Toxics Biological Observation System (TBiOS),
Puget Sound Ecosystem Monitoring Program (PSEMP)

Stormwater Action Monitoring 2017/18 Mussel Monitoring Survey

Final Report
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Data from the Stormwater Action Monitoring (SAM) program mussel monitoring will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search Study ID, SAM_MNM. Data from Pierce County will be under Study ID SAM_PC_MNM.

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Executive Summary

Toxic contaminants enter the Puget Sound from a variety of pathways including non-point sources such as stormwater runoff, groundwater releases, air deposition, and point sources like marinas, industrial and wastewater treatment plant outfalls, and combined sewer overflows. Contaminated stormwater is considered one of the biggest contributors to water pollution in the urban areas of Washington State because it is ongoing and damages habitat, degrades aquatic environments, and can have serious impacts on the health of the Puget Sound. Monitoring pollutants and their effects on the marine biota of Puget Sound is critical to inform best management practices and remediation efforts in this large and diverse estuary.

In the winter of 2017/18 the Washington Department of Fish and Wildlife (WDFW), with the help of citizen science volunteers, other agencies, tribes, and non-governmental organizations, conducted the second of a series of biennial, nearshore mussel monitoring efforts under the Stormwater Action Monitoring (SAM) program. The first SAM Mussel Monitoring survey was conducted in the winter of 2015/16 (Lanksbury et al., 2017).

SAM is a collaborative stormwater monitoring program funded by municipal stormwater permit holders in western Washington. This monitoring survey for SAM was intended to characterize the spatial extent of tissue contamination in nearshore biota residing inside the urban growth areas (UGAs) of Puget Sound, using mussels as the primary indicator organism. Future biennial SAM surveys will continue to track mussel tissue contamination in the Puget Sound nearshore to answer the question: "Is the health of biota in the urban nearshore improving, deteriorating, or remaining the same related to stormwater management?" Although the primary focus of this document was to report on SAM program data, we included data for additional sampling conducted by WDFW and its partner organizations, and note the benefits of this larger, cooperative monitoring effort.

In this study we used native mussels (*Mytilus trossulus*) as indicators of the degree of contamination of nearshore habitats. We transplanted relatively uncontaminated mussels from a local aquaculture source to over ninety locations along the Puget Sound shoreline, covering a broad range of upland land-use types from rural to highly urban. At the end of the study, after approximately three months of exposure, we measured the concentration of several major contaminants in the mussels' soft tissues including several classes of organic chemicals, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs, or flame retardants), and chlorinated pesticides (including dichlorodiphenyltrichloroethane compounds, or DDTs) and seven metals (lead, copper, zinc, mercury, arsenic, cadmium, and aluminum).

WDFW staff, volunteers, and partners deployed mussel cages to 94 monitoring sites; 41 SAM sites (38 repeated from 2015/16 survey, three new sites), one new SAM reference site, eight Pierce County (Option 2) sites, and 44 Partner sites. Mussel cages were recovered from 92 of those sites (i.e., 98%), with cages lost at one SAM and one Partner site. Similar to the 2015/16 survey results, $\sum_{42}$PAHs , TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs were the most abundant organic contaminants detected in mussels at all sites (SAM, Pierce County, Partner). When compared to the 2015/16 survey results, TPCBs and $\sum_{6}$DDTs in SAM site mussels had significantly higher median concentrations, indicating those contaminants should be closely monitored in future surveys to track whether there is an increasing trend. Similar to the 2015/16 survey results, all metals were frequently detected in mussels at all sites. Due to a change regarding the laboratory analysis methodology of the metal analytes, no temporal comparisons were made between survey years for the metals data.

The distribution of mussel tissue contaminant concentrations along the Puget Sound UGA was examined using cumulative frequency distribution (CFD) plots. The CFD plots revealed similar patterns for Σ_{42}PAHs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs, with all skewed toward the lower concentrations, suggesting that the majority of Puget Sound UGA shorelines have relatively low concentrations of these contaminants and that only a few sites have much higher concentrations, perhaps from locally high non-point sources, or site specific point sources. The CFD pattern for TPCBs was unlike the other organic contaminants in that it had a more gradual contaminant accumulation as the shoreline length increased, suggesting sources of this contaminant is more widely dispersed within the Puget Sound UGAs. The CFD patterns for most of the metals (arsenic, cadmium, lead, mercury, and zinc) had a more gradual contaminant accumulation as the shoreline increased, suggesting these contaminants are more widely dispersed within the Puget Sound UGA shoreline. The CFD pattern for copper was unlike the other metals, having a pattern more skewed to the lower concentrations, with only a few sites with much higher concentrations.

Sites with the highest concentrations of organic contaminants were located mainly in the more urbanized and industrialized south-central Puget Sound basin and sites with lowest concentrations were mainly in the remote and least developed Hood Canal basin. Similar to the organic contaminants, sites with the highest concentrations of metals were located in the urbanized south-central Puget Sound basin. However, low metal concentration sites occurred within the same urban south-central basin; a pattern not observed with the organic contaminants where all the sites had high or intermediate concentrations within the south-central basin. Further, continued positive correlations between the concentration of key organic contaminants (Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs) and metals (lead and zinc) in mussels and the percent of impervious surface in adjacent watersheds is evidence that this characteristic of urbanization provides a transport pathway for toxic chemicals from terrestrial to aquatic habitats.

Acknowledgements

This study would not have been possible without substantial help from individual volunteers and volunteer groups. Our volunteer partners helped evaluate potential monitoring sites, measure and bag mussels, deploy and retrieve mussel cages, and process mussels in the lab. Over 100 volunteers spent well over 500 hours helping us to execute this study and we are grateful for their efforts.

SAM and WDFW recognize the following organizations, their staff and volunteers for their assistance:

Bainbridge Beach Naturalists, City of Bellingham, Coastal Volunteer Partnership at Padilla Bay, Feiro Marine Life Center, Harbor Wildwatch, Jamestown S'Klallam Tribe, King County, Kitsap County Public Works, Lighthouse Environmental Programs, Nisqually Reach Nature Center, Penn Cove Shellfish, Port Gamble S'Klallam Tribe, Port Townsend Marine Science Center, Port of Tacoma, Puget Sound Corps, Puget Soundkeeper Alliance, San Juan County Marine Resources Committee (MRC), Seattle Aquarium, Snohomish County MRC, Sound Water Stewards of Island County, South Puget Sound Salmon Enhancement, Stillaguamish Tribe, Suquamish Tribe, University of Puget Sound, University of Washington-Tacoma, Vashon Nature Center, Washington Conservation Corps, Washington Department of Ecology, Washington Department of Natural Resources Aquatic Reserves Program, Western Washington University, and Whatcom County MRC.

We also thank the organizations below, who together sponsored an additional 17 sites for this study:

City of Bellingham, Jamestown S'Klallam Tribe, Jefferson County MRC, King County, Kitsap County Public Works, Port Gamble S'Klallam Tribe, Port of Tacoma, Snohomish County MRC, Stillaguamish Tribe, the Washington Department of Natural Resources Aquatic Reserves Program, and Whatcom County MRC.

Laboratory Partners

The authors thank NOAA's Northwest Fisheries Science Center (NWFSC) Environmental Chemistry Program, in Seattle Washington, for their high quality analysis of all the organic analytes reported herein; and the King County Environmental Lab in Seattle Washington for analysis of all the metal analytes.

Mussel Bagging

We extend a special thanks to Penn Cove Shellfish, Inc. of Whidbey Island, which generously donated the mussels and aquaculture bags used in this study. In addition, volunteers worked diligently during the mussel-bagging phase of the study at Penn Cove, in the winter, outdoors, under sometimes inclement weather; their efforts were central to the success of this study. We give special thanks to Kestutis (Kes) Tautvydas with Sound Water Stewards of Island County, whose volunteers made up most of our baggers.

Mussel Monitoring Program Development

The authors particularly thank Jennifer Lanksbury for her significant contribution to the implementation of WDFW's Mussel Monitoring Program and management of the 2015/16 SAM Mussel Monitoring survey. We further thank her for her contribution to this report; providing cumulative frequency distributions plots and report review.

Introduction

Stormwater runoff is considered one of the biggest water pollution problems in urban areas of Washington State (EnviroVision Corporation et al., 2008).The volumes and entrained contaminants in stormwater damages habitat, degrades aquatic environments, exacerbates flooding, and plays a major role in Puget Sound's deteriorating health (PSAT, 2005). Monitoring pollutants in the nearshore and their effects on the marine biota of Puget Sound is critical to inform stormwater best management practices and remediation efforts in this large and diverse estuary (Hamel, 2015).

The Puget Sound Ecosystem Monitoring Program (PSEMP) Stormwater Work Group (SWG) is a formal stakeholder coalition comprising federal, tribal, state and local governments, businesses, environmental and agricultural entities, and academic researchers, all with interests and a stake in the health of the Puget Sound ecosystem. The SWG was created in October 2007 at the request of municipal stormwater permittees, the Washington State Department of Ecology (Ecology), and the Puget Sound Partnership (PSP) to develop a regional stormwater monitoring strategy and to recommend monitoring requirements for National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits issued by Ecology. In 2010, the SWG finalized an overall strategy for monitoring, in a document entitled "2010 Stormwater Monitoring and Assessment Strategy for the Puget Sound Region (SWAMPPS)" (SWG, 2010). It promoted an integrated approach to quantifying stormwater pollutant impacts in Puget Sound, providing information to efficiently, effectively, and adaptively manage stormwater and reduce harm to the ecosystem.

A result of the SWG's overall strategy was the formation of the Stormwater Action Monitoring (SAM) program. SAM includes three study components: 1) Status and Trends in Receiving Waters, 2) Effectiveness Monitoring of Stormwater Management Program Activities, and 3) Source Identification Information Repository. The Status and Trends in Receiving Waters component of SAM monitors changes in Puget Sound lowland streams and Puget Sound urban shoreline areas in relation to stormwater management. Contaminant monitoring of mussels in the urban growth areas of Puget Sound's marine nearshore, hereafter referred to as SAM Mussel Monitoring, is part of SAM's Status and Trends in Receiving Waters.

The purpose of SAM Mussel Monitoring is to identify existing stormwater-related challenges to the health of nearshore biota. The objectives of the SAM Mussel Monitoring survey are to; 1) characterize the spatial extent of contamination to which nearshore biota residing inside the UGA sampling frame may be exposed, using mussels (*Mytilus* sp.) as the primary indicator organism, and 2) track changes in tissue contamination over time inside the UGA sampling frame. This second objective is aimed at answering the question, "Is the health of biota in the urban nearshore improving, deteriorating, or remaining the same related to stormwater management?".

The 2017/18 SAM Mussel Monitoring survey represents the second successful deployment of mussels in Puget Sound for the purpose of tracking toxic contaminants in nearshore biota over time, and the third Puget Sound-wide synoptic survey using transplanted mussels (Lanksbury et al., 2014 and 2017). In this survey report we largely address the first SAM survey objective, characterizing the spatial extent of contamination of nearshore biota. We provide information on the spatial extent of key contaminants present inside the UGA sampling frame (current status in mussels), identify the detection frequency and concentration range of contaminants, describe the geographic range of contaminants, and examine the relationship between land-use and the movement of contaminants from terrestrial sources to the Puget Sound nearshore. Where appropriate we also compare results between the 2015/16 and 2017/18 surveys. Results of a third mussel survey (conducted in 2019/20; analysis underway) will be used to evaluate trends in the health of urban nearshore biota. Although the primary focus of this document is to report on SAM program data, we included data from WDFW and partner organizations' sites (referred to as Partner sites in this document) in the sections describing the detection frequency and geographic range of contaminants, as well as land-use analysis. WDFW partners will be able to determine how conditions in mussels from the sites they sponsored compare with conditions in the SAM UGA sites and with the overall study. In turn, WDFW and partner data provides the SAM program with some non-UGA sites and additional sites of interest (hotspots, other reference sites) with which to compare.

Methods

GRTS Study Design and Site Selection

The 2017/18 SAM and Pierce County nearshore monitoring site locations were selected using a probabilistic random stratified sampling design that targeted the land-based UGA boundaries of Puget Sound (Figure 1). Details on the study design are available in the Quality Assurance Project Plan (QAPP) for this study (Lanksbury and Lubliner, 2015). In brief, the sampling framework was based on the EPA's spatially balanced, generalized random tessellation stratified (GRTS) multi-density survey design, as described by Stevens (1997, 2003), and Stevens and Olsen (1999, 2004). Sitka Technology Group, LLC, using the GRTS design, generated a linear Puget Sound shoreline sampling frame. The result was 2,048 possible nearshore sites in the Puget Sound UGAs. Of these, 40 locations were successfully sampled for SAM (Option 1) Mussel Monitoring in 2017/18. Ecology's 2013-2018 permits included a second option for jurisdictions to conduct monitoring in their area and contribute to the data, but not pay-in to SAM pooled resources. Pierce County selected this option and sampled eight qualifying (Option 2) shoreline sites in their own unincorporated UGAs (Table 1). Though the SAM and Pierce County mussel sites were selected from a random list of locations along the UGAs of Puget Sound, the Pierce County sites came from a much smaller substratum of the original UGA sample frame than the rest of the SAM nearshore sites: the Pierce County sites were selected only from unincorporated-UGA shorelines within Pierce County. Because of this difference in geography, the spatial weights of the regional SAM nearshore sites and the Pierce County nearshore sites are different.

Several of the original candidate sites for both SAM and Pierce County Option 2 sampling were dropped due to limited accessibility, safety issues, and mussel cages lost during the deployment period. As a result, the actual sampled nearshore length was smaller than the initial study nearshore length. SAM sites lost 28.6% of the initial frame due to the 16 rejected sites out of the first 56 evaluated candidate sites, and Pierce County lost 60% of their initial length due to their 12 rejected sites out of the first 20 evaluated candidate sites. The initial and final adjusted spatial weight for both SAM and Option 2 sites are shown in Table 1. Each SAM site represents 28.7 km of length and each Pierce County site represents 1.6 km of length. The total adjusted length of shoreline that was sampled by the total (SAM and Option 2) nearshore probabilistic framework was 1,160 km. The 40 SAM survey sites alone statistically represent 98.9% (1147 km) of the Puget Sound UGA nearshore, and the 8 Option 2 sites represent 1.1% (13 km). The spatial representation in the 2015/16 survey was similar, with SAM sites representing 99.1% of the total sampled length and Option 2 sites representing 0.9% (Song and Lubliner, 2018).

Thirty-eight of the 2015/16 SAM sites were revisited in this survey and three new sites were added to replace two of the failed 2015/16 sites and have one contingency site for any cages that could have be lost in the survey (41 SAM sites total visited). The same eight 2015/16 Pierce County sites were revisited. Additionally, a new reference site was established on the Penn Cove shoreline, near our aquaculture source, to provide a shoreline reference condition of mussel tissue contaminant concentrations. Further, mussel cages were placed at 44 additional sites sponsored by groups outside of the SAM program (hereafter referred to as Partner sites) in their areas of interest, including WDFW sites.

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

2017/18 Mussel Survey		SAM	Option 2	Total
Initial Design	# of candidate sites	2008	40	2048
	Initial study length (km)	1606	32	1638
Site Information	# of evaluated candidate sites	56	20	76
	# of sampled sites	40	8	48
	# of rejected/lost sites	16	12	28
Adjusted length of nearshore in Puget Sound UGAs	Adjusted length (km) per site	28.7	1.6	-
	Total sampled length (km)	1147	13	1160
Contribution	Contribution to total sampled length (%)	98.9	1.1	100
	Lost contribution by rejected sites to each option length (%)	28.6	60.0	-

Study area

This study largely took place in the greater Puget Sound, which is a fjord-like marine estuary on the northwestern coast of Washington State with many interconnected marine waterways and basins. Puget Sound is connected to the Pacific Ocean primarily via the Strait of Juan de Fuca, is part of the larger Salish Sea that stretches into Canada and is strongly influenced by freshwater input through major river systems.

SAM mussel monitoring focused on a single landscape scale, the shoreline parallel to cities and other developed lands in the established UGAs of the Puget Sound. A shoreline-sampling frame was defined to include the basins, channels, and embayments of Puget Sound from the US/Canada border to the southernmost bays and inlets near Olympia and Shelton, it also included the Hood Canal, portions of Admiralty Inlet, the San Juan Islands, and the eastern portion of the Strait of Juan de Fuca. Partner sites were mainly located within the Puget Sound, some falling within and outside of UGAs. However, two partner sites were located on Washington’s Pacific coast shoreline, one in Grays Harbor and one in Willapa Bay (Figure 1).

Field/Lab Methods

Field and laboratory methods for this study followed those detailed in the first SAM mussel survey report, Stormwater Action Monitoring 2015/16 Mussel Monitoring Survey (Lanksbury et al., 2017), and in the Quality Assurance Project Plan (QAPP) (Lanksbury and Lubliner, 2015). Method changes implemented for this 2017/18 survey were documented in a QAPP Amendment (Lanksbury, 2017). These changes included removal of the measurement of several field parameters, including the height of the most recent low tide, precipitation, aquatic vegetation coverage or type, adjacent upland land use type, and man-made structures on the beach. The shortened list of field measurement and observation parameters measured is shown in Table 2.

WDFW was informed in 2018, subsequent to the Lanksbury and Lubliner (2015) QAPP and its Lanksbury et al. (2017) amendment, of a change regarding the analysis methodology for arsenic, cadmium, copper, zinc, and lead at the King County Environmental Laboratory (KCEL). These metals are analyzed via Thermo Elemental X Series II CCT (Collision Cell Technology) Inductively Coupled Plasma Mass Spectrometer (ICP-MS) following KCEL SOP 624. KCEL adopted a change in the tissue digestion method, notably the addition of 1% HCl to samples during digestion. This change occurred between the 2015/16 and 2017/18 mussel analyses. WDFW and KCEL subsequently analyzed 30 tissue samples across three of its monitoring indicator species (mussels, English sole, and Pacific herring), to evaluate potential bias introduced by this method change.

WDFW is currently reviewing the strength and predictability of the correlation between ICP-MS metals results generated by the previous and current KCEL methods. Potential effects on mercury analyses are unclear as of this writing. WDFW will include in an upcoming QAPP amendment, the results of these analyses, and a discussion and decision regarding the feasibility of using a correction factor to allow use of pre-2017 data after that year for time trends analyses. Until that QAPP amendment is approved, no temporal comparisons will be made herein for mussels for time sets where both analytical methods were employed.

Table 2. Field measurement and observation parameters.

Field Measurements
Time of cage deployment/retrieval
GPS coordinates and accuracy
Field Observations/Estimates
Wave energy
Beach exposure
Substrate Type
Freshwater inputs
Erosion control structures
Shoreline use
Anthropogenic structures on beach
Outfalls present
Potential sources of pollutants

Overview of Sampling Efforts

WDFW staff, volunteers, and partners deployed mussel cages to 94 monitoring sites: 41 SAM sites, 1 SAM reference site, 8 Pierce County (Option 2) sites, and 44 Partner sites. Mussel cages were recovered from 92 of those sites (i.e., 98%): 40 SAM sites, 1 SAM reference site, 8 Pierce County sites, and 43 Partner sites (Table 3, Figure 1). We lost mussel cages from the following two monitoring sites due to storms:

1. SAM Site #20 (Port Angeles Harbor)
2. Partner Site "CPS_DM" (Des Moines Marina City Beach Park)

Mussel cages were deployed at approximately the 0 (zero) foot mean lower low water mark during low tides on the evenings of December 1 to 6, 2017. To provide an initial condition of contaminants in mussels for the study, WDFW also collected five replicate samples from the Penn Cove Shellfish aquaculture facility at the start of the study, on December 6, 2017; these samples are hereafter referred to as the Baseline mussels (location in Table 3, Figure 1). Exposure to local conditions at each mussel-monitoring site lasted approximately three months. The deployed mussel cages were recovered during low tides on the evenings of February 25 to 28, 2018.

Table 3. Site location information for ninety-four (94) nearshore mussel monitoring sites and baseline site in this study. Map IDs are used to identify sites in Figure 1. SAM sponsored sites are shaded in light grey, Pierce County (PC) sites in white, and Partner (WDFW and Other) sites in dark grey.

Source	Map ID	Site ID	Site Name	Latitude	Longitude	County	Status
SAM	1	PCB_MEAN	Baseline (i.e. Penn Cove, pre-deployment samples)	48.21863	-122.70797	Island	Retrieved
SAM	2	WB_PCR	Penn Cove Reference	48.21423	-122.71897	Island	Retrieved
SAM	3	Site #2	Arroyo Beach	47.50160	-122.38590	King	Retrieved
SAM	4	Site #3	Brackenwood Ln	47.68234	-122.50640	Kitsap	Retrieved
SAM	5	Site #4	Cherry Point North	48.85842	-122.74072	Whatcom	Retrieved
SAM	6	Site #5	Salmon Beach	47.29467	-122.53046	Pierce	Retrieved
SAM	7	Site #6	Eagle Harbor Dr	47.61889	-122.52750	Kitsap	Retrieved
SAM	8	Site #8	Chimacum Creek Delta	48.04900	-122.77230	Jefferson	Retrieved
SAM	9	Site #10	Fletcher Bay, Fox Cove	47.64447	-122.57590	Kitsap	Retrieved
SAM	10	Site #11	South Bay Trail	48.72576	-122.50621	Whatcom	Retrieved
SAM	11	Site #13	Ruston Way	47.29260	-122.49490	Pierce	Retrieved
SAM	12	Site #14	Point Heron East	47.57011	-122.60695	Kitsap	Retrieved
SAM	13	Site #15	Tugboat Park	48.48928	-122.67608	Skagit	Retrieved
SAM	14	Site #16	Meadowdale Beach	47.85569	-122.33483	Snohomish	Retrieved
SAM	15	Site #17	Budd Inlet, West Bay	47.07128	-122.92070	Thurston	Retrieved
SAM	16	Site #18	Seahurst	47.46350	-122.36920	King	Retrieved
SAM	17	Site #19	Skiff Point	47.66142	-122.49884	Kitsap	Retrieved

Source	Map ID	Site ID	Site Name	Latitude	Longitude	County	Status
SAM	18	Site #20	Port Angeles Harbor	48.11855	-123.42635	Clallam	Lost
SAM	19	Site #21	Point Defiance Ferry	47.30620	-122.51460	Pierce	Retrieved
SAM	20	Site #22	Beach Dr E	47.55947	-122.59691	Kitsap	Retrieved
SAM	21	Site #23	Wing Point	47.62229	-122.49641	Kitsap	Retrieved
SAM	22	Site #24	S of Skunk Island	48.02710	-122.75140	Jefferson	Retrieved
SAM	23	Site #25	Blair Waterway	47.27568	-122.41730	Pierce	Retrieved
SAM	24	Site #26	N of Illahee State Park	47.60237	-122.59608	Kitsap	Retrieved
SAM	25	Site #27	Chuckanut, Clark's Point	48.69074	-122.50433	Whatcom	Retrieved
SAM	26	Site #28	Oak Harbor	48.27119	-122.63876	Island	Retrieved
SAM	27	Site #29	Liberty Bay	47.73639	-122.65122	Kitsap	Retrieved
SAM	28	Site #30	Kitsap St Boat Launch	47.54167	-122.64034	Kitsap	Retrieved
SAM	29	Site #31	East Sound, Fishing Bay	48.69250	-122.90972	San Juan	Retrieved
SAM	30	Site #34	Elliott Bay, Harbor Island, Pier 17	47.58766	-122.35065	King	Retrieved
SAM	31	Site #35	Williams Olson Park	47.66582	-122.56694	Kitsap	Retrieved
SAM	32	Site #37	Saltar's Point	47.16917	-122.61295	Pierce	Retrieved
SAM	33	Site #38	Rocky Point	47.60253	-122.66998	Kitsap	Retrieved
SAM	34	Site #39	Smith Cove, Terminal 91	47.63247	-122.37847	King	Retrieved
SAM	35	Site #42	Evergreen Rotary Park	47.57554	-122.62798	Kitsap	Retrieved
SAM	36	Site #43	N Avenue Park	48.52104	-122.61525	Skagit	Retrieved
SAM	37	Site #46	Appletree Cove	47.78722	-122.49460	Kitsap	Retrieved
SAM	38	Site #47	Cherry Point Aq Reserve, Birch Bay	48.89572	-122.78265	Whatcom	Retrieved
SAM	39	Site #48	Naketa Beach	47.92769	-122.30960	Snohomish	Retrieved
SAM	40	Site #49	Donkey Creek Delta	47.33701	-122.59011	Pierce	Retrieved
SAM	41	Site #52	Port Angeles Yacht Club	48.12823	-123.45715	Clallam	Retrieved
SAM	42	Site #54	Dyes Inlet, Chico Bay	47.61033	-122.70781	Kitsap	Retrieved
SAM	43	Site #56	Fidalgo Island, Swinomish Res	48.39875	-122.54363	Skagit	Retrieved
PC	44	Site #61	Dash Point Park	47.31979	-122.42686	Pierce	Retrieved
PC	45	Site #161	Purdy, Dexters	47.38590	-122.62986	Pierce	Retrieved
PC	46	Site #185	Browns Point	47.30515	-122.44441	Pierce	Retrieved
PC	47	Site #353	Purdy, Nicholson	47.37630	-122.62530	Pierce	Retrieved
PC	48	Site #481	Gig Harbor, Boat Launch	47.33785	-122.58277	Pierce	Retrieved
PC	49	Site #625	Gig Harbor, Mulligan	47.33051	-122.57532	Pierce	Retrieved
PC	50	Site #697	Browns Point, Wolverton	47.29833	-122.43667	Pierce	Retrieved
PC	51	Site #953	Browns Point, Carlson	47.30780	-122.43523	Pierce	Retrieved
WDFW	52	AI_PTW	Port Townsend Water Street	48.10879	-122.76756	Jefferson	Retrieved
WDFW	53	CB_CBSW	Commencement Bay, Skookum Wulge	47.28979	-122.40994	Pierce	Retrieved

