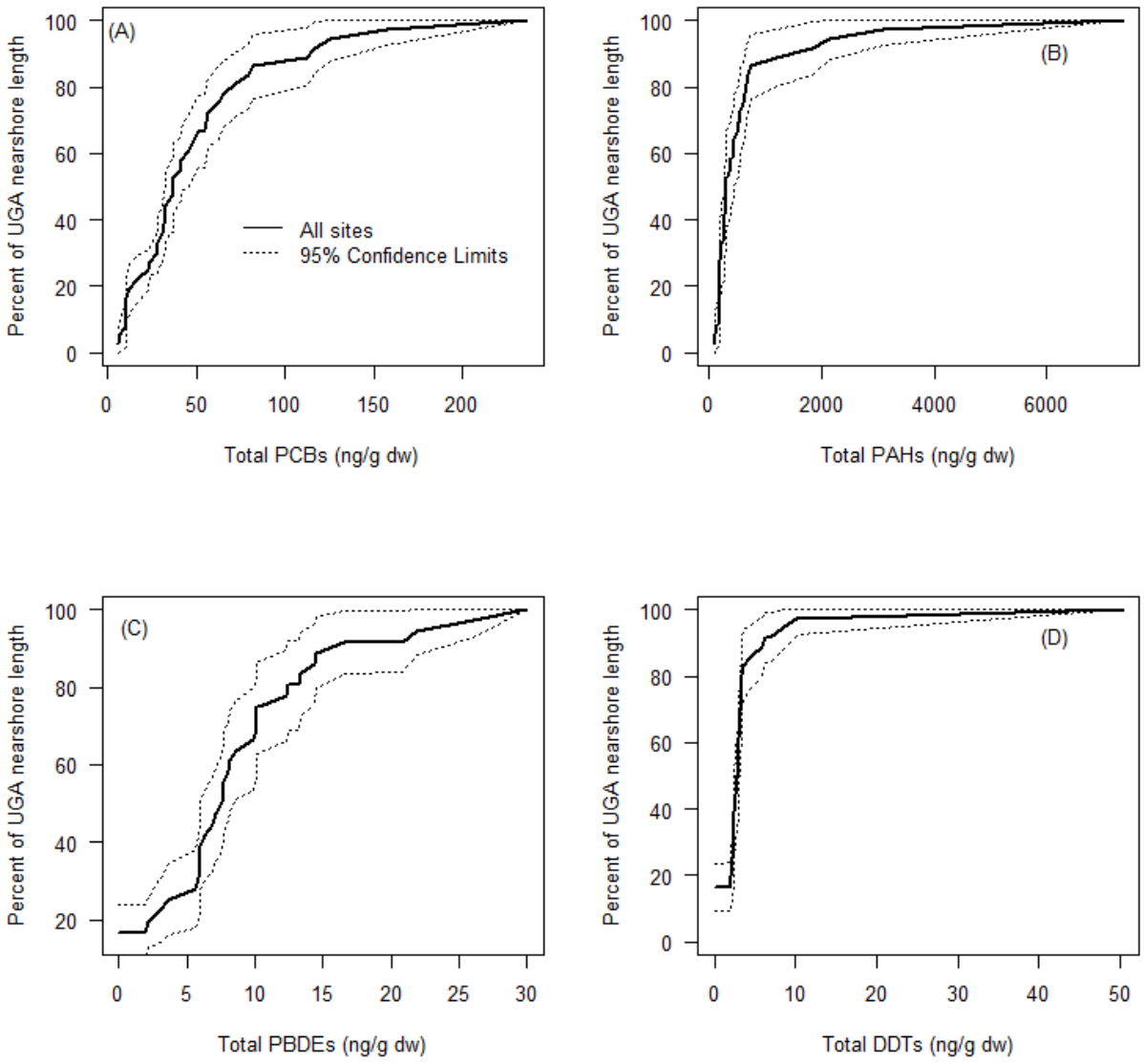

Figure 1. Cumulative frequency distribution of organic contaminant concentrations in mussels from 43 study sites, representing 1,191 km of Puget Sound UGA shoreline.

The concentration of metals in mussels was more dispersed along the Puget Sound UGA shoreline. Mussel tissues contained the highest content of zinc, followed by copper and arsenic (Figure 2).

