Marine Conditions 2008–2019 Report Series: Clam Tissue

December 2022

King County

Department of Natural Resources and Parks
Water and Land Resources Division
Science and Technical Support Section
King Street Center, KSC-NR-5600
201 South Jackson Street, Suite 5600
Seattle, WA 98104
206-477-4800 TTY Relay: 711
www.kingcounty.gov/EnvironmentalScience

Alternate Formats Available
206-477-4800 TTY Relay: 711

Marine Conditions 2008–2019 Report Series: Clam Tissue

Submitted by:

Wendy Eash-Loucks
King County Water and Land Resources Division
Department of Natural Resources and Parks

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

Acknowledgements

The author would like to thank King County Environmental Laboratory (KCEL) for their contributions to this work, including field collection, laboratory project management, and laboratory analysis by KCEL staff. Technical review was provided by King County staff including Kimberle Stark, Taylor Martin, Wafa Tafesh, Beth leDoux, and Josh Latterell of the Science and Technical Support Section, Gabriela Hannach of KCEL, and Jeff Stern and Debra Williston of the Wastewater Water Treatment Division's Environmental and Community Services Section.

Citation

King County. 2022. Marine Conditions 2008–2019 Report Series: Clam Tissue. Prepared by Staff Eash-Loucks, Wendy, Water and Land Resources Division. Seattle, Washington.

Table of Contents

1.0 Introduction 1
2.0 Methods 3
2.1 Sampling Locations 3
2.2 Sampling and Analysis Methods 5
2.2.1 Sample Collection and Processing 5
2.2.2 Sample Analysis 5
2.2.3 Data Analysis 6
3.0 Results 8
3.1 Conventional Parameters 8
3.2 Metals 9
3.3 PBDEs 15
4.0 Summary 17
5.0 References 18

Figures

Figure 1. Clam tissue sampling locations 4
Figure 2. Percent total solids in clam tissue by site and season (2008–2010). * Indicate outfall site. 8
Figure 3. Percent lipids in clam tissue by site and season (2008–2010). * Indicate outfall site. 9
Figure 4. Metal concentrations (mg/Kg ww) in clam tissue by site, year and season (2008–2010). 11
Figure 5. Box plots illustrating clam tissue metals concentrations (mg/Kg ww) by site type (ambient vs outfall), all data (2008–2010) combined. 12
Figure 6. Metal concentrations (mg/Kg ww) in clam tissue at five long-term monitoring stations (1998–2010). 14
Figure 7. Summed PBDE concentrations (µg/Kg ww) by sampling event (2008–2010). 16
Figure 8. Box plots illustrating summed PBDE concentrations (µg/Kg ww) by site type (ambient vs outfall); all data (2008–2010) combined. 16

Tables

Table 1. Clam tissue monitoring stations listed from north to south. 3

Table 2. Parameters measured in butter clam tissue including wet weight MDLs and analytical methods. 6

Table 3. Applicable FDA levels of concern for edible portions of fish and shellfish and WADOH screening levels for general and high seafood consumers. 7

Table 4. Summary of results for shell length and conventional parameters in composite clam tissues samples (2008–2010) by sampling season. 8

Table 5. Summary of metal results (mg/Kg ww) in clam tissue (2008–2010). Bold red values > WADOH screening levels for high seafood consumers. 10

Table 6. Metals with discernable overall trend ($p < .05$); all summer data combined (1998–2010) for five sites. 13

Table 7. Summary of PBDE results (µg/Kg ww) in clam tissues (2008–2010). 15

Appendices

Appendix A: Trend Analysis Results

This page intentionally left blank.

1.0 INTRODUCTION

For over 50 years, King County has conducted extensive water quality monitoring to assess conditions in the Central Puget Sound Basin (King County waters). The King County Marine Monitoring Program is managed by scientists in the Water and Land Resources Division within the Department of Natural Resources. The program includes two types of monitoring (1) baseline monitoring to assess background conditions (ambient monitoring) and (2) monitoring to assess conditions near King County's wastewater treatment plant (TP), combined sewer overflow (CSO), and CSO wet weather treatment station (TS) marine outfalls (outfall monitoring).

The goals of the Marine Monitoring Program are to characterize water quality and food web (phytoplankton and zooplankton) conditions in King County receiving waters, provide information for management decisions, and evaluate the status and trends of marine waters within King County. These data provide insight into both short and long-term variations and form a baseline from which water quality conditions can be assessed on multiple temporal and spatial scales. Please see *Marine Conditions Report Series 2008–2019: Marine Monitoring Program Overview* (King County, 2022a) for a more detailed description of the background and purpose of the Marine Monitoring Program.

The Marine Monitoring Program includes multiple sampling components and parameters. This report provides results of the clam tissue contaminant monitoring component of the Marine Monitoring Program. Results for samples collected from 2008–2010 (contaminant monitoring in clam was discontinued at the end of 2010 due to funding limitations) are presented here.

Most clams feed by filtering large volumes of water, consuming suspended matter and food particles from the water column. In addition to bioaccumulating contaminants via food particles, clams can also be exposed to some contaminants directly from water concentrating them in their tissues at higher levels than the surrounding water. Butter clams (*Saxidomus gigantea*) were selected as the target organism because they were present at all sites. Clams were sampled in both spring and summer to evaluate whether contaminant concentrations differ with season and lipid content, which can change seasonally.

Monitoring contaminant levels in clams can provide information on spatial and temporal patterns of contaminants. Additionally, while shellfish beds are closed along most of the King County shoreline due to potential bacterial contamination in a densely populated area from outfalls and runoff, people may still eat locally harvested clams. Monitoring tissue contaminant levels in clams provides additional information to inform public health agencies as well as people who may collect and consume them from the monitoring area.

Clam tissue data are used to:

- Evaluate concentrations of select contaminants in butter clam tissue for comparison to applicable state and national levels established to protect consumers of fish and shellfish
- Determine if there are seasonal and spatial (e.g., outfall vs ambient) differences in clam tissue contaminant concentrations
- Gather sufficient data to determine both short and long-term trends in clam tissue contaminant concentrations
- Assess potential changes in clam tissue contaminant concentrations following TP unexpected mechanical failures and discharges by comparing against historical data.

Summer clam tissue samples were often (but not always) collected concurrently with intertidal sediment samples, which is described in (King County, 2022b) Additionally, water quality samples for bacteria, physical parameters, and nutrients, were also collected monthly at many of the same clam sampling stations. A summary of all water quality data collected at each station is provided in *Marine Conditions Report Series 2008–2019: Marine Monitoring Program Overview* (King County, 2022a). Results for other Marine Monitoring Program components sampled between 2008–2019 (except pH), are provided in separate reports with hyperlinks (click on titles to access reports) below and include the following topics:

- Marine Monitoring Program overview
- Nutrients in offshore waters
- Nutrients in beach waters
- Dissolved oxygen in offshore waters
- Temperature, salinity, and density in offshore waters
- Temperature and salinity in beach waters
- Water clarity in offshore waters
- Fecal indicator bacteria in beach and offshore waters
- Chlorophyll in offshore waters
- Phytoplankton
- Zooplankton
- Chemical and physical parameters and benthic infauna in beach (intertidal) and offshore (subtidal) sediments.