Source	Map ID	Site ID	Site Name	Latitude	Longitude	County	Status
WDFW	54	CB_CBTF	Thea Foss Waterway	47.25934	-122.43483	Pierce	Retrieved
WDFW	55	CB_DGL	Comm Bay, Dick Gilmur Launch	47.29230	-122.41180	Pierce	Retrieved
WDFW	56	CB_JHP	Jack Hyde Park	47.27569	-122.46293	Pierce	Retrieved
Other	57	CB_MW	Comm Bay, Milwaukee Waterway	47.26940	-122.42430	Pierce	Retrieved
WDFW	58	CPS_DM	Des Moines Marina City Beach Park	47.40280	-122.33190	King	Lost
Other	59	CPS_EF	Edmonds Ferry	47.81420	-122.38220	Snohomish	Retrieved
WDFW	60	CPS_HCV	Port Madison, Hidden Cove	47.69139	-122.54333	Kitsap	Retrieved
WDFW	61	CPS_LP	Lincoln Park	47.53100	-122.40160	King	Retrieved
Other	62	CPS_MASO	Manchester, Stormwater Outfall	47.55622	-122.54281	Kitsap	Retrieved
WDFW	63	CPS_PNP	Point No Point	47.90770	-122.52606	Kitsap	Retrieved
WDFW	64	CPS_QMH	Quartermaster Harbor	47.40524	-122.44008	King	Retrieved
WDFW	65	CPS_SB	Salmon Bay	47.66620	-122.40140	King	Retrieved
Other	66	CPS_SHLB	Shilshole Bay	47.67136	-122.40654	King	Retrieved
WDFW	67	CPS_SP	Seacrest Park	47.59030	-122.38150	King	Retrieved
Other	68	CPS_SQSO	Suquamish, Stormwater Outfall	47.72963	-122.55085	Kitsap	Retrieved
WDFW	69	CPS_WPN	West Point North	47.66429	-122.42896	King	Retrieved
WDFW	70	CPS_WPS	West Point South	47.65929	-122.43342	King	Retrieved
WDFW	71	EB_FMR	Elliott Bay, Four-Mile Rock	47.63882	-122.41343	King	Retrieved
Other	72	EB_ME	Elliott Bay, Myrtle Edwards	47.61856	-122.36103	King	Retrieved
WDFW	73	EB_P59	Elliott Bay, Pier 59	47.60734	-122.34368	King	Retrieved
Other	74	HC_DBE	Duckabush Estuary	47.64610	-122.91670	Jefferson	Retrieved
WDFW	75	HC_FP	Fisherman's Point	47.78184	-122.83474	Kitsap	Retrieved
Other	76	HC_HO	Hood Canal, Holly	47.57017	-122.97122	Kitsap	Retrieved
Other	77	HC_PGPJ	Port Gamble, Point Julia	47.85269	-122.57406	Kitsap	Retrieved
WDFW	78	HC_PSP	Potlatch State Park	47.35941	-123.15751	Mason	Retrieved
Other	79	NPS_BBWW	Bellingham Bay, Whatcom Waterway	48.75042	-122.48991	Whatcom	Retrieved
Other	80	NPS_BLSC	Bellingham Bay, Little Squalicum Creek	48.76357	-122.51861	Whatcom	Retrieved
WDFW	81	NPS_CPAR4	Cherry Point Aq Reserve, Conoco Phillips	48.82085	-122.71010	Whatcom	Retrieved
Other	82	NPS_FBAR	Fidalgo Bay Aq Reserve, Weaverling Spit	48.48277	-122.58537	Skagit	Retrieved
WDFW	83	PAC_GH	Grays Harbor, Bottle Beach State Park	46.89610	-124.04837	Grays Harbor	Retrieved
WDFW	84	PAC_WBN	Willapa Bay Nahcotta	46.49500	-124.02669	Pacific	Retrieved
Other	85	SJD_DB	Discovery Bay	48.00699	-122.86290	Jefferson	Retrieved
Other	86	SJD_JSK	Jamestown	48.02717	-122.99935	Clallam	Retrieved
WDFW	87	SPS_HIAP	Hammersley Inlet, Arcadia Point	47.19896	-122.93951	Mason	Retrieved
WDFW	88	SPS_LB	Luhr Beach	47.10030	-122.72690	Thurston	Retrieved
Other	89	SPS_PBL	Purdy, Burley Lagoon	47.38679	-122.63675	Kitsap	Retrieved

Source	Map ID	Site ID	Site Name	Latitude	Longitude	County	Status
WDFW	90	SPS_SH	Shelton, Oak Bay Marina	47.21521	-123.08471	Mason	Retrieved
Other	91	WB_CB	Cavalero Beach Co. Park	48.17442	-122.47582	Island	Retrieved
WDFW	92	WB_EFP	Everett Fishing Pier	48.00304	-122.22219	Snohomish	Retrieved
Other	93	WB_KP	Kayak Point	48.13389	-122.36600	Snohomish	Retrieved
WDFW	94	WPS_PB	Point Bolin	47.69370	-122.59470	Kitsap	Retrieved
WDFW	95	WPS_SVD	Silverdale, Dyes Inlet	47.64280	-122.69670	Kitsap	Retrieved

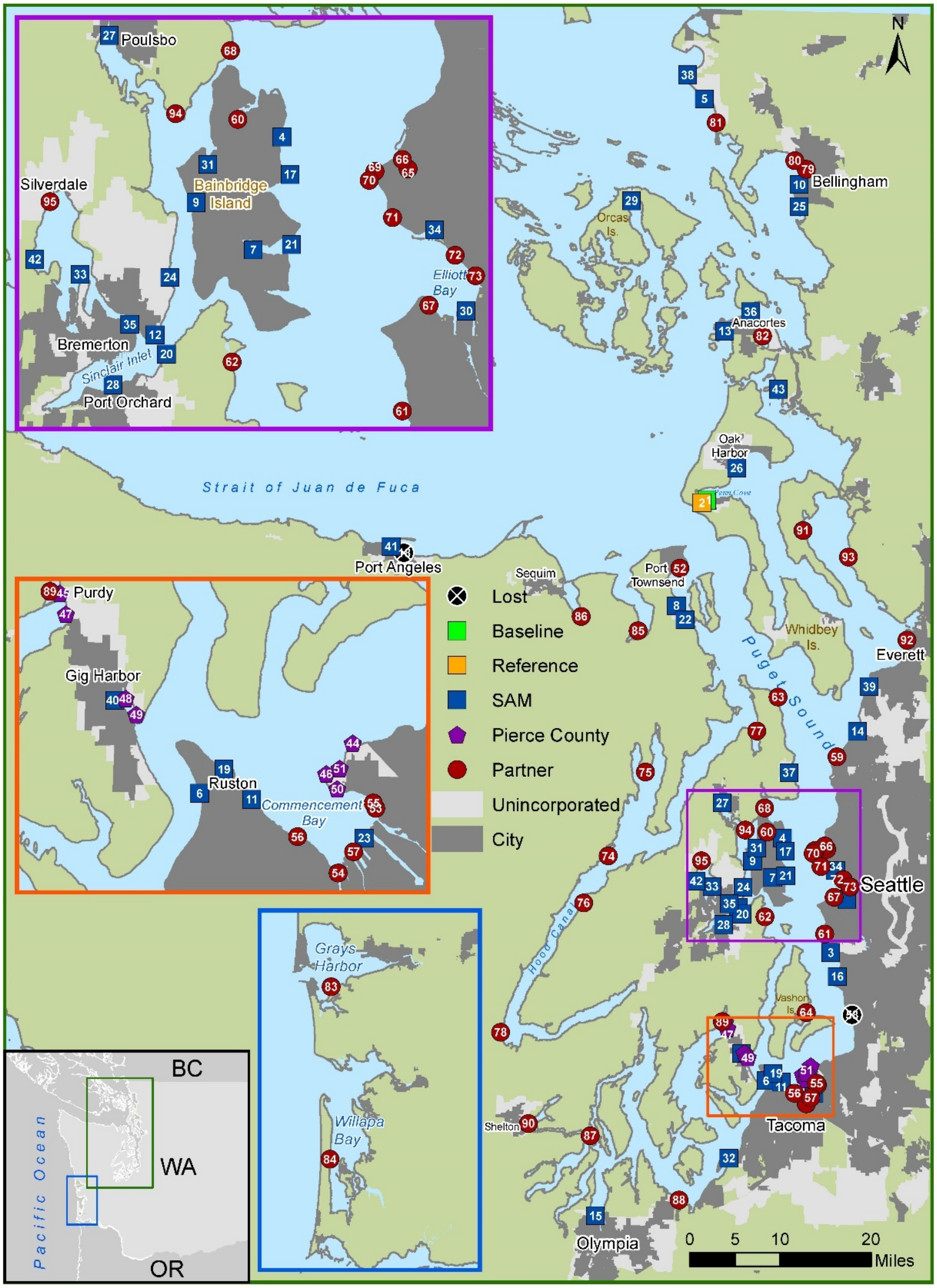

Figure 1. Nearshore mussel monitoring sites in the Puget Sound, Grays Harbor, and Willapa Bay. Site labels correspond to the "Map ID" column in Table 2. Grey shading on land represents municipal land-use designations based on urban growth area (UGA) boundaries; dark grey representing City UGA and light grey representing Unincorporated UGA.

Data Analyses

Analytes

The analytes measured for this report consist of a suite of persistent organic pollutants (POPs) that include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenylethers (PBDEs), and organochlorine pesticides (OCPs), as well as a suite of metals that include aluminum, arsenic, cadmium, copper, lead, total mercury, and zinc. All of these analytes, with the exception of aluminum, were measured in the prior 2015/16 survey. The following lists the main analytes discussed in this report and provides a brief summary of their historical use and/or potential sources.

Polycyclic aromatic hydrocarbons or polyaromatic hydrocarbons (PAHs) are found in all petroleum products including oil, coal, and tar. They are also produced by the incomplete combustion of organic matter and are found in non-combusted fuels. Ecology released a Chemical Action Plan (CAP) for PAHs in 2012 that addressed uses and releases of PAHs in Washington State (Davies et al., 2012). The CAP found that the largest anthropogenic sources of PAHs in Washington, including the Puget Sound, are wood burning stoves, creosote treated wood, and automobile emissions, which includes tire wear, motor oil leaks, and improper oil disposal.

Polychlorinated biphenyls (PCBs) are persistent organochlorine compounds once widely used as coolant fluids in electrical devices, in carbonless copy paper, and in heat transfer fluids. They were also used as plasticizers in paints and cements, stabilizers in PVC coatings, and in sealants for caulking and adhesives. Although the manufacture of PCBs in the United States was largely banned in 1979, they are still found in significant amounts in the Puget Sound basin (e.g., in building paints and caulks), and continue to find their way into stormwater (EnviroVision Corporation et al., 2008; Hart Crowser, 2007; Herrera Environmental Consultants Inc., 2009; Science Applications International Corporation, 2011). Ecology released a PCB Chemical Action Plan (CAP) in 2015, to guide Washington's strategy to find and remove PCBs and reduce PCB exposure in humans and wildlife (Davies et al., 2015).

Polybrominated diphenyl ethers (PBDEs) are persistent organobromine compounds used as flame-retardants in a wide variety of products including building materials, plastics, foams, electronics, furnishings, and vehicles.

Dichlorodiphenyltrichloroethanes (DDTs) are a group of widely used persistent organochlorine insecticides that were banned in the U.S. in 1972.

Chlordanes (i.e., Σ_8 Chlordanes or sum of 8 chlordane compounds) are persistent organochlorine insecticides that were used in the U.S. until 1988, when the EPA banned them.

Dieldrin is a persistent organochlorine insecticide banned in the 1970s.

Hexachlorocyclohexanes (i.e., Σ_3 HCHs or sum of 3 HCH isomers) are persistent byproducts of the production of the insecticide Lindane, which has not been produced or used in the U.S. since 1985.

Hexachlorobenzene (HCB) is a fungicide introduced in 1945 for crop seeds and was later banned from use in the U.S. in 1966.

Unlike many of the synthetic chemicals described above, all metals occur naturally in aquatic ecosystems, and can release naturally into the environment via soils, volcanic ash, weathering of rocks and minerals, and mineralization in groundwater. Their toxicity can relate to unnatural concentration of metals or toxic forms of metals that may originate from human activities such as those described for each metal analyte below.

Aluminum (Al) is an abundant metal in the earth's crust, which enters the aquatic environment via anthropogenic sources such as fossil fuels, mining/smelting, and fertilizers (EPA, 2018).

Arsenic (As) is primarily used by humans in alloys of lead (e.g., in car batteries and ammunition) and as a feed additive in poultry and swine production. In the past, it has also been used as a wood preservative and in various agricultural insecticides and poisons. We report total arsenic in this survey.

Cadmium (Cd) is used in batteries, pigments, and metal coatings and alloys.

Copper (Cu) is used in electrical wire, roofing and plumbing, in industrial machinery, in anti-biofouling paints on boat hulls, and in automotive brake pads (ASTDR 2004). This metal has been detected in surface runoff at elevated concentrations during storm-events in the Puget Sound basin (Herrera Environmental Consultants Inc., 2011). Contaminated urban road dust containing trace metals such as copper (by wear of brake pads) is picked up by stormwater runoff and delivered into receiving waterbodies (Hwang et al., 2016). To manage this source pathway, Washington passed a law (SB6557) mandating a reduction in the amount of copper used in automotive brake pads (2010). In 2011, Washington passed another law (SB5436, which went into effect on January 1, 2018) that restricts the use of copper paint on the bottom of boats.

Lead (Pb) is released into the environment through widespread use of leaded gasoline, lead-containing pesticides, lead-based paint, and emissions from smelters (ASTDR 1999). This metal has been detected in surface runoff at elevated concentrations during storm-events in the Puget Sound basin (Herrera Environmental Consultants Inc., 2011).

Mercury (Hg) is released into the environment through coal combustion, gold production, smelting, cement production, waste disposal/incineration, and caustic soda production. We report total mercury in this survey.

Zinc (Zn) is used as an ingredient in vitamin supplements, sun block, diaper rash ointment, deodorant, in topical medicines and in anti-dandruff shampoos (ATSDR 2005). Zinc is also used in cathodic protection of metal surfaces (i.e., an anti-corrosion and galvanizing agent), and soils can be contaminated with zinc from mining and refining. This metal has been detected in surface runoff at elevated concentrations during storm-events in the Puget Sound basin (Herrera Environmental Consultants Inc., 2011).

Reporting Concentrations

Throughout this report concentration results are presented as dry weight, to be consistent with reporting from historical mussel monitoring programs (NOAA Mussel Watch) and the previous 2015/16 survey. All results for organic chemicals are presented as ng/g dry weight, commonly referred to parts per billion (ppb). All results for metals are presented as mg/kg dry weight, commonly referred to parts per million (ppm). As in the 2015/16 survey report, all dry weights are presented to three significant figures. Summary tables of the dry weight concentration of organic contaminants and metals in mussels by site are presented in Appendix A. Mussel contaminant data are presented as summed concentrations for organic analyte groups (Table 4), except in cases with fewer than two analytes per group. Summed analytes are the sum of all detected values, with zeros substituted for non-detected analytes, within each group. In cases where all analytes in a group were not detected, the greatest limit of quantitation (LOQ) for any single analyte in the group was used as the summation concentration, and the value was preceded by a "<" (less than) qualifier.

Table 4. Analyte groups summed for the 2017/18 Mussel Monitoring Survey.

Sum 3 Hexachlorocyclohexanes (HCHs)	Sum 8 Chlordanes	Estimated Total Polychlorinated biphenyls (PCBs)	Sum 6 Dichlorodiphenyltrichloroethanes (DDTs)	Polybrominated diphenyl ethers (PBDEs)	Sum of 42 Polycyclic Aromatic Hydrocarbons (PAHs)	
alpha hexachlorocyclohexane	alpha chlordane	PCB018	pp-DDD	PBDE028	**Low Molecular Weight**	**High Molecular Weight**
beta hexachlorocyclohexane	beta chlordane	PCB028	pp-DDE	PBDE047	Naphthalene (NAP)	fluoranthene (FLA)
lindane	cis nonachlor	PCB044	pp-DDT	PBDE049	C1-naphthalenes	pyrene (PYR)
	heptachlor	PCB052	op-DDD	PBDE066	C2-naphthalenes	C1-fluoranthenes/pyrenes
	heptachlor epoxide	PCB095	op-DDE	PBDE085	C3-naphthalenes	C2-fluoranthenes/pyrenes
	nonachlor3	PCB101	op-DDT	PBDE099	C4-naphthalenes	C3-fluoranthenes/pyrenes
	Oxychlordane	PCB105		PBDE100	acenaphthylene (ACY)	C4-fluoranthenes/pyrenes
	trans Nonachlor	PCB118		PBDE153	acenaphthene (ACE)	benz[a]anthracene (BAA)
		PCB128		PBDE154	fluorene (FLU)	chrysene (CHR)Pa
		PCB138		PBDE155	C1-fluorenes	C1-benzanthracenes/chrysenes
		PCB153		PBDE183	C2-fluorenes	C2-benzanthracenes/chrysenes
		PCB170			C3-fluorenes	C3-benzanthracenes/chrysenes
		PCB180			dibenzothiophene (DBT)	C4-benzanthracenes/chrysenes
		PCB187			C1-dibenzothiophene	benzo[b]fluoranthene (BBF)
		PCB195			C2-dibenzothiophenes	benzo[k]fluoranthene (BKF)Pb
		PCB206			C3-dibenzothiophenes	benzo[e]pyrene (BEP)
		PCB209			C4-dibenzothiophenes	benzo[a]pyrene (BAP)
					phenanthrene (PHN)	perylene (PER)
					anthracene (ANT)	indeno[1,2,3-cd]pyrene (IDP)
					C1-phenanthrenes/anthracene	dibenz[a,h]anthracene (DBA)Pc
					C2-phenanthrenes/anthracenes	benzo[g,h,i]perylene (BZP)
					C3-phenanthrenes/anthracenes	
					C4-phenanthrenes/anthracenes	

***Sum of 17 congeners, then multiplied by two, PaP coelutes with triphenylene, PbP coelutes with benzo[j]flouranthene, PcP coelutes with dibenz[a,c]anthracene**

Cumulative Frequency Distribution

On each of the CFD plots presented, the Y-axis indicates the cumulative percentage (%) of UGA nearshore length covered by this study design, while the X-axis represents the concentration of each contaminant. Thus, if the reader drew a horizontal line from the 60% tick mark on the Y-axis to the data line and then a vertical line down from that point to the X-axis to a concentration of 87 ng/g, it would be interpreted as meaning 60% of the total UGA nearshore length had a contaminant concentration below 87 ng/g, while 40% had a concentration above that value. Using this method, Partners can determine where their contaminant concentrations (Appendix A and B) occur on the UGA CFD plot, to determine how conditions in the samples they sponsored compare with conditions in the UGA.

Concentration Categories by Percentile

To allow for comparison of contaminant concentrations between sites and determine possible problem areas, we established three concentration range categories related to the 25th and 75th percentiles. Percentile values for the organic analytes were determined using combined data from the initial 2012/13 Mussel Watch Pilot Expansion (MWPE) study and the 2015/16 SAM Mussel Monitoring survey. Percentile values for the metal analytes were determined using data from this survey (2017/18), as prior survey year data was not viable due to a potential bias introduced by a metal analysis methodology change detailed in the Field/Lab Methods section. These percentiles were selected as a baseline of conditions to provide a consistent frame of reference for comparison with future survey results as well. Concentration values at or below the 25th percentile were considered relatively low, concentration values at or above the 75th percentile were considered relatively high, and values in between (interquartile range, IQR) were considered intermediate within the region. To highlight sites with the highest concentrations and of particular concern, concentrations values at or above the 95th percentile were used as a fourth category. These categories reflect the concentration ranges from previous Puget Sound mussel monitoring studies and are not intended to represent or take the place of seafood consumption advisory screening levels (human health) or shellfish health thresholds, which may be applied in future surveys. The concentration range for each category is listed for each contaminant in Table 5.

Table 5. Concentration range values for each category (low, intermediate, high, highest) established by percentile for each analyte group.

Analyte	Category by Percentile	Concentration Range (Organics ng/g and Metals mg/kg, dry wt.)
Σ_{42} PAHs	Low, 25th	≤179
	Intermediate	180 – 543
	High, 75th	≥544
	Highest, 95th	≥2360
TPCBs	Low, 25th	≤18.7
	Intermediate	18.8 - 51.9
	High, 75th	≥52.0
	Highest, 95th	≥132
Σ_{11}PBDEs	Low, 25th	≤3.06
	Intermediate	3.07 - 10.0
	High, 75th	≥10.1
	Highest, 95th	≥23.8
Σ_{6}DDTs	Low, 25th	≤1.98
	Intermediate	1.99 - 3.28
	High, 75th	≥3.29
	Highest, 95th	≥14.0

Aluminum	Low, 25th	≤147
	Intermediate	148 - 209
	High, 75th	≥210
	Highest, 95th	≥269
Total Arsenic	Low, 25th	≤7.54
	Intermediate	7.55 – 8.63
	High, 75th	≥8.64
	Highest, 95th	≥9.21
Cadmium	Low, 25th	≤2.13
	Intermediate	2.14 -2.44
	High, 75th	≥2.45
	Highest, 95th	≥2.89
Copper	Low, 25th	≤8.73
	Intermediate	8.74 -11.6
	High, 75th	≥11.7
	Highest, 95th	≥23.3
Lead	Low, 25th	≤0.315
	Intermediate	0.316 - 0.704
	High, 75th	≥0.705
	Highest, 95th	≥1.28
Total Mercury	Low, 25th	≤0.0521
	Intermediate	0.0522 - 0.0644
	High, 75th	≥0.0645
	Highest, 95th	≥0.0777
Zinc	Low, 25th	≤92.4
	Intermediate	92.5 - 109
	High, 75th	≥110
	Highest, 95th	≥137

Watershed Land Use

To investigate the relationship between land-use of watershed and the movement of contaminants from terrestrial sources to the Puget Sound nearshore, we compared contaminant concentrations in mussels with percent impervious surface (a proxy for land-use types that may exacerbate stormwater runoff, e.g. urbanization) in adjacent watersheds. For this survey we focused our analyses on the percent of impervious surface cover in watersheds.

For the 2015/16 survey, the differences in nearshore contamination related to land use was examined on three geographic scales: watershed, municipal planning designation, and shoreline. In-water point sources and natural geographical/geological features were other factors also tested. Of all the factors tested, municipal land-use designation and mean percent impervious surface in the adjacent watersheds showed the strongest relationship with observed concentrations of pollutants in mussels (Lanksbury et al., 2017).

Percent impervious surface in adjacent watersheds were determined by overlaying percent impervious surface land cover data from the 2016 National Land Cover Dataset (NLCD) onto predefined, watershed catchment areas adjacent to the Puget Sound shoreline. The NLCD Percent Developed Imperviousness dataset uses Landsat satellite data with a spatial resolution of 30 meters (Homer et al., 2020). This dataset is updated every five years, allowing us to describe how urbanization is changing over time. The watershed catchment areas were originally developed by Ecology for another purpose (Stanley et al., 2012), but were determined to be of a size appropriate for use in this study (median area of 8.8 $kilometer^2$ or 3.4 $mile^2$). Using these GIS layers, we calculated the average value (i.e., percent intensity) of impervious surface within each watershed adjacent to mussel sites. Each mussel site was matched with the watershed closest in proximity and assigned the corresponding mean percent impervious value. Correlations between contaminants at sites and watershed land use were then made using a linear regression of contaminant concentration by percent impervious surface in adjacent watersheds, using log^{10}-transformed contaminant data, with a significance threshold of 0.05. To maximize the power of our likelihood to detect associations, if they existed, all sites (SAM only, reference omitted), Pierce County, Partner), with detected contaminant concentrations were included in the analyses, except for the two outer coast sites which did not have comparable watershed data.

Recognizing the efficacy of impervious surface to describe how urbanization is changing over time, and its relationship to stormwater runoff, the SAM program has altered its future nearshore monitoring study design (starting with the 2021/22 survey). The future nearshore study frame will include the whole Puget Sound nearshore area (not just the UGA), stratified by intensity of watershed percent impervious surface (four substrata: 0-10%, 11-20%, 21-40%, and 41-100%).

Data Presentation

Data presented in the following Results section focuses on SAM sites. However, data from Pierce County and Partner sites are also presented throughout the Results section as described below:

In the Detection Frequency and Distribution of Contaminant Concentration Data section, we focus on presenting SAM data, comparing the range and central tendency of contaminant concentrations between this survey and the prior 2015/16 SAM survey for organic chemicals (Figure 2) and only for the current survey (see Methods) for metals (Figure 3). Range and mean contaminant concentration data for all site types (SAM, Pierce County, Partner) are presented in Tables 6 – 16.

The Status section describes the current spatial extent of key contaminants in mussels sampled inside the SAM study sampling frame, which includes mussels from SAM and Pierce County (Option 1+2) study sites. The distribution of mussel tissue contaminant concentrations along the Puget Sound UGA are shown using cumulative frequency distribution (CFD) plots (Figure 4 and 5). Partner data are excluded as those sites are not part of the SAM program GRTS study design and site selection. However, partners can use the CFD plots to determine how conditions in mussel from the sites they sponsored compare with conditions in the SAM UGA sites (see Methods – Cumulative Frequency Distribution section).

The Geographic Distribution of Contaminants in Mussels section describes and compares the contaminant concentration data between each SAM, Pierce County, and Partner site using the percentile based low, intermediate, high and highest concentration range categories established as relative benchmarks in this report (Figure 6 – 16). Further, qualitative data on the geographic distribution of contaminants relative to Puget Sound basins and levels of urbanization are presented and for the organic contaminants we compare findings to the 2015/16 SAM survey.

The Association of Contaminants with Watershed Land Use section describes the relationship between contaminant concentrations in mussels from all study sites (SAM, Pierce County, and Partner) and the percent impervious surface in adjacent watersheds.

Results and Discussion

Detection Frequency and Distribution of Contaminant Concentration Data

Organic Contaminants

Overall, PAHs, PCBs, PBDEs, and DDTs were the most abundant organic contaminants measured in mussels from this study. The same four contaminant groups were the most abundant in the 2015/16 survey. At least one analyte from the Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs groups was detected in mussels from all 40 (100%) SAM sites, with Σ_{42}PAH concentrations detected at significantly higher concentrations than the other contaminants (Figure 2). Two other organic contaminants were less frequently detected; chlordanes were detected at 10/40 (25%) sites and dieldrin was detected at 18/40 (45%) sites. The remaining organic contaminants, hexachlorocyclohexanes (HCHs), hexachlorobenzene (HCB), Mirex, aldrin, and endosulfan 1, were not detected at any sites.

Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs were the most abundant organic contaminants detected at Pierce County and Partner sites as well. Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs were detected at 8/8 (100%) of the Pierce County sites, chlordanes at 4/8 (50%) sites, and dieldrin at 2/8 (25%). HCBs, HCHs, mirex, aldrin, and endosulfan 1, were not detected at any Pierce County sites. Σ_{42}PAHs and TPCBs were detected at 100% of the Partner sites. $\sum_{11}$PBDEs were detected at 37/43 (86%) sites, and $\sum_{6}$DDTs at 39/43 (91%) sites. Chlordanes were detected at 15/43 (35%) Partner sites, dieldrin at 17/43 (40%), HCBs at 3/43 (7%), and HCHs at 1/43 (2%). Mirex, aldrin, and endosulfan 1, were not detected at any Partner sites.

Σ_{42}PAHs, TPCBs, and $\sum_{6}$DDTs were detected in all the Baseline Site replicate samples (n = 5, 100%), which provides the initial condition of the deployed mussels. $\sum_{11}$PBDEs were detected in 3/5 (60%) Baseline samples and dieldrin in 1/5 (20%). Concentration of all contaminants in the baseline mussels were detected at low concentrations, in the lowest 10th percentile of all samples in this survey year (Figure 2). Chlordanes, aldrin, HCHs, HCBs, Mirex, and endosulfan 1 were not detected above the LOQ in any of the Baseline Site replicate samples. Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, $\sum_{6}$DDTs, and dieldrin were detected in deployed mussels from the Penn Cove Reference site (n = 1, 100%), with Σ_{42}PAHs, TPCBs, and $\sum_{11}$PBDEs detected at lower concentrations and $\sum_{6}$DDTs at a higher concentration (Figure 2). Chlordanes, HCHs, aldrin, mirex, and endosulfan 1, were not detected at the Penn Cove Reference site.