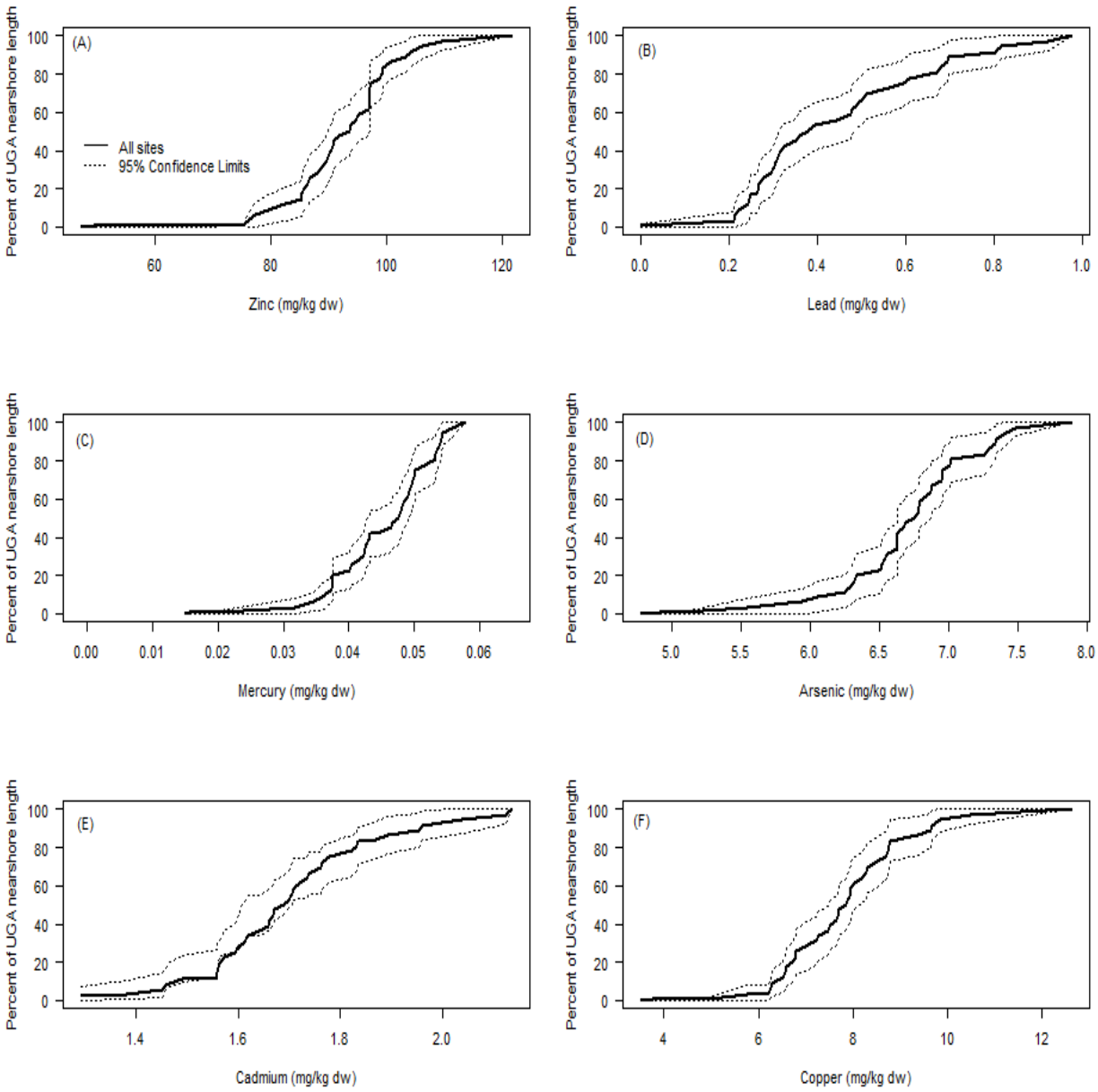

Figure 2. Cumulative frequency distribution of metal concentrations in mussels from 43 study sites representing 1,191 km of Puget Sound UGA shoreline.

Result 3. Comparison of contaminant results to initial conditions and least-disturbed site contaminant levels.

Based on initial conversations with you (as the SAM mussel study lead), other WDFW staff, and Ecology Environmental Assessment Program staff, we are unaware of any true reference conditions for Puget Sound nearshore mussel sampling sites. We have identified two study sites near Olympic National Park as the most suitable reference sites. These sites were sponsored by WDFW partners and not funded by SAM. We also used contaminant levels of mussel tissue at the beginning of the study as another reference condition, the initial (i.e. baseline) condition of the contaminants in mussels.

The concentrations of organic contaminants in mussels from the least-disturbed sites were similar to initial concentrations from Penn Cove. When compared to the initial condition and to the two least-disturbed sites, the organic contaminant concentrations were significantly higher in the mussels from the UGAs, suggesting exposure of organic contaminants in the urbanized nearshore (Figure 3).