2.0 METHODS

Sampling location information and sampling and analysis methods used to assess contaminants in butter clams are described below. More details on methods can be found in the *Marine Program Sampling and Analysis Plan* (King County, 2003).

2.1 Sampling Locations

Butter clams were collected from 10 stations located along the King County shoreline from Edwards Point in the north to Burton Acres Park in Quartermaster Harbor in the south (Table 1, Figure 1). Six stations were located near outfalls TP, TS, or CSO outfalls and four were considered ambient locations. Site MSXK01 (Burton Acres Park – Vashon Island) was only sampled in 2010.

Table 1. Clam tissue monitoring stations listed from north to south.

Locator Name	Location	Station Type
ITEDWARDSPT	Edwards Point	Ambient
JSVW04	Richmond Beach	Ambient
KSHZ03	Carkeek Park – Piper's Creek Outflow	Outfall
KSLU03	Golden Gardens Park	Ambient
KSSN04	West Point North Beach	Outfall
KSSN05	West Point South Beach	Outfall
LSKS04	Alki Point – South Side	Outfall
MSJL01	Vashon Outfall Beach	Outfall
MTLD03	Normandy Park	Outfall
MSXK01	Burton Acres Park	Ambient

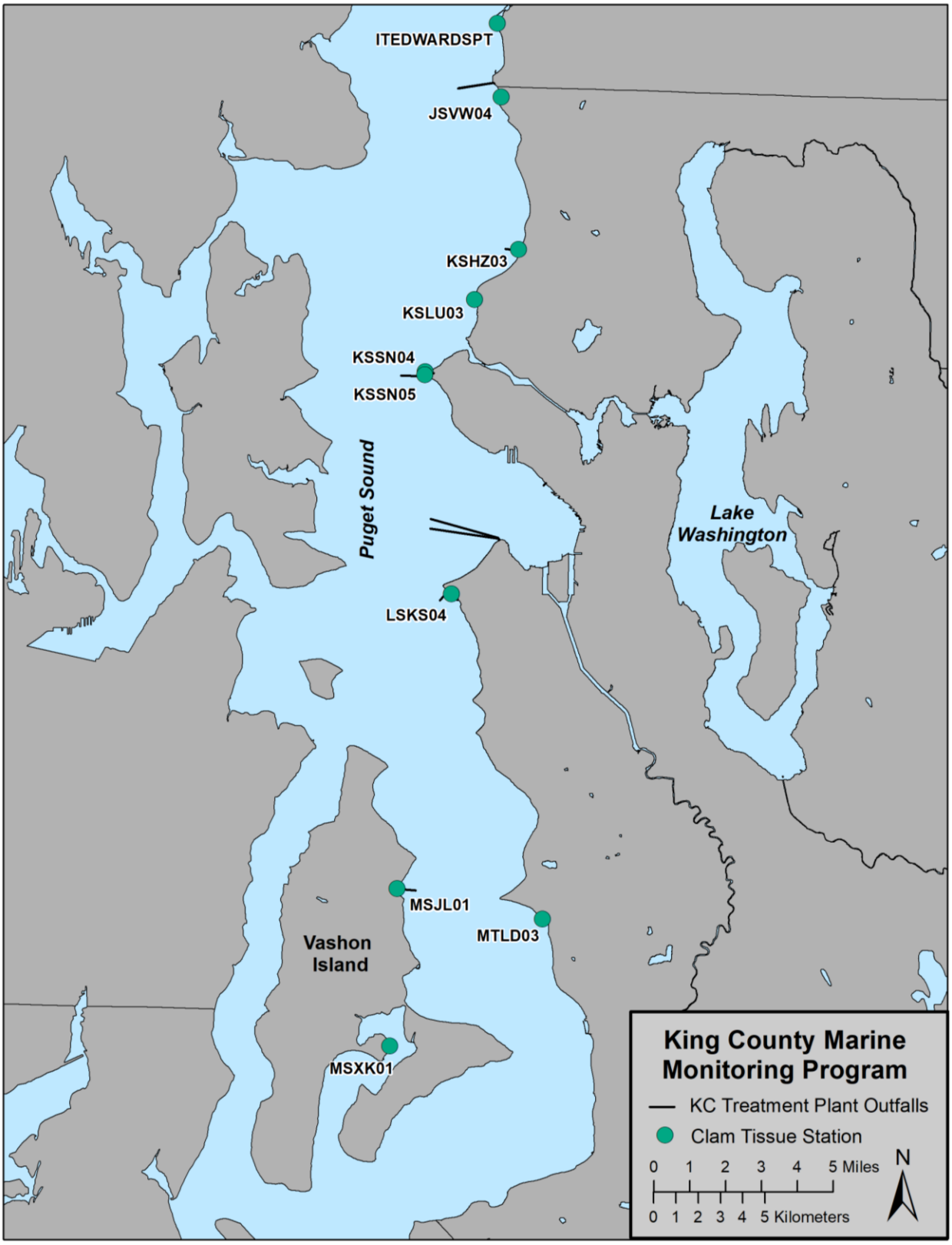

Figure 1. Clam tissue sampling locations.

2.2 Sampling and Analysis Methods

2.2.1 Sample Collection and Processing

Butter clams (*Saxidomus giganteus*) were collected in spring (March) and summer (July or August) by hand digging with shovels in the vicinity of siphon holes. A minimum of five butter clams with a shell length between 60 to 120 millimeters were collected at each station and composited into a single sample for analyses to represent each station. Clams were placed into plastic bags and stored on ice until laboratory delivery.

Clam samples were processed at the King County Environmental Laboratory (KCEL) in accordance with PSEP recommended protocols (PSEP, 1997). Prior to opening to remove the tissue, clam shells were rinsed with deionized water to remove sand and other adhering material, and shell length was recorded. Tissue from each clam was removed with ceramic scalpels, composited with the associated liquor, and then homogenized in a sterilized blender equipped with stainless steel blades.

2.2.2 Sample Analysis

Composite clam tissue samples were analyzed by KCEL for conventional parameters (lipids, total solids), metals, and polybrominated diphenyl ethers (PBDEs) (Table 2).

Total solids results were used to dry weight normalize tissue concentrations. Percent lipids were analyzed because concentration of lipids can affect accumulation of certain chemicals and can be an indicator of overall health and reproductive state. Both solids and lipids were measured gravimetrically (Table 2).

