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Snohomish MRC Mussel Watch Data Progress Report March 30, 2015

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2011 version of report, * 2015 update of report

SNOHOMISH MRC MUSSEL WATCH DATA PROGRESS REPORT
March 2015

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Snohomish MRC Mussel Watch Data Progress Report

INTRODUCTION

Project Partners

The Snohomish County Mussel Watch program is made possible by the collaborative efforts of the Snohomish County Marine Resources Committee (MRC), the Stillaguamish Tribe, the Tulalip Tribes, the National Oceanic and Atmospheric Administration (NOAA) and numerous volunteers, many who are Snohomish County Beach Watchers. In 2012-13, the MRC also advised and worked with the State Department of Fish and Wildlife to develop and implement a caged mussel study.

Project Background

NOAA's National Mussel Watch Program began monitoring the status and trends of toxic contaminants in our nation's Great Lakes and marine coastal waters, including Puget Sound, in 1986. It is the longest running continuous monitoring program in United States Coastal Waters (Kimbrough et al, 2008). There are now 300 Mussel Watch sites around the U.S. The program collects mussels and oysters and analyzes tissue samples for over 140 contaminants. Data trends from this program are useful for monitoring the impact of environmental contaminants and events such as oil spills and the effectiveness of management decisions. Some parameters have decreasing trends from the last two decades and demonstrate that environmental regulations have had the intended effect (Lauenstein, 2011). Other parameters show increasing levels of emerging contaminants such as flame retardant chemicals known as polybrominated diphenyl ethers (PBDEs). In 2008, NOAA released a 20-year Mussel Watch report summarizing the program. The report is available at NOAA's Center for Coastal Monitoring and Assessment website <http://ccma.nos.noaa.gov/stressors/pollution/nsandt/>. Due to budget shortfalls, the NOAA Mussel Watch Program is currently dormant, and has been so since 2012. The future of the Program is uncertain at this point.

In Washington State, blue mussels from the genus *Mytilus* are collected. There are 26 NOAA Mussel Watch stations in the Washington State, which are sampled every two years during winter months. These stations are located throughout Puget Sound, Hood Canal, the Straits of Juan de Fuca and Georgia, the Pacific Coast, coastal estuaries, and the mouth of the Columbia River. Sampling stations have been also established in response to extreme events. The Edmonds Ferry site was established in response to a 4,700-gallon oil spill on December 30, 2003 at Point Wells approximately 2 miles south of the ferry terminal (Lanksbury et al., 2010).

In 2007, the Snohomish County Marine Resources Committee (MRC) built on this national monitoring framework by establishing additional sites along the Snohomish County coastline. In addition, the Stillaguamish Tribe established one site in Snohomish

County (Puget Sound Kayak Point in 2007) and one in Island County in Port Susan (Puget Sound Cavalero Campground in 2006). In 2009, four additional sites were added including one at Hermosa Point with the assistance of the Tulalip Tribes. These sites were established in rural areas, suburban areas, along the railroad, port areas, by the mouth of the Snohomish River, near parks, ferry terminals, and marinas. There are now ten Mussel Watch sampling stations in Snohomish County and one in Island County that borders Port Susan. The MRC coordinated with NOAA and used trained volunteers to collect mussel samples annually between 2007 and 2012 at both the MRC and NOAA sites. Limited mussel availability prevented sampling at some stations and also funding considerations necessitated sampling fewer stations at times. The NOAA program samples only during the winter. The MRC added summer time sampling for 2007 through 2009 in order to evaluate differences in mussel contaminants between wet and dry seasons. Collectively these sampling sites (NOAA, Snohomish County MRC, Stillaguamish Tribe and Tulalip Tribes) provide overall coverage of Snohomish County's marine waters and a platform for monitoring trends of nearshore chemical pollution in this region.

This paper presents a report on data collected by the MRC, the Tulalip Tribes and the Stillaguamish Tribe. Some of the data described in this report were produced by NOAA through its National Status and Trends program. This is the third update to this report and reflects data collected from the winter of 2006 through the winter of 2012. It has been periodically updated as data were received from the TDI-Brooks International (the NOAA contract lab for Mussel Watch). As of the winter of 2012, the MRC has sampled during eight seasons. Data are available through winter of 2012, with the exception of trace metals data from winter 2009 which appear to have been lost by the lab. Comparisons with earlier and concurrent data from NOAA stations in Washington and the West Coast are also made in this report. Funding constraints have brought NOAA's Program to a temporary halt and may necessitate scaling back the sampling program in the years ahead. The Stillaguamish Tribe plans to sample their mussel watch stations in 2015. The Snohomish MRC plans to coordinate with state efforts for an alternative approach (described in the next paragraph) until such time that NOAA brings the program back.

The MRC also assisted the Washington State Department of Fish and Wildlife (DFW) in planning and carrying out a caged mussel study which sampled over 100 stations in Puget Sound in the winter of 2012-13. Caged mussels were deployed at 5 stations in Port Susan (3 within Snohomish County) and 3 stations between Everett and Edmonds. Five of these stations were the same as stations previously sampled by the MRC and Tribes, so indigenous mussels were sampled at those stations using the NOAA protocol for comparison with the caged mussel samples. The samples were analyzed by a different lab than used for past samples, so the data might not be comparable. Data from the caged mussel study are not presented here, but are available in the report published by DFW (*Toxic Contaminants in Puget Sound's Nearshore Biota: A Large-Scale Synoptic Survey Using Transplanted Mussels (Mytilus trossulus)*, 2014). The DFW report was reviewed and edited by current MRC member Lincoln Loehr and former MRC member Alan Mearns.

The caged mussels had generally lower concentrations of metals than the indigenous mussels from the same locations. The MRC suggests that this could reflect differences in sediment exposure, with most of the indigenous mussels sampled living in closer proximity to the sediment than caged mussels. One indigenous mussel site (Edmonds Ferry) had lower metal concentrations than the caged mussels, but in that situation, the caged mussels had greater sediment exposure than the indigenous mussels.

The Stormwater Monitoring Workgroup of the Puget Sound Estuary Management Program (PSEMP) adopted the caged mussel study protocol for monitoring status and trends of toxicants in the nearshore¹. Through this program, the caged mussel sampling will continue and perhaps even take the place of the NOAA Mussel Watch Program. Groups such as the MRC and the tribes may assist in these efforts and include additional stations in the studies. Future mussel watch reports by the MRC may focus on the caged mussel data, with this report providing useful information to help interpret future monitoring results.

Project Design

Mussels and other bivalve mollusks are valuable indicators of contaminants in marine ecosystems. The blue mussels (*Mytilus* spp.) found in Washington, feed by filtering large quantities of water and accumulate contaminants from the marine environment. Contaminants concentrate in mussels with little metabolic change and then over time these contaminants are released via depuration (Kimbrough et al, 2008). Through the process of uptake and depuration, contaminant concentrations in mussel tissues respond to changes in ambient environmental levels (Kimbrough et al, 2008, Lanksbury et al., 2010). Mussels of all sizes and ages can thus be sampled because mussels provide a snapshot of water quality during recent exposures rather than a history of lifetime exposure.

Mussels are collected from the intertidal zones during low tides. Mussels must be living on natural substrate, concrete, or rip-rap structures to be eligible for collection for this study. They are removed from the substrate by cutting the byssal threads. Next, the mussels are rinsed, brushed clean, and packed on ice. The samples are shipped on ice to keep the mussels alive until they reach the laboratory. The MRC sends the samples to TDI Brooks International, an analytical laboratory where all of the samples from the National Mussel Watch Program are analyzed for contaminants. Samples are also sent to Rutgers' Haskins Shellfish Research Laboratory for assessment of gonadal index and histopathology. The histopathology component measures the prevalence of nearly 70 diseases and parasites and verifies the reproductive state of the mussel.

The Mussel Watch analyses include more than 140 organic compounds and metals, many of which are Environmental Protection Agency (EPA) Priority Pollutants and regulated by federal and state laws (Kimbrough et al., 2008). The organic compounds measured in

¹Meeting Summary PSEMP Stormwater Workgroup June 11, 2014.
http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/SWworkgroupDOCS/11June2014/SWGDraftSummary.pdf

mussel tissues include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dichloro-diphenyl-trichloro-ethane (DDT), polybrominated diphenyl ethers (PBDEs) and several other chlorinated pesticides (Kimbrough et al., 2008). Many can be toxic to aquatic organisms and some also biomagnify through food chains to upper trophic levels. Possible sources of contaminants include point sources, surface water runoff, atmospheric deposition, and historical use (Lanksbury et al., 2010). Metals may also be naturally present in fine sediments which may be taken up by mussels as they filter particulates from the water column.

NOAA established Mussel Watch sites 10 to 100 km apart along the entire U.S. coastline. Sites were selected in areas with bivalve populations large enough to sustain repeated sampling (Kimbrough et al., 2008). NOAA cautions against the use of Mussel Watch data alone to address shellfish consumption issues because the sampling sites may not coincide with shellfishing areas. Thus, contaminant concentrations in adjacent shellfish could be higher or lower than levels measured in the mussels collected (Lauenstein, 2011).

Project Objectives

The purpose of Mussel Watch is to determine which contaminants are currently in the nearshore waters of Snohomish County and adjacent areas and the extent to which they are at concentrations of concern and may merit action. The data also help to evaluate status and trends, differences between rural and more urbanized areas, differences associated with rainfall, as well as occurrence of unusual events that might show up as a spike in concentrations at a single station or over an area. The project is not a health assessment of mussels but rather an important new piece of information for assessing the quality of Snohomish County marine waters to which all marine life is exposed.

The long-term goal of the MRC is to continue the expanded Mussel Watch Program in Snohomish County either in its present form, or as a caged mussel program in partnership with the WDFW Program. The 2007 expansion increased the sampling sites from three to seven, and sampling frequency from biannual to an annual wet and dry season sampling. The 2009-2010 sampling added four more stations. Mussels are not always available at each station, and budget constraints affect the number of stations sampled in a given season. The collection of Mussel Watch data provides information on marine and estuarine water quality at locations within Snohomish County and establish a baseline. The 2007-2009 data provide a comparison of wet and dry season chemical concentrations. Chemicals of interest will continue to be reviewed for trends and will be compared to mussel and water quality results from coastal waters around the nation.

The findings from this assessment will serve as the basis for MRC recommendations to the Snohomish County Council and Executive.

Project Implementation

The locations of the NOAA, MRC, Tulalip Tribes and Stillaguamish Tribe Mussel Watch stations are presented in Figure 1. The sites cover Port Susan, Possession Sound and the

northern end of the main basin of Puget Sound. One station, Cavalero Campground, is in Island County, but is included because it is representative of northern Port Susan.

As of March 2012, the MRC has sampled during eight periods including the late summer dry season of 2007, the winter of 2008, the summer of 2008, the winter of 2009, the summer of 2009 and the winters of 2010, 2011 and 2012. For all sampling efforts, permits and permissions were obtained from all entities involved in Mussel Watch collection.

A contract agreement was established with TDI-Brooks Laboratories to run chemical analyses on the mussel samples. TDI-Brooks is the NOAA contract laboratory for the National Mussel Watch Program. The MRC's use of the same laboratory as NOAA allows Snohomish County data to be included in NOAA's National Mussel Watch database. The database is found at <http://ccma.nos.noaa.gov/about/coast/nsandt/download.aspx>. Services for histopathology work at Rutgers' Haskin Shellfish Research Laboratory were contracted through TDI. Samples were sent to Rutgers' laboratory in 2009, 2010, 2011 and 2012.

The Snohomish County Mussel Watch Program differs from NOAA's Program both in sampling frequency and in the manner of collection. The Snohomish County Program uses trained citizen science volunteers for sample collection. Volunteers, from programs such as WSU Extension Snohomish County Beach Watchers and Everett Community College's ORCA program, are trained to sample following NOAA's established collection protocols. Volunteers are able to contribute knowledge about the local Mussel Watch sites. The data collection sheets provide volunteers with a place to share anecdotal information about possible contamination sources. This opportunity to incorporate local knowledge highlights the value of engaging local citizen scientists (Lanksbury et al., 2010).

In 2010, the MRC worked with regional project partners from WDFW and Washington Sea Grant on the regional expansion of the Mussel Watch program. The statewide expansion project was modeled after Snohomish County's Mussel Watch program to increase the use of citizen scientists for mussel collections. Citizen scientists from local volunteer groups and WDFW successfully sampled mussels at more than 25 sites across Western Washington.

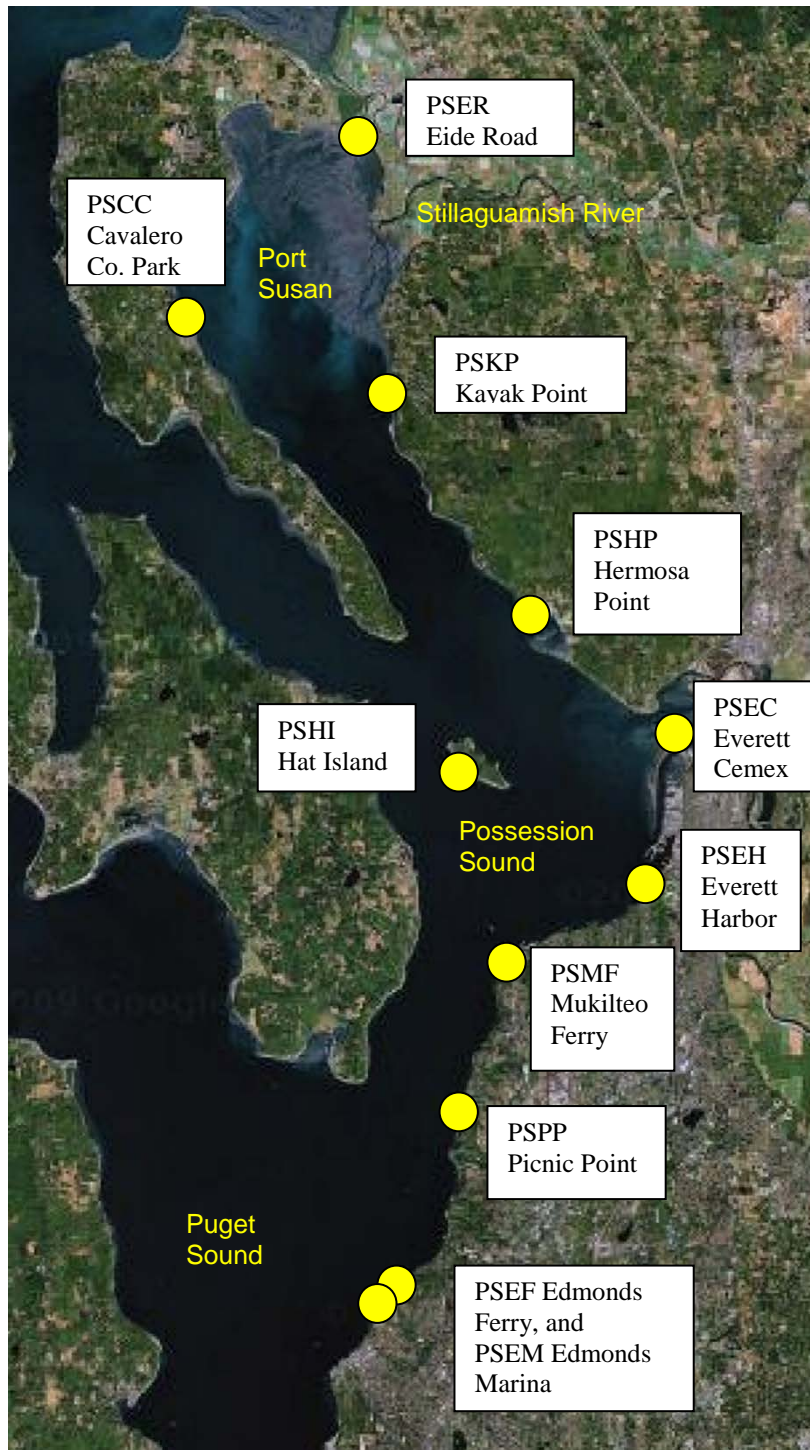
More than 65 volunteers contributed over 500 hours to sampling mussels in the 2010 statewide project, at an estimated value of more than \$12,000. Volunteers significantly reduced the amount of time professional staff were needed in the field, provided staff scientists with valuable local knowledge and natural history, and engaged citizens' desire to become involved in Puget Sound's recovery. A post-project survey indicated a high degree of satisfaction among the volunteers and an increased personal connection with their local environment and the research and monitoring community conducting these studies. The report detailing the successful regional expansion of the Mussel Watch Program is available from WDFW at <http://wdfw.wa.gov/publications/pub.php?id=01127>.

The 2010 sampling demonstrated the potential of citizen science volunteers to assist in mussel watch and showed DFW it was feasible to use volunteers on a larger scale. Consequently, DFW sought volunteer assistance for a caged mussel pilot project, which would deploy about 60 cages of mussels in November 2012 and recover them in January 2013. The interest in the project was substantial, and volunteers not only helped in many stages of the project, but also found funding to include over 40 additional sites. Volunteers helped in sizing, sorting and bagging mussels from Penn Cove Shellfish over a week and a half period under DFW supervision. Volunteers then deployed the mussels at night over a three day period in November and recovered the cages after two months deployment, in January 2013. That project in turn showed the stormwater workgroup of the Puget Sound Estuary Monitoring Program that caged mussel studies, using volunteer help, could be a useful tool for monitoring contaminants in nearshore biota. Data from the 2012-13 sampling are presented in a WDFW report (Lanksbury et al, 2014).

Throughout the project the following outreach efforts were conducted.

- A Mussel Watch poster designed by former MRC member Alan Mearns, PhD of NOAA was selected for display at the Puget Sound Georgia Basin Conference in Seattle on February 8 – 11, 2009.
- Dr. Alan Mearns presented to the Northwest Straits Commission on February 27, 2009.
- MRC staff presented a Mussel Watch poster at the Exploring the Spectrum of Citizen Science Workshop in Port Townsend on April 11, 2009.
- The Mussel Watch poster was also displayed at the April 16-18, 2009 annual meeting of the Pacific Northwest Chapter of the Society of Environmental Toxicology and Chemistry (PNWSETAC) in Port Townsend.
- On January 29, 2010, MRC Staff, Kathleen Herrmann, presented on the Snohomish County Mussel Watch Program to the NWSC.
- Kathleen Herrmann of the MRC along with Kate Litle of Washington State Sea Grant presented a talk at the April 14-16, 2010 annual meeting of PNWSETAC on the citizen collection effort statewide during the winter of 2010.
- Kathleen Herrmann presented initial findings to the Stillaguamish Clean Water Advisory Board with assistance from Lincoln Loehr on March 24, 2011.
- The Snohomish County Mussel Watch Program and initial findings were also presented during volunteer trainings for the statewide citizen collection efforts in winter of 2010 and as a part of an “MRC 101” presentation given during the 2011 WSU Snohomish County Extension Beach Watchers training.
- A Mussel Watch poster was presented by MRC member Lincoln Loehr at the Salish Sea Ecosystem Conference on October 25-27, 2011.
- Lincoln Loehr and MRC Program Assistant, Emily Whitney, presented “What’s in the Water Anyway? A look at contaminants in Snohomish County waters” at Sound Living on November 5, 2011.
- Lincoln Loehr and Emily Whitney presented on the Snohomish County Mussel Watch Program as a series of workshops hosted by WDFW in summer 2012.
- Lincoln Loehr and former MRC member Alan Mearns provided technical peer review of the DFW’s draft final in 2014.

Figure 1 Snohomish and Island County Shorelines showing Mussel Watch sites (with NOAA Codes and site descriptions) sampled by the MRC and Stillaguamish Tribe.



Puget Sound Eide Road

The site is located at the tip of Port Susan on Leque Island. Only sampled once.

Puget Sound Cavalero

The site is located at Cavalero County Park in Island County and was established by the Stillaguamish Tribe in 2006.

Puget Sound Kayak Point

The site is located at Kayak Point County Park and was established by the Stillaguamish Tribe in 2007.

Puget Sound Hermosa Point

The site is located at Hermosa Point on Tulalip Bay on the Tulalip Indian Reservation. It is sampled with permission and assistance from the Tulalip Tribes.

Puget Sound Hat Island

The site is located on the west side of Hat Island. Samples were collected from creosote pilings before the site was moved to a nearby cement structure in 2010.

Puget Sound Everett Cemex

The site is located near the Snohomish River delta on property leased by Cemex. The site was selected to evaluate the effect of the river on contaminant levels.

Puget Sound Everett Harbor

The site is located on the breakwater rocks at the south end of the Port of Everett. It is a NOAA site first sampled in 1989.

Puget Sound Mukilteo Ferry

The site is located along the shoreline near the Mukilteo ferry terminal. This NOAA site was established in 2004, in response to an oil spill near Point Wells.

Puget Sound Picnic Point

The site is located in the Snohomish County Picnic Point Park. The site was established in winter 2010. Only sampled once.

Puget Sound Edmonds Ferry

The site is located on the jetty north of the Edmonds Ferry Terminal. This NOAA site was established in 2004, in response to an oil spill near Point Wells.

Puget Sound Edmonds Marina

The site is located on the northern breakwater of the Edmonds Marina, south of the Edmonds Ferry site. The site was established in 2009 to evaluate the effect of the marina on contaminant levels.

TECHNICAL EVALUATION OF DATA FOR SPECIFIC CHEMICALS AND METALS

Data Analysis Approach

For this data assessment, where applicable, we summed total concentrations of analytes in specific classes (i.e. Total PCBs, total PAHs, total DDTs, etc.) and compared concentrations in graphic and tabular form among sites and across time, beginning with the NOAA data collected in winter 2006. This was done for selected contaminants, not all of them that were measured. The tables, one for each contaminant grouping, list the concentrations arranged in columns by site (from north to south) for each of the sampling periods. This arrangement allows a first non-statistical look at the extent to which we might infer winter stormwater runoff as a source of contaminant inputs to this coastal zone.

In addition, to gain an idea of the relative degree of contamination by these chemicals along the Snohomish Coast, we compared, where possible, the concentrations in our data with ranges that NOAA identifies as low, medium or high (i.e., Kimbrough, et. al., 2008). We also examined the 2008 NOAA West Coast Mussel Watch data, and the NOAA Washington State Mussel Watch data for comparison with the Snohomish County data.

Snohomish County Mussel Watch data have been received from TDI-Brooks for the 2007 dry season, the 2008 wet and dry seasons, the 2009 wet and dry seasons and the 2010, 2011 and 2012 wet seasons. Samples from 2012 for two NOAA stations (Everett Harbor and Edmonds Ferry) have still not been analyzed due to NOAA funding shortfalls. If funding is available, the MRC may have these samples analyzed.

