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Northwest Straits Progress Report

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This report must accompany all requests for payment, along with any other deliverables per the scope of work.

Task 5: Mussel Watch Deliverables

Attachment A: Mussel Watch Volunteer Hours

Attachment B: Plots of winter 2008 NOAA Mussel Watch data for
West Coast and Washington State

Attachment C: NOAA data set (included on CD)



Photo by Edward S. Curtis

Snohomish MRC Mussel Watch Data Progress Report June 17, 2011

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SNOHOMISH MRC MUSSEL WATCH DATA PROGRESS REPORT
June 2011

TABLE OF CONTENTS

INTRODUCTION	1
Project Partners	1
Project Background	1
Project Design	2
Project Objectives	3
Project Implementation	4
TECHNICAL EVALUATION OF DATA FOR SPECIFIC CHEMICALS AND METALS	7
Data Analysis Approach	7
Precipitation Data	7
Lipid data	9
Organic Contaminants	10
Total Butyltin (TBT)	10
Polychlorinated Biphenyls (PCBs)	13
Total DDT	20
Chlorpyrifos (Dursban TM)	22
Chlordane	24
Hexachlorohexanes (HCHs), Including Lindane	26
Dieldrin	28
Hexachlorobenzene (HCB)	30
Polycyclic Aromatic Hydrocarbons (PAHs)	32
Trace Metals	42
Copper	42
Mercury	44
Lead	46
Chromium	48
Identification of Potential Contaminant Sources	50
Human Health Issues	52
Relation to On-going Puget Sound Cleanup Actions	53
Total Butyltin (TBT)	53
Boeing PCB Clean-up Efforts	54

Copper	55
Coal-tar sealcoat ban to reduce PAHs	56
Puget Sound Initiative (PSI) Site Cleanup	57
DISCUSSION	59
Project Challenges	59
Recommendations	60
NRDA (Natural Resources Damage Assessment) in Port Gardner	60
Continue Education/outreach Efforts	60
PAH Fingerprinting to Identify Sources	61
Continue Mussel Watch Monitoring	61
Respond to request from Stillaguamish Clean Water District (CWD)	61
Photo monitoring of mussel populations	62
Continue Education and Outreach	64
CONCLUSION	64
REFERENCES	66

List of Tables

Table 1	Precipitation in Inches - 60-days Prior to Mussel Collection	8
Table 2	Precipitation in Inches - 30 days Prior to Mussel Collection	8
Table 3	Lipid data in percent dry (percent wet) from Snohomish County Mussel Watch	9
Table 4	Total butyltin data in parts per billion (dry weight) from Snohomish County Mussel Watch.....	11
Table 5	Total PCB data in parts per billion (dry weight) from Snohomish County Mussel Watch.....	17
Table 6	Total DDT data in parts per billion (dry weight) from Snohomish County Mussel Watch.	21
Table 7	Chlorpyrifos data in parts per billion (dry weight) from Snohomish County Mussel Watch.....	23
Table 8	Total Chlordanes data in parts per billion (dry weight) from Snohomish County Mussel Watch	25
Table 9	Total Hexochlorohexanes data in parts per billion (dry weight) from Snohomish County Mussel Watch.	27
Table 10	Dieldrin data in parts per billion (dry weight) from Snohomish County Mussel Watch.	29
Table 11	Hexachlorobenzene data in parts per billion (dry weight) from Snohomish County Mussel Watch.	31
Table 12	Total PAH data in parts per billion (dry weight) from Snohomish County Mussel Watch.	35
Table 13	Total Low Molecular Weight PAHs (LPAH) data in parts per billion (dry weight) from Snohomish County Mussel Watch.....	40
Table 14	Total High Molecular Weight PAHs (HPAH) data in parts per billion (dry weight) from Snohomish County Mussel Watch.....	41
Table 15	Total Copper data in parts per million (dry weight) from Snohomish County Mussel Watch...	43
Table 16	Total Mercury data in parts per million (dry weight) from Snohomish County Mussel Watch.	44
Table 17	Total Lead data in parts per million (dry weight) from Snohomish County Mussel Watch.....	46
Table 18	Total Chromium data in parts per million (dry weight) from Snohomish County Mussel Watch	48
Table 19	Snohomish County Mussel Watch sites water quality criteria threshold exceedances.....	54