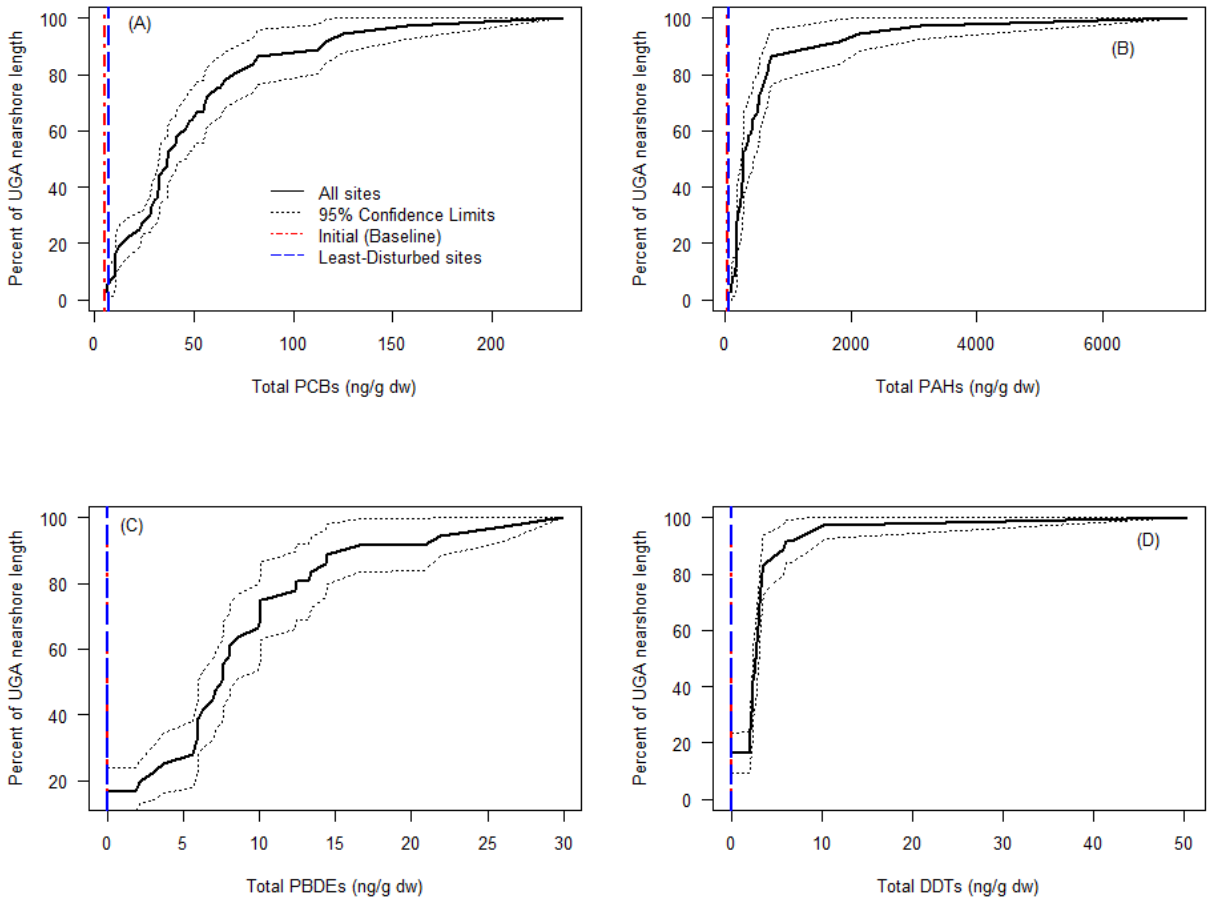

Figure 3. Cumulative frequency distribution of organic contaminant concentrations in mussels from 43 study sites representing 1,191 km of Puget Sound UGA shoreline, in in mussels from two reference conditions: initial condition from the Penn Cove aquaculture source, n = 6), and mussels from two least-disturbed sites (n = 2).

The concentration of metals in mussels was not always higher compared to initial concentrations (Figure 4). For cadmium and copper, about half (40-60 %) of the nearshore, concentration of mussel tissues were below the initial condition. For zinc, lead and arsenic, the majority of UGA nearshore had mussel tissue concentrations higher than the initial conditions.

Arsenic and lead concentrations in mussels from the least-disturbed sites were higher than initial concentration. Metals in the nearshore can come from both natural and anthropogenic sources; this fact, along with the variation in metal concentrations along the Puget Sound coast, both within and outside the UGAs, makes it difficult to find un-impacted reference locations and to separate anthropogenic from natural impacts.