Precipitation Data

We looked at precipitation data available on the Snohomish County website for sites closest to the marine shoreline, at 60 days and 30 days prior to sampling. Two stations were chosen to represent approximate precipitation data for the County marine / river shoreline. The first is at Kayak Point County Park and the second further south at Soper Hill Road and State Route 9 in the Snohomish River watershed. Precipitation for 60 days prior to sampling is presented in Table 1 and precipitation for 30 days prior to sampling is presented in Table 2.

The 60-day dry season averages are lower than the 60-day wet season averages. Among dry seasons, there was higher rainfall during the 2008 dry season than during the 2007 or 2009 dry season averages. The 2008 30-day dry season average is higher than the 2008 wet season average. Much of the rainfall in the 30 days prior to the mussel collection in August 2008 occurred in the 10 days prior to the sampling. The 2010, 2011 and 2012 wet seasons were much wetter than the 2008-2009 wet seasons with 2011 being the wettest year. This may explain why contaminant concentrations increased in those years.

Table 1. Precipitation in Inches - 60-days Prior to Mussel Collection

	07 Dry Season	08 Wet Season	08 Dry Season	09 Wet Season	09 Dry Season		10 Wet Season		11 Wet Season			12 Wet Season		
	7/9/07 - 9/6/07	1/11/08 - 3/11/08	6/29/08 - 8/27/08	1/2/09 - 3/2/09	6/18/09 - 8/16/09	6/22/09 - 8/20/09	11/26/09 - 1/24/10	11/27/09 - 1/25/10	11/19/10 - 1/17/11	11/27/10 - 1/25/11	12/24/10 - 2/21/11	12/01/11-1/29/12	12/2/11-1/30/12	12/16/11-2/13/12
Kayak Point County Park	2.14	4.05	2.59	5.01	1.66	0.8	6.0	5.48	8.25	9.36	7.89	3.97	3.95	4.82
Soper Hill Road at SR 9	2.96	5.51	3.27	5.22	2.34	1.83	7.63	7.01	12.12	14.44	13.52	6.24	6.37	7.46
Average	2.55	4.78	2.93	5.12	2.0	1.32	6.82	6.25	10.19	11.9	10.71	5.11	5.16	6.14

Table 2. Precipitation in Inches - 30 days Prior to Mussel Collection

	07 Dry Season	08 Wet Season	08 Dry Season	09 Wet Season	09 Dry Season		10 Wet Season		11 Wet Season			12 Wet Season		
	8/9/07 - 9/6/07	2/10/08 - 3/11/08	6/29/08 - 8/27/08	2/1/09 - 3/2/09	7/18/09 - 8/16/09	7/22/09 - 8/20/09	12/26/09 - 1/24/09	12/27/09 - 1/25/09	12/19/10 - 1/17/11	12/27/10 - 1/25/11	1/23/11-2/21/11	12/31/12-1/29/12	1/1/12-1/30/12	1/15/12-2/13/12
Kayak Point County Park	1.29	1.31	1.98	1.87	0.57	0.57	3.1	3.24	4.74	5.3	2.57	3.22	3.24	3.59
Soper Hill Road at SR 9	1.77	2.27	2.20	1.43	1.35	1.35	4.12	4.28	6.93	8.64	4.74	4.13	4.29	4.99
Average	1.53	1.79	2.09	1.65	.96	.96	3.61	3.76	5.84	6.97	3.66	3.68	3.77	4.29

2007, 2008, and 2009 Wet Season

All samples collected on the same day

2009 Dry Season

August 17, 2009 Collections at Everett Harbor, Hat Island, Mukilteo Ferry, Edmonds Ferry, and Edmonds Marina

August 21, 2009 Collections at Hermosa Point and Everett Cemex

2010 Wet Season

January 25, 2010 collections at Everett Cemex, Hat Island

January 26, 2010 collections at Hermosa Point, Edmonds Ferry, Everett Harbor, Mukilteo Ferry

2011 Wet Season

January 18, 2011 collection at Hermosa Point

January 26, 2011 collection at Everett Harbor and Edmonds Ferry

February 22, 2011 collection at Hat Island

2012 Wet Season

January 30, 2012 collection at Everett Cemex and Kayak Point

January 31, 2012 collection at Hat Island and Hermosa Point

February 14, 2012 collection at Cavalero Campground

Lipid data

The lipid content, both in wet weight and dry weight, is included as a measured parameter by TDI Brooks, Inc. Lipid content is not a contaminant measure, but rather a measure of the fat content of the mussels. Some types of contaminants are attracted to lipids, such as PCBs. Lipid data are presented in the following table, and were used to evaluate PCBs on a dry weight lipid normalized basis to compare with the dry weight only basis. The lipid values do not appear to relate to the dry or wet season.

Table 3. Lipid data in percent dry (percent wet) from Snohomish County Mussel Watch

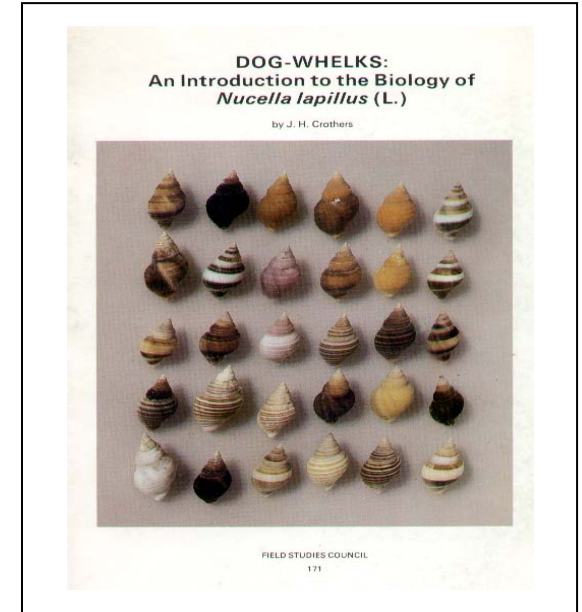
	Waterbody	06 wet season	07 dry season	08 wet season		08 "dry" season	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		12.9(1.7)								
Kayak Point	Port Susan		13.8(2.2)		12.4(1.3)		10(1.2)	13.6(1.8)			10.6(1.3)
Cavalero	Port Susan	6.3(0.7)	8.5(1.1)		4.7(0.7)	9.4(1.3)	8.6(0.8)	10.9(1.4)		9.6(1.0)	10.0(1.1)
Hermosa Point	Port Susan							7.6(1.0)	8.3(0.8)	9.7(1.1)	7.5(1.0)
Hat Island	Possession Sound				10.4(1.5)	17.8(3.1)	9.7(1.9)	12.8(2.0)	10.7(1.5)	8.7(1.1)	8.9(1.1)
Cemex	Possession Sound							8.6(1.1)	7.3(0.7)		8.6(1.0)
Everett Harbor	Possession Sound		9.6(1.5)	13.2(2.1)		10.5(1.4)	5.6(0.7)	8.1(1.2)	7.8(0.9)	10.8(1.1)	
Mukilteo Ferry	Possession Sound	5.5(0.8)	13.2(2.4)	11.2(1.7)		14.7(2.2)	11.3(2.1)	10.1(1.5)	10.7(1.4)		
Picnic Point*	Possession Sound								9.8(1.0)		
Edmonds Ferry	Main Basin Puget Sound	11.3(1.7)	10.9(1.9)	11.0(1.8)		13(2.4)	7.0 (0.9)	13.2(2.4)	8.8(1.1)	8.8(1.2)	
Edmonds Marina	Main Basin Puget Sound							12.1(1.9)			

* Picnic Point sampled in mid-March 2010

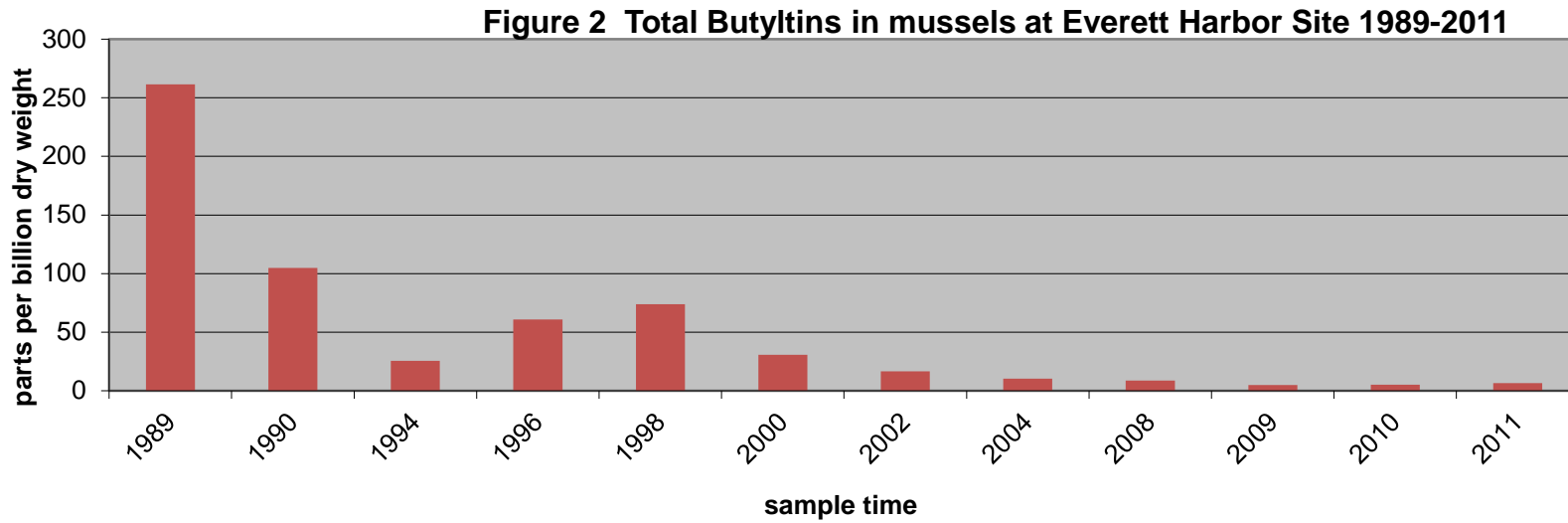
Organic Contaminants

Total Butyltin (TBT)

Anti-fouling paints enhance the performance and durability of marine vessels by slowing the growth of organisms that can attach to the hull of a ship or boat. TBT-based vessel antifouling paints were in heavy use through the 1980s, have caused reproductive injury to marine mollusks (snails and oysters) and were banned for small vessels (<25 m) in the mid 1980s and on all vessels in the early 2000s. TBT causes sexual abnormalities (Imposex – growth of penis) in female marine snails (dog whelks). Copper- and organic compound-based paints have replaced TBT-based paints. (In 2011, the Washington legislature voted to ban the use of copper-based antifouling paints (HB1785-2011-12.) TBT-containing paint chips, however, may still foul marinas.



NOAA's long-term (20 years) Mussel Watch data for the Everett Harbor station are presented in Figure 2 and show the sharp decline in TBT that resulted from the ban.



Concentrations of TBT in Snohomish and Island County (Cavalero Co. Park) samples in 2006 through 2012 samples ranged from non-detect at several Port Susan stations to 25.69 ppb dw at Edmonds Ferry and 17.82 ppb dw at Cavalero Park. The high values occurred in 2006. Concentrations appeared to decrease from south (Edmonds) to north (Cavalero). Concentrations appeared to increase for the four stations sampled in 2012. (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.) All concentrations are considered by NOAA to be low concentrations (Kimbrough, et. al, 2008). Mearns (2001) reported that TBT concentrations in Puget Sound mussels from NOAA sites were steadily declining during the 1990s. The Edmonds Ferry site is close to the Edmonds marina, an area where TBT would be expected. The data are presented in Table 4 and Figure 3 below.

Table 4. Total butyltin data in parts per billion (dry weight) from Snohomish County Mussel Watch

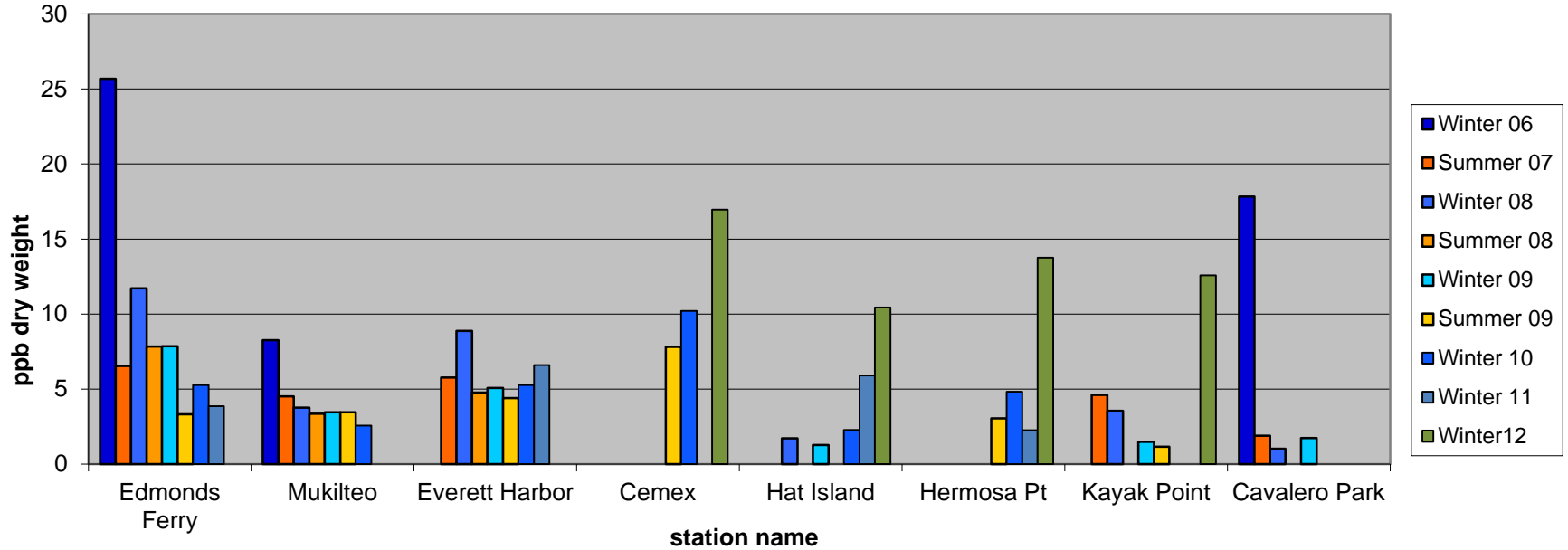
	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		1.13								
Kayak Point	Port Susan		4.61		3.54		1.49	1.15			12.57
Cavalero	Port Susan	17.82	1.88		1.0	U	1.74	U		U	U
Hermosa Point	Port Susan							3.04	4.82	2.25	13.76
Hat Island	Possession Sound				1.71	U	1.27	U	2.27	5.90	10.44
Cemex	Possession Sound							7.82	10.20		16.96
Everett Harbor	Possession Sound		5.76	8.9		4.8	5.08	4.40	5.26	6.60	
Mukilteo Ferry	Possession Sound	8.25	4.51	3.8		3.4	3.46	3.46	2.56		
Picnic Point**	Possession Sound							6.60			
Edmonds Ferry	Main Basin Puget Sound	25.69	6.54	11.72		7.84	7.86	3.32	5.26	3.85	
Edmonds Marina	Main Basin Puget Sound							U			

U= not detected

*10 day rainy period occurred before 2008 "dry" season sampling. ** Picnic Point sampled in mid-March 2010

NOAA considers concentrations between 40 and 108 ppb as medium concentrations. All Snohomish County sites were in the low range.

Figure 3 Total Butyltins in Snohomish County mussels



A side story of interest. In earlier stages of this report, the MRC was also using NOAA Mussel Watch data from station WIPP, which was located on the southeast end of Whidbey Island by Possession Point. We used the data expecting it to be representative of Possession Sound water yet removed from close sources such as harbors, ferry landings or marinas. In a similar manner, we use the Stillaguamish Tribe’s data for Cavalero Campground as representative of Port Susan even though the station is in Island County and not Snohomish County. Station WIPP had much higher TBT values (> 30 ppb dw), and for its location the TBT values didn’t follow expected trends. The PAH values were also similar to Everett, Mukilteo and Edmonds although the site appeared to be remote from sources. In 2010, we found out that the NOAA sampler in prior years did not find any mussels at the site so he (or she) went to the southwest side of Possession Point and sampled mussels from a boat harbor breakwater. The change did not follow NOAA’s protocols. The site should have been assigned a new name (Cultus Bay), description and designation but it was not. (Following our discovery, NOAA assigned the new name to the revised site.) This shows the value of local knowledge when reviewing data. NOAA staff from the east coast, not familiar with local conditions, would not have noticed the issue when reviewing the data. The MRC chose not to use the data from station WIPP, as it is not representative of Possession Sound.

Polychlorinated Biphenyls (PCBs)



Polychlorinated biphenyls (PCBs) were used as fire retardants in electrical components and paints from the 1940s until they were banned in 1976 (Kimbrough, et. al., 2010). They biomagnify through marine food webs and remain among the most ubiquitous and problematic pollutants in Puget Sound marine life. The Washington Department of Ecology is developing a Chemical Action Plan for PCBs which should be completed in 2014.

PCB measurements are reported for 39 individual congeners. To compare recent data to historical data that measured Aroclor PCB mixtures, the data for 18 specific congeners are multiplied by 2 to approximate the total of all PCB congeners. Values presented below are for total Aroclors using NOAA's formula calculation. (Note, in prior versions of this report we used a simpler formula of 2 times total congeners, which produced different values.)

Figure 4 presents NOAA 2008 Winter PCB mussel data for all the west coast and for just the Washington State stations. Puget Sound stations have higher PCB concentrations than many of the outer coast stations. Within Puget Sound, concentrations are highest in the main basin. The figures help put the Snohomish County data in context.

Figure 4 NOAA West Coast Winter 2008 Total PCBs

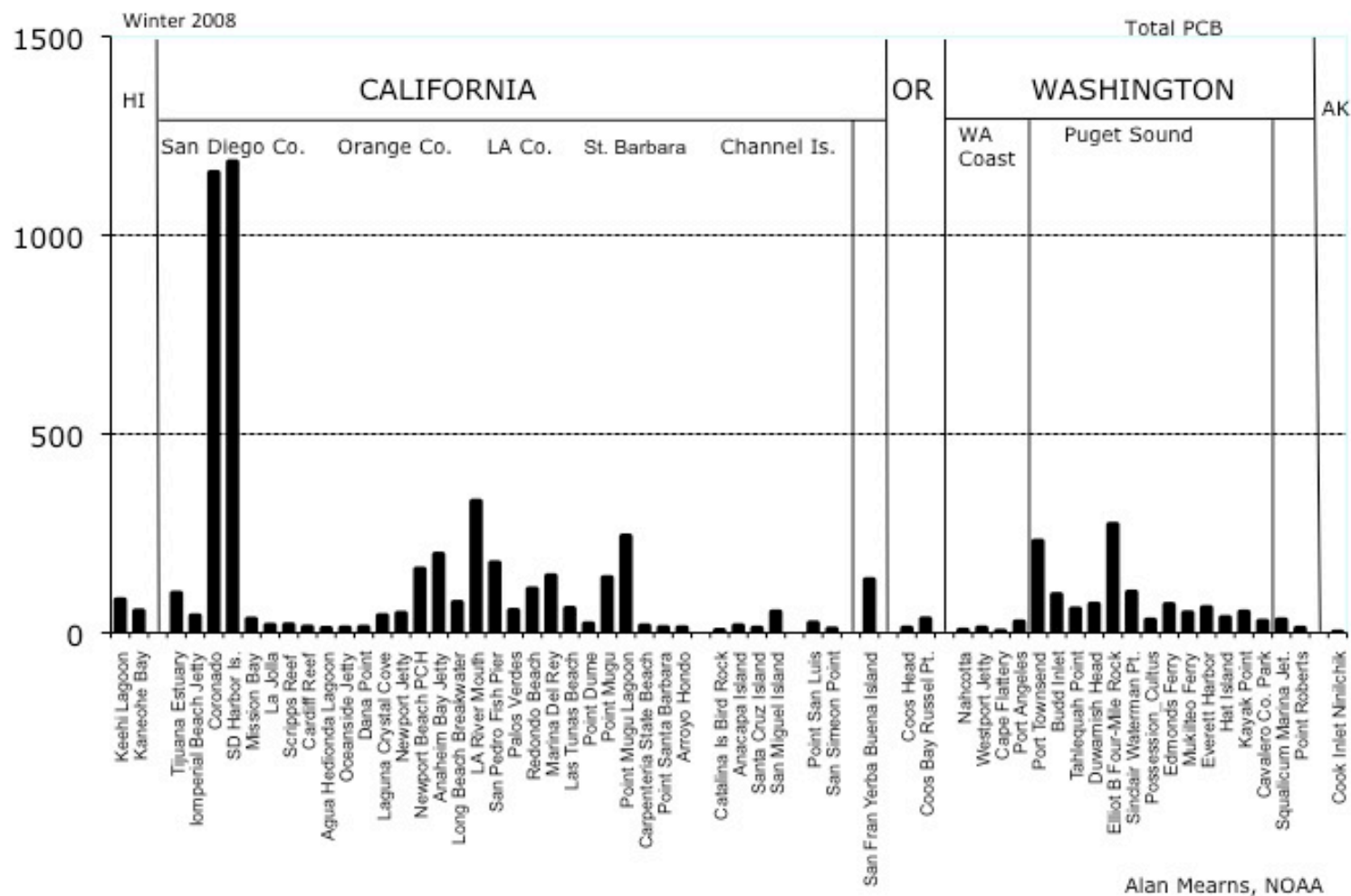
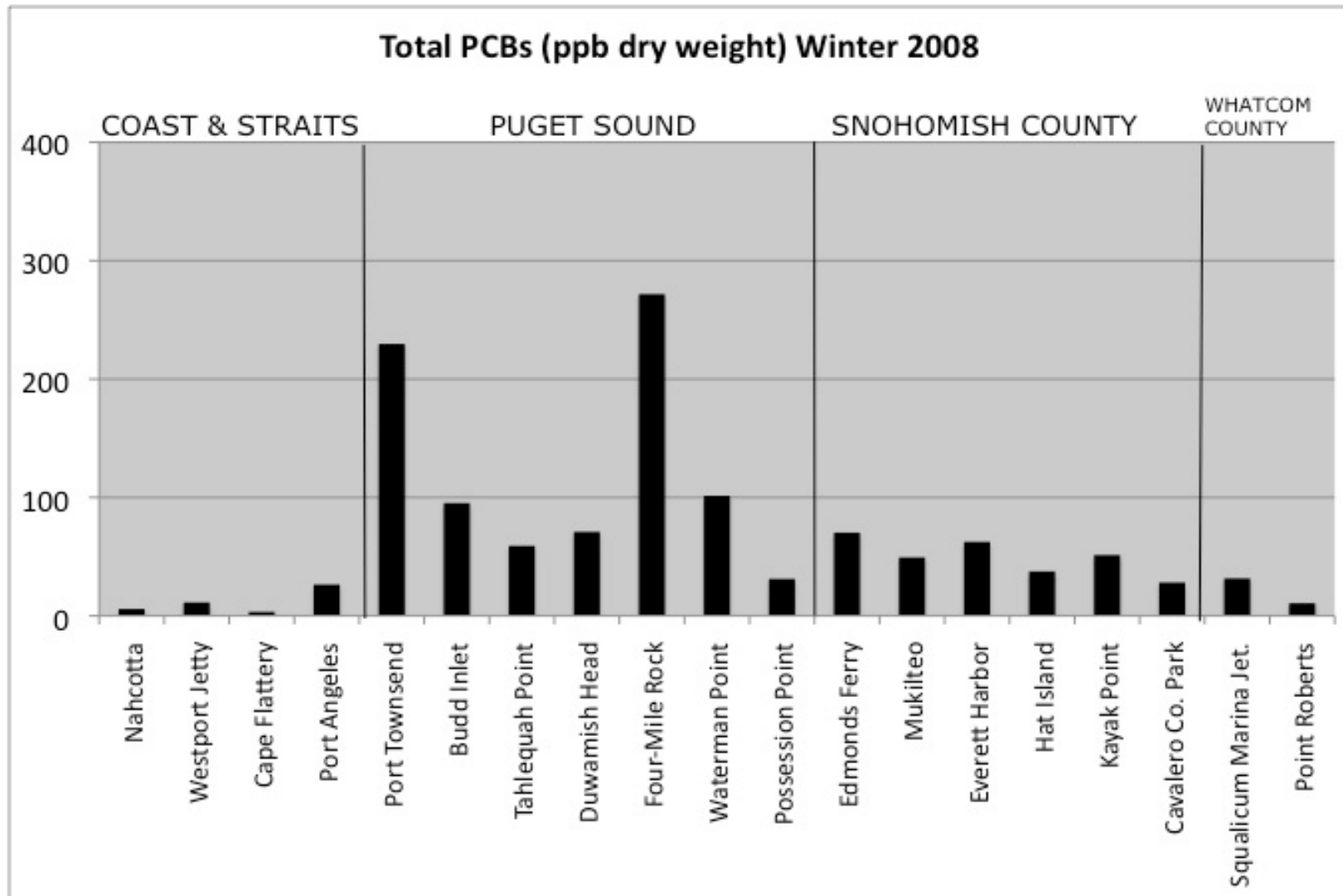