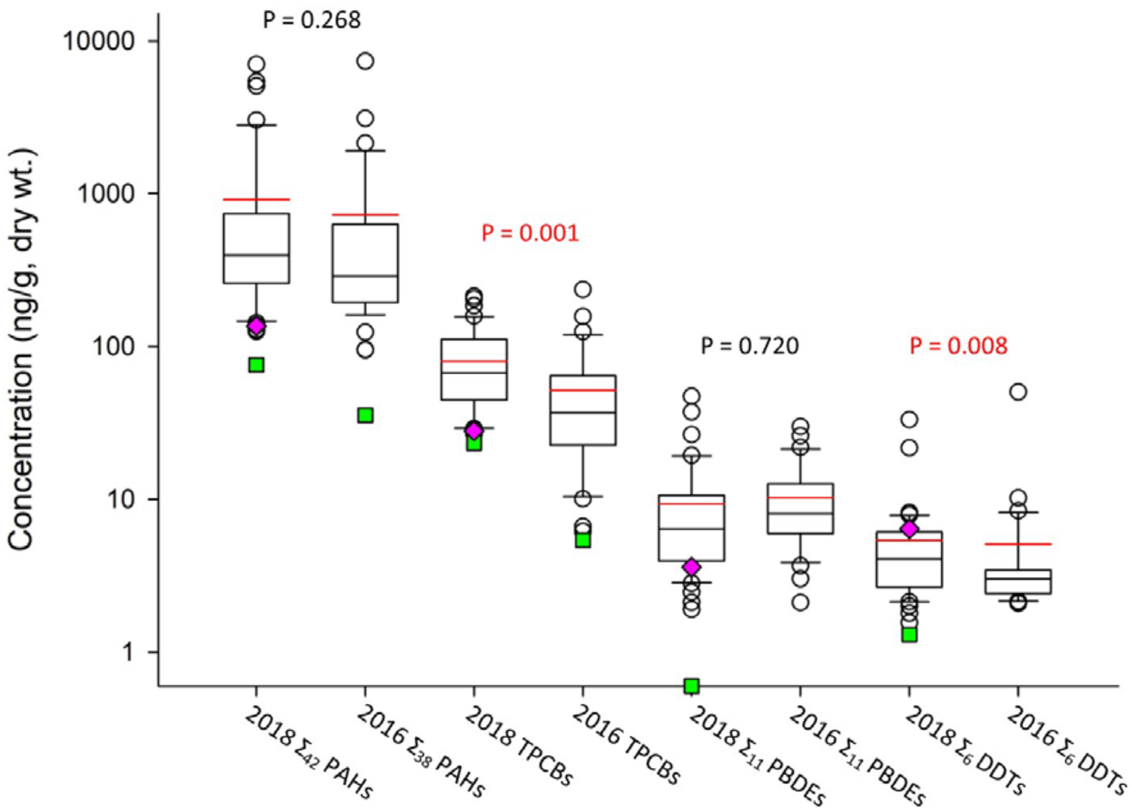

Figure 2. Box plots of the four most frequently detected organic contaminants at SAM Mussel Monitoring sites in 2018 and 2016 surveys; lower and upper hinges correspond to the 25th and 75th percentiles, whiskers are 1.5 IQR, black lines in box are median concentrations, red lines are mean concentrations, single open circles are outliers, green squares are baseline concentrations (not detected if missing), pink diamonds are the 2018 Penn Cove Reference site concentrations. Y-scale is logarithmic. Comparison of concentration levels within each contaminant group between survey years was performed by the Mann-Whitney Rank Sum test, and p-values are presented above the box plots with significant values in red font.

The Σ_{42} PAHs (sum of 42 PAH analytes) concentrations at SAM sites in this survey were similar in range to the 2015/16 survey (sum of 38 PAH analytes) (Table 6, Figure 2). Though the central tendency (both mean and median concentrations) in this survey slightly increased, possibly due to the increase from 38 to 42 PAH analytes, there was not a statistically significant difference between the two surveys ($P = 0.268$) (Figure 2). The Σ_{42} PAHs concentrations at all sites (SAM, Pierce County, Partner) in this study were higher and broader in range and had a higher average concentration compared to those from the 2015/16 survey (Table 6).

*Table 6. Range and average concentration of PAHs in mussels from the 2016 (Σ_{38} PAHs) and 2018 (Σ_{42} PAHs) sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			$\sum_{38}$PAHs (2016) or $\sum_{42}$PAHs (2018) (ng/g, dry wt.)					
Sites	**2016 n**	**2018 n**	**2016 Min**	**2018 Min**	**2016 Avg**	**2018 Avg**	**2016 Max**	**2018 Max**
Baseline	6	5	21.4	66.3	35.5	75.9	86.2	84.9
Reference	N/A	1	N/A	136	N/A	136	N/A	136
SAM	36	40	95	126	728	914	7350	7020
Pierce County*	7	8	164	149	343	533	540	844
Partner/WDFW	23	43	48.8	90.8	629	1370	3820	27600
All**	66	92	48.8	90.8	653	1080	7350	27600

N/A – sample not collected; reference site not established

The TPCB (estimated total PCBs) concentrations at SAM sites in this study were narrower in range and had a higher central tendency (both mean and median concentrations) when compared to the 2015/16 survey (Table 7, Figure 2). The difference in median values between survey years was statistically significant ($P = 0.001$) indicating a significant increase in TPCB concentrations at SAM sites in this survey (Figure 2). The TPCB concentrations at all sites in this study were similar in range to the 2015/16 survey and had a higher average concentration (Table 7).

*Table 7. Range and average concentration of estimated TPCBs in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			TPCBs (ng/g, dry wt.)					
Sites	**2016 n**	**2018 n**	**2016 Min**	**2018 Min**	**2016 Avg**	**2018 Avg**	**2016 Max**	**2018 Max**
Baseline	6	5	4.81	17.3	5.42	23.4	5.82	30.6
Reference	N/A	1	N/A	28.1	N/A	28.1	N/A	28.1
SAM	36	40	6.16	26.9	51.9	80.1	236	214
Pierce County*	7	8	31.0	50.1	45.1	81.7	62.9	120
Partner/WDFW	23	43	6.33	10.6	55.0	65.9	197	221
All**	66	92	6.16	10.6	52.3	73.1	236	221

N/A – sample not collected; reference site not established

The Σ_{11}PBDEs (sum of 11 PBDE congeners) concentrations at SAM sites in this study were broader in range when compared to the 2015/16 survey (Table 8, Figure 2). Though the central tendency (both mean and median concentrations) in this study were slightly lower, there was not a statistically significant difference between the two surveys ($P = 0.720$) (Figure 2). The Σ_{11}PBDEs at all sites in this study were similar in range to the 2015/16 survey and had a slightly lower average concentration (Table 8).

*Table 8. Range and average concentration of detected Σ_{11}PBDEs in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. Sites where PBDE values fell below the limit of quantitation (LOQ) were not included in this table. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			∑$_{11}$PBDEs (ng/g, dry wt.)					
Sites	**2016 n**	**2018 n**	**2016 Min**	**2018 Min**	**2016 Avg**	**2018 Avg**	**2016 Max**	**2018 Max**
Baseline	6	5	ND	ND	ND	0.601	ND	1.07
Reference	N/A	1	N/A	3.56	N/A	3.56	N/A	3.56
SAM	36	40	2.12	1.91	10.3	9.34	30.0	47.2
Pierce County*	7	8	1.89	2.21	8.62	9.66	20.9	21.1
Partner/WDFW	23	43	1.96	1.08	10.3	7.96	39.2	26.4
All**	66	92	1.89	1.08	10.1	8.66	39.2	47.2

ND - not detected; limit of quantitation was 1.27 for 2016 Baseline samples and 0.997 ng/g dry wt. for 2018 Baseline samples. N/A – sample not collected; reference site not established.

The Σ_6DDTs (sum of 6 DDTs isomers) concentrations at SAM sites in this study were similar in range and had a higher central tendency (both mean and median concentrations) when compared to the 2015/16 survey (Table 9, Figure 2). The difference in median values between survey years was statistically significant ($P = 0.008$) indicating a significant increase in Σ_6DDTs concentrations at SAM sites in this survey (Figure 2). The Σ_6 DDTs at all sites in this study were narrower in range and had a similar average concentration when compared to the 2015/16 survey (Table 9).

*Table 9. Range and average concentration of detected Σ_6DDTs in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. Sites where Σ_6 DDT values fell below the limit of quantitation (LOQ) were not included in this table. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			∑$_6$DDTs (ng/g, dry wt.)					
Sites	**2016 n**	**2018 n**	**2016 Min**	**2018 Min**	**2016 Avg**	**2018 Avg**	**2016 Max**	**2018 Max**
Baseline	6	5	ND	1.20	ND	1.30	ND	1.38
Reference	N/A	1	N/A	6.40	N/A	6.40	N/A	6.40
SAM	36	40	2.08	1.56	5.08	5.39	50.4	33.3
Pierce County*	7	8	1.98	1.88	4.09	4.86	10.4	11.0
Partner/WDFW	23	43	1.87	1.70	7.04	6.03	45.7	34.2
All**	66	92	1.87	1.70	5.65	5.65	50.4	34.2

ND - not detected; limit of quantitation was 1.27 ng/g dry wt. for Baseline samples. N/A – sample not collected; reference site not established.

Metals

All seven of the metals measured in this study (aluminum, arsenic, cadmium, copper, lead, mercury, and zinc) were detected in mussels from all the SAM sites (n = 40, 100% of sites, Figure 3), as well as all the Baseline Site samples (n = 5, 100%) and in the Penn Cove Reference site (n = 1, 100%). Additionally, all seven metals were detected in mussels from all Pierce County (n = 8, 100%) and Partner sites (n = 17, 100%), excluding WDFW sponsored sites which were not analyzed for metals due to limited funding.

Distribution of the metal concentration data for both survey years (2015/16 and 2017/18) is shown in the boxplots below (Figure 3). However, no temporal comparison is made between the survey years due to the potential bias introduced by a metal analysis methodology change implemented between the 2015/16 and 2017/18 surveys (see Field/Lab Methods section). The range and average concentration of each metal analyte detected in mussels from the 2015/16 and 2017/18 sites are shown by sponsoring group in Tables 10 – 16.

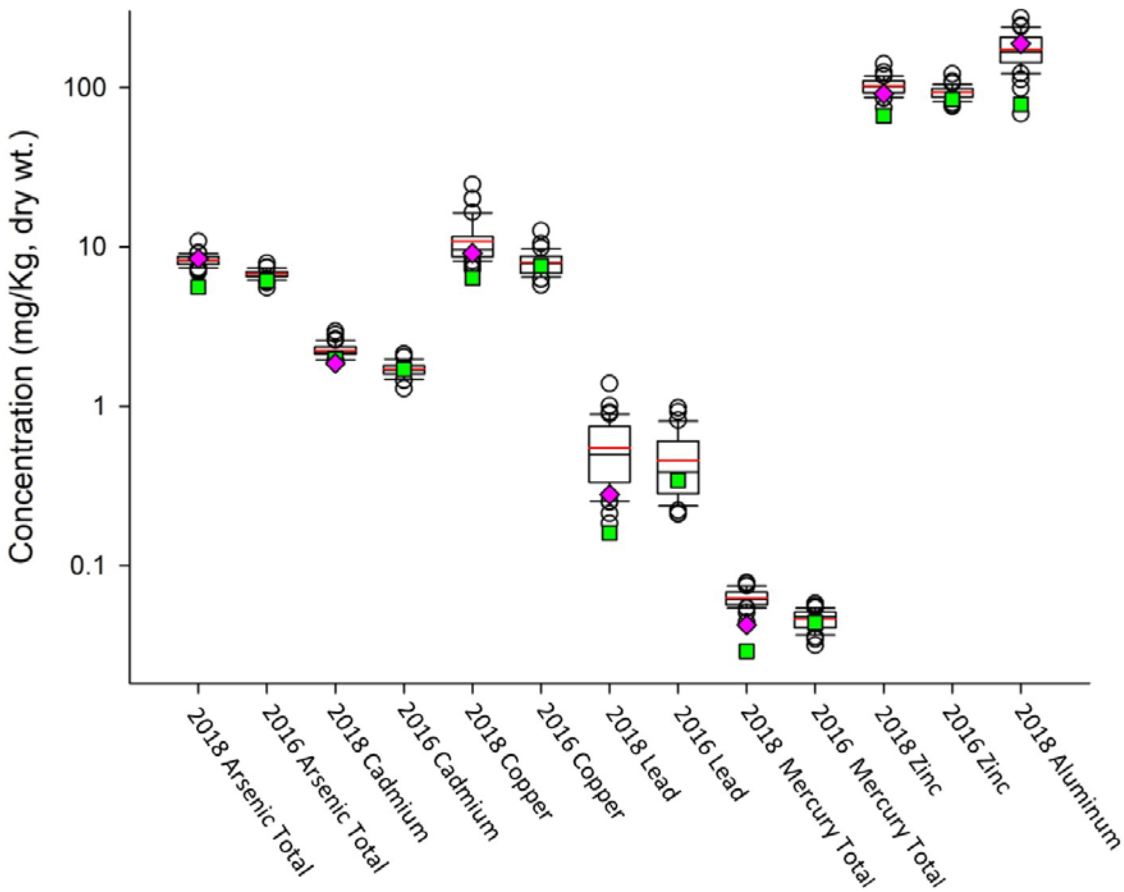

Figure 3. Box plots of metals detected at SAM Mussel Monitoring sites in 2016 and 2018 surveys; lower and upper hinges correspond to the 25th and 75th percentiles, whiskers are 1.5 IQR, black lines in box are median concentrations, red lines are mean concentrations, single open circles are outliers, green squares are baseline concentrations, pink diamonds are 2018 Penn Cove Reference site concentrations. Y-scale is logarithmic.

*Table 10. Range and average concentration of total arsenic detected in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			Arsenic (mg/kg, dry wt.)					
Sites	**2016 n**	**2018 n**	**2016 Min**	**2018 Min**	**2016 Avg**	**2018 Avg**	**2016 Max**	**2018 Max**
Baseline	6	5	5.39	5.42	6.14	5.60	7.59	5.79
Reference	N/A	1	N/A	8.45	N/A	8.45	N/A	8.45
SAM	36	40	5.54	6.96	6.76	8.23	7.89	10.8
Pierce County*	7	8	4.77	7.49	5.36	9.15	6.51	14.3
Partner/WDFW	23	17	5.82	6.11	6.89	7.65	9.45	8.97
All**	66	66	4.77	6.11	6.65	8.20	9.45	14.3

*Table 11. Range and average concentration of cadmium detected in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			Cadmium (mg/kg, dry wt.)					
Sites	**2016 n**	**2018 n**	**2016 Min**	**2018 Min**	**2016 Avg**	**2018 Avg**	**2016 Max**	**2018 Max**
Baseline	6	5	1.56	1.87	1.71	2.00	1.94	2.20
Reference	N/A	1	N/A	1.86	N/A	1.86	N/A	1.86
SAM	36	40	1.29	1.92	1.71	2.23	2.14	2.96
Pierce County*	7	8	1.38	2.04	1.61	2.51	1.86	3.70
Partner/WDFW	23	17	1.52	1.75	1.77	2.40	2.11	2.90
All**	66	66	1.29	1.75	1.72	2.31	2.14	3.70

*Table 12. Range and average concentration of cadmium detected in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			Copper (mg/kg, dry wt.)					
Sites	**2016 n**	**2018 n**	**2016 Min**	**2018 Min**	**2016 Avg**	**2018 Avg**	**2016 Max**	**2018 Max**
Baseline	6	5	6.65	5.49	7.60	6.44	8.62	7.36
Reference	N/A	1	N/A	9.13	N/A	9.13	N/A	9.13
SAM	36	40	5.75	7.24	7.98	10.8	12.6	24.7
Pierce County*	7	8	3.51	9.08	4.33	22.1	6.20	94.1
Partner/WDFW	23	17	5.82	7.24	7.91	12.2	12.7	40.2
All**	66	66	3.51	7.24	7.57	12.5	12.7	94.1

*Table 13. Range and average concentration of lead detected in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			Lead (mg/kg, dry wt.)					
Sites	2016 n	2018 n	2016 Min	2018 Min	2016 Avg	2018 Avg	2016 Max	2018 Max
Baseline	6	5	0.252	0.154	0.342	0.160	0.468	0.164
Reference	N/A	1	N/A	0.279	N/A	0.279	N/A	0.279
SAM	36	40	0.210	0.184	0.457	0.549	0.977	1.39
Pierce County*	7	8	0.261	0.289	0.261	0.727	0.261	2.27
Partner/WDFW	23	17	0.182	0.238	0.399	0.467	0.986	1.69
All**	66	66	0.182	0.184	0.433	0.545	0.986	2.27

*Table 14. Range and average concentration of total mercury detected in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			Mercury (mg/kg, dry wt.)					
Sites	2016 n	2018 n	2016 Min	2018 Min	2016 Avg	2018 Avg	2016 Max	2018 Max
Baseline	6	5	0.0385	0.0261	0.0440	0.0290	0.0475	0.0329
Reference	N/A	1	N/A	0.0426	N/A	0.0426	N/A	0.0426
SAM	36	40	0.0317	0.0442	0.0461	0.0626	0.0578	0.0784
Pierce County*	7	8	0.0148	0.0361	0.0203	0.0549	0.0443	0.0955
Partner/WDFW	23	17	0.0324	0.0486	0.0491	0.0486	0.0842	0.0599
All**	66	66	0.0148	0.0361	0.0444	0.0578	0.0842	0.0955

*Table 15. Range and average concentration of zinc detected in mussels from the 2016 and 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

			Zinc (mg/kg, dry wt.)					
Sites	2016 n	2018 n	2016 Min	2018 Min	2016 Avg	2018 Avg	2016 Max	2018 Max
Baseline	6	5	77.3	63.9	84.3	66.2	94.0	67.4
Reference	N/A	1	N/A	91.3	N/A	91.3	N/A	91.3
SAM	36	40	76.2	74.5	93.5	102	122	140
Pierce County*	7	8	47.2	83.6	56.0	115	75.3	177
Partner/WDFW	23	17	62.0	66.0	77.0	97.0	95.4	131
All**	66	66	47.2	66.0	83.8	102	122	177

*Table 16. Range and average concentration of aluminum detected in mussels from the 2018 sites by sponsoring group and totaled for all sites. *Unincorporated Pierce County mussel sites. ** All sites include the reference, SAM, Pierce County, and Partner/WDFW sites.*

		Aluminum (mg/kg, dry wt.)		
Sites	**n**	**Min**	**Average**	**Max**
Baseline	5	69.8	78.2	86.7
Reference	1	188	188	188
SAM	40	68.4	173	272
Pierce County*	8	128	199	309
Partner/WDFW	17	70.4	186	370
All**	66	68.4	179	370

Status – Spatial Extent of Contamination

The following section provides the status of the spatial extent of key contaminants in mussels residing inside the UGA sampling frame of this study. Here we present the distribution of mussel tissue contaminant concentrations along the Puget Sound UGA using cumulative frequency distribution (CFD) plots (Figure 4 and 5). Further, we examine contaminant loading by comparing the CFD patterns to the baseline condition and nearshore reference site at Penn Cove. This report provides an update on the current status of the selected contaminants. Our third survey year report (2019/20) will describe any observed trends.

Cumulative Distribution of Contaminants in Mussels Along the Puget Sound nearshore UGA

The distribution of mussel tissue contaminant concentrations along the Puget Sound nearshore UGA is shown using cumulative frequency distribution (CFD) plots (Figure 4 and 5). The Y axis indicates the cumulative parentage of UGA nearshore length covered by this study design. As the spatial weight of Pierce County sites only represents 1.1 % in total UGA nearshore length, the CFD patterns are largely driven by the results from SAM sites (98.9 % contribution). To demonstrate the difference in spatial weight between the SAM and Pierce County nearshore sites, the CFD for each group (Option 1 and Option 2) are shown individually in the plots in Appendix C.

The CFD patterns for Σ_{42}PAHs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs were similar in that they all were more skewed toward the low concentrations, suggesting that the majority of Puget Sound UGA shorelines have relatively low concentrations of these contaminants and that only a few sites have much higher concentrations, perhaps from site specific point sources (Figure 4). For example, the CFD for Σ_{42}PAHs showed that 90% of the total UGA nearshore length (1,044 of 1,160 km) had concentrations below 1,000 ng/g, dry wt. Only five of the 48 sampled sites (Site # 6, 34, 39, 43, 52) had concentrations exceeding 1,000 ng/g, dry wt. and all were located within close proximity to marinas or ferry/shipping terminals, possible point sources for Σ_{42}PAHs. $\sum_{11}$PBDEs were similar, with 92% of the total UGA nearshore length having concentrations below 20 ng/g, dry wt. and only four of the 48 sampled sites (Site # 25, 34, 43, 697) with concentrations exceeding that amount. The CFD for $\sum_{6}$DDTs showed that 94% of the total UGA nearshore length had concentrations below 9 ng/g, dry wt.; three of the 48 sampled sites (Site # 39, 52, 697) had DDT concentrations exceeding that amount. The CFD pattern for TPCBs were unlike the other organic contaminants in that it had a more gradual contaminant accumulation as the shoreline length increased, suggesting sources of this contaminant are more widely dispersed within the Puget Sound UGAs.

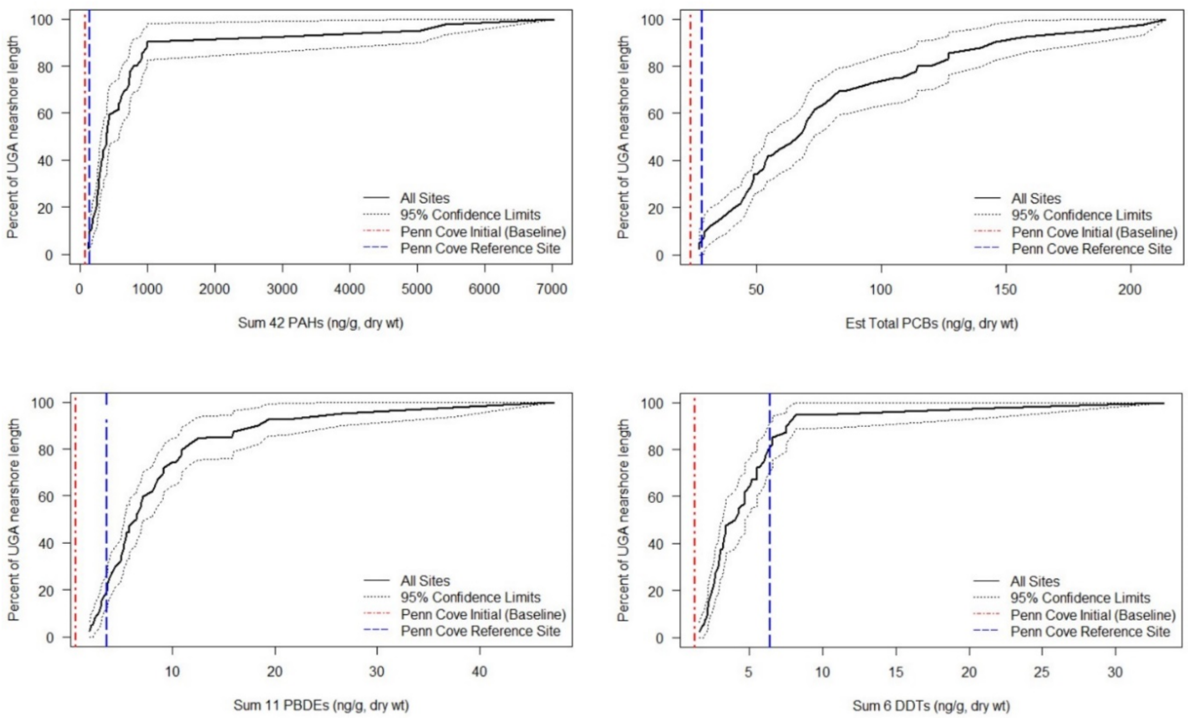

Figure 4. Cumulative frequency distribution (CFD) of organic contaminant concentrations in mussels from 48 total 2017/18 SAM and Pierce County (Option 1+2) study sites, representing 1,160 km of Puget Sound UGA shoreline. Dashed red line represents the mean baseline condition (Penn Cove baseline) and dashed blue line represents the Penn Cove reference site concentration.

The CFD patterns for most of the metals (arsenic, cadmium, lead, mercury, and zinc) had a more gradual contaminant accumulation as the shoreline increased, suggesting these contaminants are more widely dispersed within the Puget Sound UGA shoreline (Figure 5). However, there were three sites where much higher concentrations were observed for more than one metal. Site #38 (Rocky Point) had a zinc concentration over 140 mg/kg dry wt. and lead concentration over 1.0 mg/kg dry wt. Site #185 (Browns Point Lighthouse Park) had a zinc concentration over 140 mg/kg dry wt., copper concentration over 80 mg/kg dry wt., and lead concentration over 1.0 mg/kg dry wt. Site #697 (Browns Point Wolverton) had a zinc concentration over 140 mg/kg dry wt., arsenic concentration over 14 mg/kg dry wt., cadmium concentration over 3.0 mg/kg dry wt., and mercury concentration over 0.08 mg/kg dry wt. The CFD pattern for copper was unlike the other metals, having a pattern more skewed to the lower concentrations. Only four of the 48 sampled sites (Site #25, 28, 38, 185) had copper concentrations exceeding 20 mg/kg dry wt.