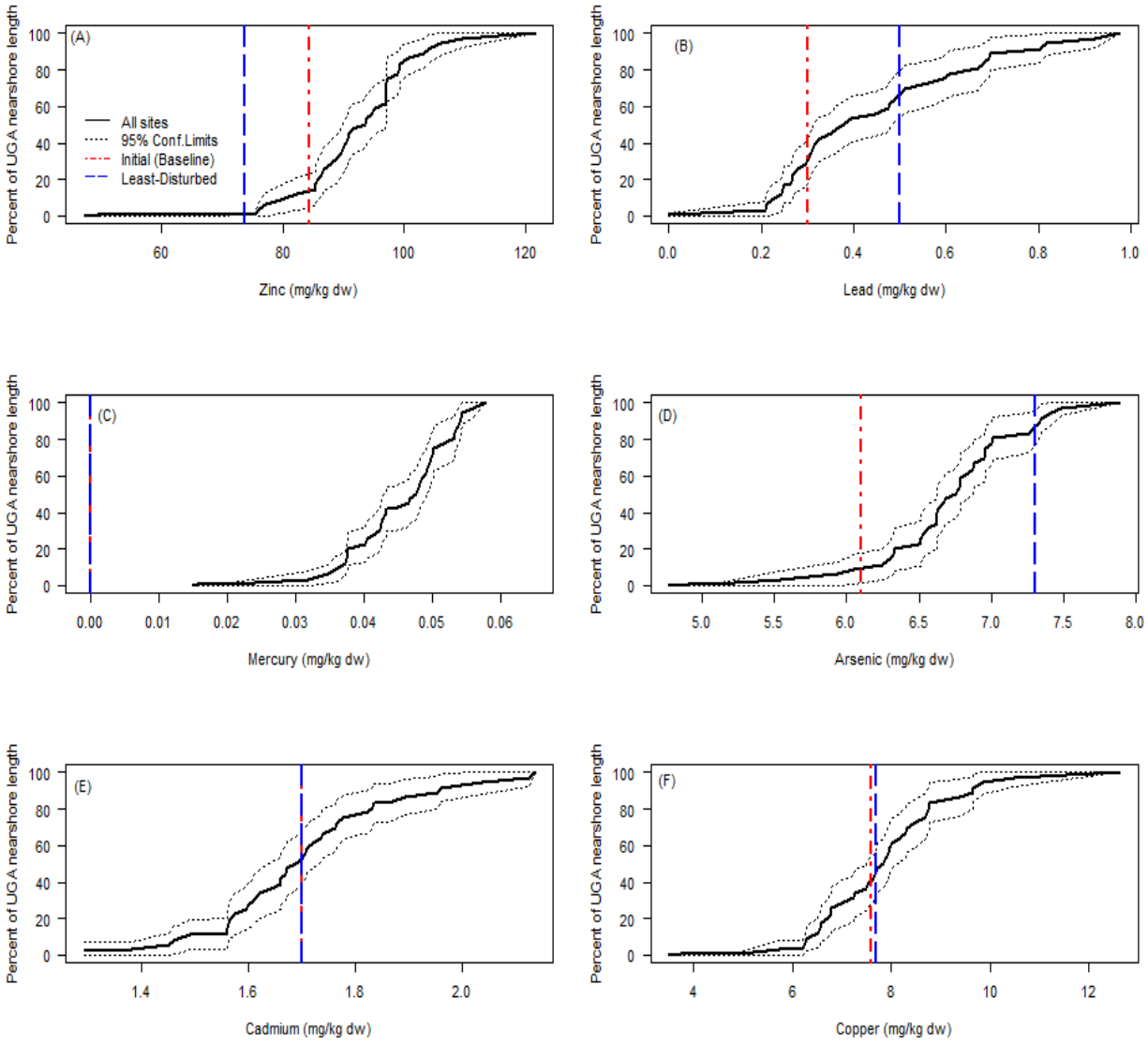

Figure 4. Cumulative frequency distribution of metal concentrations in mussels from 43 study sites, representing 1,191 km of Puget Sound UGA shoreline, and in mussels from two reference conditions: initial condition from the Penn Cove aquaculture source (n=6), and mussels from least-disturbed sites (n=2).

Result 4. Comparison of contamination concentrations between incorporated cities and unincorporated UGAs

We followed the approach in the final report (Lanksbury et al. 2017) to examine the degree of urbanization with the UGAs (incorporated cities and unincorporated areas) and contaminant concentrations (Figure 5). Concentrations of the four organic contaminants (PAHs, PCBs, PBDEs and DDTs) were higher in the cities, with significant differences in PAHs, PBDEs, and DDTs between the two subgroups (P<0.001, See Table 5 in the WDFW final report).