Figure 5 NOAA Washington State Winter 2008 Total PCBs



Total PCB (TPCB) concentrations are lowest in Port Susan stations, increase in Possession Sound and are highest at Edmonds, in the Main Basin of Puget Sound. TPCB ranged from 4.8 ppb dw in mussels from Cavalero Campground in summer 2007 to 179.6 ppb dw in mussels from Edmonds Ferry in Winter 2006. NOAA established low, medium and high concentration ranges for PCBs from the National Mussel Watch Data (Kimbrough, et. al., 2008). Of the 52 samples, 51 were in the low range and 1 was in the medium range. (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.) Mearns (2001) reported that TPCB concentrations in Puget Sound mussels from NOAA sites were declining during the 1980s and early 1990s, increased in the mid-1990s and then started to decrease again in the late 1990s.

Wet season samples are higher in TPCB than dry season samples (Table 5). This could possibly be explained by increased stormwater discharge.

The graph shown in Figure 6 illustrates how there is a significant difference between summer dry season and winter wet season concentrations as well as showing the gradient of PCBs as one moves from the urbanized south to the more rural north part of the county. Another way to view PCB tissue data is after normalizing to the tissue lipid concentration. Figure 7 presents the PCB data as normalized to total lipids, and the seasonal differences are still evident.

Table 5. Total PCB data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		17.3					NS			
Kayak Point	Port Susan		21.2		44.1		15.56	16.93			57.25
Cavalero	Port Susan	6.86	4.8		4.9	6.1	11.0	5.33		17.44	64.35
Hermosa Point	Port Susan							16.6	99.21	76.24	72.67
Hat Island	Possession Sound				31.7	20.0	24.72	9.76	106.48	43.77	67.61
Cemex	Possession Sound							37.69	102.43		88.21
Everett Harbor	Possession Sound		42.7	86.1		42.6	37.3	36.1	69.32	100.24	
Mukilteo Ferry	Possession Sound	92.6	20.6	70.9		29.5	42.70	80.77	14.24		
Picnic Point**	Possession Sound								58.78		
Edmonds Ferry	Main Basin Puget Sound	179.6#	60.1	101.4		49.8	78.1	34.2	108.43	79.73	
Edmonds Marina	Main Basin Puget Sound							37.2			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010

NOAA identifies concentrations from 154 to 478 ppb as "medium".

The seasonal differences as well as the north-south differences are evident in Figure 6. Effects of greater precipitation in 2010, 2011 and 2012 are also evident.

Figure 6 Total PCBs in Snohomish County mussels

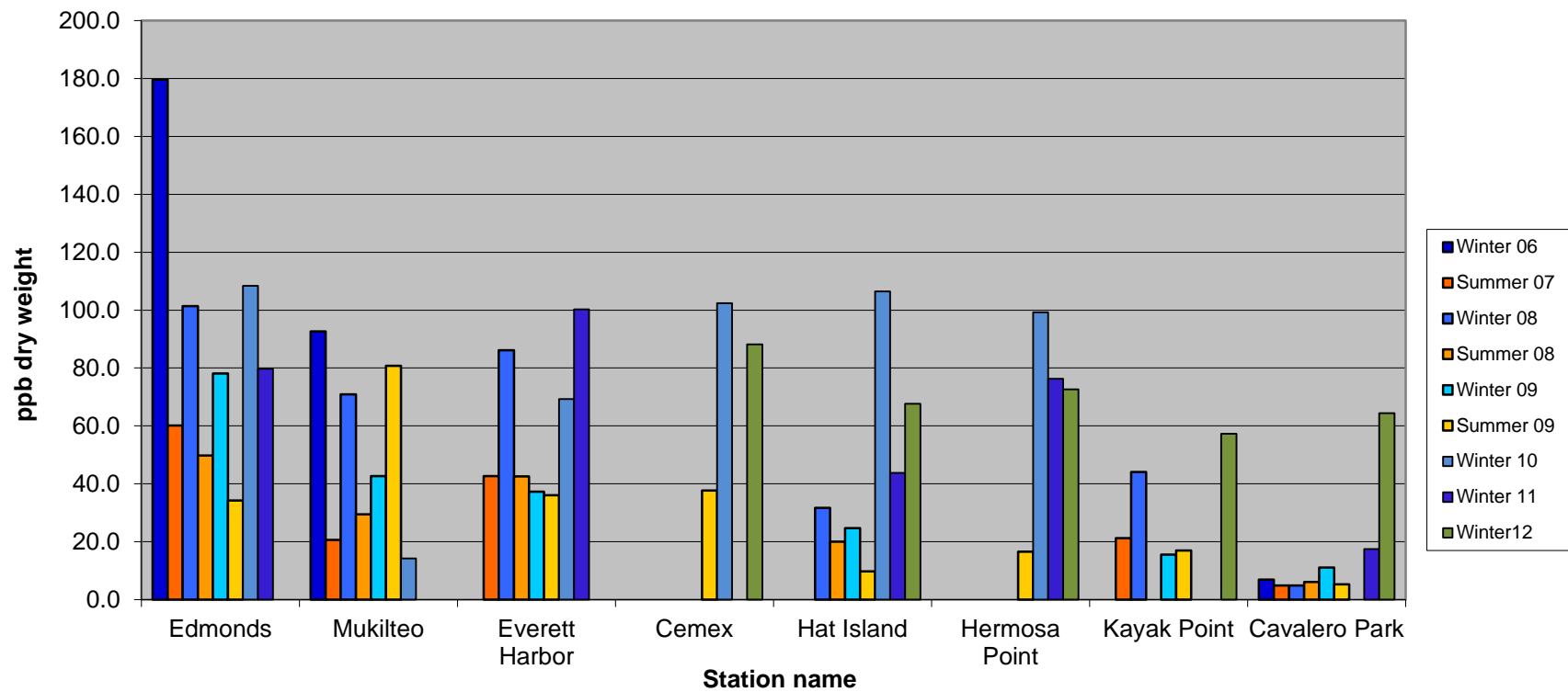
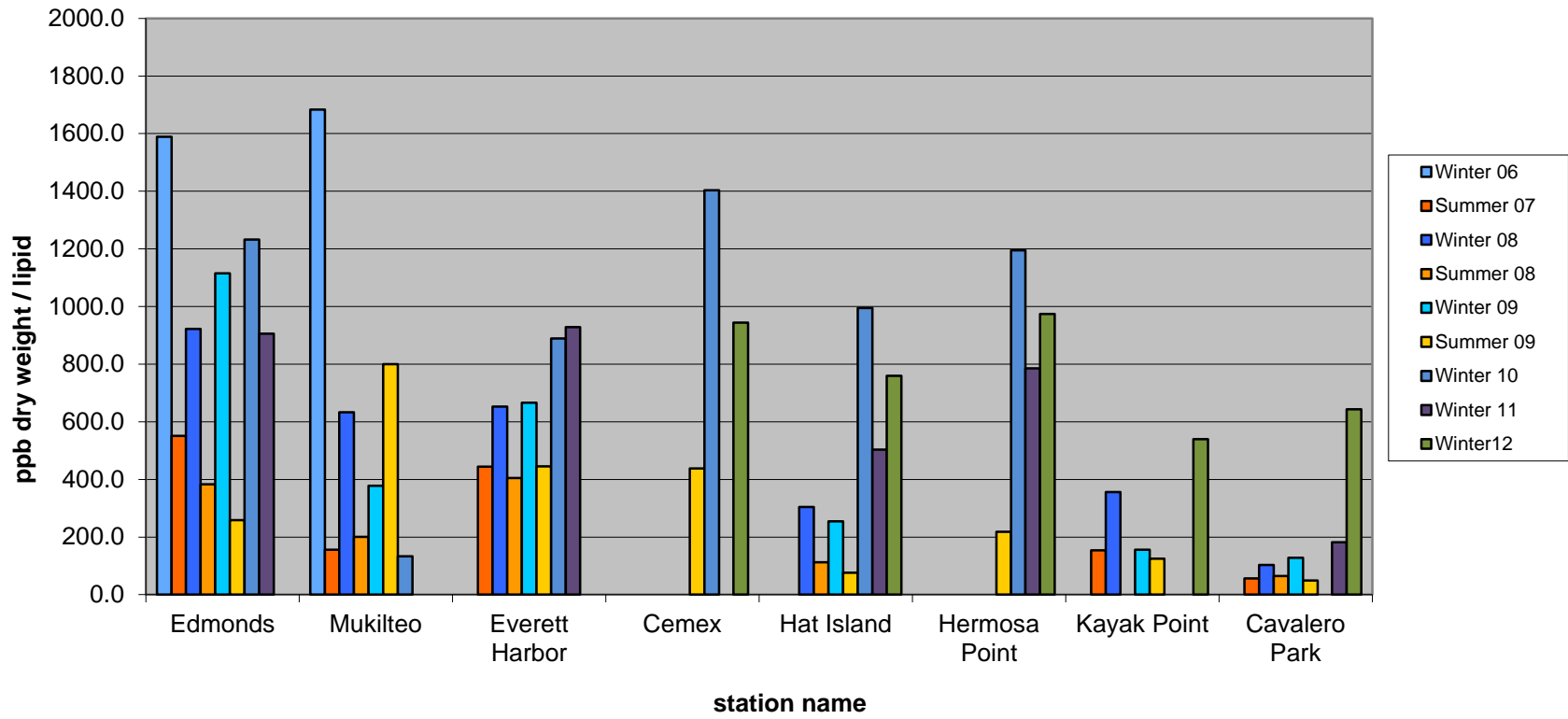
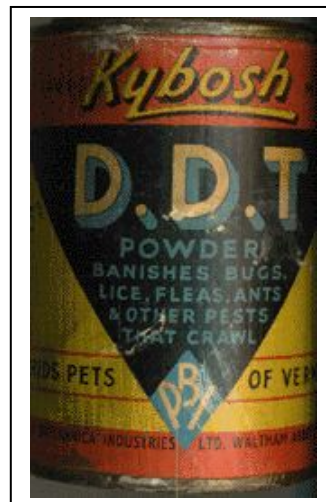


Figure 7 Lipid Normalized Total PCBs in Snohomish County mussels



Total DDT



DDT, a long-lasting insecticide, was used to control mosquitoes and many other insect pests in fields, marshes, buildings and aircraft from World War II to 1971 when it was banned in the U.S. Production and packaging plants along the west coast were point sources of DDT. DDT is biomagnified in marine, aquatic and terrestrial food webs. Concentrations in marine organisms were highest in Southern California and decreased with increasing latitude up the west coast. Total DDT (TDDT) is the sum of 6 individual compounds (isomers) analyzed by NOAA.

TDDT concentrations in mussels ranged from 0.52 ppb dw at Hat Island in August 2009 to 13.88 ppb dw at Everett Harbor in 2011. As with PCBs, in summer 2008, regional means decreased two-fold from south (3.42 ppb dw at Possession Sound sites) to north (1.86 ppb dw at Cavalero Co. Park, representing Port Susan) compared to winter values. The data suggest that high river flows and stormwater may be likely sources of TDDT. (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.)

NOAA established low, medium and high concentration ranges for TDDT from the National Mussel Watch Data (Kimbrough, et. al., 2008). All of the Snohomish County samples were in the low range.

Mearns (2001) reported that TDDT concentrations in Puget Sound mussels from NOAA sites were declining during the 1980s and early 1990s, increased in the mid-1990s and then started to decrease again in the late 1990s.

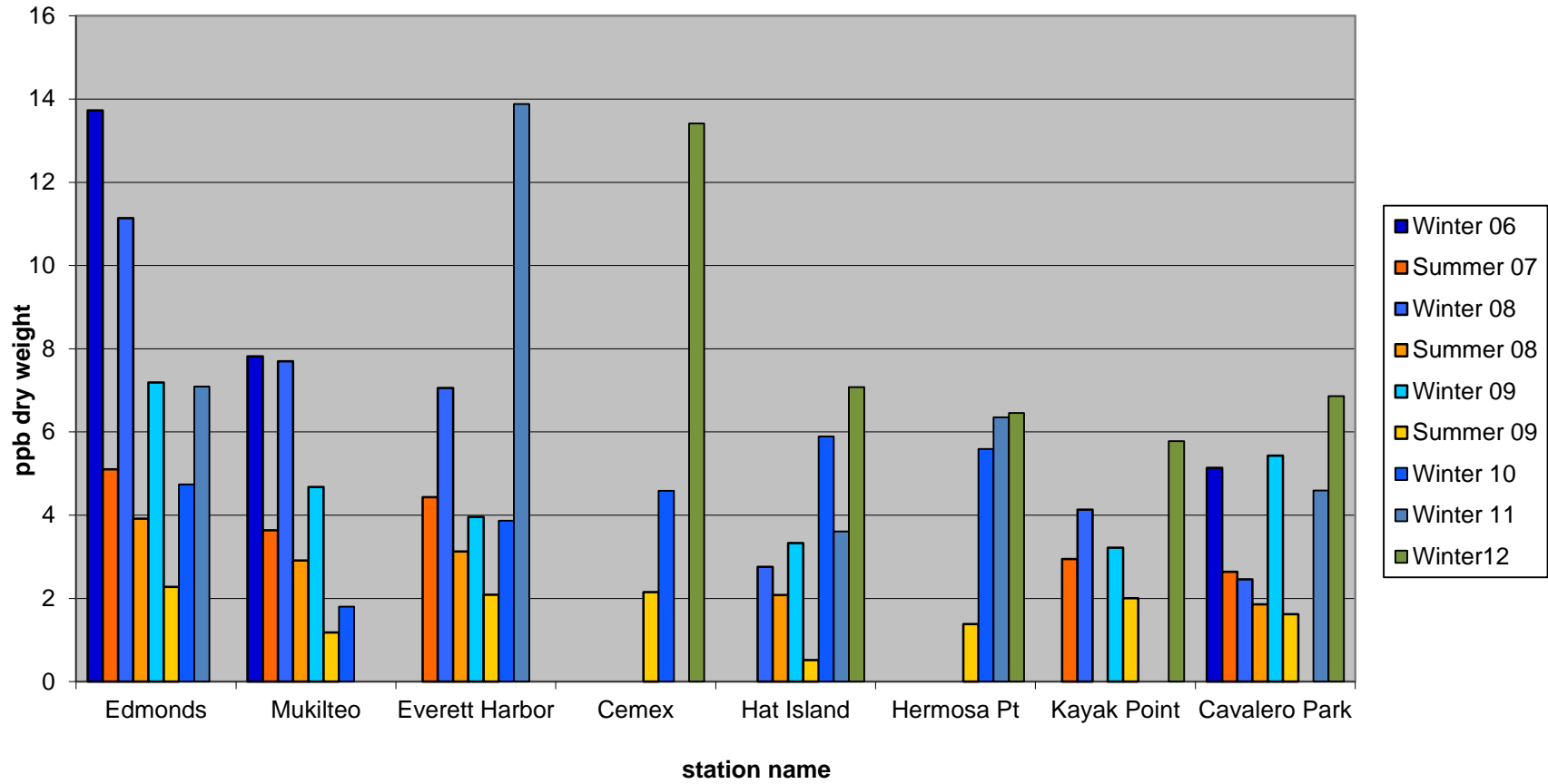
Table 6 Total DDT data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	07-08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		4.04								
Kayak Point	Port Susan		2.94		4.14		3.21	2.01			5.78
Cavalero	Port Susan	5.14	2.63		2.45	1.86	5.42	1.62		4.59	6.86
Hermosa Point	Port Susan							1.39	5.59	6.35	6.45
Hat Island	Possession Sound				2.76	2.08	3.33	0.52	5.89	3.61	7.08
Cemex	Possession Sound							2.15	4.59		13.41
Everett Harbor	Possession Sound		4.44	7.06		3.12	3.96	2.09	3.87	13.88	
Mukilteo Ferry	Possession Sound	7.82	3.64	7.69		2.93	4.68	1.18	1.80		
Picnic Point**	Possession Sound								5.20		
Edmonds Ferry	Main Basin Puget Sound	13.73	5.10	11.14		3.92	7.19	2.28	4.74	7.09	
Edmonds Marina	Main Basin Puget Sound							1.94			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010

NOAA identifies concentrations of 113 to 286 ppb as in the medium range. All Snohomish County sites were in the low range.

Figure 8 Total DDT in Snohomish County mussels



Chlorpyrifos (Dursban TM)



Until 2001 Dursban (the trade name for chlorpyrifos) was a widely sold and used as a home, garden, and golf course insecticide in the US and Puget Sound region. Chlorpyrifos is an organic phosphate insecticide that should degrade much faster than DDT, chlordanes or other organochlorine pesticides.

Chlorpyrifos was detected in 7 Snohomish and Island County mussel samples out of a total of 52 samples. The highest concentration was 4.28 ppb dw at Picnic Point, a station that was only sampled once, two months after the other wet season samples for 2010 were taken. All the other detections were very low, at or below 0.4 ppb. Note no graph is provided for this table because the concentrations were so low.

These data suggest that the control of Dursban has been effective but that traces from past use may still be present in Puget Sound and Snohomish County. The Picnic Point data suggests that this station may need to be looked at again someday.

Table 7 Chlorpyrifos data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		U								
Kayak Point	Port Susan		U		0.11		U	U			U
Cavalero	Port Susan	U	U		0.17	U	U	U		U	U
Hermosa Point	Port Susan							U	U	U	U
Hat Island	Possession Sound				U	0.30	U	U	U	U	U
Cemex	Possession Sound							U	U		U
Everett Harbor	Possession Sound		U	U		0.22	U	U	U	U	
Mukilteo Ferry	Possession Sound	U	U	U		0.40	U	U	0.37		
Picnic Point**	Possession Sound								4.28		
Edmonds Ferry	Main Basin Puget Sound	U	U	U		U	U	U	U	U	
Edmonds Marina	Main Basin Puget Sound							U			

U = not detected

*10 day rainy period occurred before sampling

** Picnic Point sampled in mid-March 2010

For more information about Chlorpyrifos/Dursban see:

http://74.125.155.132/search?q=cache:7QOky2E3KuQJ:www.beyondpesticides.org/news/pressreleases/Dursban_1.pdf+uses+of+chlorpyrifos&cd=1&hl=en&ct=clnk&gl=us

<http://www.dowagro.com/turf/prod/dursban.htm>

Chlordane



Chlordane, like DDT, is a persistent insecticide and was widely used to control ants, termites, and many other insect pests. It was banned in the US in the late 1980s. Like DDT and PCBs, chlordane compounds biomagnify in marine, aquatic and terrestrial food webs. Total Chlordane is a collection of up to 7 separate compounds all of which are summed by NOAA to produce a Total Chlordane concentration.

Chlordanes were present in mussels from all Snohomish and Island County sites sampled by the MRC. Total chlordane concentrations ranged 15-fold from 0.61 ppb dw at Cavalero Campground in August 2009 to 13.18 ppb dw at Edmonds in December 2005. The 13.18 ppb dw value at Edmonds is an outlier, as the next highest concentration at Edmonds was less than 5 ppb dw and all other sites were less than 4 ppb dw. Concentrations appeared to decrease from the south to the north. Only one sample was in the range that NOAA considers as medium range, and all others were in the low range. 2012 was unusual with all stations sampled being higher (although still in the NOAA low range). (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.)

Shigenaka (1989) and Mearns (2001) reported that total Chlordane concentrations in Puget Sound mussels from NOAA sites were declining during the 1980s and early 1990s, increased in the mid-1990s and then started to decrease again in the late 1990s.