Except for mercury, all metals were analyzed using inductively coupled plasma (ICP) or ICP – mass spectrometry (ICP-MS). Mercury was analyzed using cold vapor atomic absorption (CVAA) spectroscopy. PBDEs analyzed using an ultra-sonic solvent extraction and high-resolution gas chromatography mass spectroscopy (GC-MS). Method detection limits (MDLs) for all parameters are listed in Table 2. Prior to 2006, base neutral and acid extractables, chlorinated pesticides, and polychlorinated biphenyls were also measured in clam tissue. However, except for benzoic acid (a metabolic byproduct), these organic compounds were rarely detected in clams and were no longer analyzed.

Table 2. Parameters measured in butter clam tissue including wet weight MDLs and analytical methods.

Parameter	Units	Highest ww MDL	Method
Total Solids	%	.005	Gravimetric
Total Lipids	%	.05	Gravimetric
Aluminum	mg/Kg	1.0	ICP
Arsenic	mg/Kg	0.021	ICP-MS
Beryllium	mg/Kg	0.0083	ICP-MS
Cadmium	mg/Kg	0.0041	ICP-MS
Chromium	mg/Kg	0.03	ICP
Copper	mg/Kg	0.04	ICP
Iron	mg/Kg	0.05	ICP
Lead	mg/Kg	0.0083	ICP-MS
Manganese	mg/Kg	0.02	ICP
Mercury	mg/Kg	0.00043	CVAA
Nickel	mg/Kg	0.012	ICP-MS
Selenium	mg/Kg	0.062	ICP-MS
Silver	mg/Kg	0.08	ICP
Zinc	mg/Kg	0.05	ICP
TriBDE-17, TriBDE-28, TetraBDE-47, TetraBDE-66, TetraBDE-71, PentaBDE-85, PentaBDE-99, PentaBDE-100, HexaBDE-138, HexaBDE-153, HexaBDE-154, HeptaBDE-183, HeptaBDE-19	µg/Kg	0.021	GC-MS
DecaBDE-209	µg/Kg	0.11	GC-MS

2.2.3 Data Analysis

All sample results included in this report were reviewed prior to data analysis. Data assigned a "B" (blank contamination), "SH" (sample handling criterion not met), or "J" (estimated value) qualifier were assessed for usability. Data assigned an "R" (rejected) or deemed suspect were removed prior to data analysis.

Where applicable, tissue data were compared to available threshold concentrations established by the U.S. Food and Drug Administration (FDA) and seafood consumption advisory screening values established by Washington Department of Health (WADOH) to protect consumers of fish and shellfish (Table 3). These values developed to protect human health are typically based on daily consumption rates, toxicological data used in calculations, and risk levels. Applicable FDA levels of concern include tolerance levels for metals at which the FDA may remove the product from market. WADOH screening levels are based on two exposure scenarios: a general population and a high seafood consumer population. General population screening levels are based on consumption of 59.7 g per day seafood and high seafood consumer population levels are based on 175 g per day.

WADOH screening levels are generally compared to the mean concentration of several tissue samples from a location.

Trend analysis for metals concentrations was completed using the cenken function in the NADA package in R and consisted of data from stations with 10 or more summer samples collected between 1998 and 2010. Because spring sampling was not initiated until 2008, only results for summer collected samples were used for trend analysis to minimize any seasonal bias. Trends were only calculated for metals. The data record for PBDEs was too limited to conduct trend analysis. The presence and significance of trends in metal concentrations were determined for: (1) individual sites and (2) overall (pooled results for five stations).

Table 3. Applicable FDA levels of concern for edible portions of fish and shellfish and WADOH screening levels for general and high seafood consumers.

Metals	FDA Tolerance Level (mg/Kg ww)	WADOH Screening Level General Consumer[a] (mg/Kg ww)	WADOH Screening Level High Consumer[b] (mg/Kg ww)
Arsenic	55	N/A	N/A
Cadmium	3	1.17	0.4
Chromium	11	N/A	N/A
Manganese	N/A	164.2	56
Mercury*	N/A	0.101	0.034
Lead	0.8	N/A	N/A
Nickel	80	23.5	8
Selenium	N/A	5.86	2
Silver	N/A	5.86	2
Zinc	N/A	352	120
Organic Compounds		**(µg/Kg ww)**	**(µg/Kg ww)**
Total PBDEs	N/A	117	40

*The FDA Action Level for mercury is based on methylmercury (1.0 mg/Kg ww) which was not analyzed.
All screening levels based on non-cancer health effects.
[a] Based on 59.7 g/d seafood consumption
[b] Based on 175 g/d seafood consumption
Screening levels for arsenic, chromium, and mercury were not included because they are specific to inorganic arsenic, chromium (III) or (IV), and methylmercury not total metal concentrations, which were measured in clam tissues.

3.0 RESULTS

This section presents the conventional parameter and chemistry results for six clam tissue monitoring events conducted in spring (March) and summer (July or August) from 2008 to 2010.

3.1 Conventional Parameters

Average clam length in composite samples was 79 mm for spring samples and 83 mm for summer samples (Table 4). Percent total solids in clam tissue was slightly higher in summer (mean = 19.1 %) than in spring samples (mean = 15.4 %) (Table 4, Figure 2). Solids data are used to convert contaminant concentrations to a dry weight (dw) basis. Dry weight-based concentration patterns did not greatly differ from wet weight (ww) concentrations; therefore, all data are presented below as ww concentrations.

Lipid concentrations in clam tissue can affect accumulation of some chemicals and are also an indicator of overall health. Like solids, total lipid content was higher in clams collected in summer (mean = 1.07 %) than in spring (mean = 0.682 %) (Table 4, Figure 3).

Table 4. Summary of results for shell length and conventional parameters in composite clam tissues samples (2008–2010) by sampling season.

Parameter	Spring				Summer			
	DF	Min	Mean	Max	DF	Min	Mean	Max
Average Length (cm)	N/A	6.8	7.9	9.4	N/A	6.8	8.3	10.6
% Solids	28/28	12.5	15.4	18.7	27/27	15.1	19.1	24
% Lipids	28/28	0.197	0.682	0.968	27/27	0.686	1.07	1.69