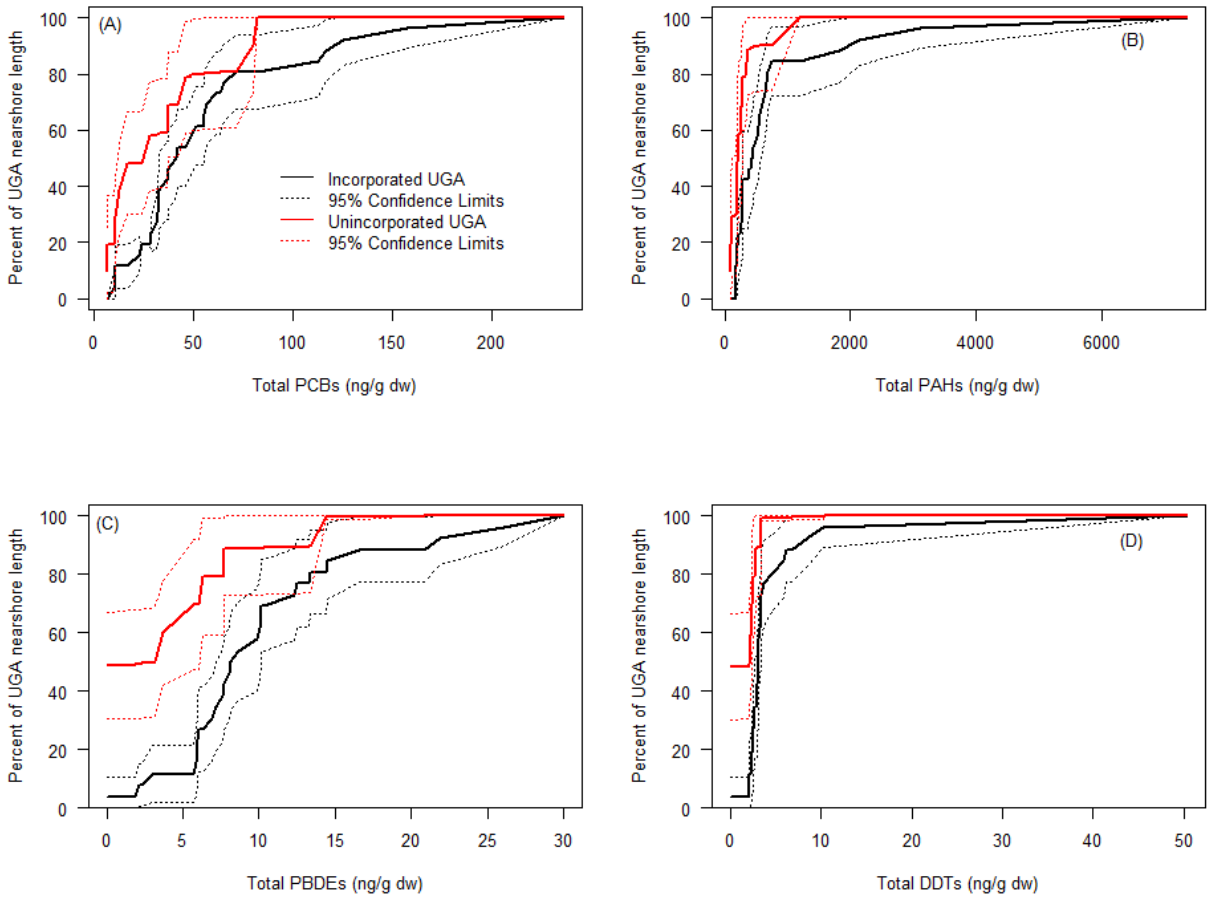

Figure 5. Cumulative frequency distribution of organic contaminant concentrations in mussels from two municipal land use subgroups (incorporated cities vs unincorporated UGAs) representing 1,191 km of Puget Sound UGA shoreline.

For metals (Figure 6), there was not such a clear distinction. The concentrations and spatial distributions tended to overlap. Mercury, copper and lead in the unincorporated UGAs were slightly lower than in the incorporated cities, but the differences were not statistically significant.