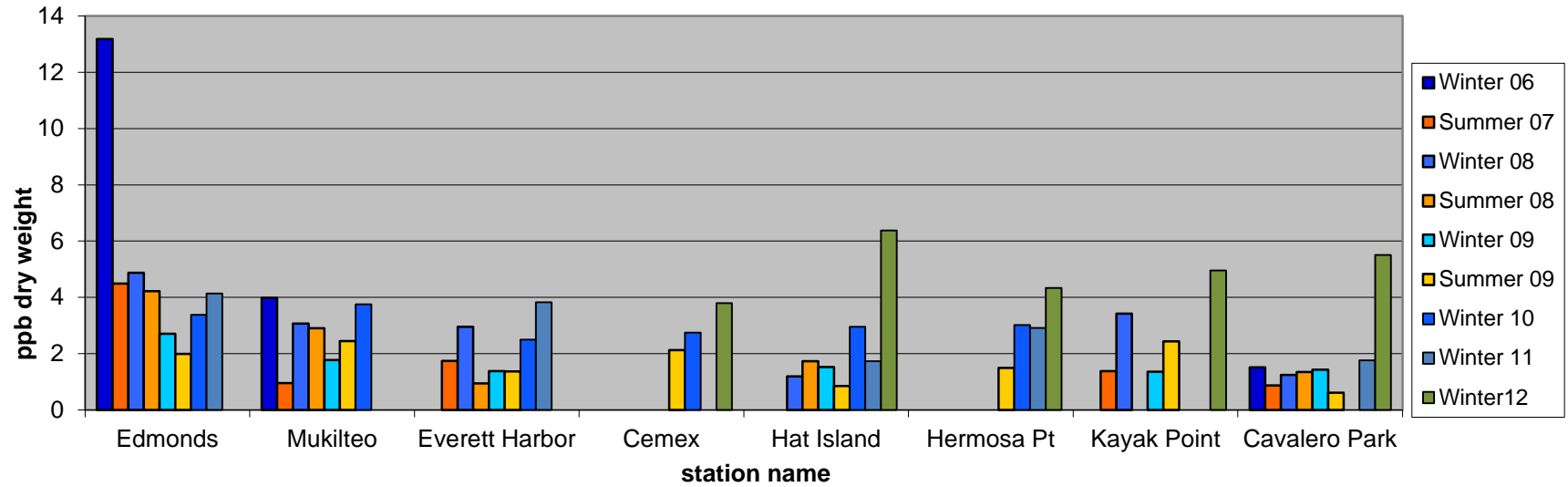
Table 8 Total Chlordane data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	07-08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		1.92								
Kayak Point	Port Susan		1.38		3.44		1.36	2.43			4.95
Cavalero	Port Susan	1.51	0.87		1.23	1.35	1.43	0.61		1.76	5.50
Hermosa Point	Port Susan							1.50	3.02	2.92	4.34
Hat Island	Possession Sound				1.19	1.73	1.52	0.85	2.95	1.74	6.28
Cemex	Possession Sound							2.13	2.75		3.80
Everett Harbor	Possession Sound		1.73	2.95		0.94	1.38	1.37	2.5	3.83	
Mukilteo Ferry	Possession Sound	3.98	0.95	3.07		2.90	1.77	2.45	3.75		
Picnic Point**	Possession Sound								5.51		
Edmonds Ferry	Main Basin Puget Sound	13.18#	4.48	4.87		4.20	2.71	1.99	3.38	4.13	
Edmonds Marina	Main Basin Puget Sound							3.27			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010

NOAA considers chlordane concentrations of 9 to 20 ppb to be in the medium range

Figure 9 Total Chlordanes in Snohomish County mussels



Hexachlorohexanes (HCHs), Including Lindane



There are four HCHs, alpha-, beta-, gamma- and delta HCH. The trade name for gamma HCH is Lindane. HCHs were first synthesized in 1825 by Michael Faraday, but were not used as insecticides until 1942. Lindane continues to be used to treat scabies and was an active component of hair lice shampoos and pet lotions and shampoos. It has also been used in agriculture; a few acres were treated in California as recently as 2007. EPA classified it for restricted use in 1985. It may be an estrogen mimic. China has been producing and exporting Lindane since 1985. Lindane undergoes atmospheric transport and sources from China as well as North Africa have been shown to impact North America.

Concentrations of Total HCH in Snohomish and Island County mussels ranged from non-detect to 11.57 ppb dw at Cemex in 2012. 2012 was unusual with all stations sampled being high. (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.) Mearns (2001) reported that HCHs were common in mussels along the entire Pacific Coast including Alaska.

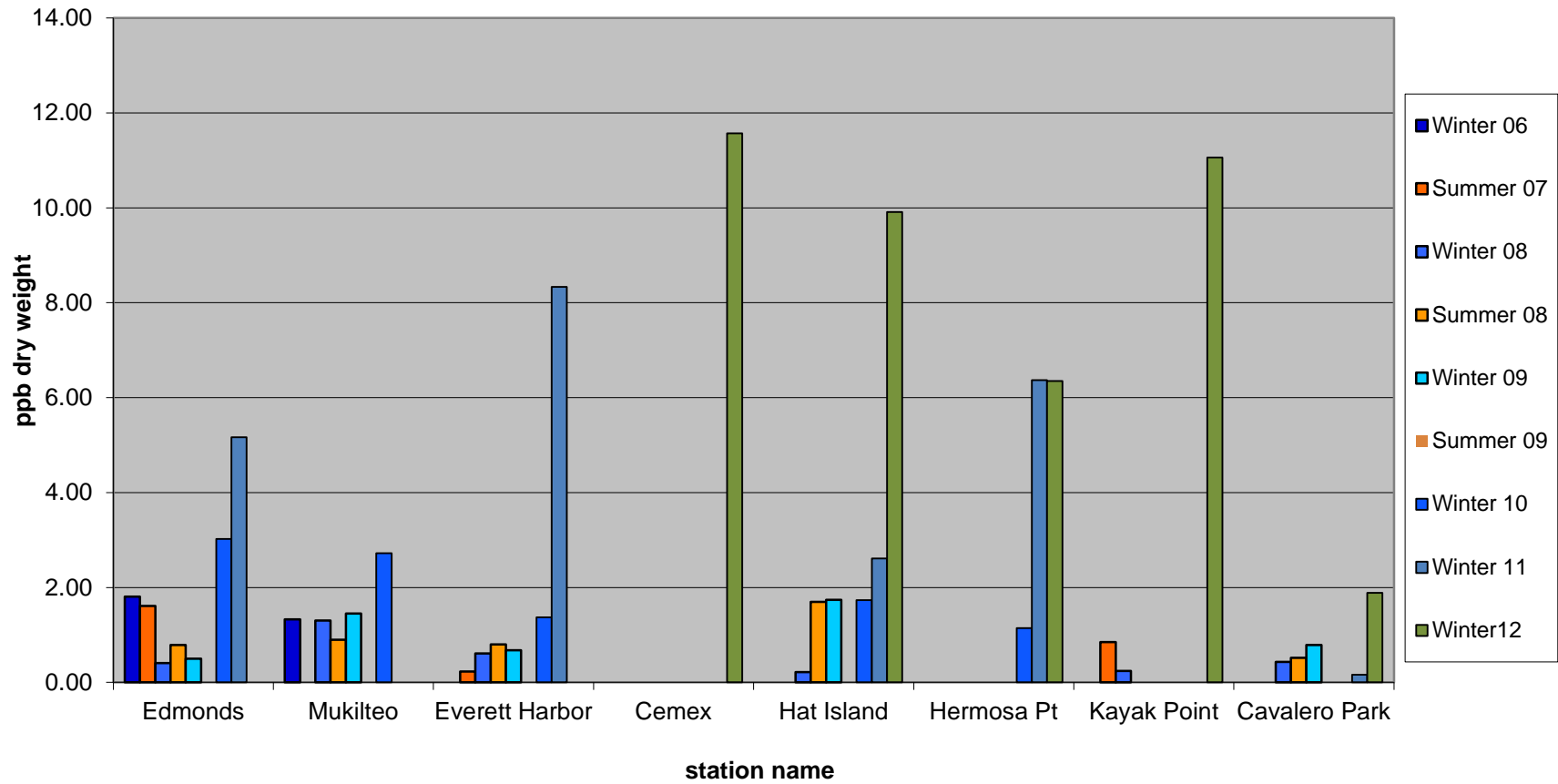
Table 9 Total Hexachlorohexanes data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		U								
Kayak Point	Port Susan		0.85		0.24		U	U			11.06
Cavalero	Port Susan	U	U		0.43	0.52	0.79	U		0.16	1.89
Hermosa Point	Port Susan							U	1.14	6.37	6.35
Hat Island	Possession Sound				0.22	1.70	1.74	U	1.73	2.61	9.91
Cemex	Possession Sound							U	U		11.57
Everett Harbor	Possession Sound		0.23	0.61		0.80	0.68	U	1.37	8.33	
Mukilteo Ferry	Possession Sound	1.33	U	1.31		0.90	1.45	U	2.72		
Picnic Point**	Possession Sound								4.26		
Edmonds Ferry	Main Basin Puget Sound	1.81	1.61	0.41		0.79	0.50	U	3.03	5.17	
Edmonds Marina	Main Basin Puget Sound							U			

U = not detected.

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010

Figure 10 Total Hexachlorohexanes in Snohomish County mussels



Dieldrin



Dieldrin is a chlorinated insecticide developed in the 1940s as an alternative to DDT and was widely used in agriculture in the 1960s and 1970s, then banned in the US in 1987, except for subsurface termite control, dipping of nonfood roots and tops, and moth-proofing in a closed manufacturing process (EPA). A related insecticide, Aldrin, breaks down to Dieldrin.

Dieldrin was detected in all but one Snohomish and Island County mussel samples between 2005 and 2012, with concentrations ranging from 0.35 ppb dw at Cavalero to a high of 3.28 at Eide Road in September 2007. NOAA established low, medium and high ranges for Dieldrin from the National Mussel Watch Data (Kimbrough, et. al., 2008). All of the Snohomish County mussels were in the low range. The higher concentration at Eide Road suggests there may have been a source in the Stanwood area or elsewhere in the Stillaguamish Drainage. Unfortunately, later samples to evaluate the site were not obtained due to lack of mussels. There appears to be some elevations in the wet season compared to the dry season. Total Dieldrin values reported are the sum of Aldrin and Dieldrin. (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.)

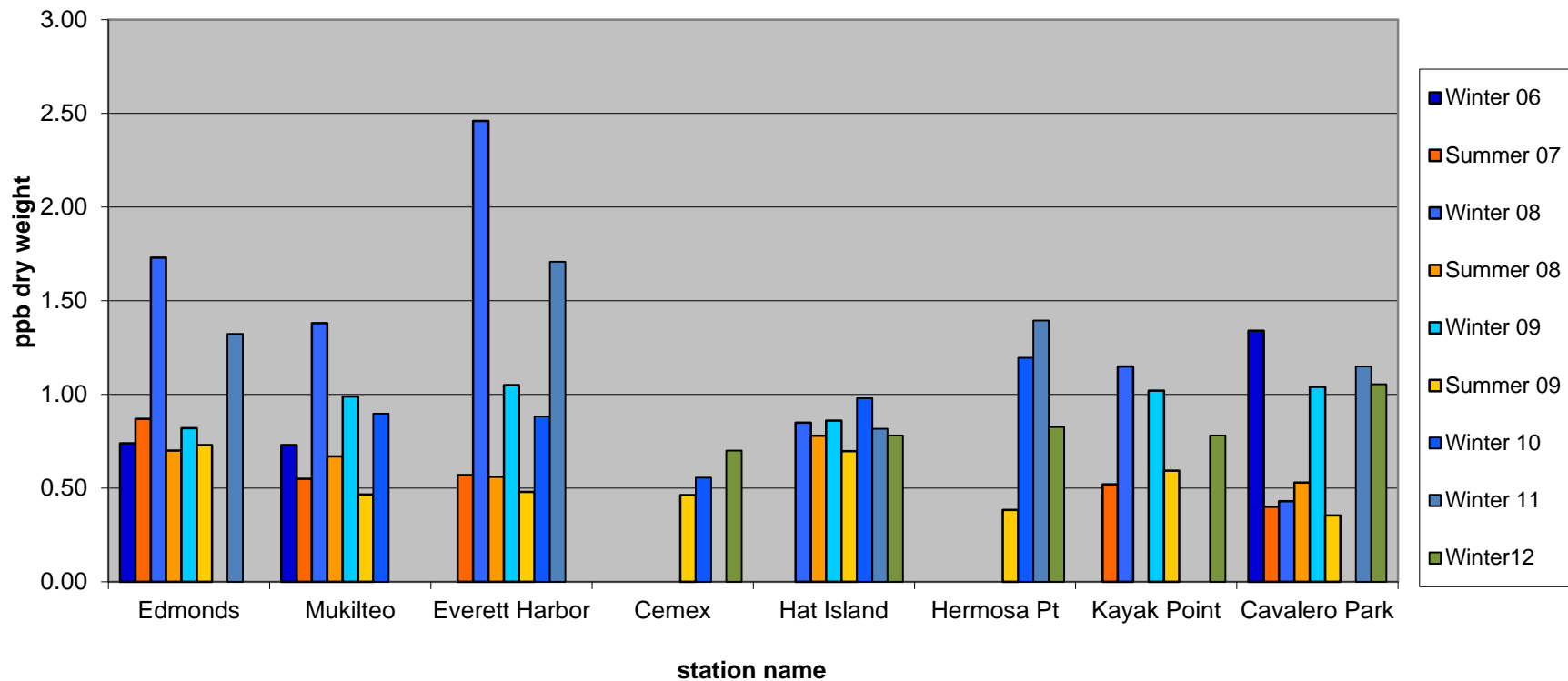
Table 10 Dieldrin data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		3.28								
Kayak Point	Port Susan		0.52		1.15		1.02	0.59			0.78
Cavalero	Port Susan	1.34	0.40		0.43	0.53	1.04	0.35		1.15	1.05
Hermosa Point	Port Susan							0.38	1.20	1.40	0.83
Hat Island	Possession Sound				0.85	0.78	0.86	0.70	0.98	0.82	0.78
Cemex	Possession Sound							0.46	0.56		0.70
Everett Harbor	Possession Sound		0.57	2.46		0.56	1.05	0.48	0.88	1.71	
Mukilteo Ferry	Possession Sound	0.73	0.55	1.38		0.67	0.99	0.47	0.90		
Picnic Point**	Possession Sound								0.57		
Edmonds Ferry	Main Basin Puget Sound	0.74	0.87	1.73		0.70	0.82	0.73	U	1.32	
Edmonds Marina	Main Basin Puget Sound							0.47			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010

NOAA considers Dieldrin concentrations from 9 to 34 ppb to be in a medium range. All Snohomish County sites were in the low range.

Figure 10 Dieldrin in Snohomish County mussels



Hexachlorobenzene (HCB)



HCB is a fungicide for seed treatment and a soap disinfectant. “As of 2003, HCB had been banned or restricted as a pesticide in 23 nations, and it had been made illegal for import in 69 nations. While many countries have restricted the use of HCB as a pesticide, its occurrence as an industrial byproduct is less strictly controlled” (NRDC, 2009). It is transported globally in the atmosphere.

HCB was detected in all but five of the 52 samples from 2005 through 2012 Snohomish County MRC mussel samples. Concentrations did not vary greatly, ranging from non-detect at three stations to 11.57 ppb dw at Cemex in 2012. The 2012 samples were all elevated compared to the prior years. (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.) HCB has been a low-level contaminant along the Pacific Coast for many years.

Table 11 Hexachlorobenzene data in parts per billion (dry weight) from Snohomish County Mussel Watch

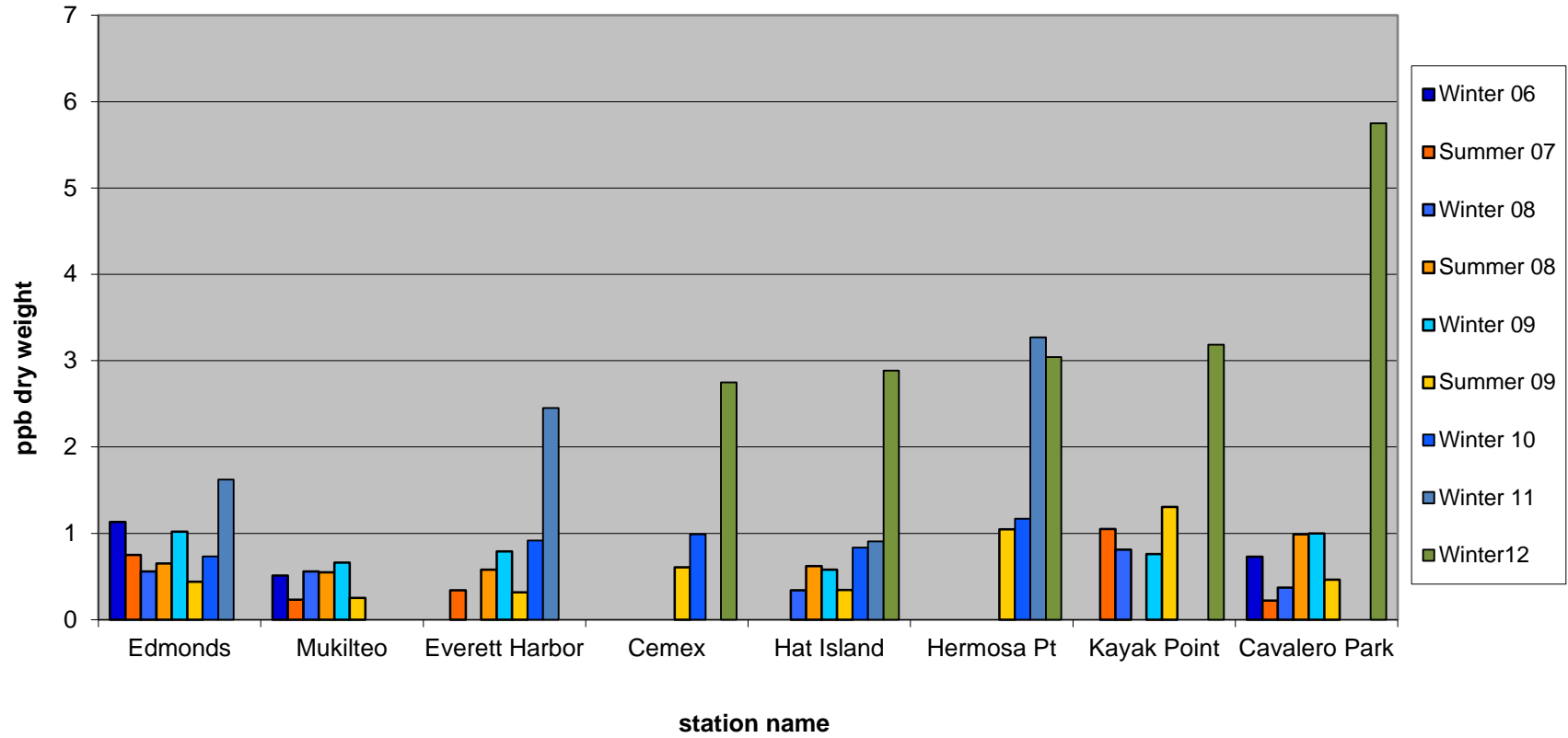
	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		U								
Kayak Point	Port Susan		0.85		0.24		0.76	1.31			11.06
Cavalero	Port Susan	0.73	U		0.93	0.99	1.00	0.46		U	1.89
Hermosa Point	Port Susan							1.05	1.17	3.27	6.35
Hat Island	Possession Sound				0.22	0.62	0.58	0.34	0.83	0.91	9.91
Cemex	Possession Sound							0.61	0.99		11.57
Everett Harbor	Possession Sound		0.23 JJ	0.61		0.58	0.79	0.32	0.92	2.45	
Mukilteo Ferry	Possession Sound	0.51	U	1.31		0.55	0.66	0.25	U		
Picnic Point**	Possession Sound								2.60		
Edmonds Ferry	Main Basin Puget Sound	1.13	1.61	0.41		0.65	1.02	0.44	0.73	1.62	
Edmonds Marina	Main Basin Puget Sound							0.25			

U= not detected

*10 day rainy period occurred before sampling

** Picnic Point sampled in mid-March 2010

Figure 12 Hexachlorobenzene in Snohomish County mussels



Polycyclic Aromatic Hydrocarbons (PAHs)



Polycyclic Aromatic Hydrocarbons (PAHs) are a group of chemicals that occur naturally in coal, crude oil and gasoline. PAHs also are present in products made from fossil fuels, such as coal-tar pitch, creosote and asphalt. PAHs also can be released into the air during the incomplete burning of fossil fuels and garbage. The less efficient the burning processes, the more PAHs are given off. Forest fires and volcanoes can produce PAHs naturally. Wood stoves produce PAHs. PAHs may be petrogenic in origin (associated with fuels) or pyrogenic (products of combustion). Cooking, barbecuing and smoke curing of meats results in pyrogenic PAHs in the food.

Brandenberger, et al., 2010 evaluated atmospheric deposition of air toxics to the surface of Puget Sound. As part of the study, they evaluated several different diagnostic ratios of distinct PAH source signatures. The ratios indicate that pyrogenic PAHs are the dominant form in atmospheric deposition, and that biomass combustion may well be greater than petroleum combustion as a source of PAHs.

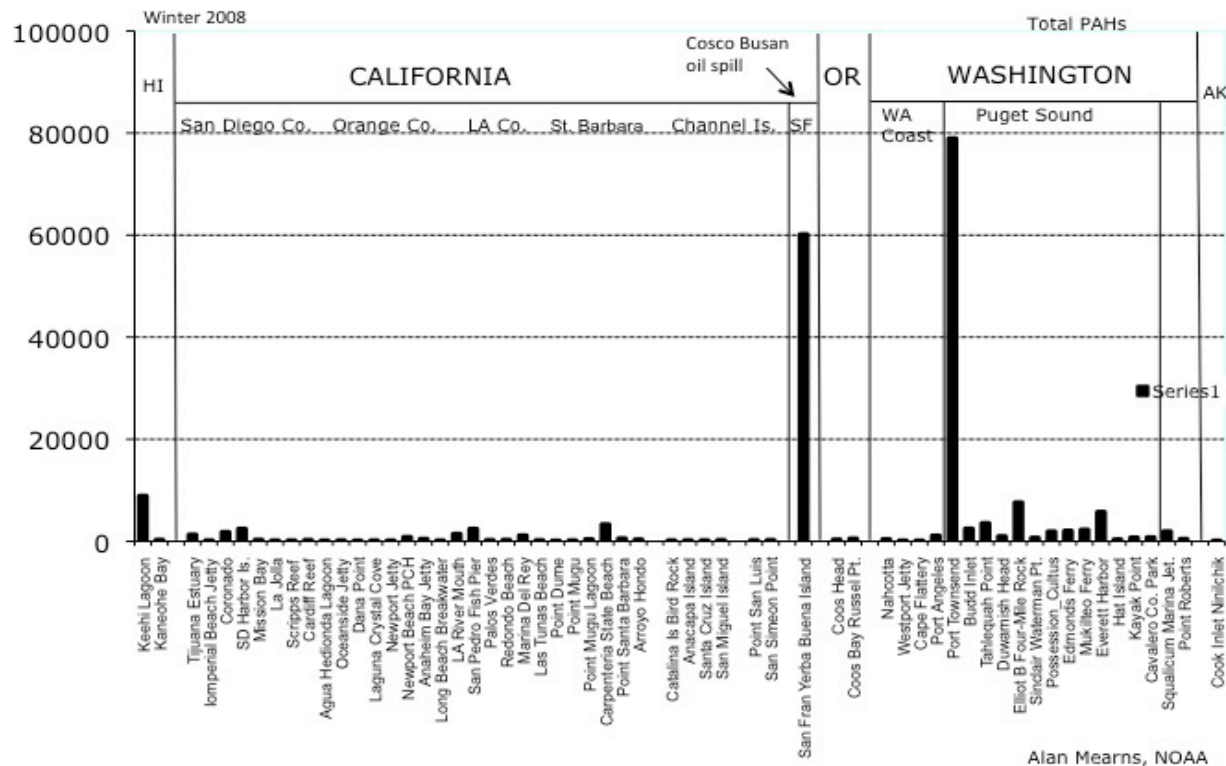
The NOAA Mussel Watch Program now analyzes over 50 different PAH compounds, and presents the concentration of total PAHs. Over time, the Mussel Watch program has included additional PAHs in their analysis, which means comparisons of total PAHs over time is not a straightforward comparison. For all practical purposes though, comparison of total PAH data over the last 8 years is not significantly affected by the increased PAH parameters measured.