DF – detection frequency

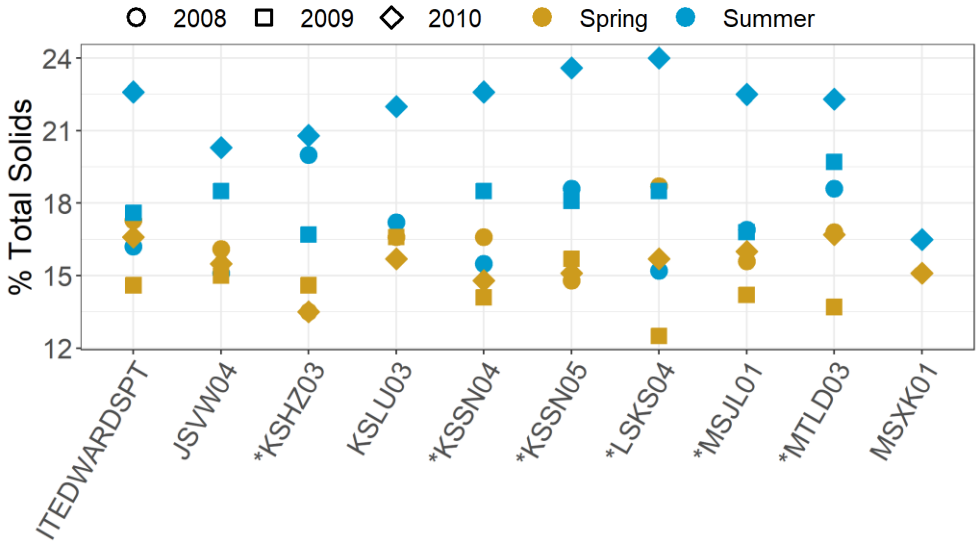

Figure 2. Percent total solids in clam tissue by site and season (2008–2010). * Indicates outfall site

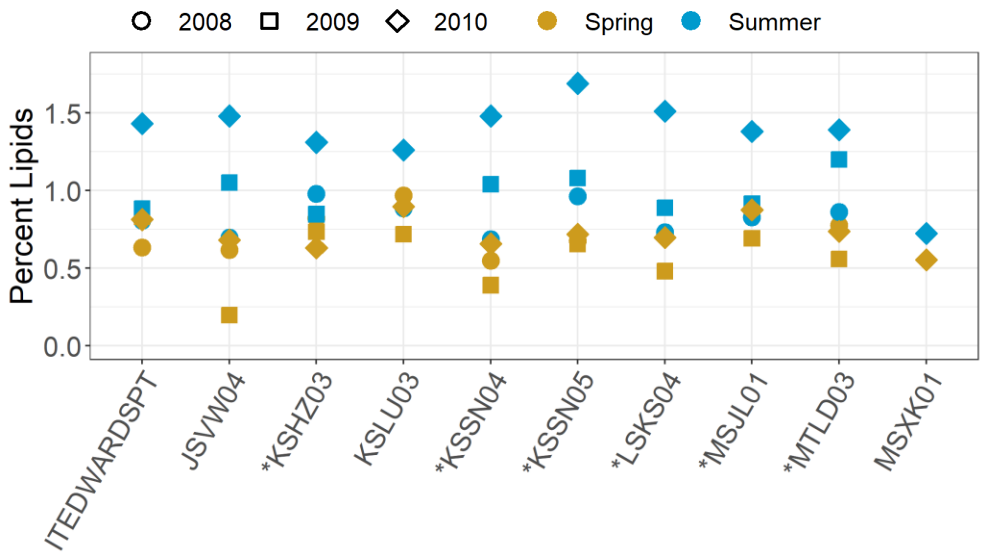

Figure 3. Percent lipids in clam tissue by site and season (2008–2010). * Indicates outfall site

3.2 Metals

Clam tissue samples were analyzed for 14 metals. All metals were detected in all samples except beryllium, which was never detected (Table 5). No seasonal or overall spatial (outfall vs. ambient) patterns in metal concentrations were observed (Figure 4 and Figure 5). The highest concentrations of aluminum, chromium, iron, manganese, and zinc were found in clams near West Point (North Beach - KSSN05), while the highest levels of copper, lead, and mercury in clams were detected in Burton Acres Park (MSXK01) samples. Additionally, all metal tissue concentrations, except silver, were below applicable FDA tolerance levels and WADOH screening levels. The silver level (2.6 mg/kg ww) in one Vashon Outfall sample (MSJL01, summer 2008) exceeded the WADOH screening level (2.0 mg/kg ww) for high consumers.

Metals were measured in clam tissue collected during the summer from some long-term monitoring stations from as early as 1998. Data for at least 10 samples (collected in July or August from 1998 to 2010) were available for five stations (JSVW04, KSHZ03, KSSN04, KSSN05, and MTLD03) and were used to assess trends. Trends were significant overall (pooled data from all five stations) for seven metals. Overall positive (increasing) trends were observed for arsenic, copper, and zinc concentrations, while negative (decreasing) overall trends were measured for aluminum, chromium, lead and mercury concentrations. Except for aluminum and lead, significant trends were also detected for these metals at individual stations (Table 6, Figure 6). On a site-specific basis only, a significantly decreasing trend was observed for selenium at KSHZ03. All trends (overall and individual sites) are available in Appendix A.

Table 5. Summary of metal results (mg/Kg ww) in clam tissue (2008–2010). Bold red values > WADOH screening levels for high seafood consumers.

Parameter	Spring				Summer			
	DF	Min	Mean	Max	DF	Min	Mean	Max
Aluminum	28/28	12.5	42.5	99.5	27/27	11.3	28	56.4
Arsenic	28/28	2.17	3.22	4.25	27/27	1.96	3.57	4.7
Beryllium	0/28	N/A	N/A	N/A	0/27	N/A	N/A	N/A
Cadmium	28/28	0.0459	0.064	0.0938	27/27	0.0446	0.0668	0.102
Chromium	28/28	0.229	0.338	0.478	27/27	0.224	0.327	0.527
Copper	28/28	1.5	2.79	6.29	27/27	1.82	2.71	4.57
Iron	28/28	26.4	78.7	262	27/27	26.9	50.3	100
Lead	28/28	0.0449	0.0775	0.217	27/27	0.0403	0.1	0.214
Manganese	28/28	1.47	4.8	71.7	27/27	0.826	1.6	3.46
Mercury	28/28	0.00376	0.00692	0.0275	27/27	0.00316	0.00619	0.0189
Nickel	28/28	0.54	0.802	1.05	27/27	0.638	0.859	1.08
Selenium	28/28	0.278	0.35	0.433	27/27	0.17	0.327	0.489
Silver	28/28	0.237	0.767	1.93	27/27	0.24	0.87	**2.6**
Zinc	28/28	9.9	13	15.7	27/27	13.6	15.4	18.3