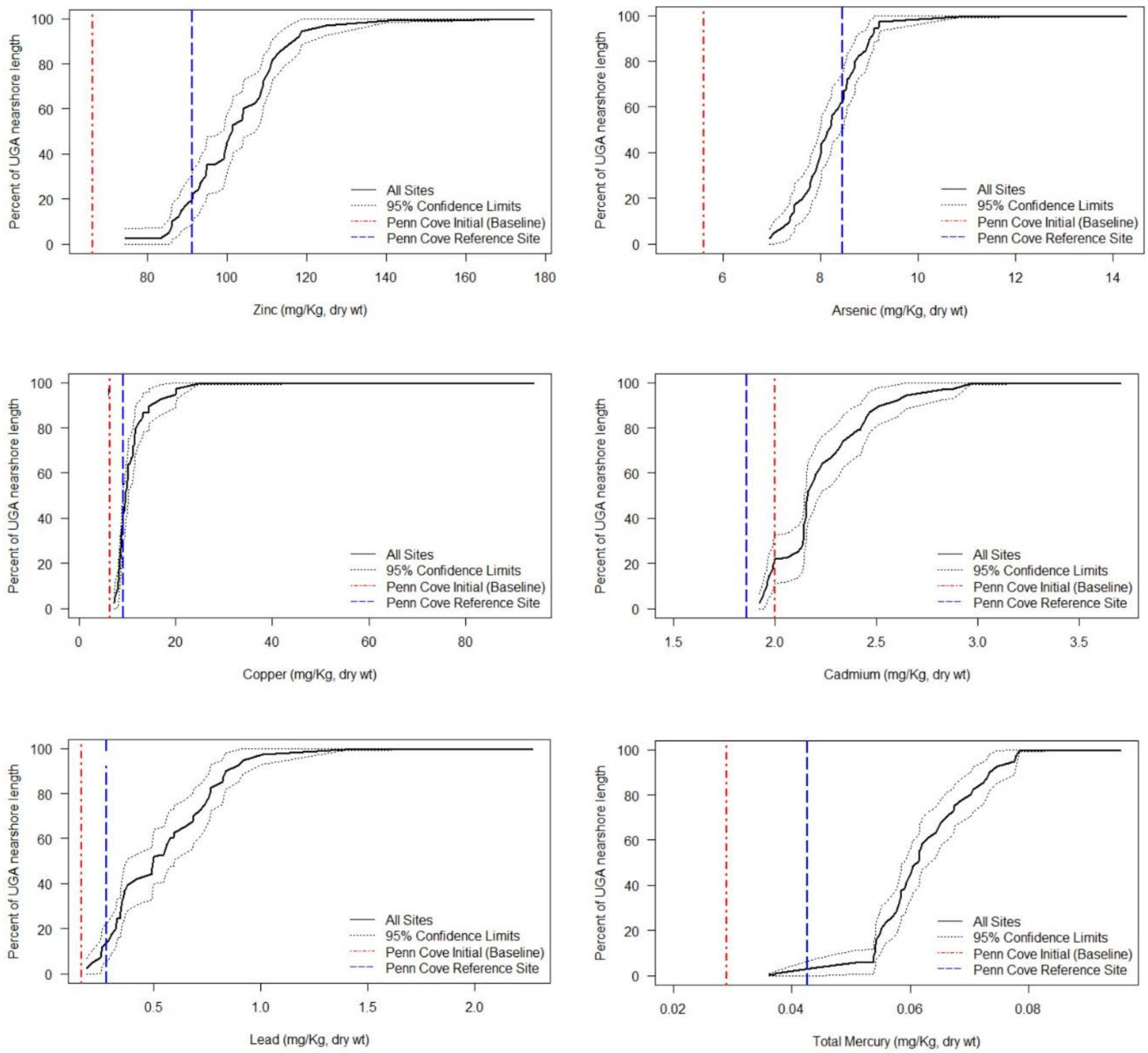

Figure 5. Cumulative frequency distribution (CFD) of zinc, arsenic, copper, cadmium, lead, and total mercury in mussels from 48 total 2017/18 SAM and Pierce County (Option 1+2) study sites, representing 1,160 km of Puget Sound UGA shoreline. Dashed red line represents the mean baseline condition (Penn Cove baseline) and dashed blue line represents the Penn Cove reference site concentration.

Comparison of Contaminant Results to Baseline Conditions and Reference Site

All 48 SAM/Pierce County sites (100%) had organic contaminant concentrations above the mean baseline concentration, indicating that all mussels in deployed cages accumulated additional contaminant loads from their deployment locations (Figure 4). Ninety-five point eight percent of sites had PAH and PCB concentrations above the Penn Cove reference site concentration, and 81.3% of sites had PBDE concentrations above the reference site concentration, indicating mussels deployed at the reference site location were exposed to some of the lowest PAH, PCB, and PBDE contaminant levels of all the sites. 20.8% of sites had DDT concentrations above the reference site concentration, indicating mussels deployed at the reference site location were exposed to slightly elevated DDT levels, compared to the other sites in this study.

All 48 SAM/Pierce County sites (100%) had zinc, arsenic, copper, lead, and mercury concentrations above the mean baseline concentrations (Figure 5). 87.5% of sites had cadmium concentrations above the mean baseline concentration, and 100% of sites had cadmium concentrations above the Penn Cove reference site concentration. 81.3% of sites had zinc concentrations above the reference site concentration, 41.7% of sites for arsenic, 64.6% of sites for copper, 89.6% of sites for lead, and 93.7% of sites for total mercury. The high percent of sites with concentrations above the mean baseline concentration indicate that all the deployed cages accumulated additional metal contaminant loads from their deployment locations. Additionally, the relatively high percent of sites with cadmium, total mercury, lead, zinc, and copper concentrations above the reference site concentration indicate mussels deployed at the reference site were likely exposed to lower metal contaminant levels.

Geographic Distribution of Contaminants in Mussels

The following section details the concentration ranges and geographic distribution of the organic contaminants and metals analyzed in SAM, Pierce County, and Partner mussel sites (n = 92). Where applicable, we present qualitative data on the geographic distribution of contaminants relative to Puget Sound basins and levels of urbanization and make comparisons to findings from the 2015/16 SAM Mussel Monitoring Survey.

We show the relative concentration of key contaminants at each site in the maps following (Figures 6 – 16), focusing on the results of the four most frequently detected organic contaminants (Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs) and all seven metals. Sites in the low (25^{th} percentile) category are shown in green, sites in the intermediate (interquartile range) category in yellow, and sites in the high (75^{th} percentile) category in red. Sites with the highest concentrations (95^{th} percentile) are highlighted in the maps using a white outline and center dot on a red symbol. Sponsors are distinguished by using different shapes; square for SAM, pentagon for Pierce County, and circles for Partners. Tables for each relative contaminant concentration map presented are provided in Appendix D; listing the Site ID/Name, and concentration for each site under each percentile based category (25^{th}, 75^{th}, and 95^{th} percentile).

Organic Contaminants

Σ_{42}PAHs

Overall for the three site types, 17 sites fell within the low concentration category (25th percentile) and 39 in the high category (75th percentile). Low concentration sites were located mainly in more remote, least developed areas, such as the Hood Canal and outer coast, away from potential point and non-point sources. High concentration sites were located mainly in the more urbanized and industrialized south-central Puget Sound basin, though a few were in the San Juan and Strait of Juan de Fuca basins. As in the 2015/16 survey, the majority of the highest concentration sites (95th percentile) were located in the Elliott Bay (Seattle) and Guemes Channel (Anacortes) areas (Figure 6).

The highest concentrations of Σ_{42}PAHs for each group of sites (SAM, Pierce County, Partner) occurred at SAM Site #39 (Smith Cove, Terminal 91), Pierce County Site #625 (Gig Harbor – Mulligan), and Partner Site EB-P59 (Elliott Bay, Pier 59). The lowest concentrations occurred at SAM Site #56 (Fidalgo Island, Swinomish Res), Pierce County Site #353 (Purdy, Nicholson), and Partner Site SPS_LB (Luhr Beach). PAH concentrations from every mussel site are listed in Appendix A.

The overall highest observed PAH concentration in this survey was at the Partner site EB_P59 (Elliott Bay, Pier 59; 27,600 ng/g dry wt.). This site was not sampled in the 2015/16 survey. However, another Elliott Bay location, Site #39 (Smith Cove, Terminal 91), the site second highest in concentration in this survey (7,020 ng/g dry wt.) and highest in the 2015/16 survey (7,350 ng/g dry wt.) had similar concentrations. The concentration of Σ_{42}PAHs was lowest at site SPS_LB (Luhr Beach; 90.8 ng/g dry wt.); whereas the concentration was lowest at site HC_HO (Hood Canal Holly; 48.8 ng/g dry wt.) for the 2015/16 survey. Tables listing site concentrations from lowest to highest values for each sponsor group (SAM, Pierce County, and Partner) under each percentile based category (25th, 75th, and 95th percentile) are in Appendix D.

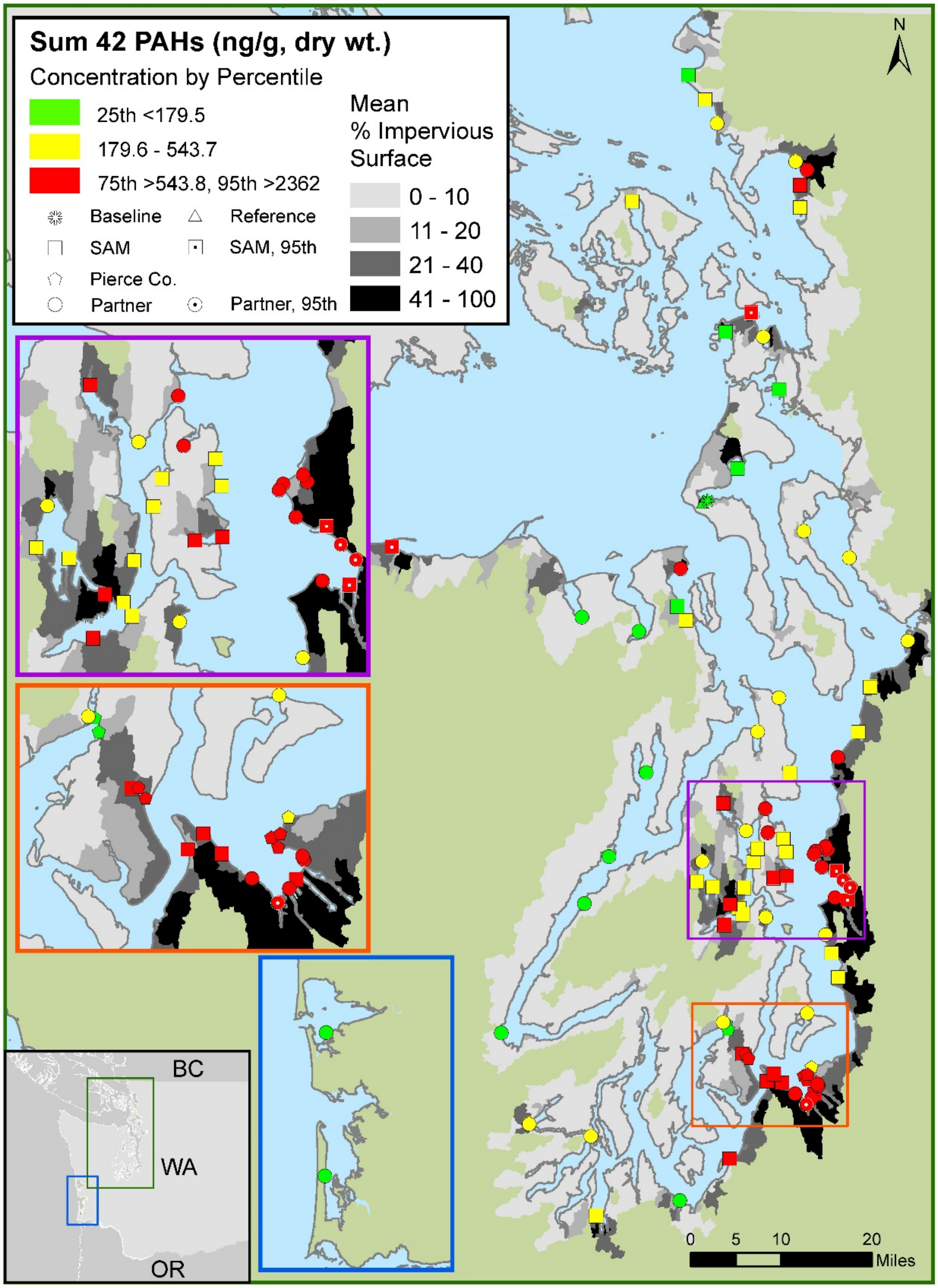

Figure 6. Map of the relative concentrations of Σ_{42} PAHs from 2017/18 Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

TPCBs

Overall for the three site types, 3 sites fell within the low concentration category (25th percentile) and 55 in the high category (75th percentile). Low concentration sites were located in the Hood Canal basin, and high concentration sites were located mainly in the south-central Puget Sound basin, though at least one high concentration site was in the south Puget Sound, Strait of Juan de Fuca, San Juan, and Whidbey basins (Figure 7). As in the 2015/16 survey, the majority of the highest concentration sites (95^{th} percentile) were located in the Elliott/Salmon Bay (Seattle), Sinclair Inlet (Port Orchard), and Gig Harbor areas (Figure 7). Eagle Harbor and an Edmonds area site (Meadowdale Beach) were also determined to have concentrations in the 95th percentile.

The highest concentrations of TPCBs for each group of sites (SAM, Pierce County, Partner) occurred at SAM Site #39 (Smith Cove, Terminal 91), Pierce County Site #481 (Gig Harbor – Boat Launch), and Partner Site EB-P59 (Elliott Bay, Pier 59). The lowest concentrations occurred at SAM Site #27 (Chuckanut, Clark's Point), Pierce County Site #353 (Purdy, Nicholson), and Partner HC_HO (Hood Canal, Holly). PCB concentrations from every mussel site are listed in Appendix A.

The overall highest observed PCB concentration in this survey was at the Partner site EB_P59 (Elliott Bay, Pier 59; 221 ng/g dry wt.). This site was not sampled in the 2015/16 survey. However, another Elliott Bay location, Site #39 (Smith Cove, Terminal 91), the site second highest in concentration in this survey (214 ng/g dry wt.) and highest in the 2015/16 survey (236 ng/g dry wt.) had similar concentrations. The concentration of TPCBs was lowest at site HC_HO (Hood Canal Holly; 10.6 ng/g dry wt.); whereas the concentration was lowest at Site #4 (Cherry Point North; 6.16 ng/g dry wt.) for the 2015/16 survey. Tables listing site concentrations from lowest to highest values for each sponsor group (SAM, Pierce County, and Partner) under each percentile based category (25th, 75th, and 95th percentile) are in Appendix D.

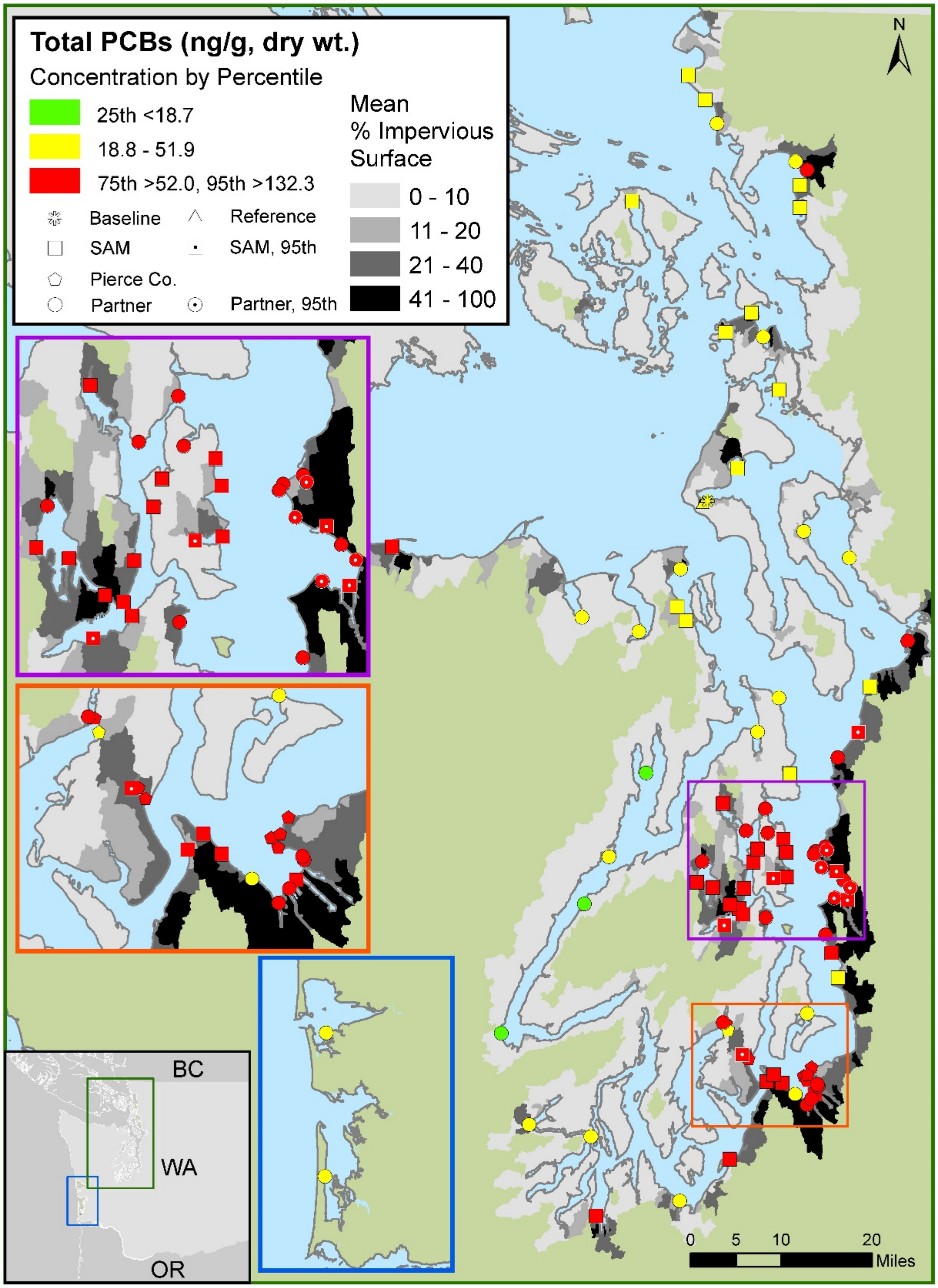

Figure 7. Map of the relative concentrations of estimated total PCBs from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

$\sum_{11}$PBDEs

Overall for the three site types, 21 sites fell within the low concentration category (25th percentile) and 25 in the high category (75th percentile). Low concentration sites were primarily located at the outer coast and Hood Canal and Strait of Juan de Fuca basins. High concentration sites were primarily located in the south-central Puget Sound, though at least one high concentration site was in the Whidbey and San Juan basins (Figure 8). As in the 2015/15 survey, the majority of the highest concentration sites (95^{th} percentile) were located in the Elliott Bay (Seattle) and Commencement Bay (Tacoma) areas (Figure 8). Bellingham and Anacortes area sites were also determined to have concentrations in the 95th percentile.

The highest concentrations for each group of sites (SAM, Pierce County, Partner) occurred at SAM site #34 (Elliott Bay, Harbor Is., Pier 17; 47.2 ng/g dry wt.), Pierce County site #697 (Browns Point – Wolverton; 21.1 ng/g dry wt.), and Partner site CB_DGL (Comm Bay, Dick Gilmur Launch; 26.4). For sites where $\sum_{11}$PBDEs were detected, the lowest detected concentrations occurred at SAM Site #56 (Fidalgo Island, Swinomish; 1.91), Pierce County Site #161 (Purdy – Dexters; 2.21 ng/g dry wt.), and Partner site PAC_GH (Grays Harbor, Bottle Beach; 1.08 ng/g dry wt.). $\sum_{11}$PBDEs were not detected at six Partner sites (HC_DBE, HC_FP, HC_HO, HC_PSP, PAC_WBN, SJD_JSK). PBDE concentrations from every mussel site are listed in Appendix A.

The overall highest observed PBDE concentration in this survey was at Site # 34 (Elliott Bay, Harbor Is., Pier 17; 47.2 ng/g dry wt.); whereas the concentration was highest at CPS_SB (Salmon Bay; 39.2 ng/g dry wt.) for the 2015/16 survey. For sites where $\sum_{11}$PBDEs were detected, the concentration was lowest at site PAC_GH (Grays Harbor, Bottle Beach; 1.08 ng/g dry wt.); whereas the concentration was lowest at Site# 353 (Purdy, Nicholson; 1.89 ng/g dry wt.) for the 2015/16 survey. Tables listing site concentrations from lowest to highest values for each sponsor group (SAM, Pierce County, and Partner) under each percentile based category (25th, 75th, and 95th percentile) are in Appendix D.

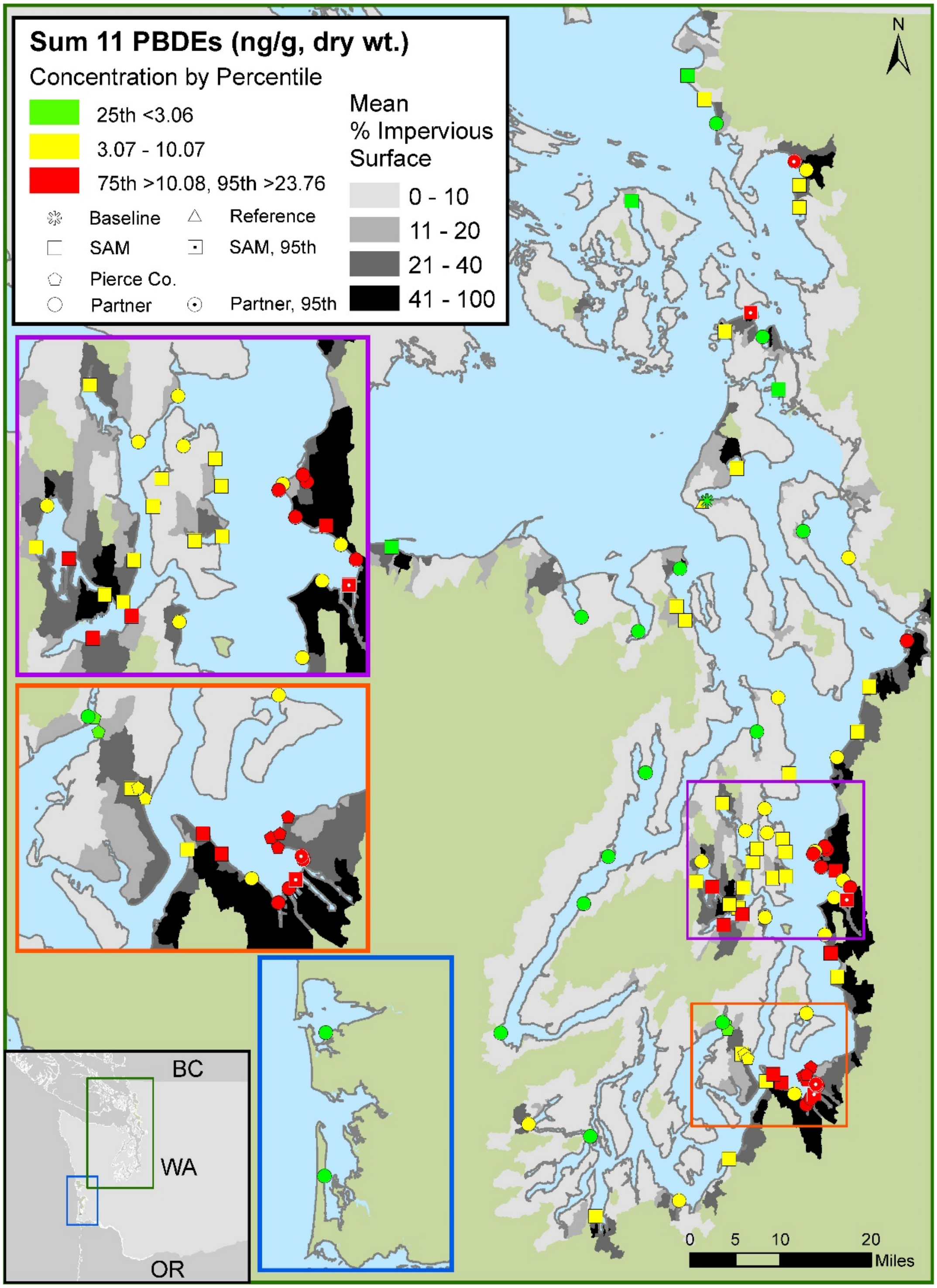

Figure 8. Map of the relative concentrations of Σ_{11}PBDEs from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

$\sum_6$DDTs

Overall for the three site types, 10 sites fell within the low concentration category (25th percentile) and 49 in the high category (75th percentile). Low concentration sites were primarily located in Hood Canal and high concentration sites were primarily located in the south-central Puget Sound, Whidbey, and San Juan basins, though at least one high concentration site was in the Strait of Juan de Fuca and south Puget Sound (Figure 9). As in the 2015/16 survey, the majority of the highest concentration sites (95th percentile) were located in the Elliott/Salmon Bay (Seattle) and Commencement Bay (Tacoma) areas (Figure 9). A newly sampled Port Angeles site was also determined to have concentrations in the 95th percentile.

The highest concentrations for each group of sites (SAM, Pierce County, Partner) occurred at SAM site #52 (Port Angeles Yacht Club; 33.3 ng/g dry wt.), Pierce County site #697 (Browns Point – Wolverton; 11.0 ng/g dry wt.), and Partner site CPS_SB (Salmon Bay, Commodore Park; 34.2). The lowest concentrations occurred at SAM Site #31 (Eastsound, Fishing Bay; 1.56), Pierce County Site #353 (Purdy – Nicholson; 1.88 ng/g dry wt.), and Partner site HC_PGPJ (Port Gamble Bay; 1.41 ng/g dry wt.). DDT concentrations from every mussel site are listed in Appendix A.

The overall highest observed PBDE concentration in this survey was at site CPS_SB (Salmon Bay, Commodore Park; 34.2 ng/g dry wt.); whereas the concentration was highest at Site #39 (Smith Cove, Terminal 91; 50.4 ng/g dry wt.) for the 2015/16 survey. For sites where $\sum_6$DDTs were detected, the concentration was lowest at site HC_PGPJ (Port Gamble Bay; 1.41 ng/g dry wt.); whereas the concentration was lowest at site NPS_CPAR4 (Cherry Pt Aq Reserve, Conoco Phillips; 1.87 ng/g dry wt.) for the 2015/16 survey. $\sum_6$DDTs were not detected at four Partner sites in Hood Canal (HC_DBE, HC_FP, HC_HO, HC_PSP). Tables listing site concentrations from lowest to highest values for each sponsor group (SAM, Pierce County, and Partner) under each percentile based category (25th, 75th, and 95th percentile) are in Appendix D.

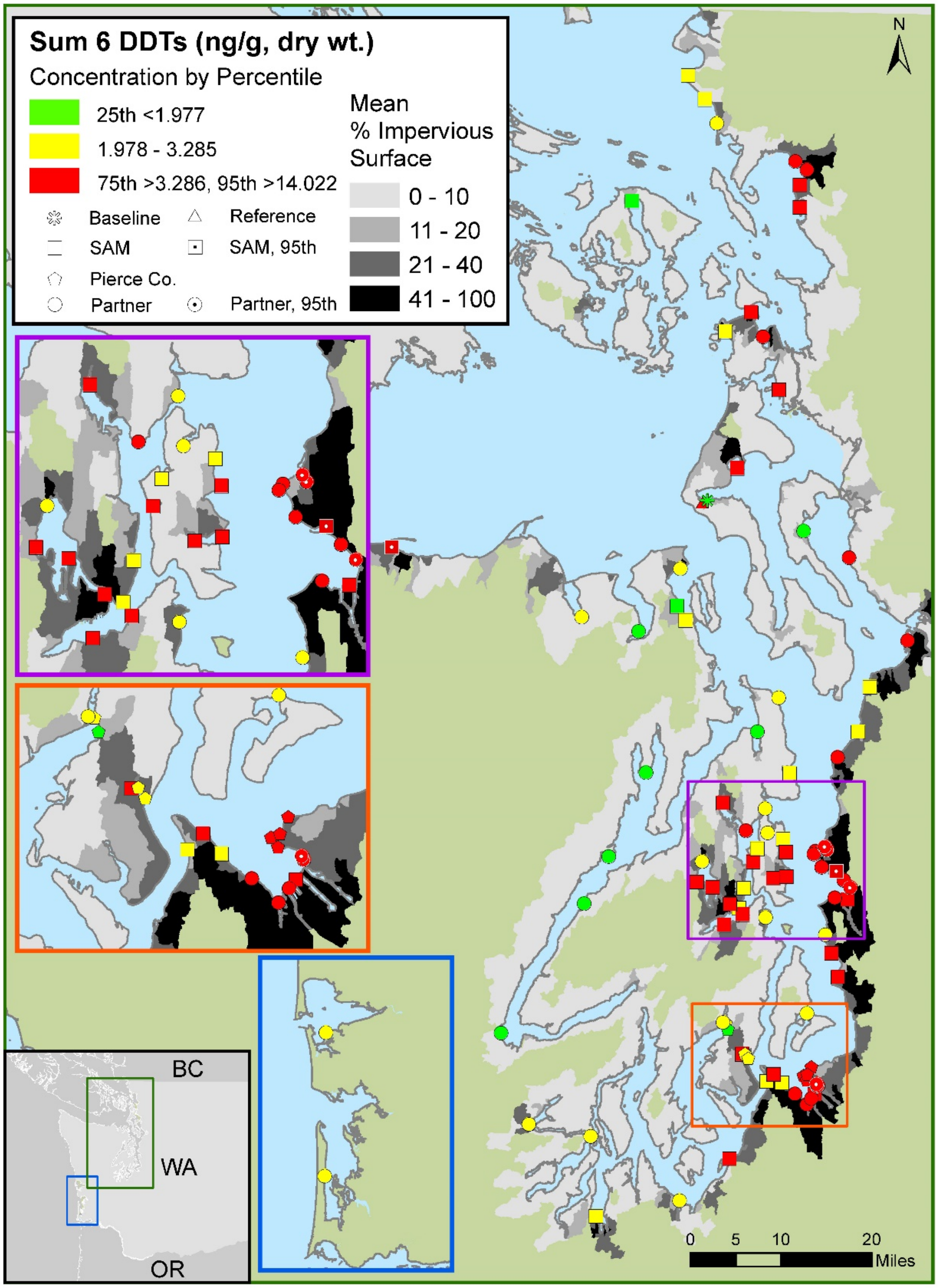

Figure 9. Map of the relative concentrations of Σ_6 DDTs from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

Chlordanes

Chlordanes were detected at 29 sites (14 SAM, 15 Partner). The concentrations in this study ranged from 0.734 to 12.9 ng/g dry wt., and limit of quantitation ranged from 0.656 to 4.92 ng/g dry wt. Chlordane mussel concentrations are listed in Appendix A.