PAHs are bioaccumulative, but not significantly so in fish because fish metabolize the PAHs. Liver disease in English sole is associated with PAH exposures. PAHs bioconcentrate in shellfish, but do not bioaccumulate.

Fuel combustion products from cars, planes, trains, ferries, small boats, and large ships as well as from wood burning stoves all contribute to PAH loadings both directly to surface waters, and indirectly by land deposition and subsequent storm water runoff. Similarly, fuel and oil leaks or spills from all modes of transportation and handling can contribute petrogenic PAHs. Another significant source of PAHs is creosote treated wood, such as in pier pilings and railroad ties. The railroad runs adjacent to the shore from Everett to the Snohomish-King County line, so railroad associated PAH contributions could come from both the railroad ties and the numerous large diesel engines passing close by.

Figure 13 presents NOAA 2008 winter PAH mussel data for all the west coast and for just the Washington State stations. Puget Sound stations have higher PAHs than many of the outer coast stations. Within Puget Sound, concentrations are highest in the main basin. The winter 2008 data had an unusual spike at Port Townsend. This may have been related to a significant creosote pile structure near the site, since removed. There was also a smaller spike at Everett Harbor. The figures help put the Snohomish County data in context.

Figure 13 2008 Winter PAH Data for the West Coast



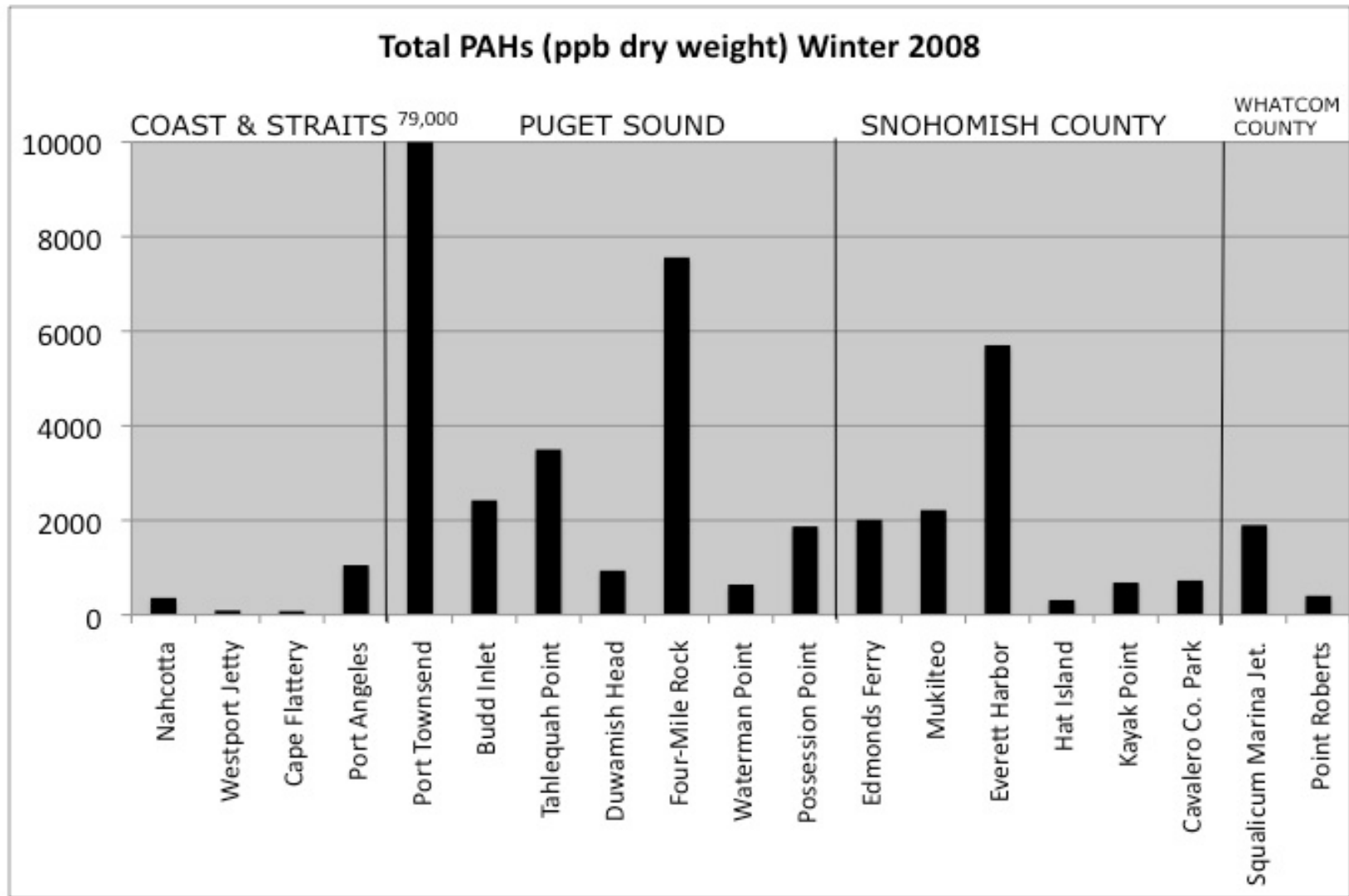


Table 12 presents Total PAH data for the Mussel Watch stations in Snohomish County.

Two patterns are evident. PAHs are lower in Port Susan than in the Possession Sound and Puget Sound stations to the south. PAHs also vary significantly with the season, indicating that stormwater runoff and/or wood burning stove emissions are probably a significant source of PAHs. Wet season samples are between 2 and 10 times higher in total PAHs than the dry season. The second time that the dry season mussels were sampled was in late August of 2008. That “dry” season was an anomaly in that the preceding 10 days had been rainy with a typical winter storm pattern, so the mussels would have been exposed to some stormwater runoff that followed an extended dry spell. The MRC expected that the 2008 “dry” season results would have higher PAHs than the 2007 dry season, and that proved to be the case. NOAA established low, medium and high ranges for total PAHs from the National Mussel Watch Data (Kimbrough, et. al., 2008). Of the 52 samples, 33 were in the low range, 17 were in the medium range, and 2 were in the high range.

The 2012 data, especially for Hat Island, really stands out. We have no possible explanation for the very high PAHs at Hat Island. The Hat Island site is not near any significant PAH source. The other stations with data for 2012 are much lower, but still running higher than usual. (Note: the NOAA stations for Everett Harbor and Edmonds Ferry were sampled in 2012, but NOAA archived the samples without analysis.)

Table 12 Total PAH data in parts per billion (dry weight) from Snohomish County Mussel Watch

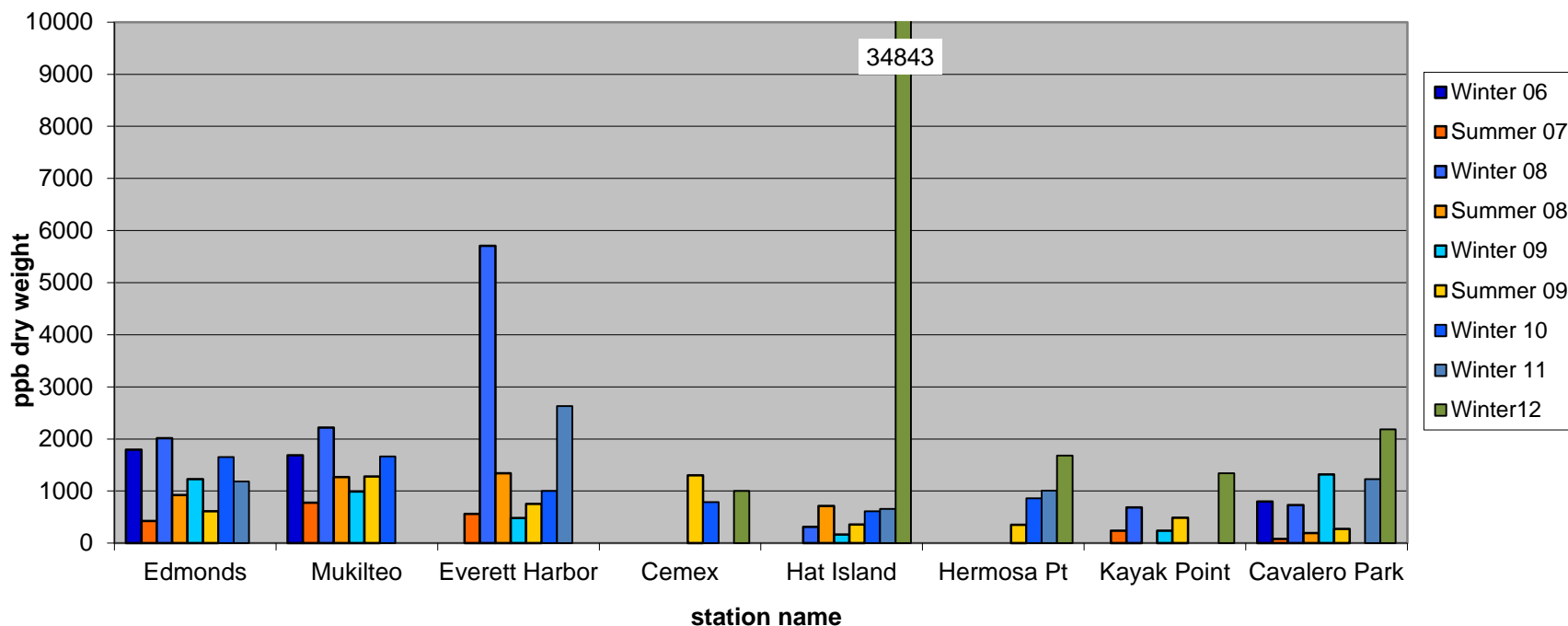
	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		128								
Kayak Point	Port Susan		292		745		257	487			1,344#
Cavalero	Port Susan	840	147		919	245	1,387#	275		1,230#	2,182#
Hermosa Point	Port Susan							354	859	1,010	1,681#
Hat Island	Possession Sound				355	791	177	356	614	658	34,843##
Cemex	Possession Sound							1,303#	787		1,003
Everett Harbor	Possession Sound		635	7,037##		1,440#	555	755	1,000	2,628#	
Mukilteo Ferry	Possession Sound	1,716#	830	2,353#		1,346#	1,041	1,281#	1,664#		
Picnic Point**	Possession Sound								792		
Edmonds Ferry	Main Basin Puget Sound	1,879#	477	2,114#		989	1,305#	612	1,655#	1183	
Edmonds Marina	Main Basin Puget Sound							695			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010

NOAA considers Total PAHs from 1188 to 4434 ppb to be in the medium range.

NOAA's high range for Total PAHs is 4435 to 7561 ppb.

Figure 14 Total PAHs in Snohomish County mussels



In addition to the 2012 Hat Island station, the winter 2008 Everett Harbor Total PAH value was quite elevated compared to other sites and other sample periods.

Although not a PAH, hopane is considered to be a useful petroleum marker that does not degrade over time. In 2008 the hopane concentration in mussels at the Everett Harbor site was the highest for all of the west coast (see Figure 14). This indicates some release must have occurred locally, perhaps via a nearby CSO, perhaps from the Port site, or perhaps from a marine vessel. We have no way of identifying the source at this time and we note that the effect did not extend far nor did it persist.

Figure 15 Winter 2008 NOAA C29 Hopane Data for West Coast

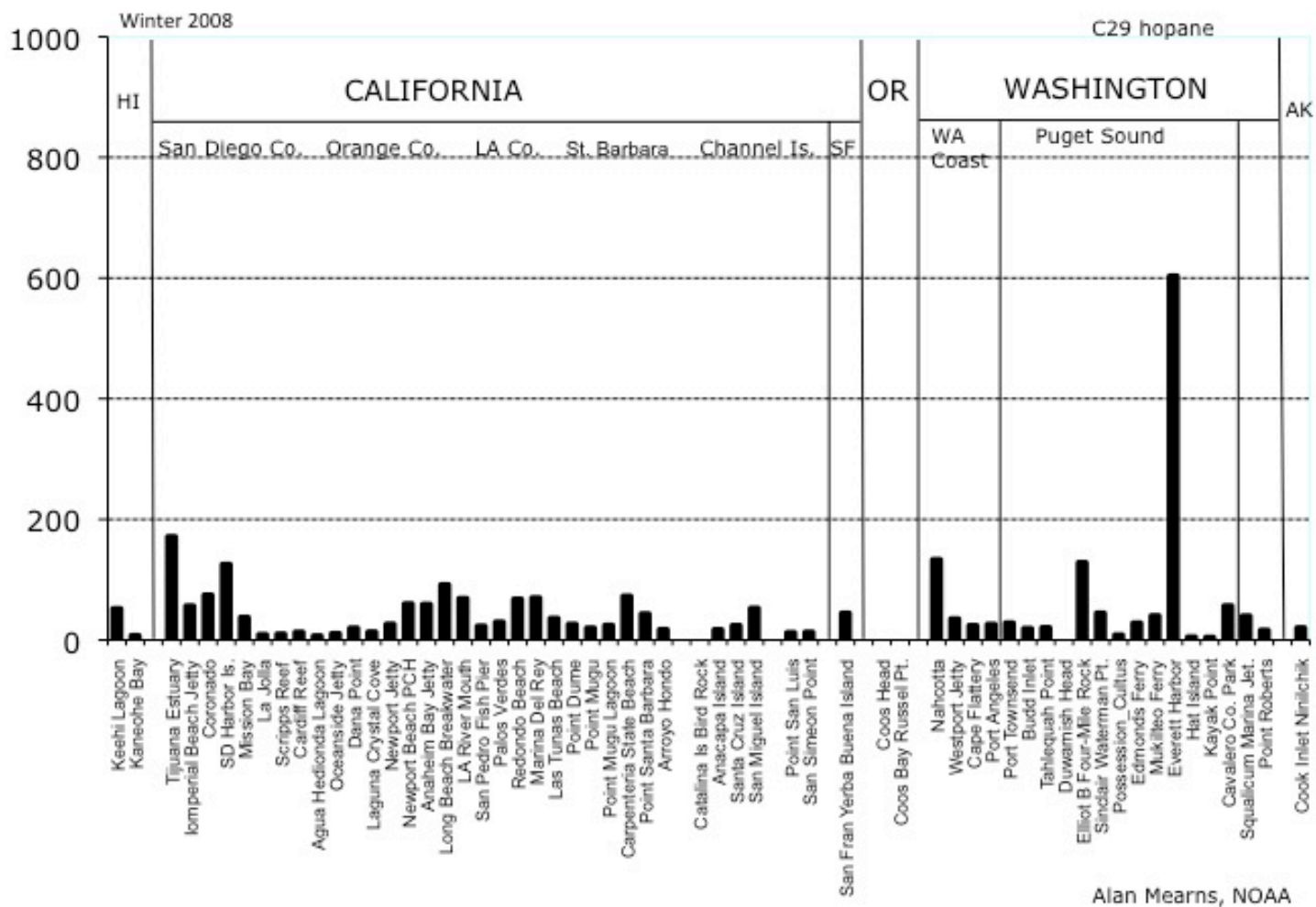
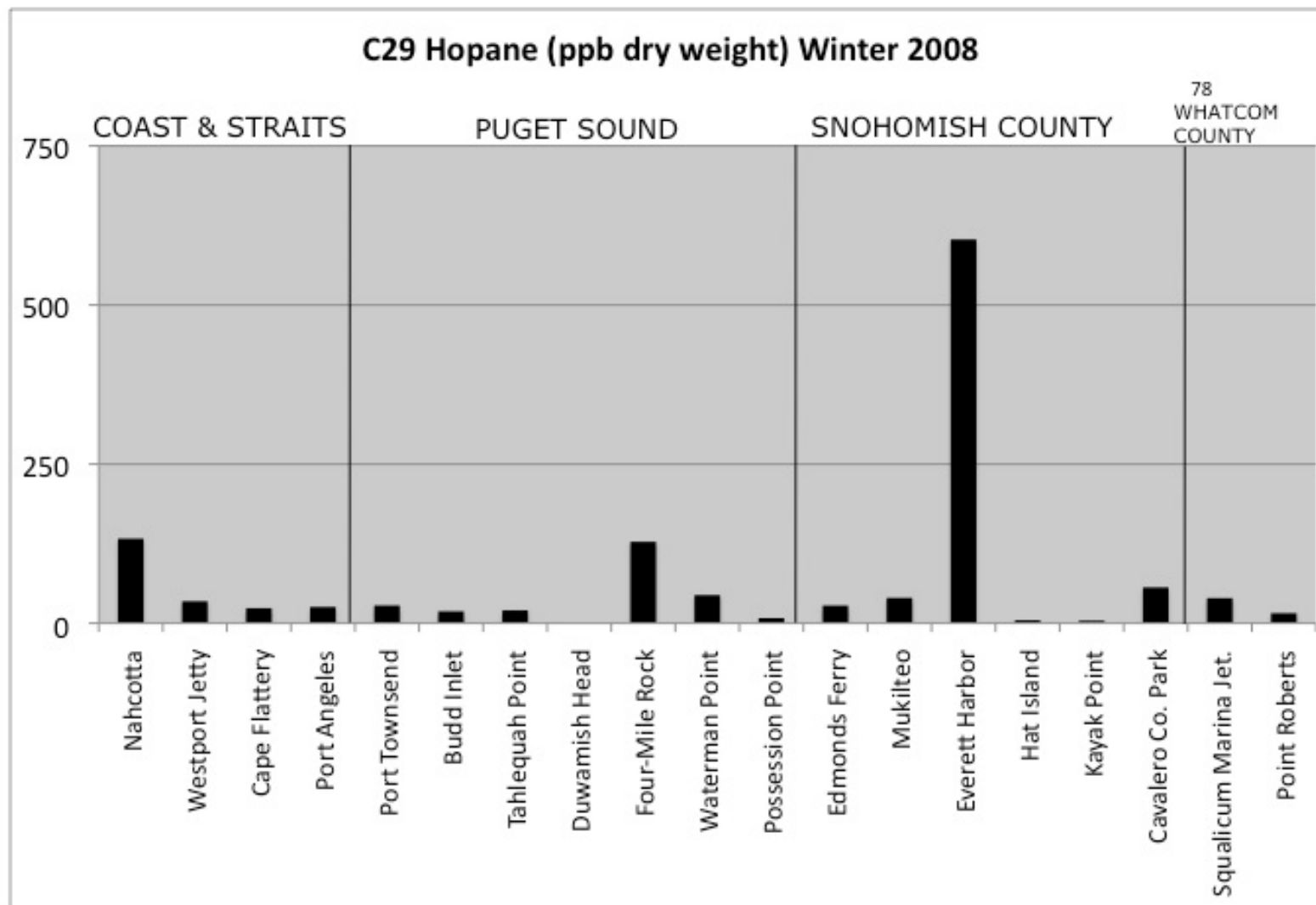


Figure 16 Winter 2008 NOAA C29 Hopane Data for Washington State



It is possible to look at the relative concentrations of the numerous different compounds that are included in the PAHs and discern information about the sources. The PAHs for the stations in Port Susan had much lower concentrations of the high molecular weight PAHs than did the stations in Possession Sound and the main basin of Puget Sound.

The NOAA Mussel Watch TPAH data is the sum of over 50 different PAHs. Washington state has numeric marine sediment quality standards in regulation (Chapter 173-204 WAC) that include standards for the sums of a number of low molecular weight PAHs (LPAH) and also the sums of a number of high molecular weight PAHs (HPAHs). For the sediment standards,

LPAH is the sum of Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene and Anthracene.

HPAH is the sum of Fluoranthene, Pyrene, Benz(a)Anthracene, Chrysene, Total Benzofluoranthenes, Benzo(a)Pyrene, Indeno(1,2,3-c,d)Pyrene, Dibenzo(a,h)Anthracene and Benzo(g,h,i)Perylene.

Recognizing that the sediment quality standards are not applicable to mussel tissue concentrations, the following tables and graphs present the total LPAH (Table 13 and Figure 17) and total HPAH (Table 14 and Figure 18) concentrations from the Mussel Watch data simply as another way to examine the data.

Note in Table 13 and Figure 17 that the LPAHs at Cavalero are not much different in the winter from the Possession Sound stations of Everett Harbor, Mukilteo and Edmonds. There is also a strong difference between winter and summer seasons at Cavalero, more so than elsewhere. Also, while the Hat Island 2012 LPAH value is high, the other 2012 values are not out of the range for LPAHs typical for their stations.

In Table 14 and Figure 18, the HPAH data show a very strong difference between winter and summer seasons at all stations. The Hat Island 2012 concentration was unexplainably high, and most of the other stations sampled in 2012 were also higher than the range normally experienced by the station. Note also that the Hat Island samples from the 2008 wet season to the 2009 wet season were all samples taken from creosote treated pilings. Creosote is considered to be a significant source of HPAHs. Beginning with the 2010 wet season, all samples from Hat Island have been sampled from an old concrete structure a short distance to the west from the pilings.

While not all-inclusive, the HPAH constituents are more representative of combustion related, or pyrogenic PAHs, while the LPAHs are more representative of petroleum or petrogenic PAHs. Hence, the HPAH component of TPAH is not associated with petroleum. The strong winter signal for HPAHs is indicative of stormwater runoff and perhaps atmospheric deposition as well. The surprisingly elevated levels in the winter at Cavalero may also be indicative of the winter weather patterns where predominant southerly winds

could push surface waters towards the head of Port Susan, and thereby result in a higher PAH exposure than local sources would produce.