DF – detection frequency

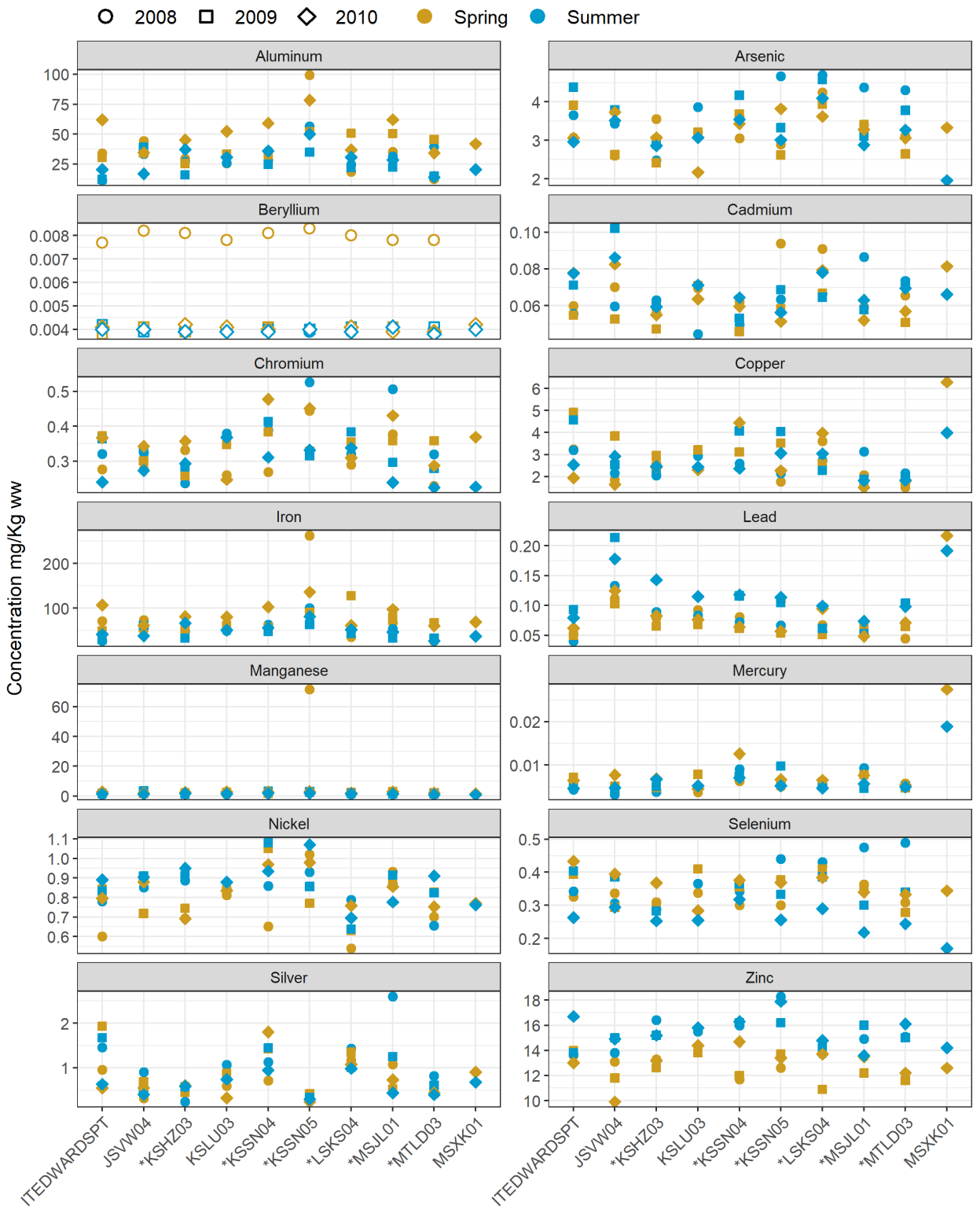

Figure 4. Metal concentrations (mg/Kg ww) in clam tissue by site, year and season (2008–2010). Open symbols represent method detection limit (MDL) when concentration < MDL. * Indicates outfall site

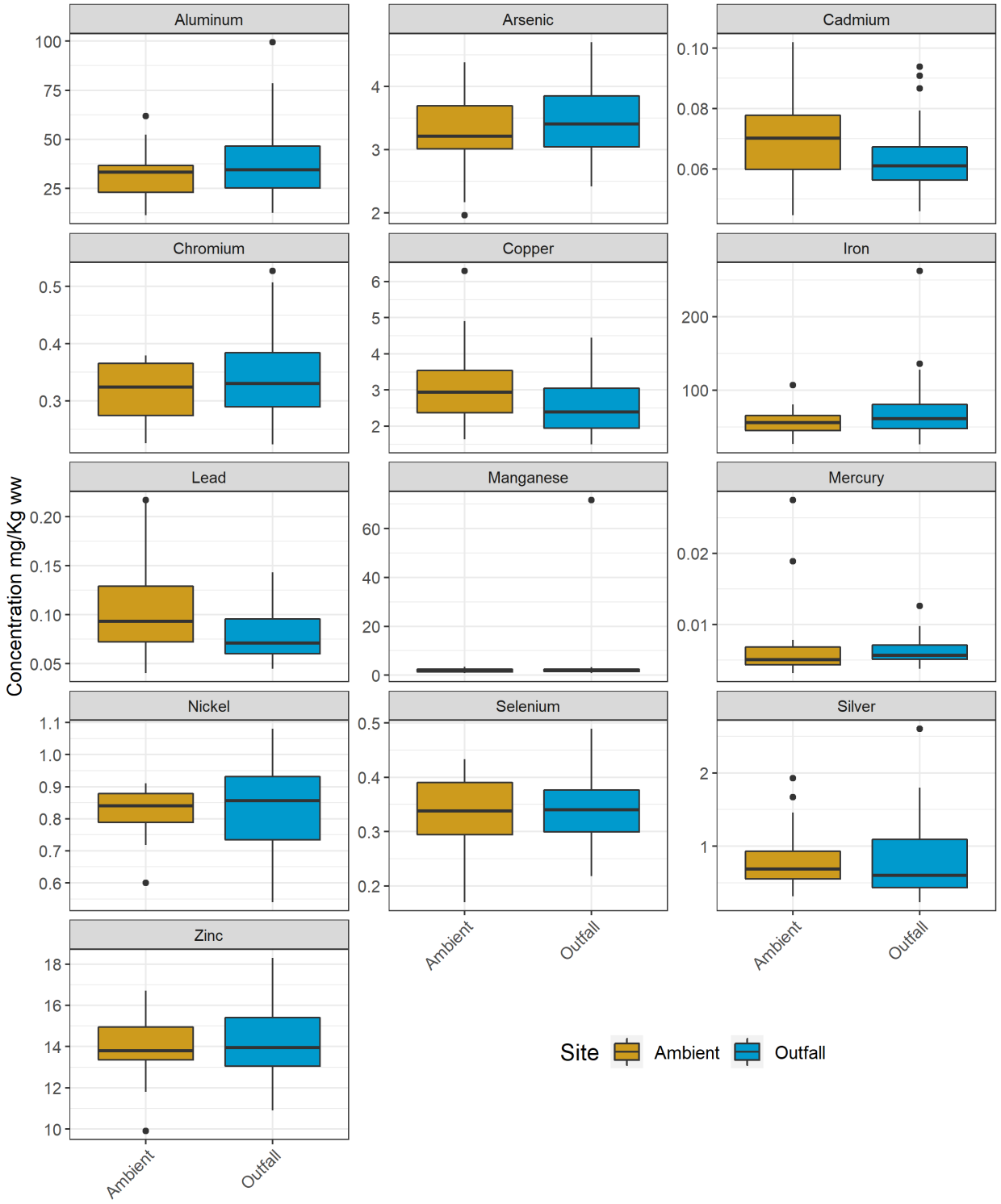

Figure 5. **Box plots illustrating clam tissue metals concentrations (mg/Kg ww) by site type (ambient vs outfall), all data (2008–2010) combined. The box indicates the bounds of the 25th and 75th percentile, while the line represents median. Whiskers represent the ±1.5x the interquartile range and dots represent outliers.**

Table 6. Metals with discernable overall trend (p < .05); all summer data combined (1998–2010) for five sites. Individual sites with significant trend in same direction also listed.