Dieldrin

Dieldrin was detected at 37 sites (20 SAM, 17 Partner). The concentrations in this study ranged from 0.754 to 3.57 ng/g dry wt., and limit of quantitation was 4.92 ng/g dry wt. Dieldrin mussel concentrations are listed in Appendix A.

HCHs

HCHs were only detected at site EB_P59 (Elliott Bay, Pier 59). At that site two HCH isomers, alpha-HCH (α-HCH) and lindane, were detected at concentrations of 11.1 and 62.2 ng/g dry wt. respectively. The limit of quantitation ranged from 0.498 to 1.59 ng/g dry wt. HCHs mussel concentrations are listed in Appendix A.

HCB

HCB was detected at three sites, CB_DGL (Comm Bay, Dick Gilmur Launch), CPS_QMH (Quartermaster Harbor), and NPS_BBWW (Bellingham Bay, Whatcom Waterway), at concentrations of 1.13, 2.75, and 1.77 ng/g dry wt. respectively. The limit of quantitation was 2.14 ng/g dry wt. HCB mussel concentrations are listed in Appendix A.

Other Organic Pollutants

Mirex (LOQ 2.14 ng/g dry wt.), aldrin (LOQ 5.00), and endosulfan 1 (LOQ 5.00) were not detected in mussels from any of the study sites.

Metals

For each metal analyte, we often observed a mix of low, moderate, or high metal concentration sites within the same basin, with high metal concentration sites located in both urban and rural basins (Figure 10 - 16). However, all of the highest concentration sites (95th percentile) were located in the south-central basin, mainly in the Commencement Bay (Tacoma) and Dyes Inlet areas. Though the general geographic distribution of the highest metal concentration sites were similar to the organic contaminant pattern, they differ in that low metal concentration sites also occurred within the same urban south-central basin; a pattern not observed with the organic contaminants where all the sites had high or intermediate concentrations within the south-central basin.

Metal concentrations in mussels at each site are listed in Appendix B. Details on the highest/lowest concentrations observed for each sponsor group (SAM, Pierce County, and Partner) and for the overall survey can be determined using the tables in Appendix D. One table for each metal analyte lists the Site ID/Name and concentration for each site under each percentile based category (25th, 75th, and 95th percentile).

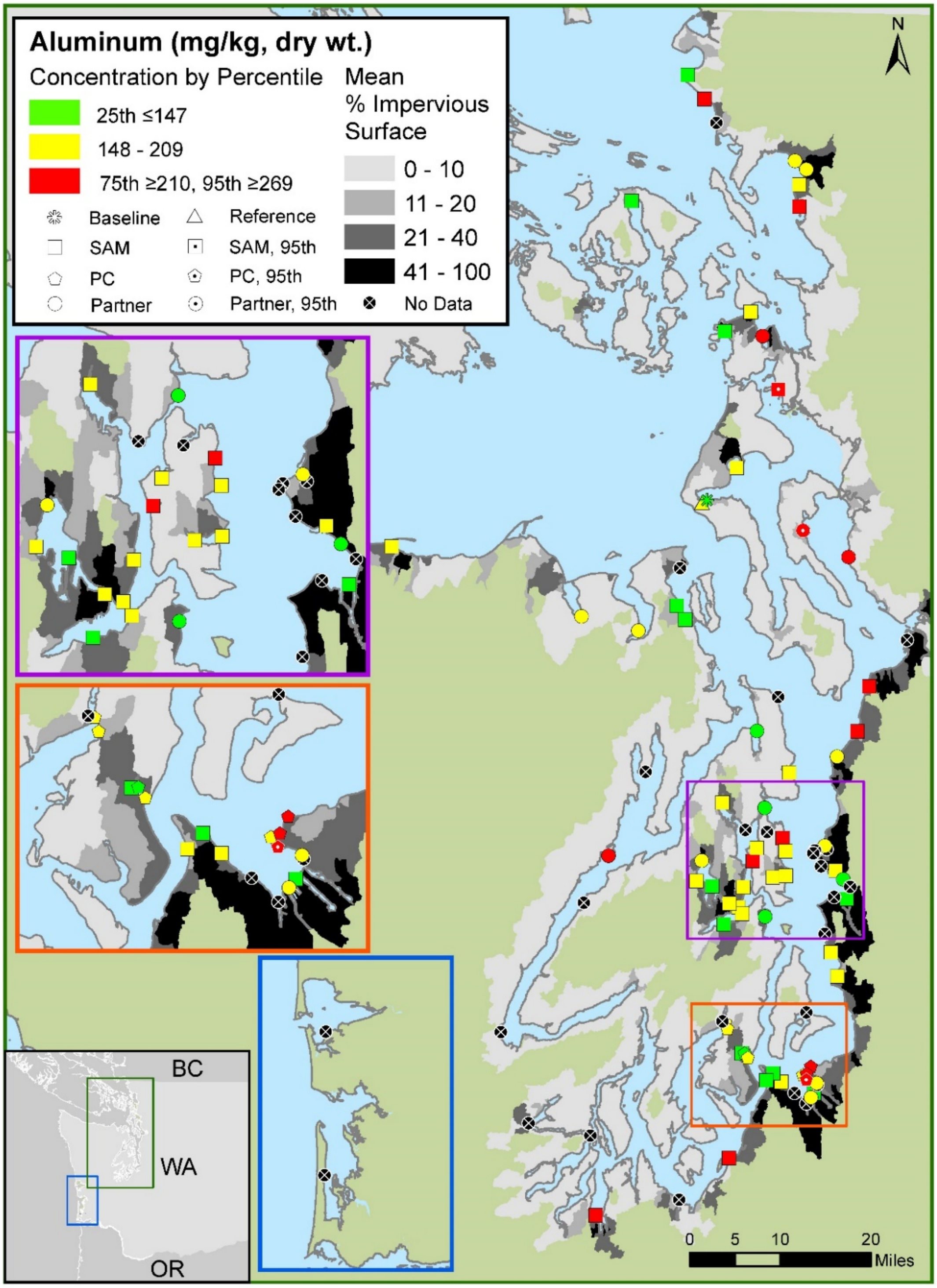

Figure 10. Map of the relative concentrations of aluminum from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

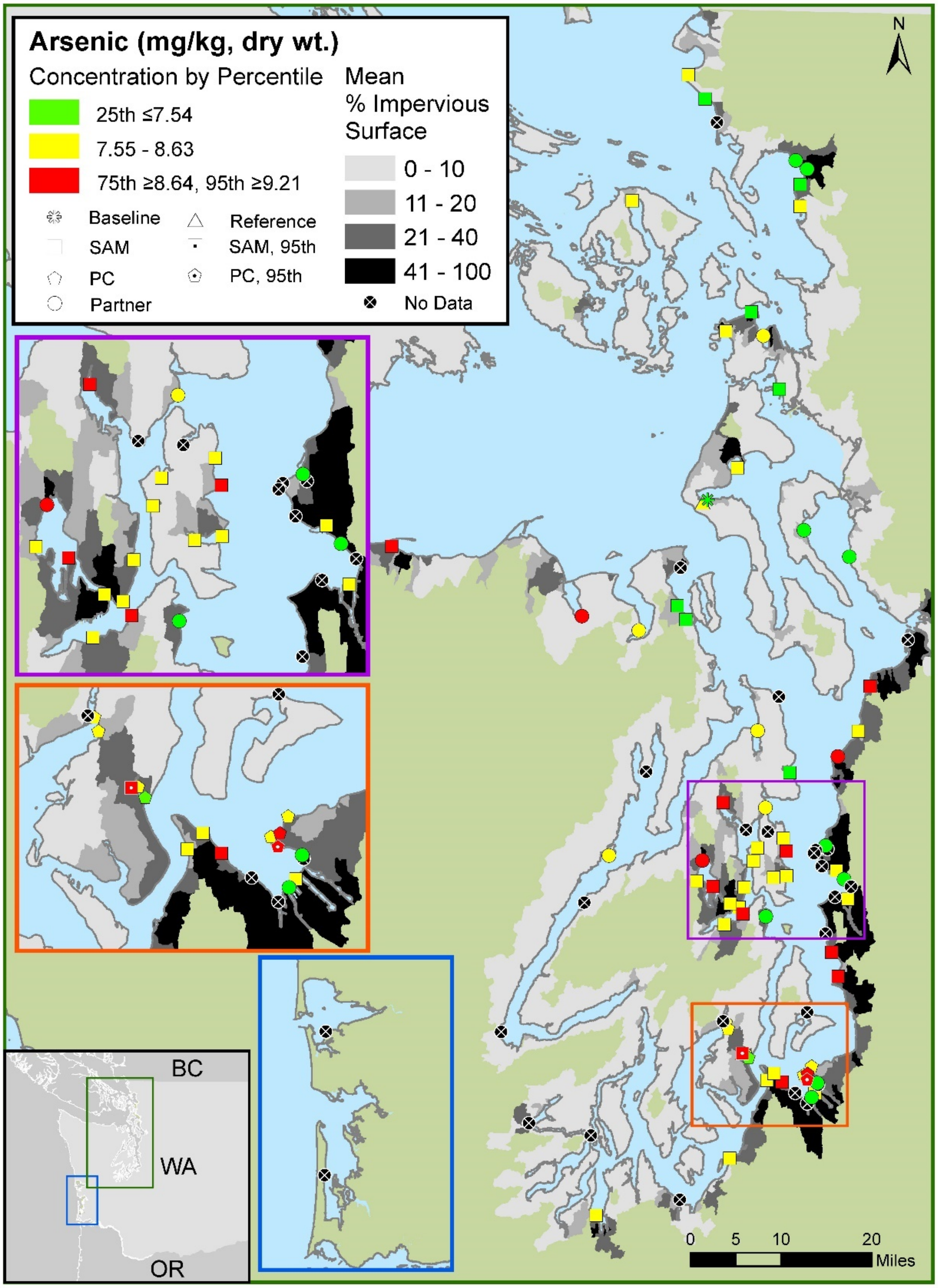

Figure 11. Map of the relative concentrations of total arsenic from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

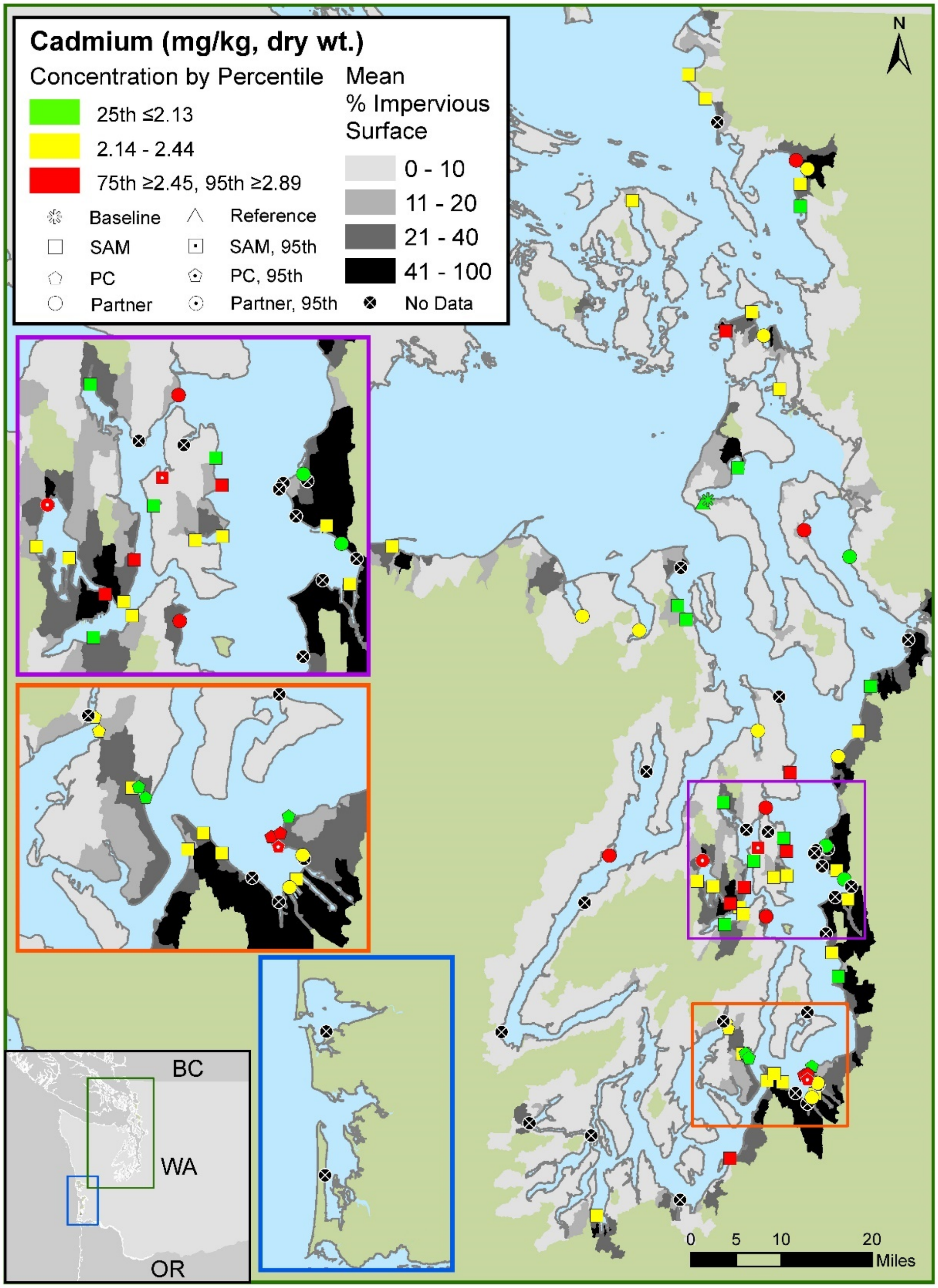

Figure 12. Map of the relative concentrations of cadmium from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

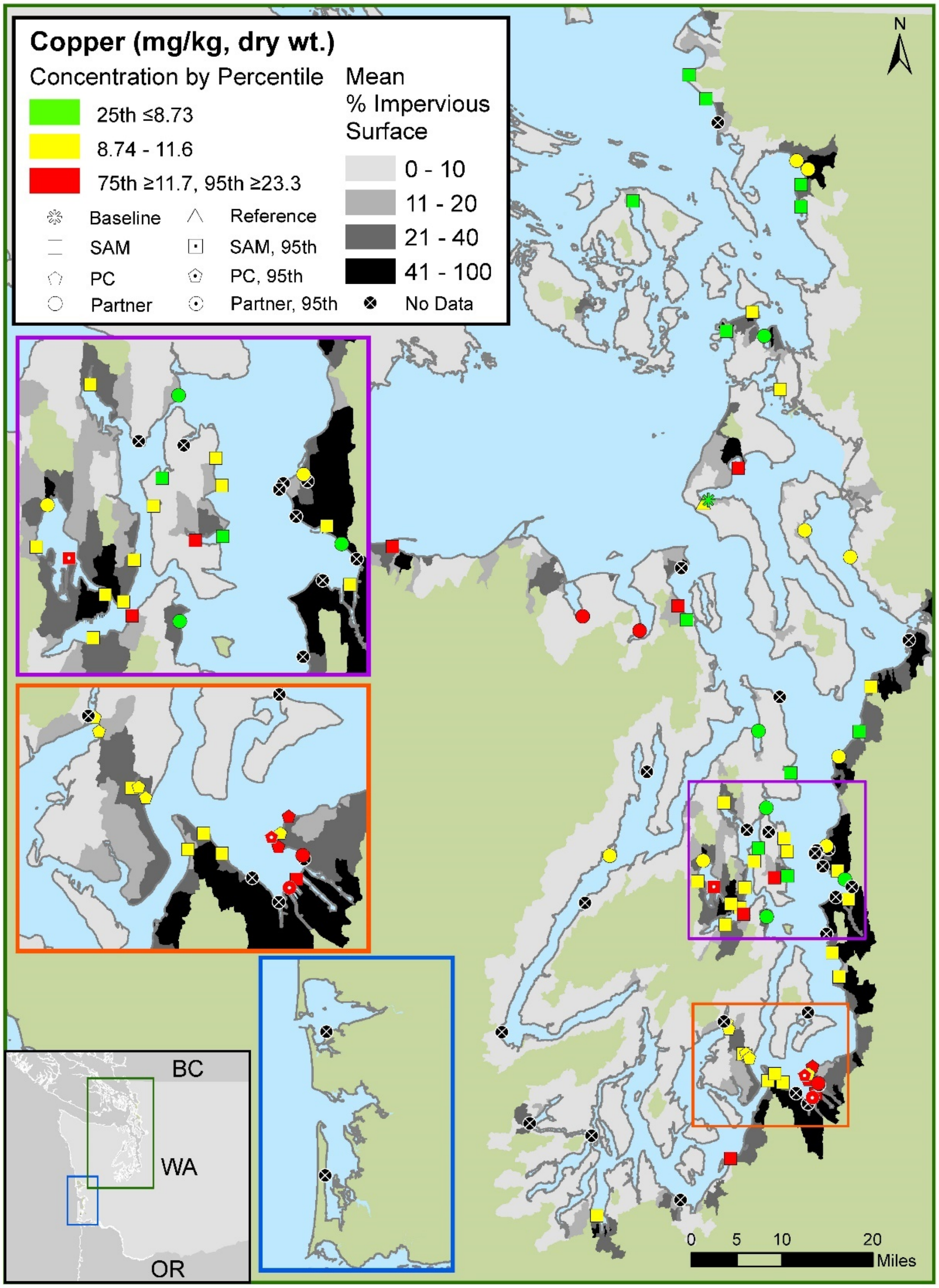

Figure 13. Map of the relative concentrations of copper from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

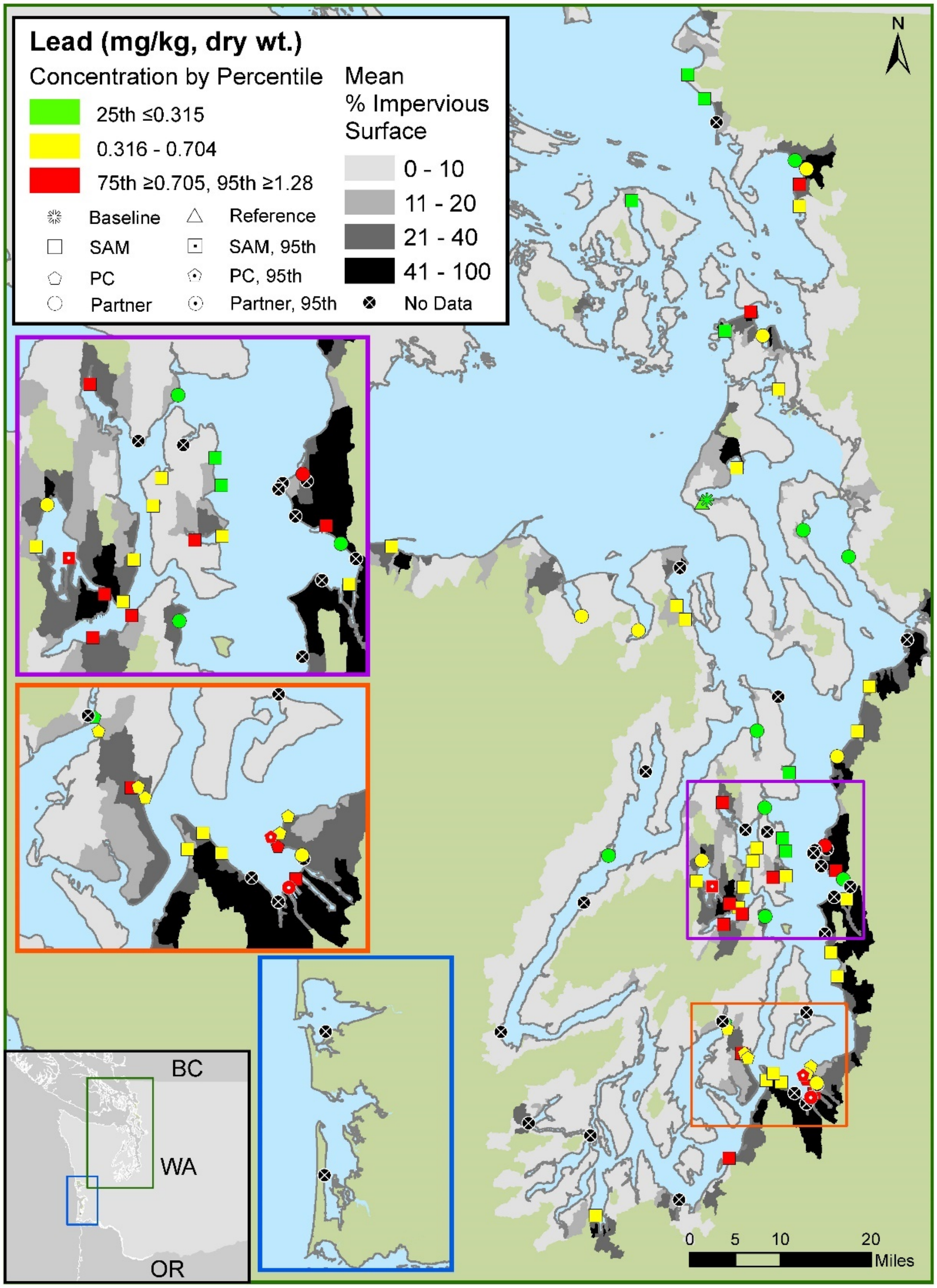

Figure 14. Map of the relative concentrations of lead from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

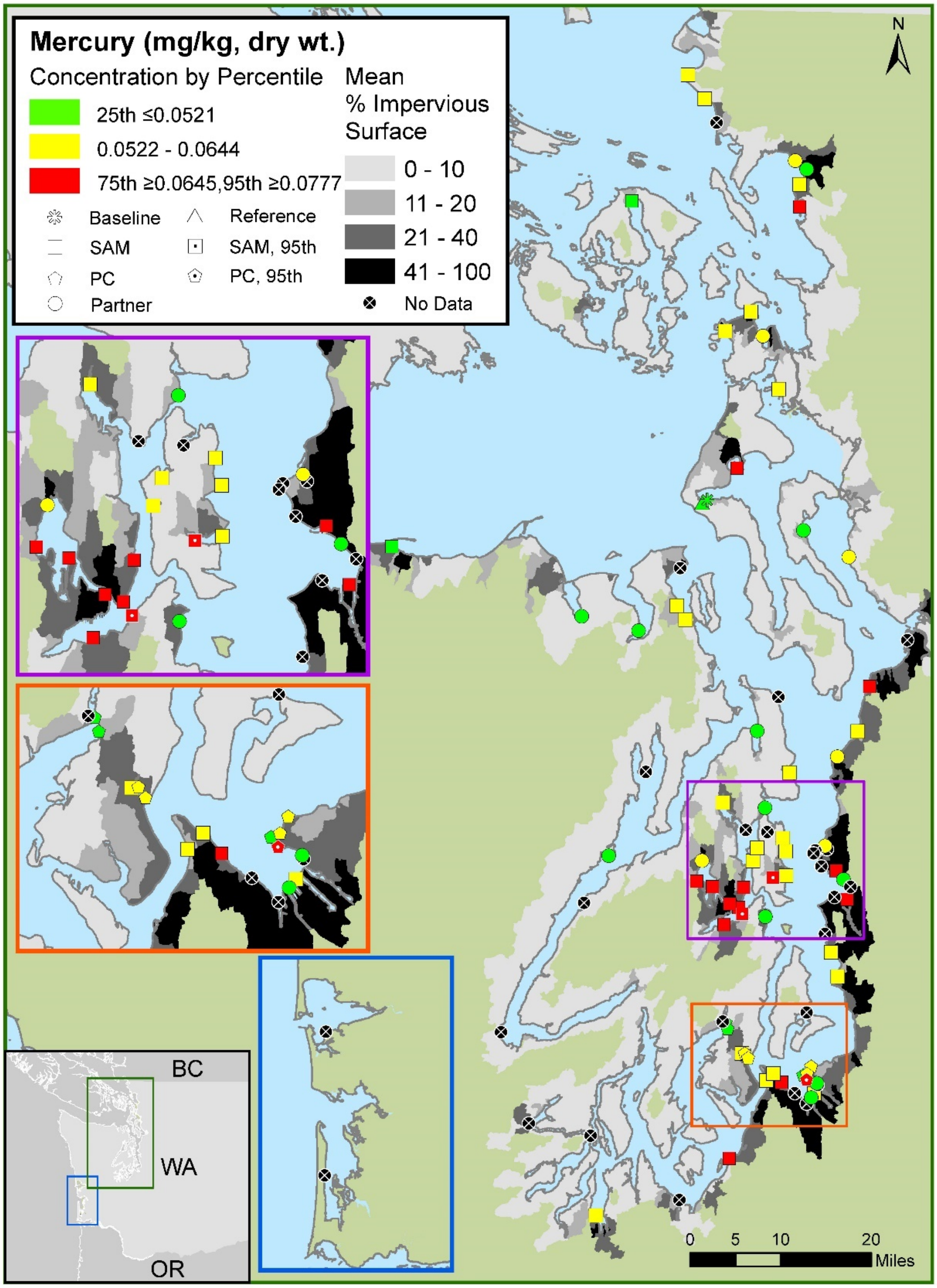

Figure 15. Map of the relative concentrations of total mercury from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

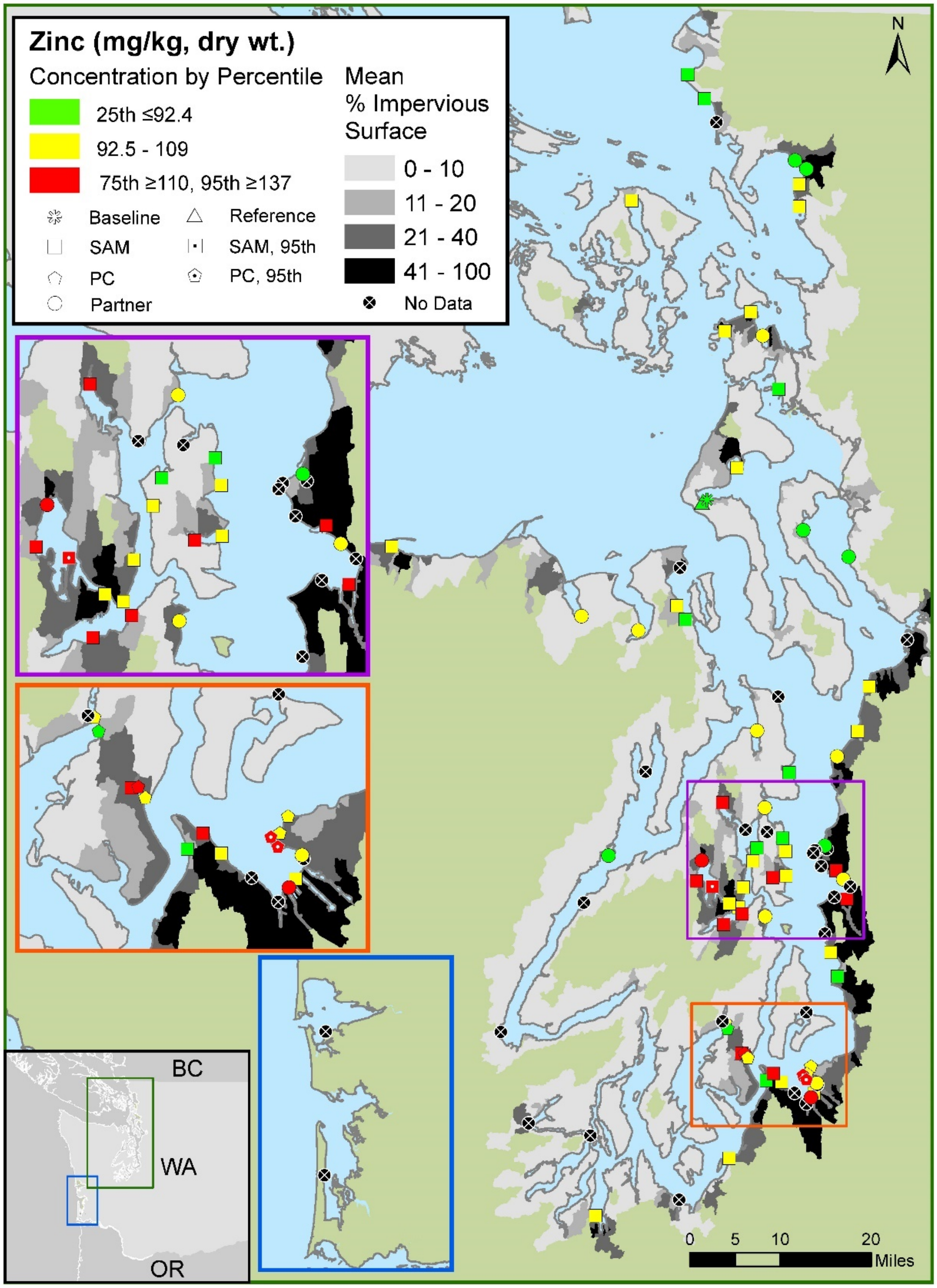

Figure 16. Map of the relative concentrations of zinc from all the 2017/18 SAM Mussel Monitoring sites. Grey shading on land represents mean percent impervious surface on the adjacent shoreline watersheds.