Table 13 Total Low Molecular Weight PAHs (LPAH) data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		28								
Kayak Point	Port Susan		44		112		77	55			90
Cavalero	Port Susan	149	17		134	43	314	35		173	311
Hermosa Point	Port Susan							51	134	130	139
Hat Island	Possession Sound				49	209	46	59	135	94	3617
Cemex	Possession Sound							209	121		144
Everett Harbor	Possession Sound		89	325		268	87	117	146	272	
Mukilteo Ferry	Possession Sound	176	146	293		216	224	204	247		
Picnic Point**	Possession Sound								163		
Edmonds Ferry	Main Basin Puget Sound	130	61	216		158	163	98	217	127	
Edmonds Marina	Main Basin Puget Sound							103			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010

Figure 17 Total Low Molecular Weight PAHs (LPAHs) in Snohomoish County mussels

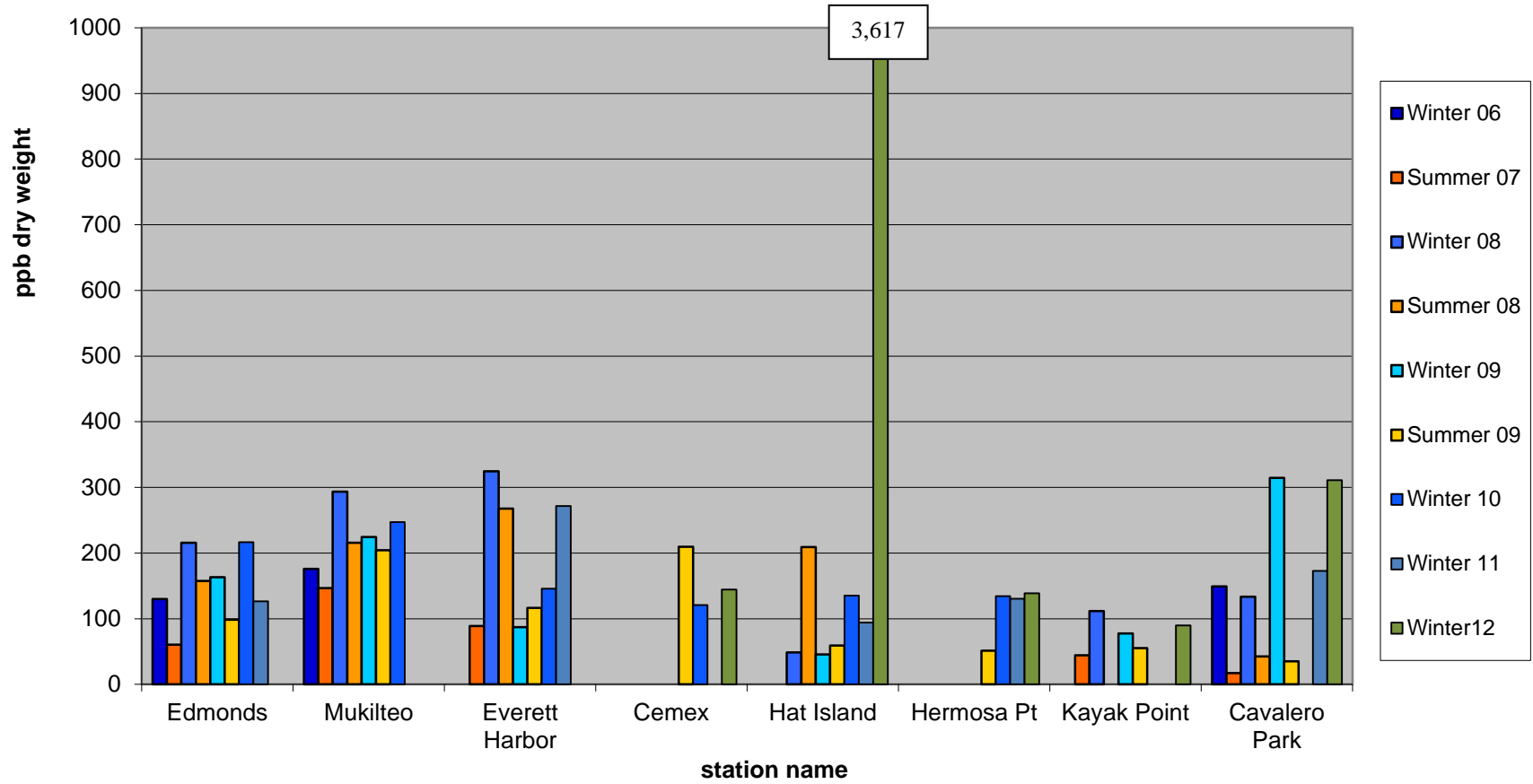


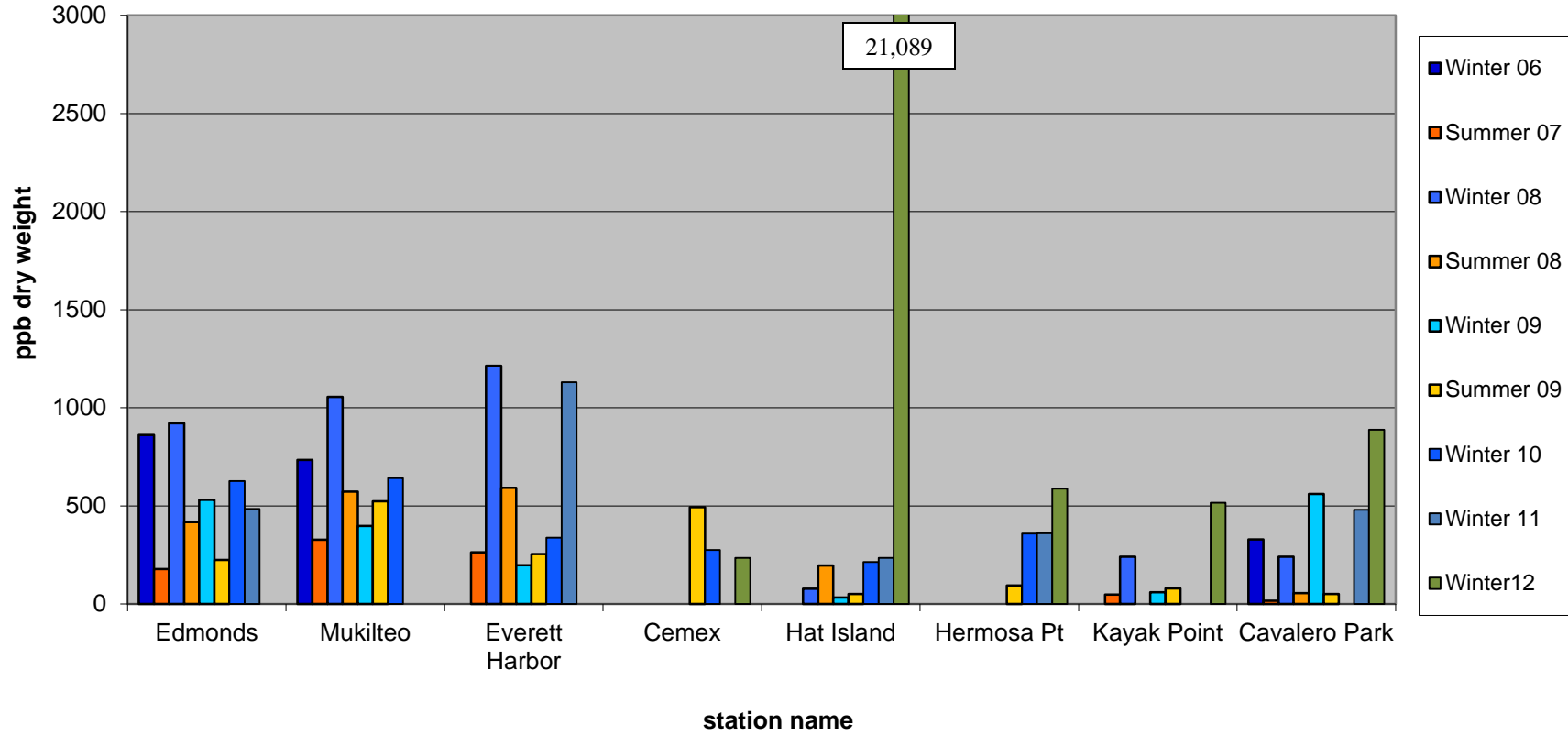
Table 14 Total High Molecular Weight PAHs (HPAH) data in parts per billion (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	008 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1&2/12
Eide Road	Port Susan		12								
Kayak Point	Port Susan		48		240		60	80			516
Cavalero	Port Susan	329	17		240	56	561	52		481	888
Hermosa Point	Port Susan							94	359	361	588
Hat Island	Possession Sound				78	593	33	52	214	235	21,089
Cemex	Possession Sound							494	276		235
Everett Harbor	Possession Sound		264	1,214		574	197	254	338	1,130	
Mukilteo Ferry	Possession Sound	734	328	1,055		196	398	524	642		
Picnic Point**	Possession Sound								246		
Edmonds Ferry	Main Basin Puget Sound	861	179	921		418	531	224	626	485	
Edmonds Marina	Main Basin Puget Sound							267			

*10 day rainy period occurred before sampling

** Picnic Point sampled in mid-March 2010

Figure 18 Total High Molecular Weigh PAHs (HPAHs) in Snohomish County mussels



Trace Metals

The NOAA Mussel Watch metals data for Puget Sound has been unremarkable. Essentially, the metals show little difference with the open ocean stations. Some of the metals data for the state are counterintuitive. Arsenic and cadmium are highest at Cape Flattery by the entrance to the Strait of Juan de Fuca. The elevated values are associated with oceanic upwelling and also with less dilution by freshwater. Human inputs of metals have little effect on concentrations in Puget Sound and the mussels pretty much bear this fact out. Mercury is a concern because it has human health ramifications and it does bioaccumulate in fish tissue and biomagnifies up the food web. Below we report on four of the 14 metals analyzed in mussels. Ecology has recently published studies that include measurements of metals in the surface and deep marine waters of Puget Sound as well as at the mouth of five major rivers including the Snohomish, Stillaguamish and Skagit (Gries and Osterberg, 2011). The metals observations were all lower than the applicable marine and fresh water quality standards in Chapter 173-201A WAC. Ecology also recently published studies that measured metals and other parameters in watersheds dominated by specific types of land uses associated with storm flow events and base flow conditions in Snohomish County (Herrera Environmental Consultants, 2011). The MRC will continue to review this information in the context of how it might relate to concentrations in mussels.

Copper

Copper is a societal concern, generally associated with wear and tear on brake pads and resultant road runoff. Copper and zinc are also components of some of the TBT-replacement vessel paints. That said, the concerns with copper should probably focus on possible impacts in small urban streams, and not in Puget Sound.

The copper data for mussels in Snohomish County are interesting in that up until 2011, the highest were in mussels from the Port Susan sites and the lowest were from the Hat Island, Edmonds Ferry and Mukilteo Ferry sites. However, the 2011 data presented some surprising spikes, with the highest being at Hat Island. The 2011 sampling (at least for some of the stations) occurred at a time when the Snohomish River was flowing high with a high suspended sediment load. This was noted during the sampling at Hermosa Point, where the water was noted to be turbid and the salinity was measured at just 5 parts per thousand. Tables 1 and 2 provide rainfall data for 60 days and 30 days prior to sampling, and shows that the days leading up to the 2011 sampling had the greatest amount of rainfall.

We note that in reviewing the NOAA mussel watch data for the state, occasional spikes in copper occur at various stations and the spikes occur in a seemingly random manner. We speculate that these spikes could be related to recent ingestion by mussels of suspended sediment, which would include a mineral loading of copper. This would be unlikely to bioconcentrate and the mussel

would be expected to depurate the suspended sediments in short time. The mussel watch protocol does not allow for time for mussels to depurate following collection, so mineral chemistry may add to the measured tissue levels.

A feature of Hat Island is its location, which presents a non-urbanized, non-commercial exposure, but a high exposure to runoff from 3 major rivers, the Skagit, the Stillaguamish and the Snohomish.

NOAA established low, medium and high ranges for copper from the National Mussel Watch Data (Kimbrough, et. al., 2008). Of the 44 samples, 30 were in the low range, 13 were in the medium range and 1 was in the high range.

Table 15 Total Copper data in parts per million (dry weight) from Snohomish County Mussel Watch

	Water body	06 wet season	07 dry season	08 wet season		08 “dry” season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1/12
Eide Road	Port Susan		32.4#								
Kayak Point	Port Susan		29.3#		8.0			13.0			26.1#
Cavalero	Port Susan	10.7	8.7		26.1#			10.7		17.4#	27.6#
Hermosa Point	Port Susan							9.77	12.7	25.1#	18.8#
Hat Island	Possession Sound				6.2	5.2		6.6	8.71	54.5##	18.1#
Cemex	Possession Sound							18.6#	9.65		11.3
Everett Harbor	Possession Sound		24.4#	18.9#		8.7		6.87	12.0	13.7	
Mukilteo Ferry	Possession Sound	10	8.0	6.6		7.0		7.59	8.69		
Picnic Point**	Possession Sound								9.43		
Edmonds Ferry	Main Basin Puget Sound	8.2	6.7	13.7		5.8		6.21	9.62	32.0#	
Edmonds Marina	Main Basin Puget Sound							10.9			

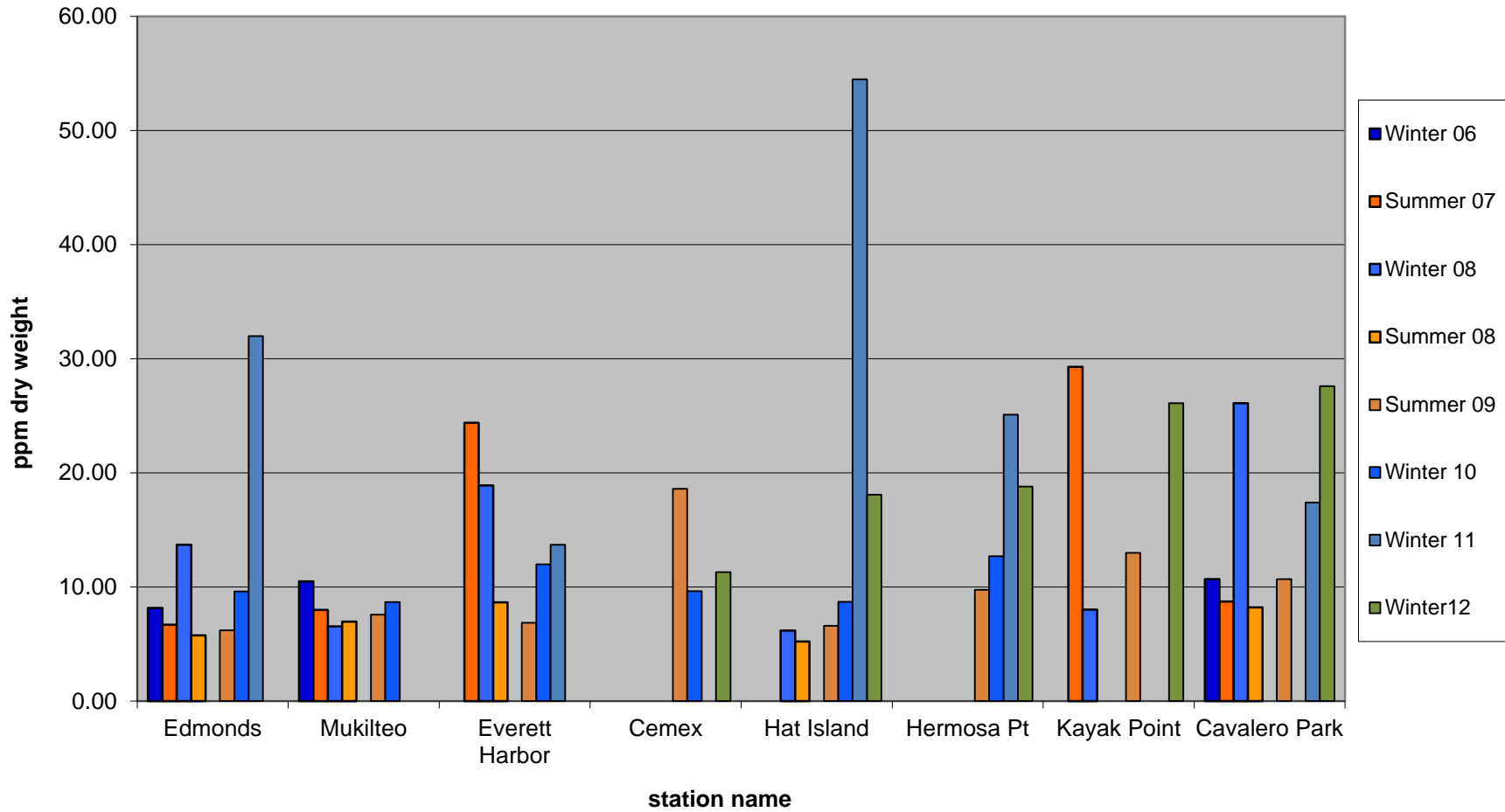
*10 day rainy period occurred before sampling.

** Picnic Point sampled in mid-March 2010

NOAA considers copper concentrations of 17 to 39 ppm to be in the medium range.

NOAA considers copper concentrations greater than 39 ppm to be in the high range.

Figure 19 Copper in Snohomish County mussels



Mercury

Among the metals, mercury is the one with the most human health concerns. Mercury bioaccumulates in fish tissue as methylmercury and is a neurotoxin.

NOAA established low, medium and high ranges for mercury from the National Mussel Watch Data (Kimbrough, et. al., 2008.) One sample at Cavalero Park was in the NOAA medium range. The remaining 42 samples were in the low range. As with copper, the stations in Port Susan have higher mercury than the stations in Possession Sound.

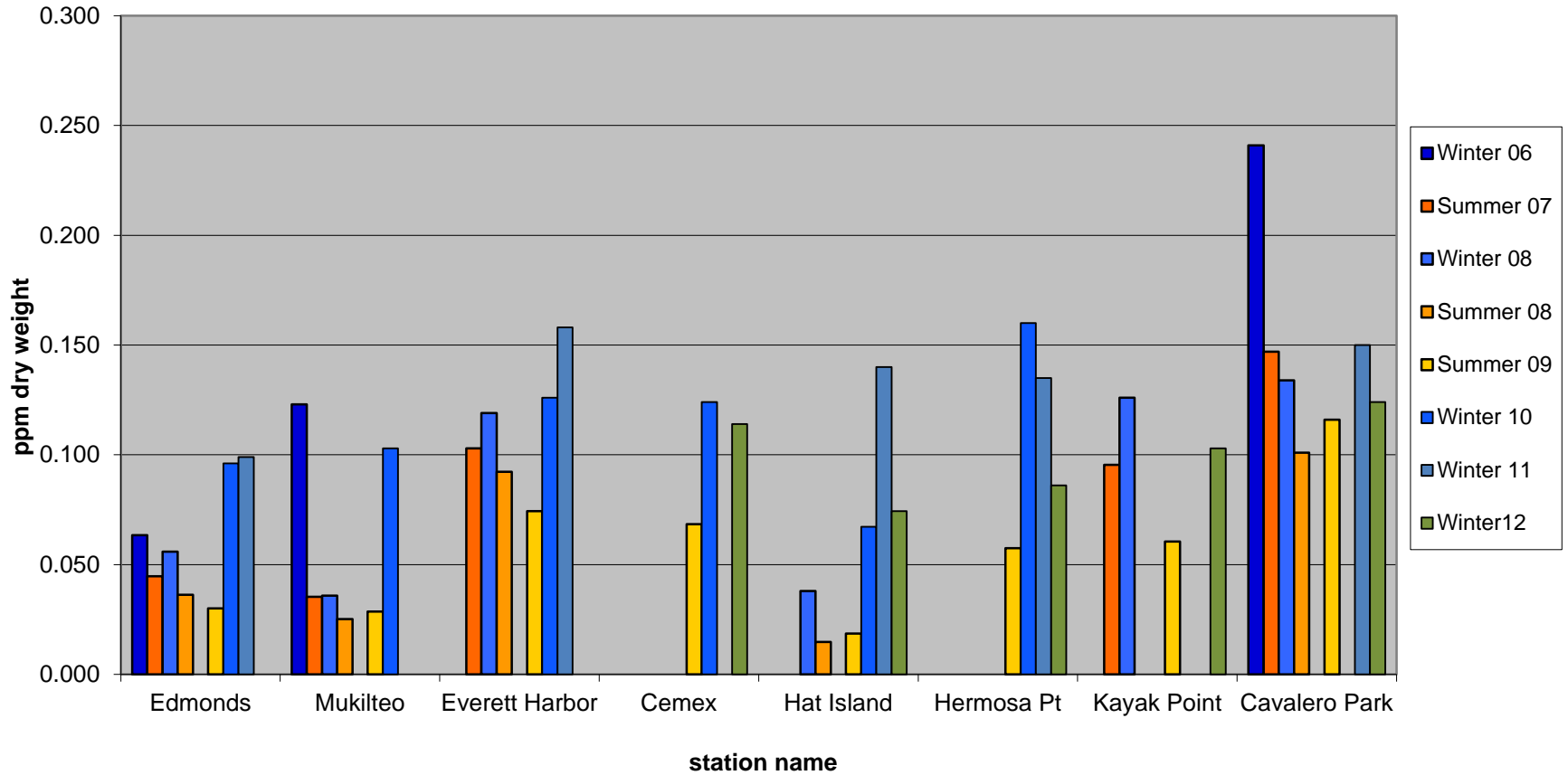
Table 16 Total Mercury data in parts per million (dry weight) from Snohomish County Mussel Watch.

	Water body	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1/12
Eide Road	Port Susan		0.141								
Kayak Point	Port Susan		0.095		0.126			0.06			0.10
Cavalero	Port Susan	0.241#	0.147		0.134	0.101		.0116		0.150	0.124
Hermosa Point	Port Susan							0.058	0.160	0.135	0.086
Hat Island	Possession Sound				0.038	.015		0.019	0.067	0.140	0.074
Cemex	Possession Sound							0.068	0.124		0.114
Everett Harbor	Possession Sound		0.103	0.119		.092		0.074	0.126	0.158	
Mukilteo Ferry	Possession Sound		0.035	0.036		.025		0.029	0.103		
Picnic Point**	Possession Sound								0.097		
Edmonds Ferry	Main Basin Puget Sound	0.063	0.045	0.056		.036		0.030	0.096	0.099	
Edmonds Marina	Main Basin Puget Sound							0.024			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010.