Parameter	Trend	p-value	Sites with significant trend
Aluminum	Decreasing	.03661	None
Arsenic	Increasing	2.74 E-4	JSVW04
Chromium	Decreasing	2.28 E-4	MTLD03
Copper	Increasing	5.61 E-4	KSHZ03, KSSN04, KSSN05
Lead	Decreasing	.03759	None
Mercury	Decreasing	8.39 E-5	KSHZ03, KSSN04, MTLD03
Selenium	No Trend	N/A	KSHZ03
Zinc	Increasing	.00193	KSSN05, MTLD03

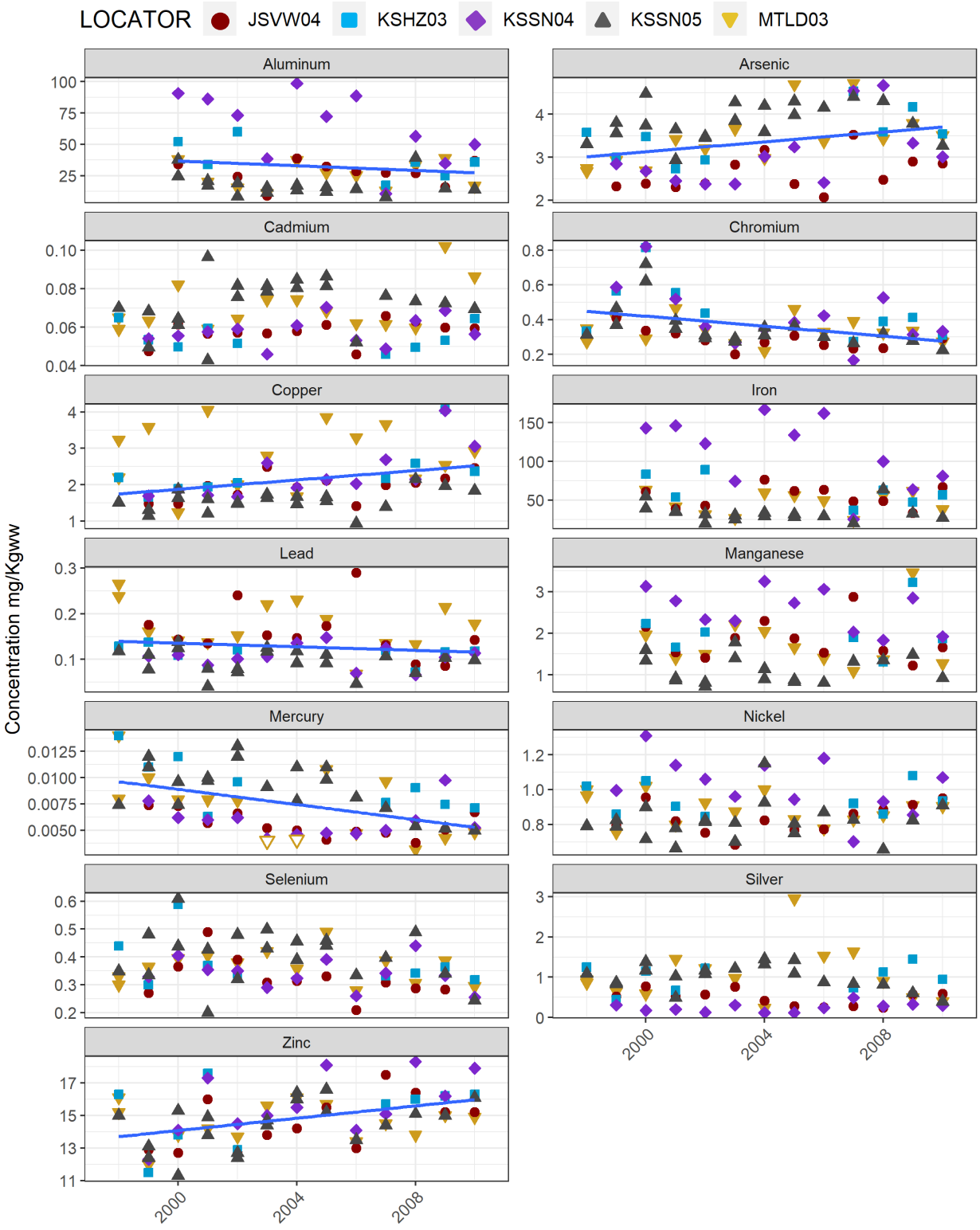

Figure 6. **Metal concentrations (mg/Kg ww) in clam tissue at five long-term monitoring stations (1998–2010). Solid symbols represent detected concentrations; open symbols represent method detection limits (MDL) when concentration < MDL. Blue lines indicate overall trend of all five sites when p <.05.**

3.3 PBDEs

While analysis of most organic chemicals in clam tissue was discontinued in 2006 due to lack of detections, polybrominated diphenyl ethers (PBDEs), manufactured flame-retardant chemicals, were analyzed in samples collected in 2008 to 2010. One or more PBDE congener was detected in all spring, and all but one summer clam tissue sample (MSJL01, Vashon Island, 2009 [only detects with blank contamination]). Generally, TetraBDE-71 was detected at the highest concentration, followed by TetraBDE-47 (Table 7). In spring 2008, summed PBDE concentrations in clams from five stations (four ambient and one outfall) were about three times higher than levels measured during subsequent sampling events. Lipid normalized data had the same pattern, with elevated spring 2008 concentrations. Like other results, concentrations were dominated by TetraBDE-71 which coelutes with TetraBDE-49 (Figure 7). Summed PBDE concentrations were much lower in clams collected during all subsequent sampling events. All summed PBDE concentrations were below WADOH Screening Levels for both general and high seafood consumers. Summed PBDE concentrations in clam tissue collected near outfalls were generally similar, or lower than those collected from ambient sites (Figure 8).

Table 7. Summary of PBDE results (µg/Kg ww) in clam tissues (2008–2010).