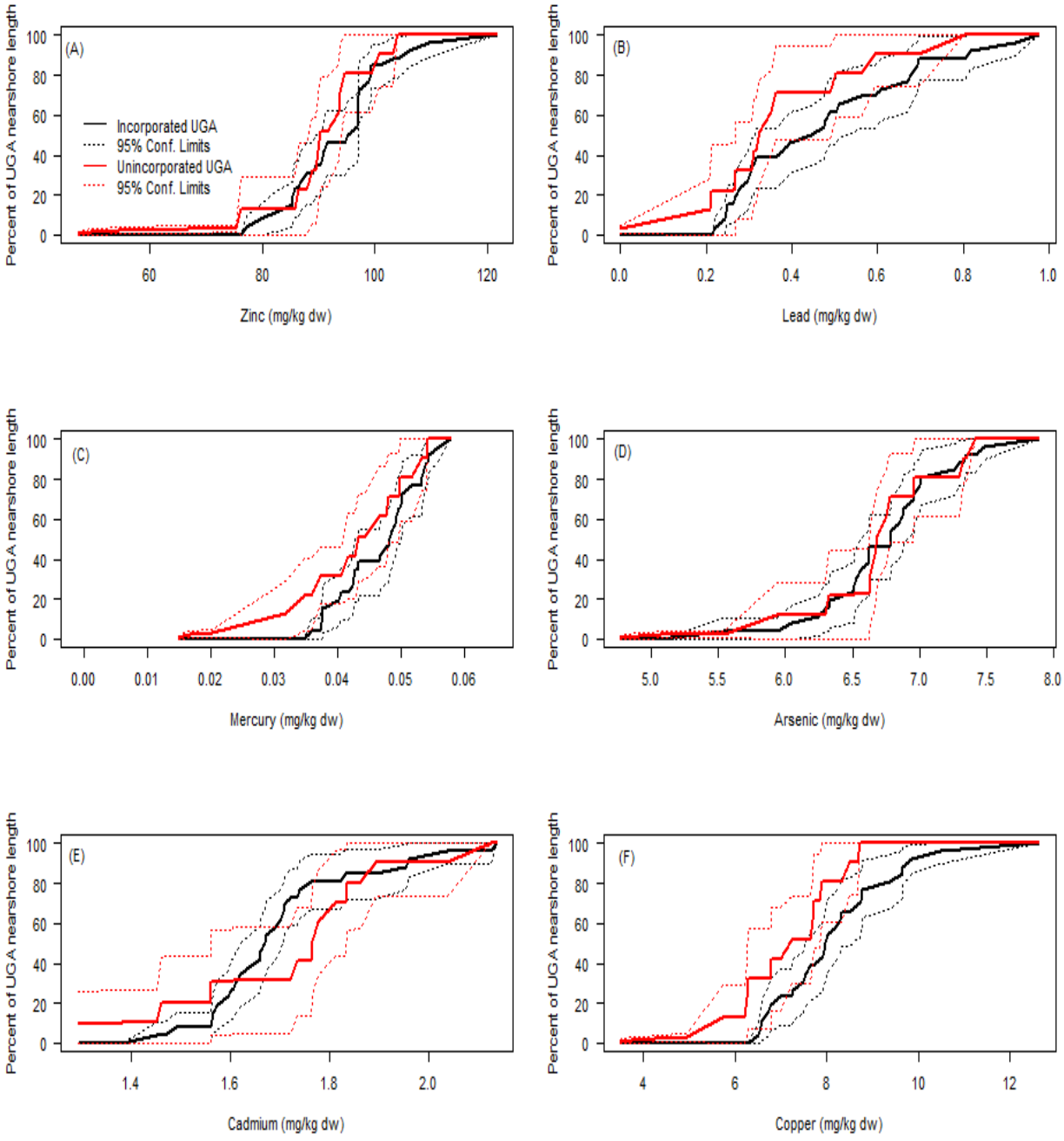

Figure 6. Cumulative frequency distribution of metal concentrations in mussels from two municipal land use subgroups (incorporated cities vs unincorporated UGAs) representing 1,191 km of Puget Sound UGA shoreline.

Result 5. Contaminant concentrations at SAM sites and Pierce County Option 2 sites

Figures 7 and 8 show the CDF plots of organic contaminants and metals from the SAM and Pierce County Option 2 sites separately. The Y axis displays the percent of UGA nearshore represented by each group of sites. Pierce County sites (n = 7) only represent 11 km, or 0.9% of the total Puget Sound UGA shoreline length, as compared to SAM sites (n = 36) representing 1180 km (99.1%). Pierce County Option 2 sites are all in unincorporated UGAs. Concentrations of contaminants, especially metals in mussels at Pierce County Option 2 sites were lower than regionally scaled (SAM) values.