#NOAA considers mercury concentrations of 0.18 to 0.35 ppm to be in the medium range.

Figure 20 Mercury in Snohomish County mussels



Lead

NOAA established low, medium and high ranges for lead from the National Mussel Watch Data (Kimbrough, et. al., 2008). NOAA considers lead concentrations of greater than 3 to 6 ppm to be in the medium range. NOAA specifically noted that the winter 2004-05 lead data for Washington State had the highest levels at the Mukilteo Ferry, Edmonds Ferry and Everett Harbor sites (all of which are Snohomish County sites). NOAA evaluated Everett Harbor at 7.6 ppm in 2004 as being in the high range for lead and Mukilteo Ferry and Edmonds Ferry were in the medium range. Consequently, we have included the 2004-5 winter data with Table 17.

The sparse data show that the 2006 wet season had low range levels of lead for Mukilteo Ferry and Edmonds Ferry, and no data were obtained for Everett Harbor. The data also show that lead levels in the 2007 dry season were lower than prior wet seasons for the stations, with Everett Harbor still in NOAA's medium range. The lead data continue to suggest that Everett Harbor is a high spot for lead with the 2008 dry season value of 26.4 ppm being the highest in the set and clearly in NOAA's high range. Remember that there was considerable rainfall in the 10-day period before the 2008 "dry" season sample event. The lead spike at the Everett Harbor site in the 2008 dry season is quite high and very unusual, implying some localized source. Another high spike occurred in 2011, and may be related to high turbid river flow. The 2009 dry season had low lead levels.

Table 17 Total Lead data in parts per million (dry weight) from Snohomish County Mussel Watch.

	Water body	04 wet season	06 wet season	07 dry season	08 wet season		08 "dry" season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
			12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1/12
Eide Road	Port Susan			1.32								
Kayak Point	Port Susan			1.04		0.61			0.50			1.38
Cavalero	Port Susan		1.22	0.85		1.12	0.75		0.80		0.80	1.54
Hermosa Point	Port Susan								0.51	1.15	1.34	1.11
Hat Island	Possession Sound					0.26	0.22		0.20	0.55	1.97	1.07
Cemex	Possession Sound								1.12	0.92		0.90
Everett Harbor	Possession Sound	7.62###		4.87#	2.23		26.4###		1.75	2.09	19.40###	
Mukilteo Ferry	Possession Sound	4.65#	2.06	0.92	0.79		1.33		1.07	0.90		
Picnic Point**	Possession Sound									0.65		
Edmonds Ferry	Main Basin Puget Sound	3.05#	2.57	0.85	1.8		1.05		0.64	1.33	1.41	
Edmonds Marina	Main Basin Puget Sound								0.42			

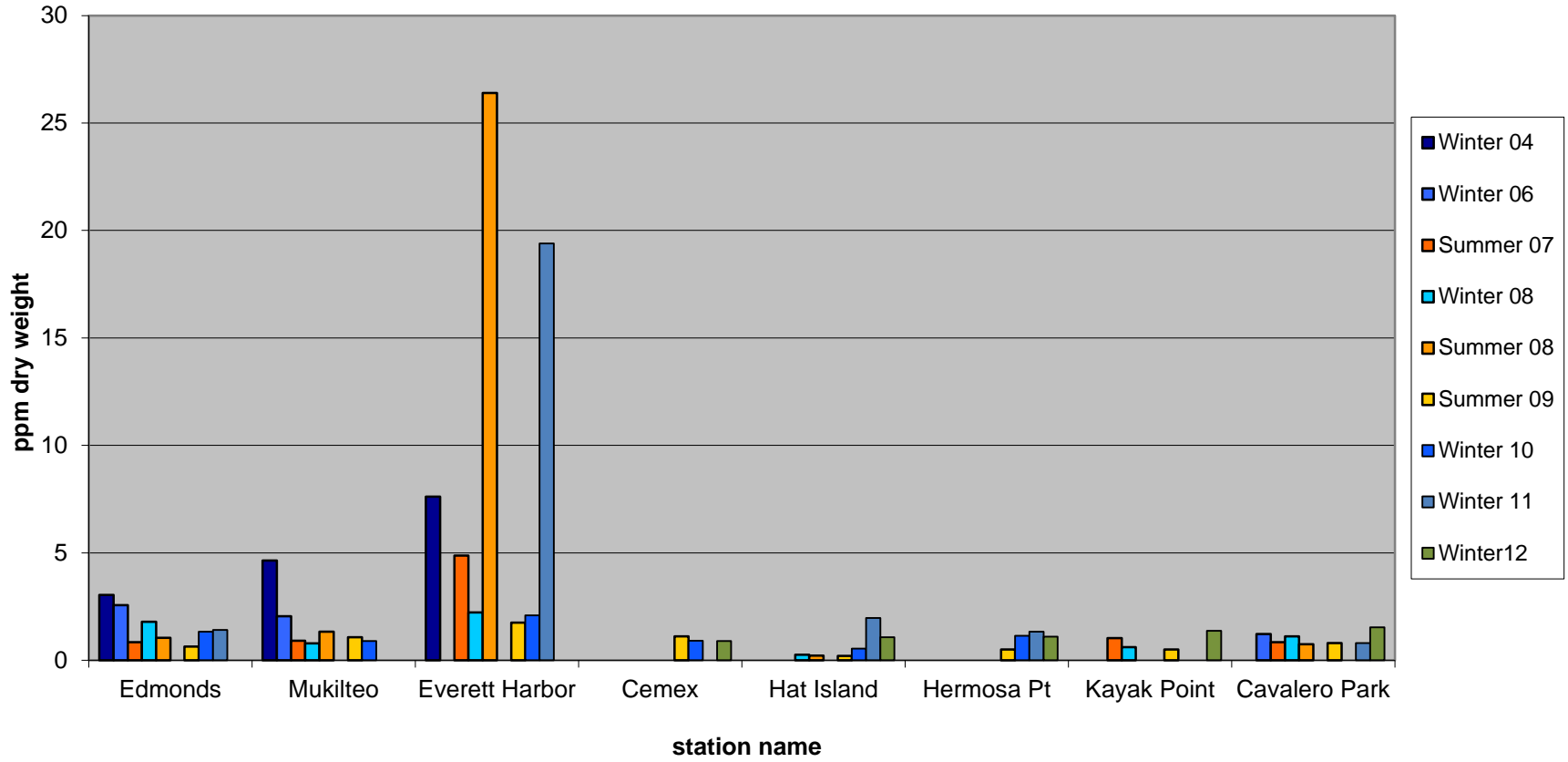
*10 day rainy period occurred before sampling.

** Picnic Point sampled in mid-March 2010.

NOAA considers lead concentrations of greater than 3 to 6 ppm to be in the medium range.

NOAA considers lead concentrations greater than 6 ppm to be in the high range.

Figure 19 Lead in Snohomish County mussels



Chromium

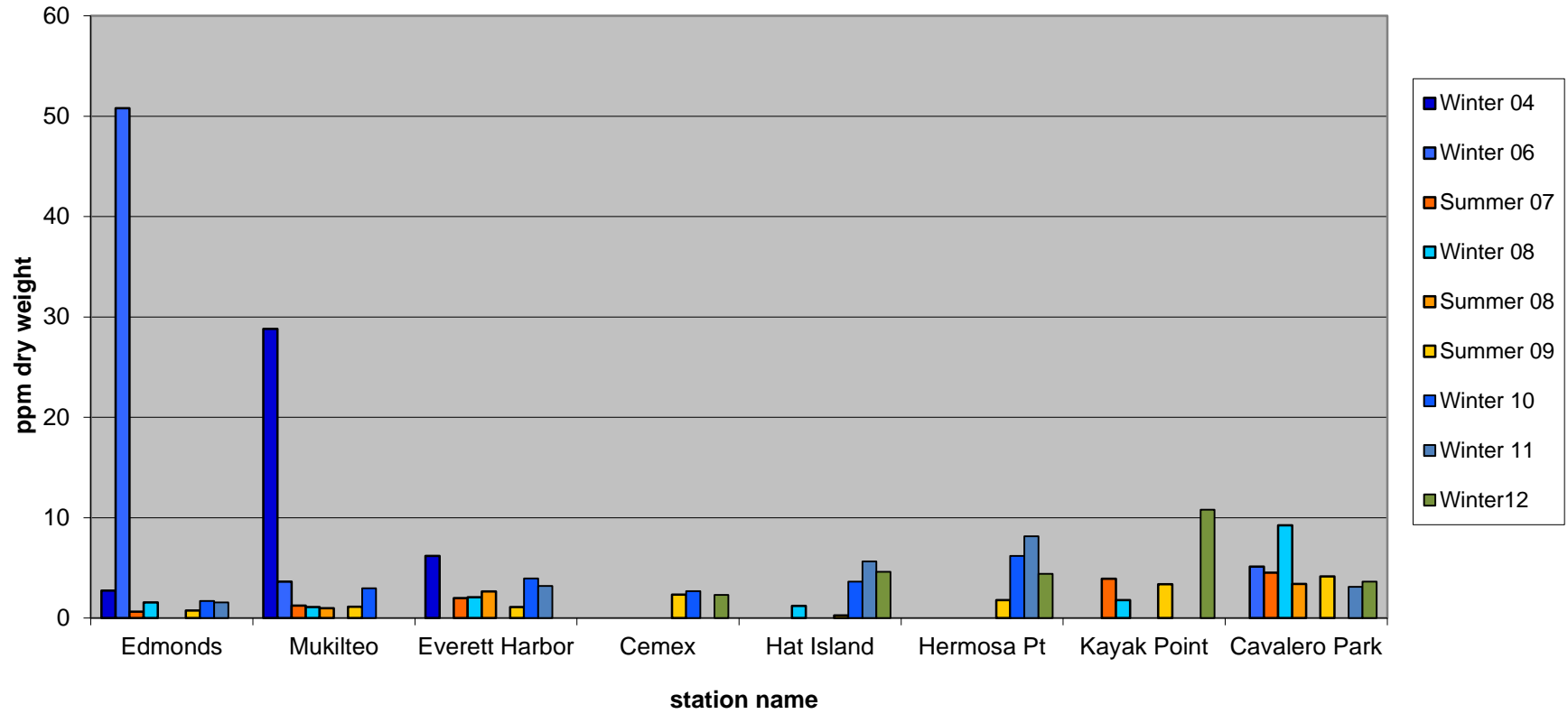
NOAA did not present chromium data or describe low, medium and high ranges for the National Mussel Watch Data (Kimbrough, et. al., 2008). In response to a request by the Tulalip Tribe, the MRC selected chromium as a metal to include in this report. (Note that the data set includes additional metals than we present here and all the metals data can be viewed in Attachment C). Although we have no low, medium or high ranges from NOAA to compare the data to, it is evident that unusually high values occurred at Edmonds Ferry (50.8 ppm) in winter 2006 and at Mukilteo Ferry (28.8 ppm) in winter 2004. The source or sources of these spikes are unknown but do not appear to be ongoing. Both sites are near ferry terminals suggesting maintenance activities such as sandblasting might be a cause elevated chromium levels.

Table 18 Total Chromium data in parts per million (dry weight) from Snohomish County Mussel Watch.

	Water body	04 wet season	06 wet season	07 dry season	08 wet season		08 “dry” season*	09 wet season	09 dry season	10 wet season	11 wet season	12 wet season
			12/05	9/07	12/07	3/08	8/08	3/09	8/09	1/10	1/11	1/12
Eide Road	Port Susan			2.46								
Kayak Point	Port Susan			3.93		1.78			3.37			10.80
Cavalero	Port Susan		5.13	4.52		9.24	3.40		4.15		3.11	3.62
Hermosa Point	Port Susan								1.78	6.18	8.15	4.41
Hat Island	Possession Sound					1.21	U		0.27	3.64	5.66	4.62
Cemex	Possession Sound								2.33	2.69		2.30
Everett Harbor	Possession Sound	6.19		2.00	2.07		2.66		1.09	3.95	3.19	
Mukilteo Ferry	Possession Sound	28.8	3.64	1.24	1.09		0.98		1.13	2.98		
Picnic Point**	Possession Sound									6.60		
Edmonds Ferry	Main Basin Puget Sound	2.75	50.8	0.64	1.55		U		0.75	1.69	1.57	
Edmonds Marina	Main Basin Puget Sound								1.13			

*10 day rainy period occurred before sampling. ** Picnic Point sampled in mid-March 2010
Unusually high values are highlighted in red.

Figure 22 Chromium in Snohomish County mussels



INITIAL FINDINGS

Identification of Potential Contaminant Sources

Within Snohomish County, there are numerous different potential sources of contaminants to consider. The contaminant patterns observed will represent an integrated mix of inputs from various sources. The seasonal differences we observe for PAHs and PCBs implies a possible stormwater component. We deliberately tested both dry and wet seasons to see if there were differences, and there were. The differences between years also appear to be related to the amount of rainfall. Some wet seasons were wetter than others. Stormwater runoff can be more significant in areas with greater amounts of impermeable surfaces, and with that in mind, it makes sense that the mussels south of the Snohomish River would have higher concentrations of stormwater borne contaminants than mussels to the north of the Snohomish River. We see that pattern for some contaminants.

Agricultural land uses can also be a source of some contaminants. Since the Stillaguamish drains an agricultural area, we might expect some pesticides or herbicides to be elevated in Port Susan stations, and sometimes we see that in the data. Ecology's studies of contaminants in stormwater identified higher copper concentrations from agricultural land runoff (Herrera, 2011). We see higher copper concentrations in mussels in Port Susan than to the south. High river flows can carry significant loads of suspended sediments, which filter feeders, such as mussels, can ingest. For some metals, naturally present in minerals, this suspended sediment ingestion might account for occasional spikes in the data. If such spikes are associated with mineral ingestion, then it is also likely that mussels would depurate the particles and not bioconcentrate much from them. Hence, the spikes would be expected to be of short duration. A different study design might be able to evaluate this hypothesis.

When considering PAHs, recognize that most of the PAHs we see in mussels are high molecular weight, which come predominantly from pyrogenic sources. Atmospheric deposition studies conducted for Ecology have shown PAHs are higher in the winter than the summer, and a good amount of them are associated with wood burning (Brandenberger, et. al., 2010). PAHs also are associated with vehicle emissions, including cars, trains, ferries, smaller boats and marinas. Historically, PAH data from NOAA's west coast stations show higher values near marinas. Many boats intentionally emit their exhaust underwater in order to reduce exhaust fumes around the boaters. It makes sense that combustion PAHs might be high near boat marinas. A sampling station near the Edmonds Ferry site was added on the outer edge of the Edmonds Marina breakwater in August 2009. Although the site is not located near the marina mouth, water movement driven by tidal action within Edmonds Marina was observed to flow parallel to shore and pass readily through the large rip-rap boulders of the marina protection. Thus, the contaminant concentrations found in the mussels are expected to be influenced by the marina (Lanksbury et al., 2010). The summer 2009 data included the Edmonds Marina site and the PAHs were similar to the Edmonds Ferry site which is nearby. Additionally, numerous trains run along the coast each day, and often with three or more engines running per train. As of 2011, Burlington Northern Santa Fe Railroad reports 15 trains per day running between Everett and Bellingham and about 27 trains running between Everett and Seattle (Sheets, 2011). Since then,

oil and coal train traffic along these routes has increased. Emissions from trains would be a year round source, much like the ferries. Winter rains could promote nearshore deposition of diesel exhaust. Creosote treated railroad ties could be a winter time source of PAHs, and railroad beds are very permeable and close to mussels by the Edmonds and Everett Harbor sites.

There are high molecular weight PAHs found in creosote pilings. The early Hat Island (PSHI) station samples in our current database were collected from creosote pilings. Samples are now collected from a concrete structure. Both sites had low total PAHs until the winter 2012 sample, which pegged the highest PAH concentration ever observed in the Snohomish County data. We cannot offer any suggestions as to the cause although creosote piling exposure is unlikely. We also expect that the condition does not persist. Unfortunately, we have no data or samples from Hat Island since 2012 to confirm our expectation.

We are aware of a PCB remediation project conducted by Boeing from 2001 through 2007 at their Everett plant. Runoff from the plant site passes through stormwater ponds, to Powder Mill Gulch Creek and then to the shore between Mukilteo and Everett Harbor. Ecology stormwater data still shows elevated PCBs in stormwater from the site (Herrera, 2011). Everett Harbor has a long history of mussel data. Perhaps there has been some contribution of PCBs from the Boeing facility to mussels at our stations, but if so, it is not strongly evident in our data.

There used to be a fuel tank farm in Mukilteo. It had a lengthy remediation of fuel contamination in the ground water, next to the intertidal zone. The ground water contamination remediation was completed in the early 2000s. The Mukilteo Ferry Mussel Watch site is very close to the area where the groundwater contamination was present. Lincoln Loehr remembers walking the shore at low tide just to the northeast of the Mussel Watch site and smelling strong hydrocarbon or solvent smells. The remediation was complete before the Mukilteo Ferry Mussel Watch site was added. We believe that petrogenic PAHs would have been higher when the groundwater contamination was present. The fuel tank farm also has a long, very old derelict pier with lots of old creosote treated pilings, and is located close to the Mukilteo Ferry Mussel Watch site. The pier is due to be removed in 2015-2016 as part of a plan to relocate the Mukilteo ferry terminal. This will remove about 3,000 old creosote pilings and will likely reduce PAH inputs at the Mukilteo Ferry Mussel Watch over time.

Most metals in mussels are not at levels of concern and marine water quality for metals is not a problem. An interesting metal is arsenic, which is naturally higher in marine water than in freshwater. Since Puget Sound is marine water that is diluted with freshwater, it makes sense that arsenic in mussels in Puget Sound is lower than at Cape Flattery at the entrance to the Strait of Juan de Fuca. This is a natural source and not a problem.

The Everett Harbor data are intriguing, as the site has occasional onetime spikes for parameters such as lead, PAHs or hopane (a petroleum marker that does not degrade over time). The site is by a marine terminal of the Port of Everett that handles various cargos, and has various small ship visits. The site is also near contaminated soils owned by the Port, and a combined storm sewer overflow outfall of the City of Everett. Perhaps these are sources but more studies are needed to evaluate this hypothesis. The fact that the nearby Mukilteo Ferry site does not show the elevated levels shows that the effect of the source or sources was localized.

Human Health Issues

Section 303(d) of the Clean Water Act requires states to periodically prepare lists of water bodies that are considered to be impaired, which generally means water bodies that are not meeting one or more surface water quality standards. In 2011, the Department of Ecology released a draft list for public comment specific to just the marine waters of the state, and in this list, for the first time, the Department is using mussel watch data. The list was finalized and submitted to EPA in 2012.

Washington State surface water quality criteria are found in Chapter 173-201A WAC. EPA human health-based surface water quality criteria are included in 40 CFR 131.36. The human health criteria applicable to marine waters are established to protect human health from risks from consuming organisms that live in the water. The criteria are based on an organism consumption rate of 6.5 grams a day, which is low (not conservative) compared to consumption rates of some consumer groups, especially tribes. For carcinogens, such as certain PAHs, the criteria are based also on a hypothetical risk level of one additional life time cancer per million people (a conservative risk level). The Department used dry weight contaminant data from mussels, converted it to wet weight, and compared it to tissue concentrations linked to the human health criteria by bioconcentration factors. For carcinogenic PAHs, the criteria assume all are equal in carcinogenicity to Benzo(a)pyrene (a conservative assumption). It is well recognized that not all carcinogenic PAHs are equal. Consequently, a human health based surface water quality standard is established of 0.031 ug/L for each of the carcinogenic PAHs, such as Chrysene, Benzo(a)pyrene, Benz(a)anthracene, and Benzo(b)fluoranthene. The Department established 0.93 ppb wet weight as the tissue concentration equivalent to the human health criteria risk level. Based on that threshold, and using the 2006 to 2008 mussel watch data, six Mussel Watch stations in Snohomish County were proposed for listing as impaired as follows:

Table 19 Snohomish County Mussel Watch sites water quality criteria threshold exceedances

Station	Parameters
Cavalero County Park	Chrysene, Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene
Kayak Point	Chrysene
Hat Island	Chrysene
Everett Harbor	Chrysene, Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene
Mukilteo Ferry	Chrysene, Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene
Edmonds Ferry	Chrysene, Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene

Sometimes it is useful to examine other food items and PAHs levels for comparison. PAHs levels increase in foods that are barbecued over hot coals, or that are smoke cured. The levels of PAHs observed in mussels in Snohomish County are similar to the levels found in smoked salmon based on smoked salmon data from two split samples that were measured by NOAA in 1990 (Varanasi et al., 1990).

Relation to On-going Puget Sound Cleanup and/or Restoration Actions

Regulations that ban or restrict contaminants have had a direct effect on concentrations of contaminants found in mussels in Snohomish County, as shown in the information on total butyltin (see Figure 2 and Table 4). We anticipate that on-going monitoring may also show reductions in copper, PAHs, PCBs, and other contaminants based on recent laws and on-going cleanup activities. Mussel Watch monitoring data can be used to see if contaminant concentrations in marine waters are actually falling over time. Some of the recent laws and planned cleanup actions are described below.

Total Butyltin (TBT) (Showalter, 2005)

In 1988, Congress enacted a partial ban on TBT antifouling paints. The Organotin Antifouling Paint Control Act (OAPCA) banned the application of antifouling paint containing organotin to vessels less than 25 meters in length.² Organotin is defined as “any compound of tin used as a biocide in an antifouling paint.”³ The prohibition does not prevent the application of organotin antifouling paints to the aluminum hull, outboard motor, or lower drive unit of a vessel less than 25 meters in length.⁴

OAPCA directed the Administrator to issue final water quality standards for organotin compounds by March 30, 1989.¹⁰ The EPA released its final ambient water quality criteria for TBT in January 2004, pursuant to Section 304(a) of the Clean Water Act (CWA).¹¹ The criteria apply to both fresh and saltwater, and were designed for use by states and Tribes in the development of their own TBT water quality standards. Though the EPA’s criteria are not legally binding, National Pollution Discharge Elimination System (NPDES) permits and related environmental programs may make the criteria enforceable.

The EPA negotiated with TBT-bearing coating vendors for the voluntarily cancellation of their registrations. The last registered TBT coating vendor, New Nautical, requested and was approved for voluntary cancellation. This manufacturer was allowed to sell its remaining TBT stocks to vendors until December 31, 2005.

As shown in Figure 2 on page 10, TBT concentrations in mussels at the Everett Harbor site have significantly declined since the 1988 law imposing a partial ban.

Boeing PCB Cleanup Efforts

In 1989 a study was published documenting high concentrations of PCBs (Arochlor-1254) were measured in sediments from Boeing Pond outlet in Powder Mill Gulch. Powder Mill Creek is located between the Mukilteo Ferry and Everett Harbor mussel collection sites. Only trace PCB contamination was found in sediments at the mouth of Powder Mill Creek (Johnson, 1989). Elevated zinc levels and PAHs were also found in the Creek.