Parameter	Spring				Summer			
	DF	Min	Mean	Max	DF	Min	Mean	Max
DecaBDE-209	5/25*	0.11	0.156	0.21	6/27	0.11	0.2	0.28
HeptaBDE-190	1/28	0.027	0.027	0.027	0/27	N/A	N/A	N/A
HeptaBDE-183	1/28	0.022	0.022	0.022	0/27	N/A	N/A	N/A
HexaBDE-154	5/28	0.021	0.0294	0.0449	6/27	0.021	0.0465	0.136
HexaBDE-153	5/28	0.023	0.0342	0.0618	3/27	0.031	0.0834	0.169
HexaBDE-138	0/28	N/A	N/A	N/A	1/27	0.032	0.032	0.032
PentaBDE-100	25/28	0.022	0.0441	0.0876	18/27	0.021	0.0464	0.195
PentaBDE-99*	19/19*	0.0562	0.153	0.436	20/20*	0.0538	0.187	1.27
PentaBDE-85	13/28	0.023	0.0317	0.0527	15/27	0.021	0.0365	0.0863
TetraBDE-71	18/28	0.667	3.03	9.05	9/27	0.319	0.624	0.899
TetraBDE-66	0/28	N/A	N/A	N/A	2/27	0.0482	0.0716	0.0949
TetraBDE-47*	18/19*	0.262	0.379	0.685	12/12*	0.129	0.405	0.827
TriBDE-28	0/28	N/A	N/A	N/A	0/27	N/A	N/A	N/A
TriBDE-17	0/28	N/A	N/A	N/A	0/27	N/A	N/A	N/A
Total PBDEs	28/28	0.0744	2.39	9.18	26/27	0.021	0.673	2.8102

*Some results not included here due to presence of blank contamination.
DF – detection frequency

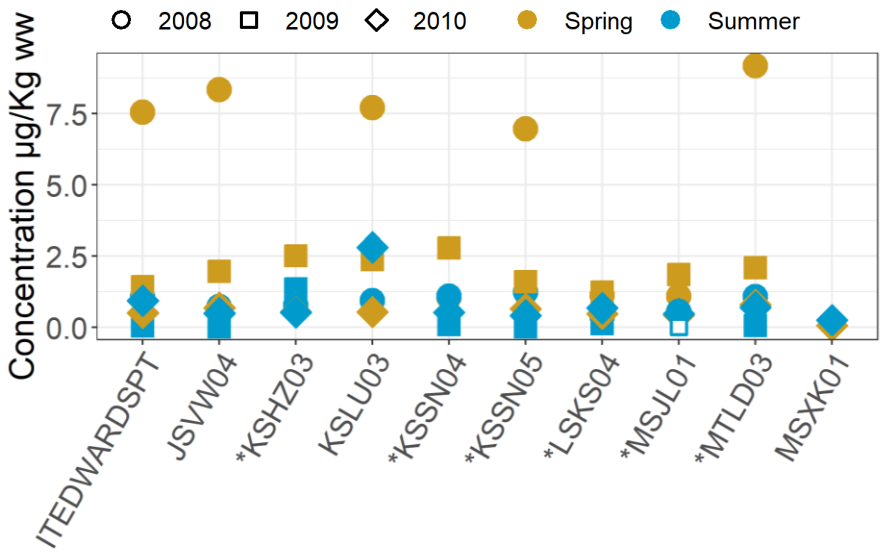

Figure 7. **Summed PBDE concentrations (µg/Kg ww) by sampling event (2008–2010). Open symbols indicate method detection limit (MDL) when concentration < MDL. * Indicates outfall site**

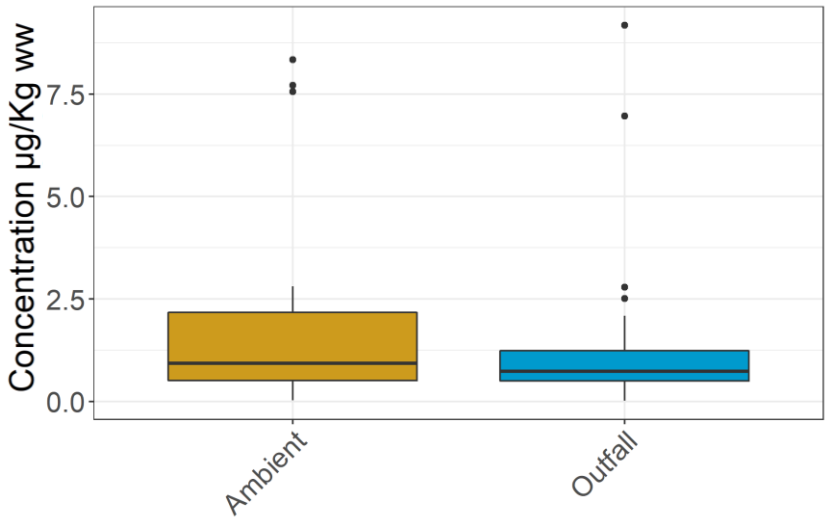

Figure 8. **Box plots illustrating summed PBDE concentrations (µg/Kg ww) by site type (ambient vs outfall); all data (2008–2010) combined. The box indicates the bounds of the 25th and 75th percentile, while the line represents median. Whiskers represent the ±1.5x the interquartile range and dots represent outliers.**

4.0 SUMMARY

A few clam tissue observations of note are provided below:

- Metals concentrations in clam tissue showed some spatial or temporal variation.
- Metals and PBDEs concentrations were generally similar or lower at outfall stations when compared to ambient stations.
- All samples collected during this time period had metals concentrations below FDA tolerance levels, which are concentrations at which the FDA may remove the product from market.
- Samples were also below all WADOH screening levels with the exception of silver in one sample (MSJL01 – Vashon Outfall – Summer 2008), where that sample exceeded the level deemed safe for high seafood consumers. Subsequent results had much lower levels of silver.

Similar to previously published reports analyzing King County clam tissue data (King County, 2000, 2001, 2002, 2005, 2006, 2009, 2019, 2021), all metals, except beryllium were detected in clam tissue samples. Some spatial or temporal patterns were observed in clam tissue metals concentrations. Some concentrations varied seasonally. In general, levels of crustal (earth) metals (e.g., aluminum, iron, and manganese) were higher in spring collected samples, while concentrations of metals more indicative of human activity (e.g., zinc, lead, nickel) were higher in summer samples when percent solids and lipid content were also higher. On average, PBDE concentrations in clam tissue were slightly higher in spring samples, but the difference was largely driven by the anomalously high concentrations of TetraBDE-71 at five stations in spring of 2008. Additionally, positive (increasing) trends were observed for arsenic, copper, and zinc concentrations, while negative (decreasing) trends were measured for aluminum, chromium, lead, and mercury. Concentrations of metals and PBDEs were generally similar or lower at outfall stations relative to levels measured at ambient stations. However, some metals concentrations were slightly elevated near West Point (North Beach - KSSN05) and Burton Acres Park (MSXK01) in Quartermaster Harbor when compared to results from other stations.