Association of Contaminants with Watershed Land Use

Similar to prior survey years (Lanksbury et al., 2014 and 2017) this study shows a significant positive correlation between the average percent impervious surface (%IS) in adjacent watersheds and all four classes of organic contaminants (Figure 17, Table 17). Impervious surface accounted for a relatively large percentage of variability in the organic contaminant concentrations in mussels, including 42.8% of the variability for Σ_{42}PAHs, 23.5% for TPCBs, 38.5% for $\sum_{11}$PBDEs, and 29.2% for $\sum_{6}$DDTs (Table 17). High-concentration outliers in each model suggest there are likely other sources of contamination in the nearshore besides impervious surface that are contributing to nearshore contamination. These may be point sources in the nearshore such as industrial outfalls, wastewater treatment plant outfalls, combined sewer overflows, marinas, ship/ferry terminals, and superfund sites.

Unlike the 2015/16 survey, which showed no relationship between concentrations of metals (arsenic, cadmium, copper, lead, mercury, zinc) in mussels and %IS in the adjacent watershed, this study shows a significant positive correlation for lead and zinc (Figure 18, Table 18). However, the correlation is weak, with %IS accounting for a relatively small percentage of variability in lead (12.8%) and zinc (11.1%) concentrations in mussels (Table 18). These results are similar to those from the 2012/13 MWPE study, where significant positive correlations were also observed for lead (r^2=0.198, p<0.0001) and zinc (r^2=0.055, p=0.016). There was no relationship found between %IS and the other metal (aluminum, arsenic, copper, cadmium, mercury) concentrations in mussels measured in this study (Figure 19, Table 18).

The ongoing positive correlations observed for organic contaminants as well as lead and zinc support the assertion that increasing presence of impervious surface continues to exacerbate the transport of toxic chemicals from terrestrial sources to nearshore aquatic habitats. With urbanization likely increasing into the future in the Puget Sound lowland, these results predict increase of contaminant loads to the nearshore without intervention through stormwater management action.

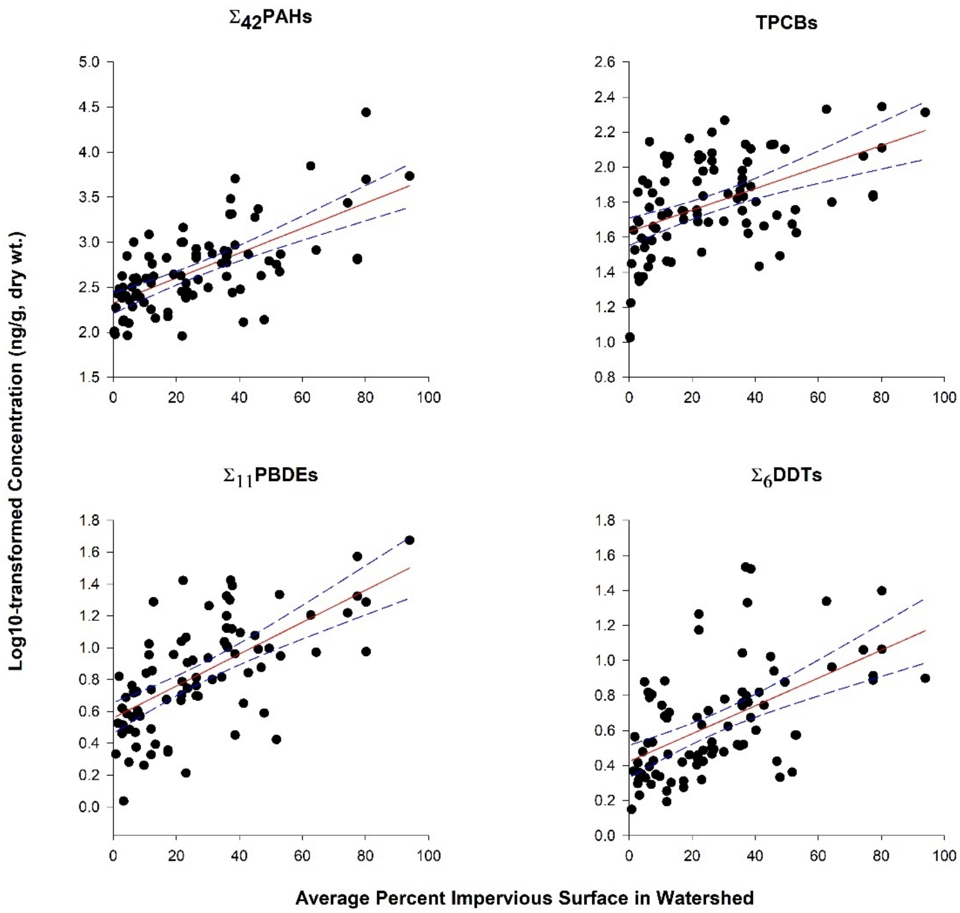

Figure 17. Relationship between the average percent impervious surface in adjacent watersheds and concentration (log10 transformed) of organic contaminants in mussels at nearshore sites (SAM, Pierce County, Partner). Regression is shown as solid red line and 95% confidence band as blue dashed lines.

Table 17. Regression model results of the relationship between concentration (ng/g, dry wt.) of organic contaminants in mussel tissue and the percent impervious surface in adjacent upland watershed units. All chemical concentrations were log^{10}-transformed for regression analyses.

Organic Contaminant	n	Impervious Surface				Adj. r^2	Full Regression Model Parameters	
		Slope		Y-intercept				
		coefficient	p-value	coefficient	p-value		F-ratio (df = 1, 87)	p-value
$\sum_{42}$PAHs	89	0.0139	<0.0001	2.3241	<0.0001	0.428	66.909	<0.0001
TPCBs	89	0.0061	<0.0001	1.6313	<0.0001	0.235	27.979	<0.0001
$\sum_{11}$PBDEs	84	0.0100	<0.0001	0.5594	<0.0001	0.385	52.931	<0.0001
$\sum_{6}$DDTs	85	0.0079	<0.0001	0.4229	<0.0001	0.292	35.716	<0.0001

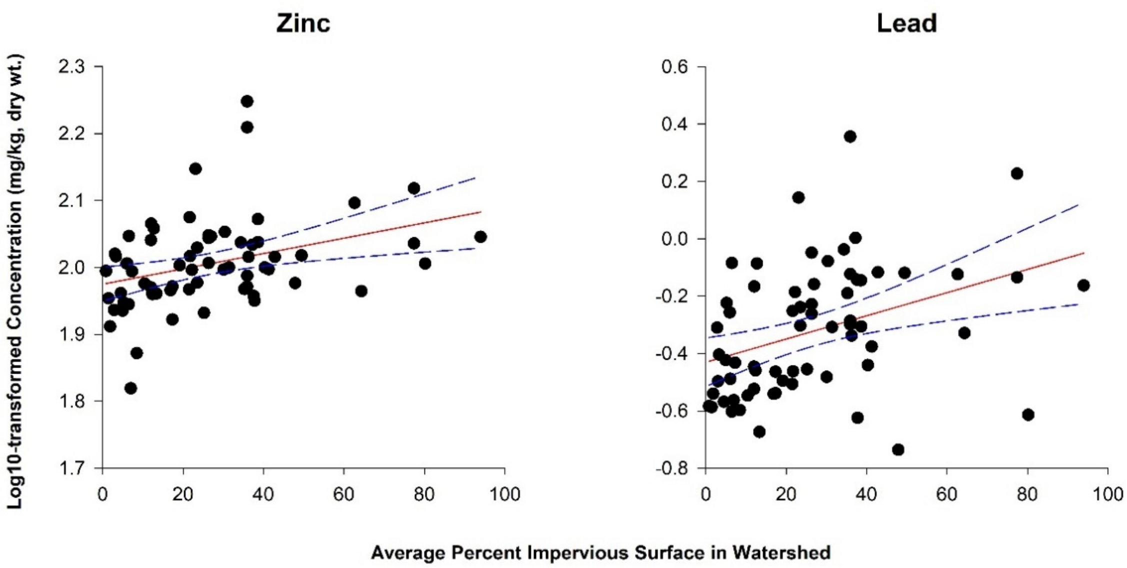

Figure 18. Relationship between the average percent impervious surface in adjacent watersheds and concentration (log10 transformed) of zinc and lead in mussels at nearshore sites (SAM, Pierce County, Partner). Regression is shown as solid red line and 95% confidence band as blue dashed lines.

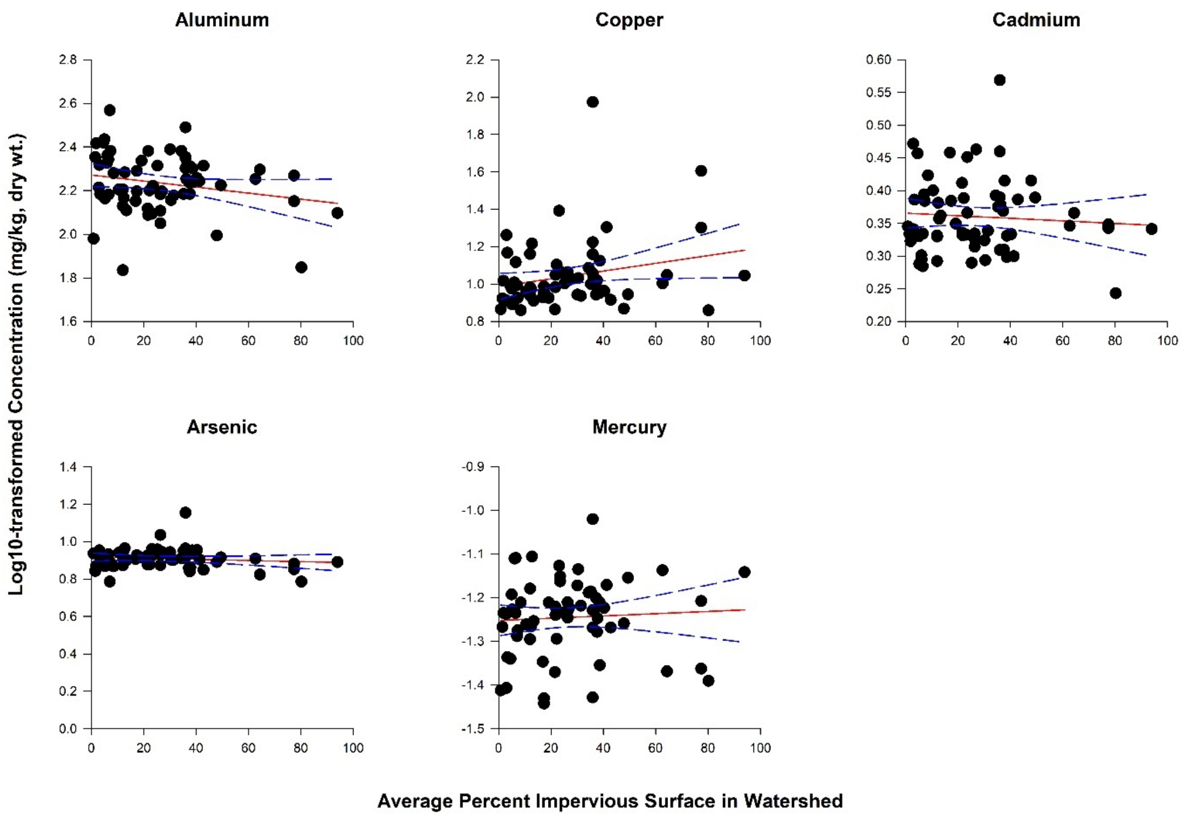

Figure 19. Relationship between the average percent impervious surface in adjacent watersheds and concentration (log10 transformed) of aluminum, arsenic, cadmium, copper, and total mercury in mussels at nearshore sites (SAM, Pierce County, Partner). Regression is shown as solid red line and 95% confidence band as blue dashed lines.

Table 18. Regression model results of the relationship between concentration (mg/kg, dry wt.) of metals in mussel tissue and the percent impervious surface in adjacent upland watershed units. All chemical concentrations were log10-transformed for regression analyses.

Metal	n	Impervious Surface				Adj. r^2	Full Regression Model Parameters	
		Slope		Y-intercept				
		coefficient	p-value	coefficient	p-value		F-ratio (df = 1, 63)	p-value
Aluminum	65	-0.0014	0.0846	2.2713	<0.0001	0.0313	3.0694	0.0846
Total Arsenic	65	-0.0003	0.3263	0.9183	<0.0001	-0.0003	0.9785	0.3263
Cadmium	65	-0.0002	0.5632	0.3656	<0.0001	-0.0105	0.3377	0.5632
Copper	65	0.0021	0.0527	0.9873	<0.0001	0.0434	3.9004	0.0527
Lead	65	0.0040	0.0020	-0.4305	<0.0001	0.1279	10.3890	0.0020
Total Mercury	65	0.0003	0.6295	-1.2519	<0.0001	-0.0121	0.2350	0.6295
Zinc	65	0.0011	0.0038	1.9751	<0.0001	0.1115	9.0337	0.0038

Conclusions

The 2017/18 Mussel Monitoring survey represented the second successful deployment of mussels in Puget Sound for the purpose of tracking toxic contaminants in nearshore biota. In this survey we characterized the spatial extent of nearshore biota contamination. We provided the status of the spatial extent of key mussel contaminants inside the UGA sampling frame, identified the detection frequency and concentration range of contaminants, described the geographic range of contaminants, and examined the relationship between land-use and nearshore mussel contamination, which illustrates the association between terrestrial sources and the Puget Sound nearshore. Further, we established reference sites and a method for comparing contaminant concentrations between sites/survey years. From this analysis the following conclusions are drawn:

- $\sum_{42}$PAHs , TPCBs, $\sum_{11}$PBDEs , and $\sum_{6}$DDTs continue to be the most abundant organic contaminants detected in mussels of the Puget Sound nearshore (100% of SAM/Pierce County sites; 100% of Partner sites for $\sum_{42}$PAHs/TPCBs, 86% for $\sum_{11}$PBDEs and 91% for $\sum_{6}$DDTs).
- TPCBs and $\sum_{6}$DDTs in SAM site mussels had significantly higher median concentrations in this survey than in the 2015/16 survey, suggesting those contaminants should be closely monitored in future surveys to track whether there is an increasing trend.
- $\sum_{42}$PAHs in SAM site mussels had slightly elevated median concentrations in this survey than in the 2015/16 survey, and $\sum_{11}$PBDEs in mussels had slightly lower concentrations. However, there was not a statistically significant difference between the 2015/16 and 2017/18 survey median concentrations for both organic contaminants.
- All metals continue to be frequently detected in mussels (100% of all sites).
- The cumulative frequency distribution (CFD) patterns for Σ_{42}PAHs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs were similar in that they all were more skewed toward the low concentrations, suggesting that the majority of Puget Sound UGA shorelines have relatively low concentrations of these contaminants and that only a few sites have much higher concentrations, perhaps from site specific point sources. The CFD pattern for TPCBs were unlike the other organic contaminants in that it had a more gradual contaminant accumulation as the shoreline length increased, suggesting sources of this contaminant is more widely dispersed within the Puget Sound UGAs.
- The CFD patterns for most of the metals (arsenic, cadmium, lead, mercury, and zinc) had a more gradual contaminant accumulation as the shoreline increased, suggesting these contaminants are more widely dispersed within the Puget Sound UGA shoreline. The CFD pattern for copper was unlike the other metals, having a pattern more skewed to the lower concentrations, with only a few sites with much higher concentrations.
- The majority of sites had organic and metal contaminant concentrations above the Baseline concentration, indicating that all deployed cages accumulated additional contaminant loads from their deployment locations and that initial conditions of Penn Cove mussels represent an effective baseline.
- Using the 25th and 75th percentiles of contaminant concentrations from previous Puget Sound mussel surveys as relative benchmarks for low and high categories provided a regional context in

which to compare concentrations between sites. Future survey results will continue to be compared against these survey baseline conditions to help identify possible problem areas.

- Sites with high organic contaminant concentrations were located mainly in the more urbanized south-central Puget Sound basin, while sites with low organic contaminant concentrations were mainly in the remote Hood Canal basin. Similar to the organic contaminants, sites with the highest concentrations of metals were located in the urbanized south-central Puget Sound basin. However, low metal concentration sites occurred within the same south-central basin; a pattern not observed with the organic contaminants where all the sites had high or intermediate concentrations within the south-central basin.
- Ongoing significant positive correlations between the concentration of key organic contaminants (Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs) and metals (lead and zinc) in mussels and the mean percent of impervious surface in adjacent watersheds supports the hypothesis that impervious surface continues to provide a transport pathway for toxic chemicals from terrestrial to aquatic habitats in the Puget Sound.
- WDFW and partner data allows SAM to compare their survey results to data from the entire Puget Sound nearshore areas, including those outside the UGA sampling frame, providing valuable additional context for status assessments and trends monitoring. Taken as a whole, this partnership with SAM provides a stronger, more comprehensive tool for evaluating the effectiveness of management actions targeting contaminant reductions in the nearshore. Furthermore, WDFW and other funding partners established additional sites for local interest (e.g. effectiveness studies, local monitoring) and provided further context for the larger regional monitoring effort.

Future Cooperative Monitoring

Although the primary focus of this document was to report on SAM program data, we included data for WDFW and partner organizations and noted the benefits of this cooperative monitoring effort for all parties involved. Future WDFW lead surveys will continue this cooperative approach. The 2019/20 survey included partnerships with a number of returning and new partners, including the NOAA National Centers for Coastal Ocean Science (NCCOS) Mussel Watch program. The national Mussel Watch program collaborated with the 2019/20 mussel survey effort; resampling their historic monitoring sites using the caged mussel method employed by this program, instead of sampling wild mussels as they had previously. As a result of this partnership with NCCOS, contaminants of emerging concern (CEC) will be analyzed for 55 of our 2019/20 mussel sites (15 historic NOAA Mussel Watch sites and 40 other survey sites). As opportunities and funding become available, additional chemicals will be analyzed by WDFW’s Toxics Biological Observation System (TBiOS) team (see James et al., 2020).

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Appendix A: Dry Weight Concentrations of Organic Contaminants in Mussels by Site

* Mean of five replicate samples from Penn Cove, Whidbey Island aquaculture facility, the source of mussels for this effort (i.e., starting condition)

< Indicates the concentration was not measured above the limit of quantitation (LOQ), which is the value reported instead

Table A- 1. Dry weight concentrations (ng/g) of organic contaminants in mussels at each mussel monitoring site.

Site Type	Site ID	Site Name	Concentrations in ng/g, dry weight (ppb)							
			$\sum_{42}$PAHs	TPCBs	$\sum_{11}$PBDEs	$\sum_6$ DDTs	$\sum_8$ Chlordanes	$\sum_3$ HCHs	Dieldrin	HCB
SAM	PCB_MEAN	Penn Cove, Pre-test Baseline Mean	75.9	23.4	0.601	1.29	<0.932	<0.932	<0.932	<0.930
SAM	WB_PCR	Penn Cove Reference	136	28.1	3.56	6.37	<0.822	<0.822	0.960	<0.822
SAM	Site #2	Arroyo Beach	299	63.4	12.4	3.98	1.89	<0.810	0.945	<0.810
SAM	Site #3	Brackenwood Ln	396	58.8	5.28	2.47	<0.803	<0.803	<0.803	<0.803
SAM	Site #4	Cherry Point North	265	43.6	3.34	2.33	<0.873	<0.800	<0.800	<0.800
SAM	Site #5	Salmon Beach	573	54.6	7.17	2.91	<1.21	<1.21	<1.21	<1.21
SAM	Site #6	Eagle Harbor Dr	1000	139	5.19	6.13	<0.809	<0.809	0.944	<0.809
SAM	Site #8	Chimacum Creek Delta	179	40.1	3.09	1.79	<0.668	<0.668	<0.668	<0.668
SAM	Site #10	Fletcher Bay, Fox Cove	316	80.1	5.77	3.37	<1.12	<1.12	<1.12	<1.12
SAM	Site #11	South Bay Trail	733	46.0	6.95	5.55	<1.33	<1.33	<1.25	<1.33
SAM	Site #13	Ruston Way	800	73.3	10.9	3.25	<1.21	<1.21	1.36	<1.21
SAM	Site #14	Point Heron East	280	94.7	8.06	3.06	<1.12	<1.12	<1.12	<1.12
SAM	Site #15	Tugboat Park	137	31.1	3.88	2.15	<0.901	<0.901	<0.901	<0.901
SAM	Site #16	Meadowdale Beach	437	146	9.05	2.89	<1.01	<1.01	1.33	<1.01
SAM	Site #17	Budd Inlet, West Bay	282	53.5	5.06	2.75	<0.867	<0.867	1.01	<0.867
SAM	Site #18	Seahurst	258	48.4	8.32	5.16	2.99	<0.590	1.28	<0.590
SAM	Site #19	Skiff Point	397	52.8	6.91	5.54	1.86	<0.505	1.04	<0.505
SAM	Site #21	Point Defiance Ferry	990	82.9	10.9	4.73	<0.912	<0.912	<0.912	<0.912
SAM	Site #22	Beach Dr E	417	115	19.4	5.04	0.917	<0.764	0.993	<0.764
SAM	Site #23	Wing Point	743	70.0	6.30	4.20	<0.771	<0.771	1.12	<0.771
SAM	Site #24	S of Skunk Island	224	37.8	3.07	2.14	<0.856	<0.856	<0.856	<0.856
SAM	Site #25	Blair Waterway	660	69.3	37.4	8.20	6.30	<1.02	1.34	<1.02
SAM	Site #26	N of Illahee State Park	252	68.3	5.55	2.65	<1.21	<1.21	<1.21	<1.21