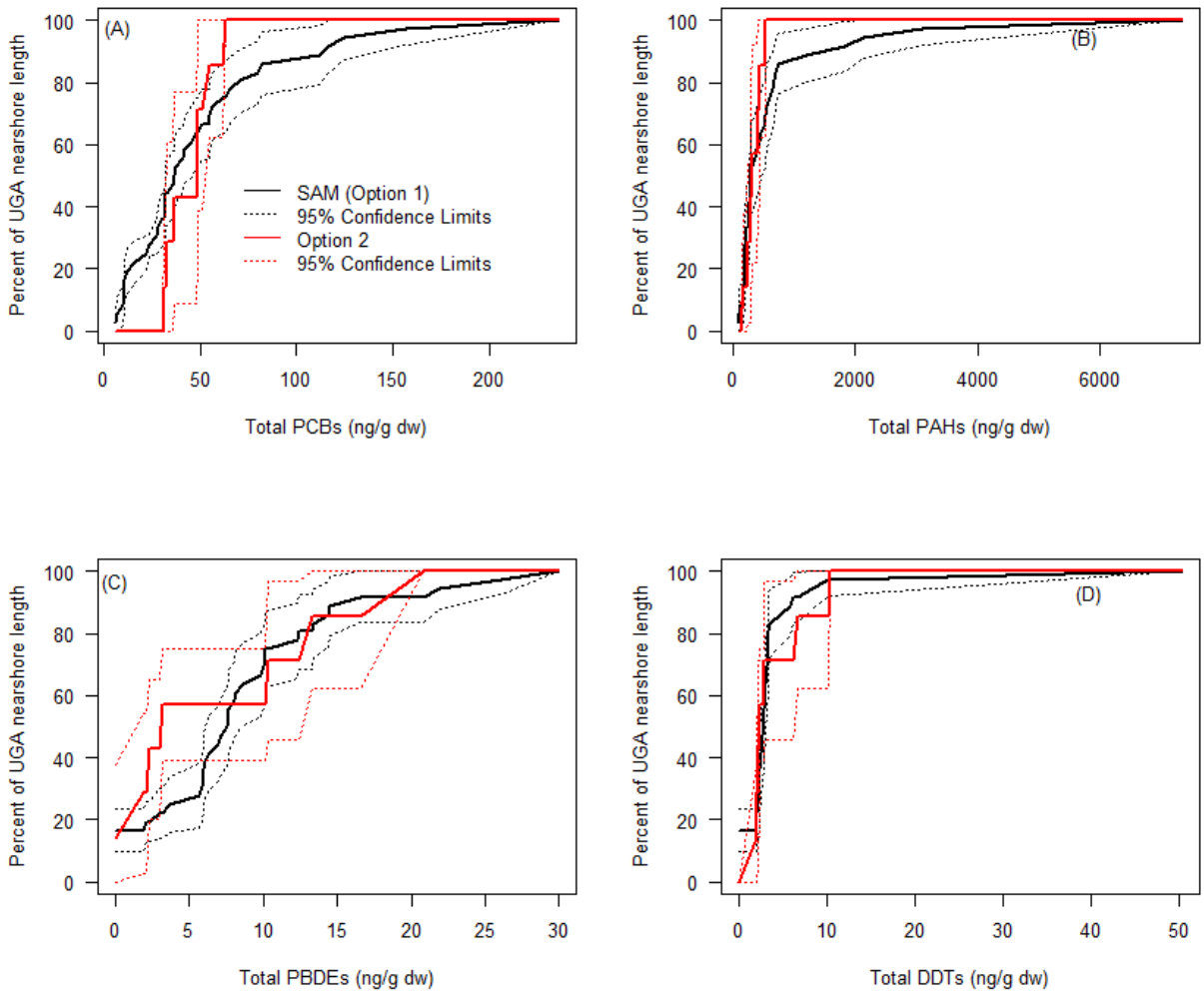

Figure 7. Cumulative frequency distribution of organic contaminant concentrations in mussels from two subgroups: SAM sites (representing 1,180 km of Puget Sound UGA incorporated and unincorporated shoreline) and Pierce County Option 2 sites (representing 11 km of Puget Sound unincorporated UGA shoreline).