² 33 UNITED STATES CODE § 2403(a) (2005).

³ *Id.* §2402(4).

⁴ *Id.* §2403(b).

In December 2005, Boeing Commercial Airplanes, Everett Plant removed PCB-containing joint compound material from the flight line located southwest of the Boeing plant. The joint compound was a significant source of PCB's to Powder Mill Creek and associated wetlands. After the flight line work was initiated, additional investigation conducted from 2004-2006 detected PCBs in Powder Mill Creek. The highest concentrations were near the Boeing detention basin, with lower concentrations detected in downstream portions of the Creek and at the mouth of the Creek. The PCBs were detected throughout the stormwater detention and treatment systems, in the upper and lower Powder Mill Creek associated wetlands on the Boeing property, and in surface waters in the Creek on Boeing property and downstream. In addition, the following constituents were detected in sediments in the upstream portions of the Creek: chromium, lead, barium, zinc, copper, carcinogenic and non-carcinogenic PAHs (Boeing Company and Ecology).

In the summer of 2006, Boeing removed sediment in Powder Mill Creek containing relatively higher concentrations of PCBs (as compared to concentrations in other downstream reaches of the creek) in order to minimize the potential future distribution of these PCBs further downstream through bedload and suspended load transport. The upper 120-foot reach of Powder Mill Creek was excavated and reconstructed.

In the summer of 2007, the stormwater conveyance system was cleaned by removal of accumulated solids and decontamination of selected catch basins, conveyance pipes, oil/water separators, and other structures of the stormwater system located on both the South Complex and North Complex of the Boeing Plant. Boeing has subsequently removed solids that accumulated in catch basins on the Flightline and other areas where PCBs were previously detected on a periodic basis. Boeing is continuing to monitor stormwater facilities, surface waters and sediments on an annual basis until implementation of the final remedy to be specified in a future Cleanup Action Plan (CAP) for the site (URS, 2010).

The Mussel Watch data do not show any effect from the remediation effort. The PCBs go up and down over time in the Everett Harbor mussels. Perhaps the differences over all the winter data reflect different degrees of rain events in the weeks or months before the samples.

Copper

In 2010 and 2011, the Washington State Legislature passed bills that will phase out the use of copper in antifouling paints on recreational water vessels and in brake pads.

Antifouling Paints – On May 3, 2011, Governor Christine Gregoire signed Substitute Senate Bill 5436 that will phase out the use of copper-based antifouling paints used on recreational water vessels. It provides that:

(1) Beginning January 1, 2018, no manufacturer, wholesaler, retailer, or distributor may sell or offer for sale in this state any new recreational water vessel manufactured on or after January 1, 2018, with antifouling paint containing copper.

(2) Beginning January 1, 2020, no antifouling paint that is intended for use on a recreational water vessel and that contains more than 0.5 percent copper may be offered for sale in this state.

(3) Beginning January 1, 2020, no antifouling paint containing more than 0.5 percent copper may be applied to a recreational water vessel in this state.

Brake Pads - Washington is now the first US state to restrict the amount of copper in brake pads used in cars and trucks. On March 19, 2010, Governor Gregoire signed Substitute Senate Bill 6557 that provides that

(1) Beginning January 1, 2014, no manufacturer, wholesaler, retailer, or distributor may sell or offer for sale brake friction material in Washington State containing any of the following constituents in an amount exceeding the specified concentrations:

(a) Asbestiform fibers, 0.1 percent by weight.

(b) Cadmium and its compounds, 0.01 percent by weight.

(c) Chromium(VI)-salts, 0.1 percent by weight.

(d) Lead and its compounds, 0.1 percent by weight. (e) Mercury and its compounds, 0.1 percent by weight.

(2) Beginning January 1, 2021, no manufacturer, wholesaler, retailer, or distributor may sell or offer for sale brake friction material in Washington State containing more than five percent copper and its compounds by weight.

(3) Brake friction material manufactured prior to 2015 is exempt from subsection (1) of this section for the purposes of clearing inventory. This exemption expires January 1, 2025.

(4) Brake friction material manufactured prior to 2021 is exempt from subsection (2) of this section for the purposes of clearing inventory. This exemption expires January 1, 2031.

(5) Brake friction material manufactured as part of an original equipment service contract for vehicles manufactured prior to January 1, 2015, is exempt from subsection (1) of this section.

(6) Brake friction material manufactured as part of an original equipment service contract for vehicles manufactured prior to January 1, 2021, is exempt from subsection (2) of this section.

When dissolved copper gets into streams it can affect a salmon's sense of smell -- and they use their noses to find food, mates, their spawning streams, and to avoid predators. Scientists at the Northwest Fisheries Science Center (NFSC) in Seattle find that very low levels of copper -- levels that match what is found in nature -- deadens Coho's response to an alarm pheromone that warns schoolmates that a predator is near. However, scientists at EPA defend their water quality criteria and the presence of dissolved organic carbon in freshwater also reduces the toxicity of copper. The research by the NFSC to date does not apply to salt water. Research by scientists at the NOAA lab at Mukilteo demonstrates that the effect of copper on salmon in marine water is less of a concern than in fresh water.

Research in the San Francisco Bay area found that the top two sources of human-caused [copper pollution](#) come from pesticides (42 percent) and brake pads on cars and trucks (36 percent). Some of the pesticides' copper is trapped in the soil and plants, putting more of a focus on the brake pads copper that travels from roadways and the air to waterways (Sightline Daily, 03/2010). Much of the brake pad copper is in a particulate form and is less of a toxic concern than the dissolved form.

Coal-tar sealcoat ban to reduce PAHs

On May 5, 2011, Governor Christine Gregoire signed Engrossed Substitute House Bill 1721 that bans coal tar-based asphalt sealants. The bill provides that

(1) After January 1, 2012, no person may sell at wholesale or retail a coal tar pavement product that is labeled as containing coal tar.

(2) After July 1, 2013, a person may not apply a coal tar pavement product on a driveway or parking area.

The Bill Report states,

Sealcoats, or sealants, are used to protect and beautify driveways and parking lots. Over time, the sealants wear off and small particles are washed from roads, driveways, and parking lots into streams, lakes, and Puget Sound accumulating in the sediment. There are two primary types of sealcoat material used: coal-tar-pitch based emulsion and asphalt-based emulsion. Coal tar sealants have a coal tar pitch base, which is 50 percent or more polycyclic aromatic hydrocarbons (PAHs) by weight, and contain concentrations of PAHs approximately 1000 times higher than asphalt-based products.

PAHs are a group of chemicals formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances. There are more than 100 different PAHs, some of which are known human and animal carcinogens. PAHs are suspected to cause cancer, reproductive problems, and weakened immune systems in aquatic organisms such as oysters, amphibians, and fish inhabiting areas where PAHs accumulate in the sediment (ESHB 1721 Report).

The MRC is unsure as to how much coal-tar based sealants were used in the area. Perhaps there will be some reduction of PAHs in runoff, and perhaps that will show up in future Mussel Watch data.

Other Measures to Reduce PAHs

The Department of Ecology has prepared a chemical action plan (CAP) for PAHs. Among the actions identified, restrictions on wood burning stoves and removal of creosote pilings are promoted. In 2015-2016, approximately 3,000 creosote pilings will be removed when the old fuel pier in Mukilteo is removed. This will be part of the project to relocate the Mukilteo ferry landing. The process of removing creosote pilings will initially result in a spike in PAHs in local organisms such as mussels, but that will be expected to decrease significantly in a short time.

Puget Sound Initiative (PSI) Site Cleanup

The Department of Ecology Toxics Cleanup Program (TCP) has been identifying and cleaning up contaminated sites in the Puget Sound area through the Model Toxics Control Act for many years. In response to the Puget Sound Initiative and increased funding, Ecology has accelerated its efforts to clean and restore contaminated sites within identified priority bays. Port Gardner Bay was selected as a priority bay and 10 sites are currently in the program in various stages of analysis. (See Figure 21 for site locations.) Cleanup construction has been ongoing at these sites over the last few years including several that have been completed. Contaminants in the sediments and uplands found to-date include, but are not limited to, wood debris, PCBs, PAHs, bis (2-ethylhexyl) phthalate, phenols, dioxin/furans, benzene, ethylbenzene, xylenes, tributyltin, petroleum, vinyl chloride, benzoic acid, copper, cadmium, chromium, zinc, lead, arsenic and other metals. (Ecology PSI Website, 2011)



Figure 23 PSI Sites

One such cleanup addressed groundwater contamination with petroleum fuels at an old tank farm to the east of the Mukilteo Ferry. This was actually very close to the Mukilteo Ferry Mussel Watch station. The remediation was completed before the Mukilteo Ferry site was added to the NOAA stations. Consequently, the data set cannot show the effect of this cleanup action.



Figure 24 City of Everett CSOs

City of Everett Combined Sewer Overflows (CSOs)
(City of Everett, 2010)

The Everett wastewater collection system is divided into two distinct areas: a north-end combined sewer system and the south-end separated sewer system.

Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, the combined sewer system conveys all of the wastewater to the Everett Water Pollution Control Facility, where it is treated and then discharged to either the Snohomish River or Port Gardner Bay. During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system

can exceed the capacity of the sewer system. For this reason, the combined

sewer system is designed to overflow occasionally and discharge directly to the Snohomish River or Port Gardner Bay. These overflows are called combined sewer overflows (CSOs). The City has six Snohomish River outfalls and seven Puget Sound outfalls.

The City has made significant progress in reducing combined sewer overflows during the first 20 years of the CSO Reduction Program. The annual CSO volume has been reduced by 93% since 1987. However, improvements are still needed for achieving the State-required limit of one CSO event per year per outfall. *The 1987 CSO Control Plan*, which was approved by the Department of Ecology in March of 1988, recommended construction of a series of projects to convey increased volume of combined sewage to the Everett Water Pollution Control Facility on Smith Island.

The City has constructed all the CSO control projects for the Snohomish River combined sewer outfalls and for the north Port Gardner Bay combined sewer outfalls. However, no projects have been completed for the three south Port Gardner Bay outfalls that are closest to the Everett Harbor Mussel Watch site. Design for the final control project for the south Port Gardner Bay combined sewer outfalls was completed in 2008. This project is called the Bond Street CSO Control Facilities and must be operational by 2017. Several components of the project have been completed. Additional work will be constructed as funding is available. In 2010, 31.6 million gallons of combined sewage were released at these 3 sites over 101 events total (events are

counted at each site, and may occur on the same day). Generally the main concern when a CSO release occurs is for bacterial contamination, and elevated bacteria concentrations are generally of short duration. A combined sanitary and sewer system is not necessarily bad, even with occasional overflows. Much of the stormwater that enters the system is actually routed to the wastewater treatment plant and is not discharged nearshore without treatment. If the stormwater was separated out entirely from the combined system, then there would be more untreated stormwater discharged locally. It is possible that the CSO events over the years may have contributed to the contaminants found in mussels at the Everett Harbor site. Figure 24 shows the locations of CSO outfalls. The CSO outfalls are not right at the Everett Harbor site, so maybe the effects of the CSOs on the mussels is small. As improvements to the sewer system are completed, contaminants in the Everett Harbor mussels might decrease.

DISCUSSION

Project Challenges

NOAA funding for its mussel watch program has diminished and it is not known when or if the program will resume. Similarly, the Northwest Straits Initiative has had to make adjustments on its funding. Consequently, the mussel watch program in Snohomish County is on hold. However, the Stillaguamish Tribe and the Tulalip Tribes may continue with mussel watch monitoring. Another development in our state is the use of caged mussels to measure nearshore contaminants, and that program will continue throughout Puget Sound. The MRC should look for opportunities to help that program with volunteer labor, and to possibly also fund a number of additional stations in Snohomish County.

The caged mussel study conducted by DFW also included samples of indigenous mussels from the same sites as caged mussels, and all but one of these were sites in Snohomish County. It illustrated that caged mussel data should not be directly equated to indigenous mussel data. Most of the indigenous mussels had higher concentrations of substances than the caged mussels. We speculate that this could be because the indigenous mussels had a greater exposure to sediment due to proximity to sediment than did the caged mussels. This is an area that should be investigated more.

With indigenous mussel sampling, several Mussel Watch sites in Snohomish County had mussel populations insufficient for sampling. Throughout the project, inter-annual variation in mussel populations has been observed. Alan Mearns has observed similar variations in mussel populations in Prince William Sound. The Mearns' Rock time series uses pictures to illustrate varying mussel populations over time on a large boulder in Prince William Sound (See Figure 25). Predation, recruitment, and weather conditions could contribute to these changes in population. For example, at the Mukilteo Ferry Site, collection volunteers noted and photographed an abundance of Surf Scooters in the area. Surf Scooters are known to prey on mussels. Extreme weather conditions could also play a role. Mussel die offs at Kayak Point Park were observed following a stretch of freezing temperatures. One possible explanation is that ice formed in Port Susan and scraped mussels from the substrate. This process has been

observed by Alan Mearns in Prince William Sound. Additionally, the Tulalip Tribes have confirmed that ice can form in Port Susan. In any case, this variation affects the MRC's ability to sample consistently the same sites over time. This demonstrates a reason to use caged mussels in the future, although the data cannot be directly compared to the long term NOAA mussel watch data.

Recommendations

PAH Fingerprinting to Identify Sources

As stated in the Section of this report addressing PAH's in Snohomish County mussels, it is possible to look at the relative concentrations of the numerous different compounds that are included in the PAHs and discern information about the sources. For example, the most likely sources of combustion related PAHs are wood smoke and engine exhaust with wood smoke being seasonally variable. Low levels of the combustion related high molecular weight PAHs occur in Port Susan, while higher levels occur in Possession Sound and the Main Basin of Puget Sound. As more data become available we will be conducting a more rigorous assessment of the data to try to decipher sources of the PAHs. Our future analysis of potential sources of pollutants should include fingerprinting examples to show PAH patterns for different substances, and the PAH patterns found in Snohomish County mussels. A recent study of atmospheric deposition of contaminants to Puget Sound by Brandenberger et. al., 2010 employed a number of different fingerprinting techniques to evaluate PAH sources. The Mussel Watch data include measurements for over 50 different PAHs and can be used in fingerprinting. All the PAH data are included in the lab analyses from TDI Brooks.

Continue Mussel Watch Monitoring

The long-term goal of the MRC is to continue the Mussel Watch program in Snohomish County. While the NOAA Mussel Watch program is inactive, the MRC may have the opportunity to partner with WDFW on caged mussel studies. The MRC should also continue to be involved with the Stormwater Work Group (composed of municipalities with stormwater permit monitoring requirements) and their use of caged mussels to monitor effectiveness and status and trends. It will present an opportunity to volunteer in the studies, and also to piggy-back additional sites at reasonable prices.

Because we believe in the value of having a long-term monitoring data available, and because the additional sites the MRC added provide a more comprehensive look at Snohomish County's marine water quality, we will look for funding opportunities to continue future collections at the MRC sites.

Respond to request from Stillaguamish Clean Water District (CWD)

On March 24, 2011, Kathleen Hermann and Lincoln Loehr gave a presentation to the Stillaguamish Clean Water District (CWD) on the mussel watch program. After the presentation, the CWD sent a letter to Snohomish County Surface Water Management (SWM) requesting that SWM provide leadership on shellfish monitoring for human consumption. Specifically the Board recommended:

“For the purpose of assessing any possible threats to the shellfish resource and to human health from chemical toxins in Port Susan and South Skagit Bay, **the**

Board recommends compiling and evaluating the Mussel Watch data being collected in Port Susan, and any dependable related water quality data from the tribes and other shellfish stakeholders. **We ask** that SWM coordinate with the appropriate stakeholders to accomplish this and that SWM encourage the relevant government agencies to consider establishing shellfish consumption guidelines for South Skagit Bay and Port Susan, and to focus future program planning on filling any data gaps identified in the course of this evaluation”.

To address the CWD’s recommendation, SWM worked with the Washington Department of Health (WDOH) to evaluate the potential human health threat from chemical contaminants in mussels and Eastern softshell clams collected from Warm Beach. As a result of WDOH findings and Washington Department of Ecology’s current process to establish new state-wide fish consumption guidelines, it was determined to be unnecessary to establish shellfish consumption guidelines specifically for South Skagit Bay and Port Susan. WDOH found that concentrations of chemicals in both clams and mussels sampled from Warm Beach are not expected to harm human health. The WDOH evaluation for Warm Beach is available www.doh.wa.gov/consults.

Photo monitoring of mussel populations

The Discussion of Project Challenges earlier in this report describes the interannual variations in mussel populations that have resulted in too few mussels to collect at some of the Snohomish County sites. The MRC should recruit volunteers to photograph intertidal rocks/rip-rap containing mussels over time to document changes to mussel population. The photos could be used to understand better the interannual variations, as well as to build understanding of the importance of mussels to intertidal life (food availability to other wildlife).

Alan Mearns has documented changes over time at rocks/boulders in Prince William Sound, Alaska. Figure 23 is a composite of 20 annual mid-summer photos of Boulder Ernie. There may have been mussels on the boulder in 1989, but it was covered by oil. The next major appearance of mussels was in 1992-93. They started disappearing in 1994, then appeared again in 1998, were moderately dense through 2000, then increased dramatically in 2002 and 2003, then disappeared in 2004 and then a new heavy batch appeared in 2009 (lower right hand corner). Overall, there were about 4 periods of moderately heavy mussel cover with intervening years of low or no cover.

Puget Sound may have similar "cycles" of paucity and abundance. Along with photo documentation, other environmental changes/ possible causes could be documented, such as predation by sea stars (*Pisaster*, sun stars), whelks (*Nucella*), birds, humans, and differences in storm/wave exposure.

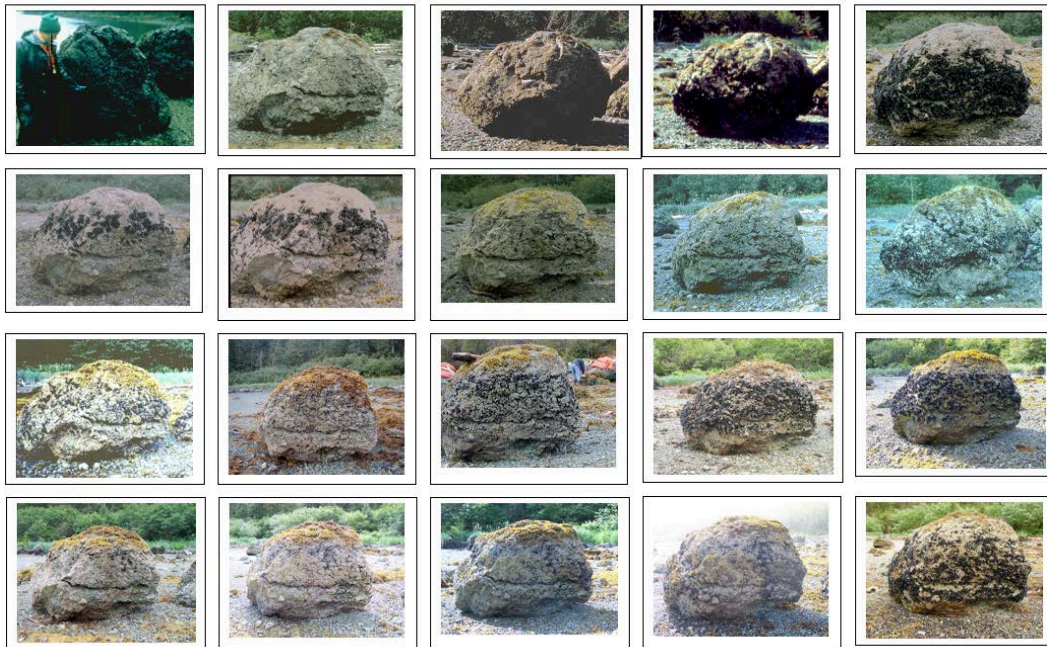


Figure 25 Interannual variation in mussel cover on previously oiled rock “Ernie” from Shelter Bay site, 1989 (upper left) to 2008 (lower right)

The NOAA website also has substantial documentation of Mearns Rock that can be found at www.noaa.gov under the search term “Mearns rock.”

Continue Education and Outreach

The MRC plans to continue public education and outreach. Proposals include developing at least one PowerPoint presentation, a poster, and a brochure to hand out at public events. We will use those resources in our presentations and other outreach on the project findings. Outreach materials will include data findings, discussion of possible sources, and recommendations for future actions.

The Snohomish MRC’s website (www.snocomrc.org) includes a page dedicated to the mussel watch project. This report and supporting data as well as links to other mussel studies will be made available on the site.

CONCLUSIONS

From 2007-2012, the Snohomish MRC has devoted a tremendous amount of volunteer and staff time to the success of the Mussel Watch Program. This success has been evident as our work has been nationally recognized by NOAA, the State of Washington, and the Puget Sound Partnership. The recent grant funding provided by PSP is just one example of the recognized

regional value of the program. The expansion project allowed the MRC members and staff to connect with other MRCs around the Northwest Straits and also the newly created Outer Coast MRCs. In the United States, 56 sites were considered to have elevated PBDE tissue concentrations; of these sites two were located in Snohomish County. These elevated concentrations generated local interest as the PBDE spikes were at Everett Harbor and Edmonds Ferry. Snohomish MRC Members have worked to educate other MRCs through direct contact and presentations at the monthly NWSC meetings. As mentioned earlier in the report, the work of the MRC locally contributes to the largest continuous contaminant monitoring program in the history of the United States.

Specifically, a variety of groups have expressed interest in hearing more about Mussel Watch Program and using the data. The WSU Snohomish County Extension Beach Watchers have asked for a presentation about the contaminants found in local waters. The Edmonds Community College used the Mussel Watch Program in one of their courses to conduct interviews to determine the original sources of some of the pollutants. As mentioned above, the Snohomish MRC recently provided the “Washington State 2009/10 Mussel Watch Pilot Project: A Collaboration between National, State and Local Partners” report to the Tulalip Tribes to support the States consideration of a NRDA for Port Gardner Bay.

Unfortunately, federal funding reductions have effectively ended the NOAA Mussel Watch Program. If it starts up again, the MRC is ready to assist. However, a modified version of Mussel Watch is going to continue and the MRC will assist. The MRC worked with WDFW and NOAA to design and implement a program using caged mussels to evaluate nearshore contamination throughout all of Puget Sound. Use of caged mussels will continue through municipal storm water permittees funding to evaluate status and trends and effectiveness.

The MRC plans to continue to support this current work and strengthen the link between these data; how it is used in the community, by other agencies, and by local decision-makers.

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