5.0 REFERENCES

King County. 2000. Water Quality Status Report for Marine Waters: 1998. Prepared by K. Stark and S. Mickelson. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2001. Water Quality Status Report for Marine Waters, 1999 and 2000. Prepared by the Marine & Sediment Assessment Group. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2002. Water Quality Status Report for Marine Waters, 2001. Prepared by the Marine & Sediment Assessment Group, King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2003. Marine Ambient and Outfall Monitoring Program-2003 Sampling and Analysis Plan. Prepared by Daniel Smith. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2005. Water Quality Status Report for Marine Waters, 2002 and 2003. Prepared by K. Stark, A. Grout, J. Engebretson, and B. Nairn. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2006. Water Quality Status Report for Marine Waters, 2004. Prepared by K. Stark, A. Grout, S. Mickelson, and J. Engebretson. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2009. Water Quality Status Report for Marine Waters, 2005-2007. Prepared by K. Stark, S. Mickelson, and S. Keever. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2019. West Point Flooding Event Intertidal Sediment Clam Tissue Report. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2021. Existing Conditions Along the Marine Nearshore Within the King County Wastewater Service Area Outside of Elliott Bay. King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, WA.

King County. 2022a. Marine Conditions 2008–2019 Report Series: Marine Monitoring Program Overview. Prepared by Kimberle Stark and Taylor Martin, Water and Land Resources Division. Seattle, Washington.

King County. 2022b. Marine Conditions 2008–2019 Report Series: Sediment. Prepared by Wendy Eash-Loucks, Water and Land Resources Division. Seattle, Washington.

PSEP. 1997. Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound. Prepared for the U.S. Environmental Protection Agency Region 10, Seattle, WA and Puget Sound Water Quality Authority, Olympia WA by King County Environmental Lab, Seattle, WA.

Appendix A: Trend Analysis Results

Table A-1 Overall metals trends in clam tissue (pooled from five sites, summers 1998–2010). Metals concentrations were measured in mg/Kg wet weight.

Parameter	p-value	Significant?	Trend
Aluminum	.0366	Yes	↓
Arsenic	2.74E-04	Yes	↑
Cadmium	.119	No	N/A
Chromium	2.28E-04	Yes	↓
Copper	5.61E-04	Yes	↑
Iron	.0687	No	N/A
Lead	.0376	Yes	↓
Manganese	.189	No	N/A
Mercury	8.39E-05	Yes	↓
Nickel	.688	No	N/A
Selenium	.0935	No	N/A
Silver	.554	No	N/A
Zinc	.00193	Yes	↑

Table A-2 Metals trends in clam tissue from individual sites (summers 1998–2010). Metals concentrations were measured in mg/Kg wet weight.

Parameter	Locator	Thiel-Sen Slope	p-value	Significant?	Trend
Aluminum	JSVW04	0.111111	1.00	No	N/A
	KSHZ03	-0.28333	1.00	No	N/A
	KSSN04	-1.62	.764	No	N/A
	KSSN05	-4.44	.0618	No	N/A
	MTLD03	-0.95324	.0818	No	N/A
Arsenic	JSVW04	0.086812	.00366	Yes	↑
	KSHZ03	0.048159	.131	No	N/A
	KSSN04	0.051562	.466	No	N/A
	KSSN05	0.075618	.130	No	N/A
	MTLD03	0.055	.134	No	N/A
Cadmium	JSVW04	4.59E-04	.409	No	N/A
	KSHZ03	4.59E-04	.193	No	N/A
	KSSN04	-1.94E-04	.602	No	N/A
	KSSN05	9.63E-04	.304	No	N/A
	MTLD03	9.00E-04	.515	No	N/A
Chromium	JSVW04	-0.0018	.583	No	N/A
	KSHZ03	-0.00816	.115	No	N/A
	KSSN04	-0.01668	.175	No	N/A
	KSSN05	-0.02328	.115	No	N/A
	MTLD03	-0.01333	.00685	Yes	↓
Copper	JSVW04	0.013711	.869	No	N/A
	KSHZ03	0.065952	.0392	Yes	↑
	KSSN04	0.065459	.0285	Yes	↑
	KSSN05	0.120402	.00319	Yes	↑
	MTLD03	0.03	.143	No	N/A
Iron	JSVW04	-0.38889	.876	No	N/A
	KSHZ03	0.6	.640	No	N/A
	KSSN04	-2.68	.548	No	N/A
	KSSN05	-7.21111	.161	No	N/A
	MTLD03	-1.07905	.0896	No	N/A
Lead	JSVW04	-0.00322	.170	No	N/A
	KSHZ03	-0.00567	.150	No	N/A
	KSSN04	-0.00109	.251	No	N/A
	KSSN05	6.38E-05	1.00	No	N/A
	MTLD03	-0.0015	.361	No	N/A
Manganese	JSVW04	-0.0325	.310	No	N/A
	KSHZ03	-0.03286	.640	No	N/A
	KSSN04	-0.02	.764	No	N/A

Parameter	Locator	Thiel-Sen Slope	p-value	Significant?	Trend
	KSSN05	-0.08	0.119	No	N/A
	MTLD03	-2.27E-04	1.00	No	N/A
Mercury	JSVW04	-4.73E-04	0.0535	No	N/A
	KSHZ03	-2.34E-04	0.0335	Yes	↓
	KSSN04	-4.09E-04	0.0286	Yes	↓
	KSSN05	-3.87E-05	0.783	No	N/A
	MTLD03	-4.62E-04	0.0203	Yes	↓
Nickel	JSVW04	-0.00495	0.510	No	N/A
	KSHZ03	0.012235	0.115	No	N/A
	KSSN04	0.002571	0.754	No	N/A
	KSSN05	-0.02156	0.130	No	N/A
	MTLD03	0.0045	0.415	No	N/A
Selenium	JSVW04	-3.24E-04	1.00	No	N/A
	KSHZ03	-0.01057	0.0467	Yes	↓
	KSSN04	-0.0054	0.348	No	N/A
	KSSN05	-0.00354	0.373	No	N/A
	MTLD03	-0.005	0.602	No	N/A
Silver	JSVW04	-0.01131	0.869	No	N/A
	KSHZ03	-0.02431	0.304	No	N/A
	KSSN04	0.023283	0.754	No	N/A
	KSSN05	0.011046	0.336	No	N/A
	MTLD03	-0.0259	0.434	No	N/A
Zinc	JSVW04	-6.56E-08	1.00	No	N/A
	KSHZ03	0.25	0.0850	No	N/A
	KSSN04	0.25	0.295	No	N/A
	KSSN05	0.362891	0.0278	Yes	↑
	MTLD03	0.228572	0.0466	Yes	↑