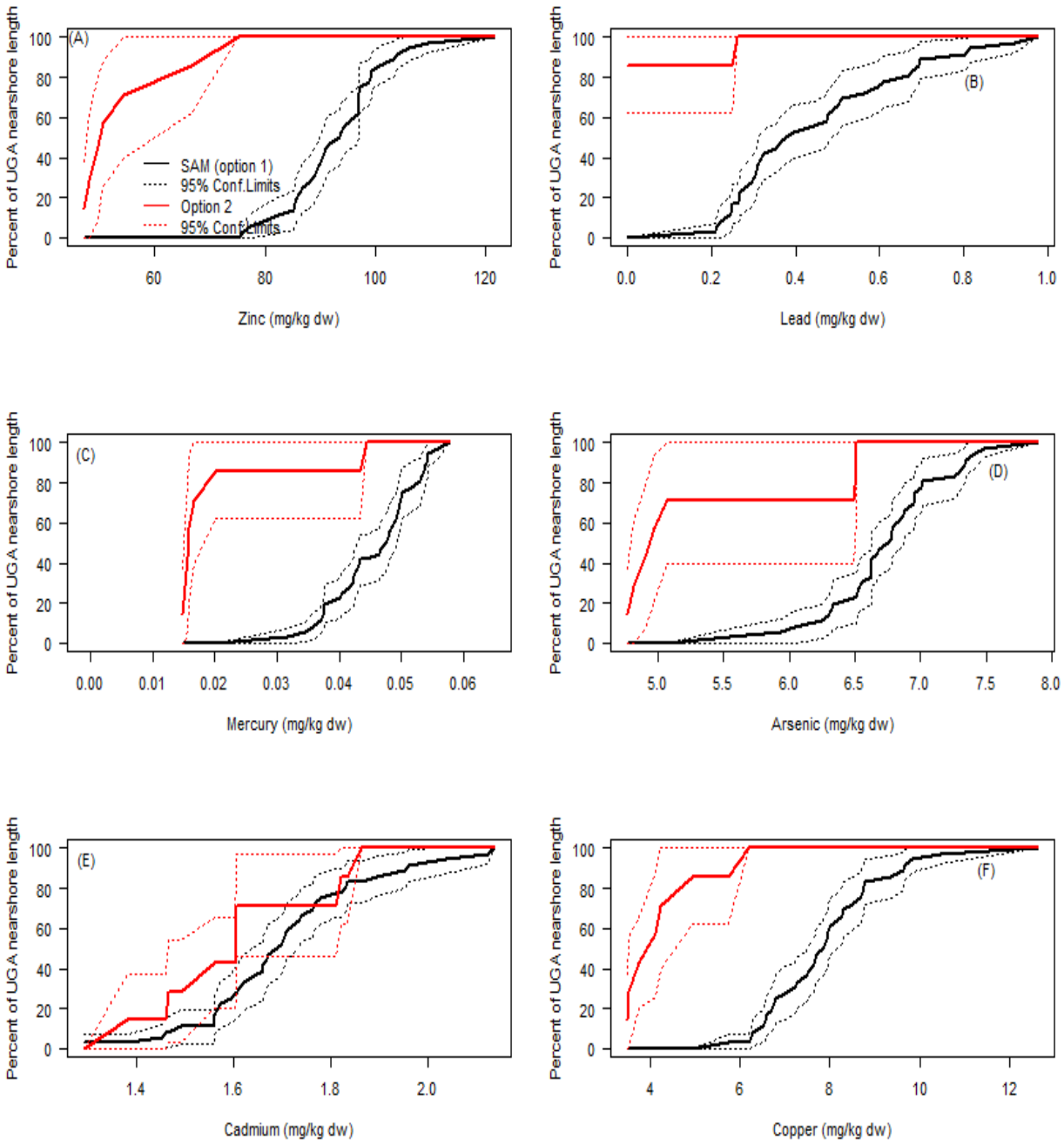

Figure 8. Cumulative frequency distribution of metal concentrations in mussels from two subgroups: SAM sites representing 1,180 km of Puget Sound UGA incorporated and unincorporated shoreline, and Pierce County Option 2 sites representing 11 km of Puget Sound unincorporated-UGA shoreline.

List of abbreviations

As = arsenic
Cd = cadmium
Cu = copper
DDTs = dichlorodiphenyltrichloroethane
dw = dry weight
g = gram
Hg = mercury
kg = kilogram
km = kilometer
ng = nanogram
PAHs = polycyclic aromatic hydrocarbons
Pb = lead
PCBs = polychlorinated biphenyls
PBDEs = polybrominated diphenyl ethers
SAM = Stormwater Action Monitoring
UGAs = urban growth areas
Zn = zinc

References

Jennifer Lanksbury, Brandi Lubliner, Mariko Langness, and James West, August, 2017. Stormwater Action Monitoring 2015/16 Mussel Monitoring Survey: Final Report. Washington Department of Fish and Wildlife FPT 17-06 (http://wdfw.wa.gov/publications/01925/).