SAM	Site #27	Chuckanut, Clark's Point	191	26.9	3.66	6.58	<0.972	<0.972	1.05	<0.972
SAM	Site #28	Oak Harbor	129	27.1	4.47	6.57	<0.949	<0.949	1.15	<0.949
SAM	Site #29	Liberty Bay	926	77.4	9.15	4.72	<0.985	<0.985	1.20	<0.985
SAM	Site #30	Kitsap St Boat Launch	905	185	18.3	6.01	<1.08	<1.08	<1.1	<1.08
SAM	Site #31	East Sound, Fishing Bay	394	29.0	2.12	1.56	<0.779	<0.779	<0.779	<0.779
SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	5410	205	47.2	7.91	1.14	<1.14	<1.14	<1.14
SAM	Site #35	Williams Olson Park	420	71.9	4.16	2.60	<0.866	<0.866	<0.866	<0.866
SAM	Site #37	Saltar's Point	580	66.1	6.53	3.30	<0.901	<0.901	1.05	<0.901
SAM	Site #38	Rocky Point	348	114	11.6	4.28	1.74	<0.712	1.06	<0.713
SAM	Site #39	Smith Cove, Terminal 91	7020	214	16.0	21.7	8.79	<0.713	2.14	<0.713
SAM	Site #42	Evergreen Rotary Park	618	127	9.89	7.52	1.82	<0.791	<0.791	<0.791
SAM	Site #43	N Avenue Park	3030	47.8	26.5	6.27	<0.663	<0.663	<0.656	<0.663
SAM	Site #46	Appletree Cove	244	44.6	3.72	2.23	<0.785	<0.785	<0.785	<0.784
SAM	Site #47	Cherry Point Aq Reserve, Birch Bay	143	28.6	2.47	2.01	<1.00	<1.00	<0.927	<1.00
SAM	Site #48	Naketa Beach	313	49.0	8.62	3.00	<0.869	<0.869	0.949	<0.869
SAM	Site #49	Donkey Creek Delta	732	158	4.99	3.41	<1.33	<1.33	<1.25	<1.33
SAM	Site #52	Port Angeles Yacht Club	5050	127	2.83	33.3	<0.848	<0.848	<0.848	<0.848
SAM	Site #54	Dyes Inlet, Chico Bay	351	105	5.45	4.68	1.89	<0.838	0.977	<0.838
SAM	Site #56	Fidalgo Island, Swinomish Res	126	34.7	1.91	7.55	<1.13	<1.13	<1.04	<1.13
PC	Site #61	Dash Point Park	415	56.4	10.3	5.50	1.95	<0.836	0.906	<0.836
PC	Site #161	Purdy, Dexters	166	56.0	2.21	2.05	<1.18	<1.18	1.26	<1.18
PC	Site #185	Browns Point	743	80.6	13.3	6.60	1.25	<1.17	<3.52	<1.17
PC	Site #353	Purdy, Nicholson	149	50.2	2.27	1.88	<4.55	<1.49	<4.55	<1.49
PC	Site #481	Gig Harbor, Boat Launch	668	120	5.76	3.18	<3.96	<1.29	<3.96	<1.29
PC	Site #625	Gig Harbor, Mulligan	844	108	6.50	2.92	<5.00	<1.58	<4.92	<1.58
PC	Site #697	Browns Point, Wolverton	692	95.5	21.1	11.0	2.00	<1.39	<4.34	<1.39
PC	Site #953	Browns Point, Carlson	590	86.2	15.8	5.71	9.37	<1.40	<4.42	<1.40
Partner	AI_PTW	Port Townsend Water Street	564	47.3	2.65	2.30	<0.690	<0.683	<0.683	<0.683
Partner	CB_CBSW	Commencement Bay, Skookum Wulge	995	117	26.4	14.9	4.03	<0.942	1.29	<0.942
Partner	CB_CBTF	Thea Foss Waterway	2720	116	16.5	11.5	4.19	<0.723	1.08	<0.723
Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	1450	111	26.4	18.4	6.54	<0.959	1.57	1.10
Partner	CB_JHP	Jack Hyde Park	736	42.1	8.88	3.75	<2.14	<2.14	<2.14	<2.14
Partner	CB_MW	Comm Bay, Milwaukee Waterway	641	67.7	21.0	7.71	6.29	<0.813	1.34	<0.813

Partner	CPS_EF	Edmonds Ferry	782	67.8	10.0	3.31	<2.75	<0.888	<2.75	<0.888
Partner	CPS_HCV	Port Madison, Hidden Cove	701	84.0	3.85	3.01	0.840	<0.700	1.05	<0.700
Partner	CPS_LP	Lincoln Park	424	53.1	7.51	2.65	0.734	<0.734	0.847	<0.734
Partner	CPS_MASO	Manchester, Stormwater Outfall	425	56.9	4.66	2.53	<2.66	<0.869	<2.61	<0.869
Partner	CPS_PNP	Point No Point	253	39.2	4.87	2.25	<0.683	<0.683	0.871	<0.683
Partner	CPS_QMH	Quartermaster Harbor	367	45.8	4.01	2.68	<0.986	<0.986	<0.986	2.75
Partner	CPS_SB	Salmon Bay	2040	135	19.9	34.2	12.9	<0.643	3.57	<0.643
Partner	CPS_SHLB	Shilshole Bay	2050	107	13.1	21.4	8.67	<0.816	2.36	<0.816
Partner	CPS_SP	Seacrest Park	2330	135	9.78	8.70	2.56	<0.742	2.23	<0.742
Partner	CPS_SQSO	Suquamish, Stormwater Outfall	669	56.3	4.73	2.63	<2.93	<0.975	<2.93	<0.975
Partner	CPS_WPN	West Point North	691	82.6	9.01	4.81	0.901	<0.901	0.976	<0.901
Partner	CPS_WPS	West Point South	1220	116	10.6	7.63	1.90	<0.725	1.23	<0.724
Partner	EB_FMR	Elliott Bay, Four-Mile Rock	1890	134	11.9	10.5	2.40	<1.14	<1.14	<1.14
Partner	EB_ME	Elliott Bay, Myrtle Edwards	4990	129	9.43	11.6	1.70	<0.757	0.964	<0.757
Partner	EB_P59	Elliott Bay, Pier 59	27600	221	19.3	24.9	<3.75	73.2	1.45	<1.19
Partner	HC_DBE	Duckabush Estuary	91.7	23.6	<0.951	<0.951	<0.951	<0.951	<0.951	<0.951
Partner	HC_FP	Fisherman's Point	99.3	10.7	<1.39	<1.39	<4.29	<1.39	<1.39	<1.34
Partner	HC_HO	Hood Canal, Holly	102	10.6	<1.59	<1.59	<4.77	<1.59	<1.59	<1.59
Partner	HC_PGPJ	Port Gamble, Point Julia	187	28.1	2.15	1.41	<0.674	<0.674	<0.674	<0.674
Partner	HC_PSP	Potlatch State Park	94.6	16.8	<1.20	<1.20	<3.67	<1.20	<1.20	<1.20
Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	813	63.0	9.34	9.18	1.10	<0.842	1.00	1.80
Partner	NPS_BLSC	Bellingham Bay, Little Squalicum Creek	275	41.8	24.5	5.78	<3.38	<1.07	<3.38	<1.07
Partner	NPS_CPAR4	Cherry Point Aq Reserve, Conoco Phillips	240	32.6	1.63	2.08	<4.43	<1.45	<1.45	<1.45
Partner	NPS_FBAR	Fidalgo Bay Aq Reserve, Weaverling Spit	399	38.1	2.37	6.39	<2.59	<0.862	<2.59	<0.862
Partner	PAC_GH	Grays Harbor, Bottle Beach State Park	120	38.9	1.08	2.09	<3.10	<1.01	<1.01	<1.01
Partner	PAC_WBN	Willapa Bay Nahcotta	92.2	26.2	<1.31	2.25	<3.84	<1.22	<1.22	<1.22
Partner	SJD_DB	Discovery Bay	136	22.3	1.09	1.70	<0.951	<0.951	<0.951	<0.951
Partner	SJD_JSK	Jamestown	131	23.7	<1.19	2.30	<1.19	<1.19	<1.19	<1.19
Partner	SPS_HIAP	Hammersley Inlet, Arcadia Point	240	49.5	2.89	1.98	<2.82	<0.913	<0.913	<0.913
Partner	SPS_LB	Luhr Beach	90.8	48.6	6.12	2.87	<1.11	<1.11	<1.11	<1.11
Partner	SPS_PBL	Purdy, Burley Lagoon	213	63.5	1.83	2.17	<1.22	<1.22	<1.22	<1.22
Partner	SPS_SH	Shelton, Oak Bay Marina	313	48.6	3.27	2.07	<1.04	<1.04	<1.04	<1.04
Partner	WB_CB	Cavalero Beach Co. Park	249	30.0	2.94	1.96	<0.979	<0.979	<0.979	<0.979

Partner	WB_EFP	Everett Fishing Pier	470	57.0	21.6	3.74	<1.06	<1.06	1.22	<1.06
Partner	WB_KP	Kayak Point	302	33.6	6.61	3.66	<0.675	<0.675	0.933	<0.675
Partner	WPS_PB	Point Bolin	270	71.1	5.30	3.41	<0.871	<0.871	<0.871	<0.871
Partner	WPS_SVD	Silverdale, Dyes Inlet	384	96.1	4.96	3.11	1.00	<0.814	<2.44	<0.814

Appendix B: Dry Weight Concentrations of Metals in Mussels by Site

* Mean of five replicate samples from Penn Cove, Whidbey Island aquaculture facility, the source of mussels for this effort (i.e., starting condition)
< Indicates the concentration was not measured above the reporting detection limit (RDL), which is the value reported instead
NT = Not tested; sample was not submitted for metals analysis due to lack of funding

Table B - 1. Dry weight concentrations (mg/kg) of metals in mussels at each mussel monitoring site.

Site Type	Site ID	Site Name	Concentrations in mg/kg, dry weight (ppm)						
			Aluminum	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
SAM	PCB_MEAN	Penn Cove, Pre-test Baseline MEAN	78.2	5.60	2.00	6.40	0.160	0.0290	66.2
SAM	WB_PCR	Penn Cove Reference	188	8.45	1.86	9.13	0.279	0.0426	91.3
SAM	Site #2	Arroyo Beach	181	9.01	2.16	9.19	0.363	0.0598	100
SAM	Site #3	Brackenwood Ln	220	8.55	1.92	9.94	0.250	0.0582	88.1
SAM	Site #4	Cherry Point North	226	6.96	2.16	8.38	0.259	0.0541	89.9
SAM	Site #5	Salmon Beach	147	7.91	2.41	9.39	0.347	0.0542	91.2
SAM	Site #6	Eagle Harbor Dr	152	7.97	2.16	13.1	0.823	0.0778	111
SAM	Site #8	Chimacum Creek Delta	135	7.47	1.96	14.5	0.358	0.0543	93.3
SAM	Site #10	Fletcher Bay, Fox Cove	212	7.79	2.00	10.2	0.553	0.0585	101
SAM	Site #11	South Bay Trail	206	7.06	2.43	8.24	0.765	0.0539	104
SAM	Site #13	Ruston Way	153	8.93	2.37	10.0	0.646	0.0652	92.9
SAM	Site #14	Point Heron East	164	8.53	2.32	11.5	0.577	0.0706	107
SAM	Site #15	Tugboat Park	98.7	7.78	2.60	7.39	0.184	0.0551	94.8
SAM	Site #16	Meadowdale Beach	217	8.21	2.24	8.43	0.320	0.0615	101
SAM	Site #17	Budd Inlet, West Bay	240	8.48	2.15	11.2	0.345	0.0576	104
SAM	Site #18	Seahurst	206	9.08	1.95	10.1	0.351	0.0585	85.5
SAM	Site #19	Skiff Point	160	8.72	2.51	9.12	0.284	0.0548	94.6
SAM	Site #21	Point Defiance Ferry	123	8.35	2.17	9.62	0.560	0.0602	119
SAM	Site #22	Beach Dr E	192	9.21	2.27	16.5	0.820	0.0784	114
SAM	Site #23	Wing Point	150	8.00	2.18	8.65	0.492	0.0605	100

SAM	Site #24	S of Skunk Island	146	7.38	1.94	7.79	0.597	0.0593	88.6
SAM	Site #25	Blair Waterway	142	7.63	2.20	20.0	0.734	0.0620	109
SAM	Site #26	N of Illahee State Park	167	8.48	2.83	11.7	0.498	0.0688	94.9
SAM	Site #27	Chuckanut, Clark's Point	230	7.82	1.97	8.16	0.324	0.0776	101
SAM	Site #28	Oak Harbor	175	8.03	1.99	20.1	0.420	0.0675	99.4
SAM	Site #29	Liberty Bay	200	8.97	1.99	8.97	0.716	0.0616	118
SAM	Site #30	Kitsap St Boat Launch	143	8.01	1.97	10.8	0.836	0.0733	113
SAM	Site #31	East Sound, Fishing Bay	68.4	8.22	2.14	8.68	0.299	0.0507	110
SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	125	7.78	2.19	11.1	0.687	0.0722	111
SAM	Site #35	Williams Olson Park	164	8.41	2.96	8.18	0.489	0.0579	86.4
SAM	Site #37	Saltar's Point	241	8.14	2.47	12.2	0.917	0.0648	109
SAM	Site #38	Rocky Point	124	9.11	2.15	24.7	1.39	0.0747	140
SAM	Site #39	Smith Cove, Terminal 91	179	8.10	2.22	10.1	0.752	0.0729	125
SAM	Site #42	Evergreen Rotary Park	168	8.24	2.45	8.80	0.761	0.0701	104
SAM	Site #43	N Avenue Park	173	7.23	2.34	8.78	1.01	0.0630	108
SAM	Site #46	Appletree Cove	191	7.37	2.65	7.24	0.253	0.0615	74.5
SAM	Site #47	Cherry Point Aq Reserve, Birch Bay	129	7.93	2.30	8.14	0.212	0.0558	91.4
SAM	Site #48	Naketa Beach	245	8.78	2.11	8.78	0.329	0.0673	99.3
SAM	Site #49	Donkey Creek Delta	112	10.8	2.16	11.6	0.894	0.0568	111
SAM	Site #52	Port Angeles Yacht Club	173	8.70	2.14	13.3	0.494	0.0442	109
SAM	Site #54	Dyes Inlet, Chico Bay	160	8.64	2.14	9.61	0.682	0.0662	116
SAM	Site #56	Fidalgo Island, Swinomish Res	272	7.46	2.14	9.46	0.378	0.0642	86.2
PC	Site #61	Dash Point Park	223	8.59	2.04	14.4	0.517	0.0591	93.6
PC	Site #161	Purdy, Dexters	157	8.45	2.42	9.08	0.289	0.0371	93.7
PC	Site #185	Browns Point	201	8.22	2.88	94.1	2.27	0.0373	177
PC	Site #353	Purdy, Nicholson	195	8.43	2.42	9.71	0.344	0.0361	83.6
PC	Site #481	Gig Harbor, Boat Launch	128	8.52	2.12	10.9	0.547	0.0616	112
PC	Site #625	Gig Harbor, Mulligan	152	7.49	2.06	10.5	0.591	0.0588	102
PC	Site #697	Browns Point, Wolverton	309	14.3	3.70	16.7	0.753	0.0955	162
PC	Site #953	Browns Point, Carlson	225	9.20	2.45	11.4	0.503	0.0539	97.2
Partner	AI_PTW	Port Townsend Water Street	NT	NT	NT	NT	NT	NT	NT
Partner	CB_CBSW	Commencement Bay, Skookum Wulge	NT	NT	NT	NT	NT	NT	NT
Partner	CB_CBTF	Thea Foss Waterway	NT	NT	NT	NT	NT	NT	NT

Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	159	7.53	2.45	12.7	0.652	0.0508	99.2
Partner	CB_JHP	Jack Hyde Park	NT	NT	NT	NT	NT	NT	NT
Partner	CB_MW	Comm Bay, Milwaukee Waterway	185	7.11	2.23	40.2	1.69	0.0434	131
Partner	CPS_EF	Edmonds Ferry	179	8.73	2.39	10.7	0.459	0.0590	104
Partner	CPS_HCV	Port Madison, Hidden Cove	NT	NT	NT	NT	NT	NT	NT
Partner	CPS_LP	Lincoln Park	NT	NT	NT	NT	NT	NT	NT
Partner	CPS_MASO	Manchester, Stormwater Outfall	131	7.54	2.58	7.32	0.312	0.0426	92.8
Partner	CPS_PNP	Point No Point	NT	NT	NT	NT	NT	NT	NT
Partner	CPS_QMH	Quartermaster Harbor	NT	NT	NT	NT	NT	NT	NT
Partner	CPS_SB	Salmon Bay	NT	NT	NT	NT	NT	NT	NT
Partner	CPS_SHLB	Shilshole Bay	153	6.94	2.04	10.5	0.720	0.0527	90.6
Partner	CPS_SP	Seacrest Park	NT	NT	NT	NT	NT	NT	NT
Partner	CPS_SQSO	Suquamish, Stormwater Outfall	142	8.08	2.87	8.49	0.288	0.0450	92.5
Partner	CPS_WPN	West Point North	NT	NT	NT	NT	NT	NT	NT
Partner	CPS_WPS	West Point South	NT	NT	NT	NT	NT	NT	NT
Partner	EB_FMR	Elliott Bay, Four-Mile Rock	NT	NT	NT	NT	NT	NT	NT
Partner	EB_ME	Elliott Bay, Myrtle Edwards	70.4	6.11	1.75	7.24	0.243	0.0407	101
Partner	EB_P59	Elliott Bay, Pier 59	NT	NT	NT	NT	NT	NT	NT
Partner	HC_DBE	Duckabush Estuary	263	7.92	2.86	9.77	0.270	0.0457	91.5
Partner	HC_FP	Fisherman's Point	NT	NT	NT	NT	NT	NT	NT
Partner	HC_HO	Hood Canal, Holly	NT	NT	NT	NT	NT	NT	NT
Partner	HC_PGPJ	Port Gamble, Point Julia	95.3	8.64	2.21	7.34	0.261	0.0387	98.8
Partner	HC_PSP	Potlatch State Park	NT	NT	NT	NT	NT	NT	NT
Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	198	6.66	2.32	11.2	0.469	0.0428	92.2
Partner	NPS_BLSC	Bellingham Bay, Little Squalicum Creek	204	7.27	2.60	9.42	0.238	0.0566	89.2
Partner	NPS_CPAR4	Cherry Point Aq Reserve, Conoco Phillips	NT	NT	NT	NT	NT	NT	NT
Partner	NPS_FBAR	Fidalgo Bay Aq Reserve, Weaverling Spit	241	7.69	2.42	8.44	0.369	0.0531	98.6
Partner	PAC_GH	Grays Harbor, Bottle Beach State Park	NT	NT	NT	NT	NT	NT	NT
Partner	PAC_WBN	Willapa Bay Nahcotta	NT	NT	NT	NT	NT	NT	NT
Partner	SJD_DB	Discovery Bay	153	8.52	2.43	14.7	0.394	0.0461	104
Partner	SJD_JSK	Jamestown	208	8.97	2.19	18.3	0.318	0.0392	105
Partner	SPS_HIAP	Hammersley Inlet, Arcadia Point	NT	NT	NT	NT	NT	NT	NT
Partner	SPS_LB	Luhr Beach	NT	NT	NT	NT	NT	NT	NT

Partner	SPS_PBL	Purdy, Burley Lagoon	NT	NT	NT	NT	NT	NT	NT
Partner	SPS_SH	Shelton, Oak Bay Marina	NT	NT	NT	NT	NT	NT	NT
Partner	WB_CB	Cavalero Beach Co. Park	370	6.11	2.48	9.85	0.273	0.0515	66.0
Partner	WB_EFP	Everett Fishing Pier	NT	NT	NT	NT	NT	NT	NT
Partner	WB_KP	Kayak Point	261	7.41	2.10	10.4	0.288	0.0582	81.6
Partner	WPS_PB	Point Bolin	NT	NT	NT	NT	NT	NT	NT
Partner	WPS_SVD	Silverdale, Dyes Inlet	157	8.80	2.90	10.5	0.694	0.0599	111

Appendix C: Cumulative Frequency Distribution Plots (SAM Option 1 and 2)

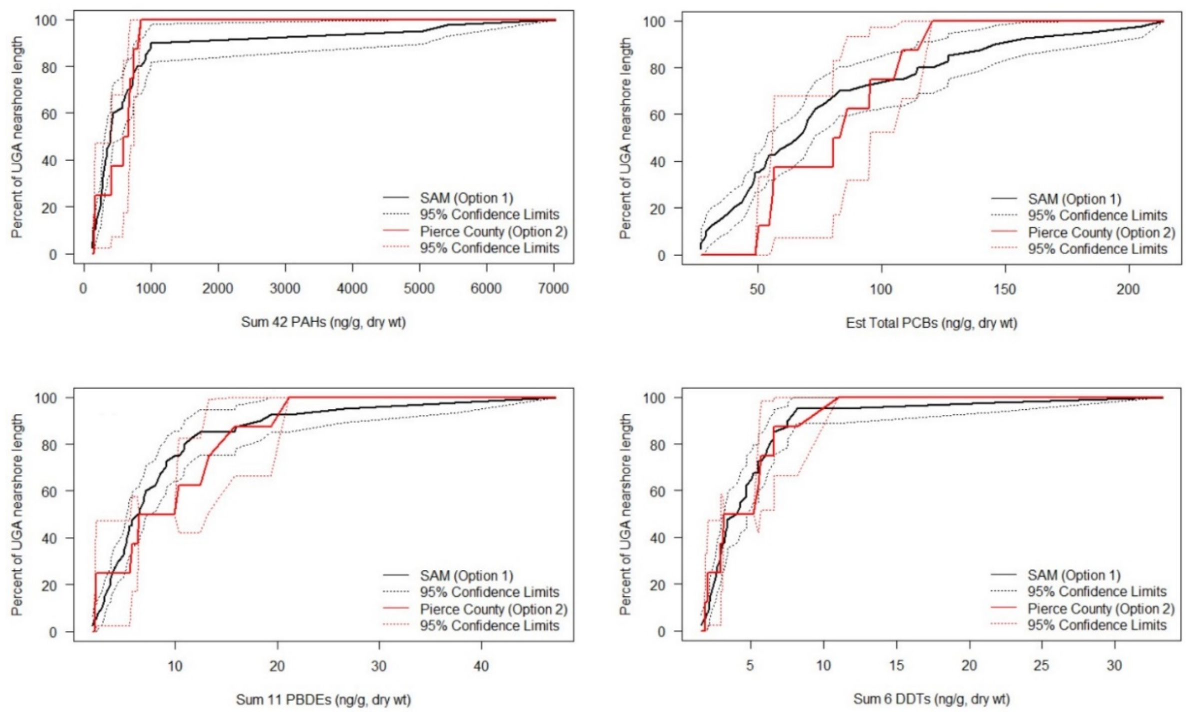

Figure C- 1. Cumulative frequency distribution (CFD) plots of Σ_{42}PAHs, TPCBs, $\sum_{11}$PBDEs, and $\sum_{6}$DDTs for 2017/18 SAM (Option 1 – black line) and Pierce County (Option 2 – red line) sites.

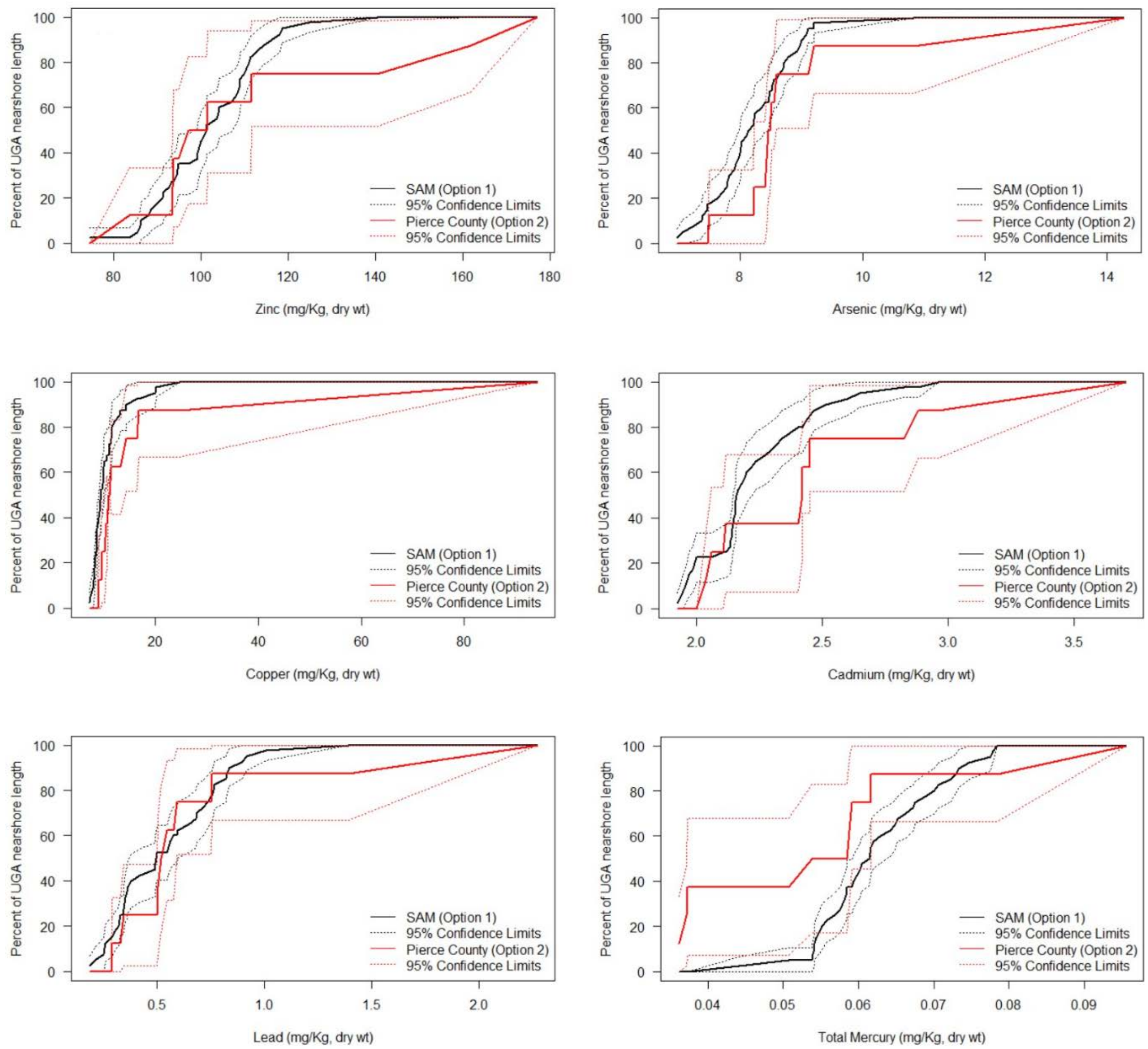

Figure C- 2. Cumulative frequency distribution (CFD) plots of zinc, arsenic, copper, cadmium, lead, and total mercury for 2017/18 SAM (Option 1 – black line) and Pierce County (Option 2 – red line) sites.

Appendix D: Mussel Site Contaminant Concentration Category by Percentile

Table D - 1 . Mussel sites with low (25th percentile), high (75th percentile), and highest (95th percentile) PAH concentrations of 92 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Σ_{42}PAHs (ng/g, dry wt.)
25th Percentile	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	75.9
	Partner	SPS_LB	Luhr Beach	90.8
	Partner	HC_DBE	Duckabush Estuary	91.7
	Partner	PAC_WBN	Willapa Bay Nahcotta	92.2
	Partner	HC_PSP	Potlach State Park	94.6
	Partner	HC_FP	Fisherman's Point	99.3
	Partner	HC_HO	Hood Canal Holly	102
	Partner	PAC_GH	Grays Harbor, Bottle Beach	120
	SAM	Site #56	Fidalgo Island, Swinomish Res	126
	SAM	Site #28	Oak Harbor	129
	Partner	SJD_JSK	Jamestown	131
	SAM	WB_PCR	Penn Cove Reference	136
	Partner	SJD_DB	Discovery Bay	136
	SAM	Site #15	Tugboat Park	137
	SAM	Site #47	Birch Bay	143
	PC	Site #353	Purdy - Nicholson	149
	PC	Site #161	Purdy - Dexters	166
	SAM	Site #8	Chimacum Creek delta	179
75th Percentile	Partner	AI_PTW	Port Townsend Water Street	564
	SAM	Site #5	Salmon Beach	573
	SAM	Site #37	Saltar's Point	580
	PC	Site #953	Browns Point - Carlson	590
	SAM	Site #42	Evergreen Rotary Park	618
	Partner	CB_MW	Comm Bay, Milwaukee Wtrwy	641
	SAM	Site #25	Blair Waterway	660
	PC	Site #481	Gig Harbor - Boat Launch	668
	Partner	CPS_SQSO	Suquamish, Stormwater Outfall	669
	Partner	CPS_WPN	West Point North	691
	PC	Site #697	Browns Point - Wolverton	692
	Partner	CPS_HCV	Port Madison, Hidden Cove	701
	SAM	Site #49	Donkey Creek Delta	732
	SAM	Site #11	South Bay Trail	733

	Partner	CB_JHP	Jack Hyde Park	736
	SAM	Site #23	Wing Point	743
	PC	Site #185	Browns Point Lighthouse Park	743
	Partner	CPS_EF	Edmonds Ferry - Brackett's Landing	782
	SAM	Site #13	Ruston Way	800
	Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	813
	PC	Site #625	Gig Harbor - Mulligan	844
	SAM	Site #30	Kitsap St Boat Launch	905
	SAM	Site #29	Liberty Bay	926
	SAM	Site #21	Point Defiance Ferry	990
	Partner	CB_CBSW	Comm Bay Skookum	995
	SAM	Site #6	Eagle Harbor Dr	1000
	Partner	CPS_WPS	West Point South	1220
	Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	1450
	Partner	EB_FMR	Elliott Bay, Four Mile Rock	1890
	Partner	CPS_SB	Salmon Bay, Commodore Park	2040
	Partner	CPS_SHLB	Shilshole	2050
	Partner	CPS_SP	Seacrest Park	2330
95th Percentile	Partner	CB_CBTF	Thea Foss Waterway	2720
	SAM	Site #43	N Avenue Park	3030
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	4990
	SAM	Site #52	Port Angeles Yacht Club	5050
	SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	5410
	SAM	Site #39	Smith Cove, Terminal 91	7020
	Partner	EB_P59	Elliott Bay, Pier 59	27600

Table D - 2. Mussel sites with low (25th percentile), high (75th percentile), and highest (95th percentile) TPCB concentrations of 92 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. TPCBs (ng/g, dry wt.)
25th Percentile	Partner	HC_HO	Hood Canal Holly	10.6
	Partner	HC_FP	Fisherman's Point	10.7
	Partner	HC_PSP	Potlach State Park	16.8
75th Percentile	SAM	Site #19	Skiff Point	52.8
	Partner	CPS_LP	Lincoln Park	53.1
	SAM	Site #17	Budd Inlet, West Bay	53.5
	SAM	Site #5	Salmon Beach	54.6
	PC	Site #161	Purdy - Dexters	56.0
	Partner	CPS_SQSO	Suquamish, Stormwater Outfall	56.3
	PC	Site #61	Dash Point Park	56.4
	Partner	CPS_MASO	Manchester, Stormwater Outfall	56.9
	Partner	WB_EFP	Everett Fishing Pier	57.0
	SAM	Site #3	Brackenwood Ln	58.8
	Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	63.0
	SAM	Site #2	Arroyo Beach	63.4
	Partner	SPS_PBL	Purdy-Burley Lagoon	63.5
	SAM	Site #37	Saltar's Point	66.1
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	67.7
	Partner	CPS_EF	Edmonds Ferry - Brackett's Landing	67.8
	SAM	Site #26	N of Illahee State Park	68.3
	SAM	Site #25	Blair Waterway	69.3
	SAM	Site #23	Wing Point	70.0
	Partner	WPS_PB	Point Bolin	71.1
	SAM	Site #35	Williams Olson Park	71.9
	SAM	Site #13	Ruston Way	73.3
	SAM	Site #29	Liberty Bay	77.4
	SAM	Site #10	Fletcher Bay, Fox Cove	80.1
	PC	Site #185	Browns Point Lighthouse Park	80.6
	Partner	CPS_WPN	West Point North	82.6
	SAM	Site #21	Point Defiance Ferry	82.9
	Partner	CPS_HCV	Port Madison, Hidden Cove	84.0
	PC	Site #953	Browns Point - Carlson	86.2
	SAM	Site #14	Point Heron East	94.7
	PC	Site #697	Browns Point - Wolverton	95.5

	Partner	WPS_SVD	Silverdale, Dyes Inlet	96.1
	SAM	Site #54	Dyes Inlet, Chico Bay	105
	Partner	CPS_SHLB	Shilshole	107
	PC	Site #625	Gig Harbor - Mulligan	108
	Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	111
	SAM	Site #38	Rocky Point	114
	SAM	Site #22	Beach Dr E	115
	Partner	CPS_WPS	West Point South	116
	Partner	CB_CBTF	Thea Foss Waterway	116
	Partner	CB_CBSW	Comm Bay Skookum	117
	PC	Site #481	Gig Harbor - Boat Launch	120
	SAM	Site #42	Evergreen Rotary Park	127
	SAM	Site #52	Port Angeles Yacht Club	127
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	129
95th Percentile	Partner	EB_FMR	Elliott Bay, Four Mile Rock	134
	Partner	CPS_SP	Salmon Bay, Commodore Park	135
	Partner	CPS_SB	Seacrest Park	135
	SAM	Site #6	Eagle Harbor Dr	139
	SAM	Site #16	Meadowdale Beach	146
	SAM	Site #49	Donkey Creek Delta	158
	SAM	Site #30	Kitsap St Boat Launch	185
	SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	205
	SAM	Site #39	Smith Cove, Terminal 91	214
	Partner	EB_P59	Elliott Bay, Pier 59	221

Table D - 3. Mussel sites where $\sum_{11}$PBDEs were not detected above the limit of quantitation (LOQ) and sites with low (25th percentile), high (75th percentile), and highest (95th percentile) PBDE concentrations of 92 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. $\sum_{11}$PBDEs (ng/g, dry wt.)
25th Percentile	Partner	HC_DBE	Duckabush Estuary	ND
	Partner	HC_FP	Fisherman's Point	ND
	Partner	HC_HO	Hood Canal Holly	ND
	Partner	HC_PSP	Potlach State Park	ND
	Partner	PAC_WBN	Willapa Bay Nahcotta	ND
	Partner	SJD_JSK	Jamestown	ND
	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	0.601
	Partner	PAC_GH	Grays Harbor, Bottle Beach	1.08
	Partner	SJD_DB	Discovery Bay	1.09
	Partner	NPS_CPAR4	Cherry Point Aquatic Reserve, Conoco Phillips	1.63
	Partner	SPS_PBL	Purdy-Burley Lagoon	1.83
	SAM	Site #56	Fidalgo Island, Swinomish Res	1.91
	SAM	Site #31	Eastsound, Fishing Bay	2.12
	Partner	HC_PGPJ	Port Gamble Bay	2.15
	PC	Site #161	Purdy - Dexters	2.21
	PC	Site # 353	Purdy - Nicholson	2.27
	Partner	NPS_FBAR	Fidalgo Bay Aq Reserve, Weaverling Spit	2.37
	SAM	Site #47	Birch Bay	2.47
	Partner	AI_PTW	Port Townsend Water Street	2.65
	SAM	Site #52	Port Angeles Yacht Club	2.83
	Partner	SPS_HIAP	Hammersley Inlet-Arcadia Point	2.89
	Partner	WB_CB	Cavalero Beach	2.94
75th Percentile	PC	Site #61	Dash Point Park	10.3
	Partner	CPS_WPS	West Point South	10.6
	SAM	Site #13	Ruston Way	10.9
	SAM	Site #21	Point Defiance Ferry	10.9
	SAM	Site #38	Rocky Point	11.6
	Partner	EB_FMR	Elliott Bay, Four Mile Rock	11.9
	SAM	Site #2	Arroyo Beach	12.4
	Partner	CPS_SHLB	Shilshole	13.1
	PC	Site #185	Browns Point Lighthouse Park	13.3
	PC	Site #953	Browns Point - Carlson	15.8
	SAM	Site #39	Smith Cove, Terminal 91	16.0
	Partner	CB_CBTF	Thea Foss Waterway	16.5

	SAM	Site #30	Kitsap St Boat Launch	18.3
	Partner	EB_P59	Elliott Bay, Pier 59	19.3
	SAM	Site #22	Beach Dr E	19.4
	Partner	CPS_SB	Salmon Bay, Commodore Park	19.9
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	21.0
	PC	Site #697	Browns Point - Wolverton	21.1
	Partner	WB_EFP	Everett Fishing Pier	21.6
95th Percentile	Partner	NPS_BLSC	Bellingham Little Squalicum Creek	24.5
	Partner	CB_CBSW	Comm Bay Skookum	26.4
	Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	26.4
	SAM	Site #43	N Avenue Park	26.5
	SAM	Site #25	Blair Waterway	37.4
	SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	47.2

ND - not detected; limit of quantitation ranged from 0.95 to 1.59 ng/g, dry weight.

Table D - 4. Mussel sites where $\sum_6$DDTs were not detected above the limit of quantitation (LOQ) and sites with low (25th percentile), high (75th percentile), and highest (95th percentile) DDT concentrations of 92 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. $\sum_6$DDTs (ng/g, dry wt.)
25th Percentile	Partner	HC_DBE	Duckabush Estuary	ND
	Partner	HC_FP	Fisherman's Point	ND
	Partner	HC_HO	Hood Canal Holly	ND
	Partner	HC_PSP	Potlach State Park	ND
	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	1.29
	Partner	HC_PGPJ	Port Gamble Bay	1.41
	SAM	Site #31	Eastsound, Fishing Bay	1.56
	Partner	SJD_DB	Discovery Bay	1.70
	SAM	Site #8	Chimacum Creek Delta	1.79
	PC	Site #353	Purdy - Nicholson	1.88
	Partner	WB_CB	Cavalero Beach	1.96
	Partner	SPS_HIAP	Hammersley Inlet-Arcadia Point	1.98
75th Percentile	SAM	Site #37	Saltar's Point	3.30
	Partner	CPS_EF	Edmonds Ferry - Brackett's Landing	3.31
	SAM	Site #10	Fletcher Bay, Fox Cove	3.37
	Partner	WPS_PB	Point Bolin	3.41
	SAM	Site #49	Donkey Creek Delta	3.41
	Partner	WB_KP	Kayak Point	3.66
	Partner	WB_EFP	Everett Fishing Pier	3.74
	Partner	CB_JHP	Jack Hyde Park	3.75
	SAM	Site #2	Arroyo Beach	3.98
	SAM	Site #23	Wing Point	4.20
	SAM	Site #38	Rocky Point	4.28
	SAM	Site #54	Dyes Inlet, Chico Bay	4.68
	SAM	Site #29	Liberty Bay	4.72
	SAM	Site #21	Point Defiance Ferry	4.73
	Partner	CPS_WPN	West Point North	4.81
	SAM	Site #22	Beach Dr E	5.04
	SAM	Site #18	Seahurst	5.16
	PC	Site #61	Dash Point Park	5.50
	SAM	Site #19	Skiff Point	5.54
	SAM	Site #11	South Bay Trail	5.55
	PC	Site #953	Browns Point - Carlson	5.71
	Partner	NPS_BLSC	Bellingham Little Squalicum Creek	5.78
	SAM	Site #30	Kitsap St Boat Launch	6.01
	SAM	Site #6	Eagle Harbor Dr	6.13

	SAM	Site #43	N Avenue Park	6.27
	SAM	WB_PCR	Penn Cove Reference	6.37
	Partner	NPS_FBAR	Fidalgo Bay Aq Reserve, Weaverling Spit	6.39
	SAM	Site #28	Oak Harbor	6.57
	SAM	Site #27	Chuckanut, Clark's Point	6.58
	PC	Site #185	Browns Point Lighthouse Park	6.60
	SAM	Site #42	Evergreen Rotary Park	7.52
	SAM	Site #56	Fidalgo Island, Swinomish Res	7.55
	Partner	CPS_WPS	West Point South	7.63
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	7.71
	SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	7.91
	SAM	Site #25	Blair Waterway	8.20
	Partner	CPS_SP	Seacrest Park	8.70
	Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	9.18
	Partner	EB_FMR	Elliott Bay, Four Mile Rock	10.5
	PC	Site #697	Browns Point - Wolverton	11.0
	Partner	CB_CBTF	Thea Foss Waterway	11.5
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	11.6
95th Percentile	Partner	CB_CBSW	Comm Bay Skookum	14.9
	Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	18.4
	Partner	CPS_SHLB	Shilshole	21.4
	SAM	Site #39	Smith Cove, Terminal 91	21.7
	Partner	EB_P59	Elliott Bay, Pier 59	24.9
	SAM	Site #52	Port Angeles Yacht Club	33.3
	Partner	CPS_SB	Salmon Bay, Commodore Park	34.2

ND - not detected; limit of quantitation ranged from 0.95 to 1.59 ng/g, dry weight.

Table D - 5. Mussel sites with low (25th percentile), high (75th percentile), and highest (95th percentile) aluminum concentrations of 66 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Al (mg/kg, dry wt.)
25th Percentile	SAM	Site #31	Eastsound, Fishing Bay	68.4
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	70.4
	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	78.2
	Partner	HC_PGPJ	Port Gamble Bay	95.3
	SAM	Site #15	Tugboat Park	98.7
	SAM	Site #49	Donkey Creek Delta	112
	SAM	Site #21	Point Defiance Ferry	123
	SAM	Site #38	Rocky Point	124
	SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	125
	PC	Site #481	Gig Harbor - Boat Launch	128
	SAM	Site #47	Birch Bay	129
	Partner	CPS_MASO	Manchester, Stormwater Outfall	131
	SAM	Site #8	Chimacum Creek Delta	135
	SAM	Site #25	Blair Waterway	142
	Partner	CPS_SQSO	Suquamish, Stormwater Outfall	142
	SAM	Site #30	Kitsap St Boat Launch	143
	SAM	Site #24	S of Skunk Island	146
	SAM	Site #5	Salmon Beach	147
75th Percentile	SAM	Site #10	Fletcher Bay, Fox Cove	212
	SAM	Site #16	Meadowdale Beach	217
	SAM	Site #3	Brackenwood Ln	220
	PC	Site #61	Dash Point Park	223
	PC	Site #953	Browns Point - Carlson	225
	SAM	Site #4	Cherry Point	226
	SAM	Site #27	Chuckanut, Clark's Point	230
	SAM	Site #17	Budd Inlet, West Bay	240
	SAM	Site #37	Saltar's Point	241
	Partner	NPS_FBAR	Fidalgo Bay Aq Reserve, Weaverling Spit	241
	SAM	Site #48	Naketa Beach	245
	Partner	WB_KP	Kayak Point	261
	Partner	HC_DBE	Duckabush Estuary	263
95th Percentile	SAM	Site #56	Fidalgo Island, Swinomish Res	272
	PC	Site #697	Browns Point - Wolverton	309
	Partner	WB_CB	Cavalero Beach	370

Table D - 6. Mussel sites with low (25th percentile), high (75th percentile), and highest (95th percentile) arsenic concentrations of 66 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Total As (mg/kg, dry wt.)
25th Percentile	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	5.60
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	6.11
	Partner	WB_CB	Cavalero Beach	6.11
	Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	6.66
	Partner	CPS_SHLB	Shilshole	6.94
	SAM	Site #4	Cherry Point	6.96
	SAM	Site #11	South Bay Trail	7.06
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	7.11
	SAM	Site #43	N Avenue Park	7.23
	Partner	NPS_BLSC	Bellingham Little Squalicum Creek	7.27
	SAM	Site #46	Appletree Cove	7.37
	SAM	Site #24	S of Skunk Island	7.38
	Partner	WB_KP	Kayak Point	7.41
	SAM	Site #56	Fidalgo Island, Swinomish Res	7.46
	SAM	Site #8	Chimacum Creek delta	7.47
	PC	Site #625	Gig Harbor - Mulligan	7.49
	Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	7.53
	Partner	CPS_MASO	Manchester, Stormwater Outfall	7.54
75th Percentile	SAM	Site #52	Port Angeles Yacht Club	8.70
	SAM	Site #19	Skiff Point	8.72
	Partner	CPS_EF	Edmonds Ferry - Brackett's Landing	8.73
	SAM	Site #48	Naketa Beach	8.78
	Partner	WPS_SVD	Silverdale, Dyes Inlet	8.80
	SAM	Site #13	Ruston Way	8.93
	SAM	Site #29	Liberty Bay	8.97
	Partner	SJD_JSK	Jamestown	8.97
	SAM	Site #2	Arroyo Beach	9.01
	SAM	Site #18	Seahurst	9.08
	SAM	Site #38	Rocky Point	9.11
	PC	Site #953	Browns Point - Carlson	9.20
	SAM	Site #22	Beach Dr E	9.21

95th Percentile	SAM	Site #49	Donkey Creek Delta	10.8
	PC	Site #697	Browns Point - Wolverton	14.3

Table D - 7. Mussel sites with high (75th percentile) and highest (95th percentile) cadmium concentrations of 66 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Cd (mg/kg, dry wt.)
25th Percentile	Partner	EB_ME	Elliott Bay, Myrtle Edwards	1.75
	SAM	WB_PCR	Penn Cove Reference	1.86
	SAM	Site #3	Brackenwood Ln	1.92
	SAM	Site #24	S of Skunk Island	1.94
	SAM	Site #18	Seahurst	1.95
	SAM	Site #8	Chimacum Creek Delta	1.96
	SAM	Site #30	Kitsap St Boat Launch	1.97
	SAM	Site #27	Chuckanut, Clark's Point	1.97
	SAM	Site #29	Liberty Bay	1.99
	SAM	Site #28	Oak Harbor	1.99
	SAM	Site #10	Fletcher Bay, Fox Cove	2.00
	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	2.00
	PC	Site #61	Dash Point Park	2.04
	Partner	CPS_SHLB	Shilshole	2.04
	PC	Site #625	Gig Harbor - Mulligan	2.06
	Partner	WB_KP	Kayak Point	2.10
	SAM	Site #48	Naketa Beach	2.11
	PC	Site #481	Gig Harbor - Boat Launch	2.12
75th Percentile	SAM	Site #42	Evergreen Rotary Park	2.45
	PC	Site #953	Browns Point - Carlson	2.45
	SAM	Site #37	Saltar's Point	2.47
	Partner	WB_CB	Cavalero Beach	2.48
	SAM	Site #19	Skiff Point	2.51
	Partner	CPS_MASO	Manchester, Stormwater Outfall	2.58
	Partner	NPS_BLSC	Bellingham Little Squalicum Creek	2.60
	SAM	Site #15	Tugboat Park	2.60

	SAM	Site #46	Appletree Cove	2.65
	SAM	Site #26	N of Illahee State Park	2.83
	Partner	HC_DBE	Duckabush Estuary	2.86
	Partner	CPS_SQSO	Suquamish, Stormwater Outfall	2.87
	PC	Site #185	Browns Point Lighthouse Park	2.88
95th Percentile	SAM	Site #35	Williams Olson Park	2.96
	PC	Site #697	Browns Point - Wolverton	3.70
	Partner	WPS_SVD	Silverdale, Dyes Inlet	2.90

Table D - 8. Mussel sites with high (75th percentile) and highest (95th percentile) copper concentrations of 66 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Cu (mg/kg, dry wt.)
25th Percentile	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	6.40
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	7.24
	SAM	Site #46	Appletree Cove	7.24
	Partner	CPS_MASO	Manchester, Stormwater Outfall	7.32
	Partner	HC_PGPJ	Port Gamble Bay	7.34
	SAM	Site #15	Tugboat Park	7.39
	SAM	Site #24	S of Skunk Island	7.79
	SAM	Site #47	Birch Bay	8.14
	SAM	Site #27	Chuckanut, Clark's Point	8.16
	SAM	Site #35	Williams Olson Park	8.18
	SAM	Site #11	South Bay Trail	8.24
	SAM	Site #4	Cherry Point	8.38
	SAM	Site #16	Meadowdale Beach	8.43
	Partner	NPS_FBAR	Fidalgo Bay Aq Reserve, Weaverling Spit	8.44
	Partner	CPS_SQSO	Suquamish, Stormwater Outfall	8.49
	SAM	Site #23	Wing Point	8.65
	SAM	Site #31	Eastsound, Fishing Bay	8.68
75th Percentile	SAM	Site #37	Saltar's Point	12.2
	Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	12.7
	SAM	Site #6	Eagle Harbor Dr	13.1
	SAM	Site #52	Port Angeles Yacht Club	13.3

	PC	Site #61	Dash Point Park	14.4
	SAM	Site #8	Chimacum Creek Delta	14.5
	Partner	SJD_DB	Discovery Bay	14.7
	SAM	Site #22	Beach Dr E	16.5
	PC	Site #697	Browns Point - Wolverton	16.7
	Partner	SJD_JSK	Jamestown	18.3
	SAM	Site #25	Blair Waterway	20.0
	SAM	Site #28	Oak Harbor	20.1
95th Percentile	SAM	Site #38	Rocky Point	24.7
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	40.2
	PC	Site #185	Browns Point Lighthouse Park	94.1

Table D - 9. Mussel sites with low (25th percentile), high (75th percentile) and highest (95th percentile) lead concentrations of 66 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Pb (mg/kg, dry wt.)
25th Percentile	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	0.160
	SAM	Site #15	Tugboat Park	0.184
	SAM	Site #47	Birch Bay	0.212
	Partner	NPS_BLSC	Bellingham Little Squalicum Creek	0.238
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	0.243
	SAM	Site #3	Brackenwood Ln	0.250
	SAM	Site #46	Appletree Cove	0.253
	SAM	Site #4	Cherry Point	0.259
	Partner	HC_PGPJ	Port Gamble Bay	0.261
	Partner	HC_DBE	Duckabush Estuary	0.270
	Partner	WB_CB	Cavalero Beach	0.273
	SAM	WB_PCR	Penn Cove Reference	0.279
	SAM	Site #19	Skiff Point	0.284
	Partner	CPS_SQSO	Suquamish, Stormwater Outfall	0.288
	Partner	WB_KP	Kayak Point	0.288
	PC	Site #161	Purdy - Dexters	0.289
	SAM	Site #31	Eastsound, Fishing Bay	0.299

	Partner	CPS_MASO	Manchester, Stormwater Outfall	0.312
75th Percentile	SAM	Site #29	Liberty Bay	0.716
	Partner	CPS_SHLB	Shilshole	0.720
	SAM	Site #25	Blair Waterway	0.734
	SAM	Site #39	Smith Cove, Terminal 91	0.752
	PC	Site #697	Browns Point - Wolverton	0.753
	SAM	Site #42	Evergreen Rotary Park	0.761
	SAM	Site #11	South Bay Trail	0.765
	SAM	Site #22	Beach Dr E	0.820
	SAM	Site #6	Eagle Harbor Dr	0.823
	SAM	Site #30	Kitsap St Boat Launch	0.836
	SAM	Site #49	Donkey Creek Delta	0.894
	SAM	Site #37	Saltar's Point	0.917
	SAM	Site #43	N Avenue Park	1.01
95th Percentile	SAM	Site #38	Rocky Point	1.39
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	1.69
	PC	Site #185	Browns Point Lighthouse Park	2.27

Table D - 10. Mussel sites with low (25th percentile), high (75th percentile) and highest (95th percentile) mercury concentrations of 66 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Hg (mg/kg, dry wt.)
25th Percentile	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	0.0290
	PC	Site #353	Purdy - Nicholson	0.0361
	PC	Site #161	Purdy - Dexters	0.0371
	PC	Site #185	Browns Point Lighthouse Park	0.0373
	Partner	HC_PGPJ	Port Gamble Bay	0.0387
	Partner	SJD_JSK	Jamestown	0.0392
	Partner	EB_ME	Elliott Bay, Myrtle Edwards	0.0407
	Partner	CPS_MASO	Manchester, Stormwater Outfall	0.0426
	SAM	WB_PCR	Penn Cove Reference	0.0426
	Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	0.0428
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	0.0434
	SAM	Site #52	Port Angeles Yacht Club	0.0442
	Partner	CPS_SQSO	Suquamish, Stormwater Outfall	0.0450
	Partner	HC_DBE	Duckabush Estuary	0.0457

	Partner	SJD_DB	Discovery Bay	0.0461
	SAM	Site #31	Eastsound, Fishing Bay	0.0507
	Partner	CB_DGL	Comm Bay, Dick Gilmur Launch	0.0508
	Partner	WB_CB	Cavalero Beach	0.0515
75th Percentile	SAM	Site #37	Saltar's Point	0.0648
	SAM	Site #13	Ruston Way	0.0652
	SAM	Site #54	Dyes Inlet, Chico Bay	0.0662
	SAM	Site #48	Naketa Beach	0.0673
	SAM	Site #28	Oak Harbor	0.0675
	SAM	Site #26	N of Illahee State Park	0.0688
	SAM	Site #42	Evergreen Rotary Park	0.0701
	SAM	Site #14	Point Heron East	0.0706
	SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	0.0722
	SAM	Site #39	Smith Cove, Terminal 91	0.0729
	SAM	Site #30	Kitsap St Boat Launch	0.0733
	SAM	Site #38	Rocky Point	0.0747
	SAM	Site #27	Chuckanut, Clark's Point	0.0776
95th Percentile	SAM	Site #6	Eagle Harbor Dr	0.0778
	SAM	Site #22	Beach Dr E	0.0784
	PC	Site #697	Browns Point - Wolverton	0.0955

Table D - 11. Mussel sites with low (25th percentile), high (75th percentile) and highest (95th percentile) zinc concentrations of 66 monitoring sites and the baseline sample.

	Source	Site ID	Site Name	Conc. Zn (mg/kg, dry wt.)
25th Percentile	Partner	WB_CB	Cavalero Beach	66.0
	SAM	PCB_MEAN	Baseline (Penn Cove, pre-deployment samples)	66.2
	SAM	Site #46	Appletree Cove	74.5
	Partner	WB_KP	Kayak Point	81.6
	PC	Site #353	Purdy - Nicholson	83.6
	SAM	Site #18	Seahurst	85.5
	SAM	Site #56	Fidalgo Island, Swinomish Res	86.2
	SAM	Site #35	Williams Olson Park	86.4
	SAM	Site #3	Brackenwood Ln	88.1
	SAM	Site #24	S of Skunk Island	88.6

	Partner	NPS_BLSC	Bellingham Little Squalicum Creek	89.2
	SAM	Site #4	Cherry Point	89.9
	Partner	CPS_SHLB	Shilshole	90.6
	SAM	Site #5	Salmon Beach	91.2
	SAM	WB_PCR	Penn Cove Reference	91.3
	SAM	Site #47	Birch Bay	91.4
	Partner	HC_DBE	Duckabush Estuary	91.5
	Partner	NPS_BBWW	Bellingham Bay, Whatcom Waterway	92.2
75th Percentile	SAM	Site #49	Donkey Creek Delta	111
	SAM	Site #34	Elliott Bay, Harbor Island, Pier 17	111
	Partner	WPS_SVD	Silverdale, Dyes Inlet	111
	SAM	Site #6	Eagle Harbor Dr	111
	PC	Site #481	Gig Harbor - Boat Launch	112
	SAM	Site #30	Kitsap St Boat Launch	113
	SAM	Site #22	Beach Dr E	114
	SAM	Site #54	Dyes Inlet, Chico Bay	116
	SAM	Site #29	Liberty Bay	118
	SAM	Site #21	Point Defiance Ferry	119
	SAM	Site #39	Smith Cove, Terminal 91	125
	Partner	CB_MW	Comm Bay, Milwaukee Waterway	131
95th Percentile	SAM	Site #38	Rocky Point	140
	PC	Site #697	Browns Point - Wolverton	162
	PC	Site #185	Browns Point Lighthouse Park	177