List of Figures

Figure 1	Snohomish and Island County Shorelines showing Mussel Watch sites.....	6
Figure 2	Total Butyltins at Everett Harbor Site 1989-2009.....	10
Figure 3	Total Butyltins in Snohomish County mussels.....	12
Figure 4	NOAA West Coast Winter 2008 Total PCBs.....	14-15
Figure 5	Total PCBs in Snohomish County mussels	17
Figure 6	Lipid Normalized Total PCBs in Snohomish County mussels	18
Figure 7	Total DDT in Snohomish County mussels.....	20
Figure 8	Total Chlordanes in Snohomish County mussels	24
Figure 9	Total Hexachlorohexanes in Snohomish County mussels	26
Figure 10	Dieldrin in Snohomish County mussels.....	28
Figure 11	Hexachlorobenzene in Snohomish County mussels	30
Figure 12	2008 Winter PAH Data for the West Coast	33-33
Figure 13	Total PAHs in Snohomish County mussels	35
Figure 14	Winter 2008 NOAA CC9 Hopane Data	37-37
Figure 15	Total Low Molecular Weight PAHs (LPAHs) in Snohomish County mussels	39
Figure 16	Total High Molecular Weight PAHs (HPAHs) in Snohomish County mussels	40
Figure 17	Copper in Snohomish County mussels.....	42
Figure 18	Mercury in Snohomish County mussels.....	44
Figure 19	Lead in Snohomish County mussels.....	46
Figure 20	Chromium in Snohomish County mussels.....	48
Figure 21	PSI Sites.....	57
Figure 22	City of Everett CSOs.....	58
Figure 23	Interannual variation in mussel cover on previously oiled rock “Ernie” from Shelter Bay site, 1989 (upper left) to 2008 (lower right.).....	63

Snohomish MRC Mussel Watch Data Progress Report June 2011

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.

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 analyses 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. Decreasing data trends from the last two decades demonstrate that environmental regulations have had the intended effect (Lauenstein). Others trends trace 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/>.

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 established in response to extreme events. The Edmonds Ferry site was established in response to a 4,700-gallon 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 and one in Island County in the Port Susan area. 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. The MRC coordinates with NOAA and uses trained volunteers to collect mussel samples annually at both the MRC and NOAA sites. Limited mussel availability has prevented sampling at some stations and also funding considerations necessitate sampling fewer stations at times. The NOAA program samples only during the winter. The MRC added summer time sampling in order to evaluate differences in mussel contaminants between wet and dry seasons. Collectively these sampling sites (NOAA, Snohomish County MRC and Stillaguamish Tribe) provide overall coverage of Snohomish County's marine waters and a platform for monitoring trends of chemical pollution in this region.

This paper presents a report on data collected by the MRC and Stillaguamish Tribe. It is periodically updated as data are received from the TDI-Brooks International (the NOAA contract lab for Mussel Watch). A record of changes page indicates the addition of new data as well as other changes or corrections. Unfortunately, the lab's turnaround time for analysis is quite slow. As of September 2011, the MRC has sampled during seven seasons. Data to date are only available for five of these periods (through summer of 2009). Comparisons with earlier and concurrent data from NOAA stations are also made in this report. Funding constraints may necessitate scaling back the sampling program in the years ahead.

Project Design

Mussels and other bivalve mollusks are valuable indicators of contaminants in marine ecosystems. The blue mussels (*Mytilus* species) found in Washington, feed by filtering large quantities of water and accumulate contaminants from the marine environment. Contaminants accumulate 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. Only samples from natural substrates are collected. 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). Metals and organic compounds are measured. The organic compounds measured in 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 run-off, atmospheric deposition, and historical use (Lanksbury et al., 2010).

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). Washington State Department of Ecology has recently used Mussel Watch data as a basis for relating tissue concentrations with the state's human health surface water quality criteria. This has resulted in proposed listing of many Mussel Watch sites as impaired, primarily for PAHs, and in some cases for PCBs. The listing is part of a requirement under Section 303(d) of the Clean Water Act. This recent development will be discussed further in the Discussion section near the end of this report.

Project Objectives

The purpose of Mussel Watch is to find out what 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 project is not a health assessment of mussels but rather an important new piece of information for judging 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. 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 completion of this four-year program will allow the MRC to obtain current information on marine and estuarine water quality at locations never tested within Snohomish County, establish a baseline and make 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.

Additionally, the MRC seeks to use this information to develop an assessment of environmental health and habitat impacts from poor water quality in our county waters if it is deemed necessary in the future. 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 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.

As of June 2011, the MRC has sampled during seven periods including the late summer dry season of 2007, the winter of 2008, the dry season of 2008, the winter of 2009, the dry season of 2009 and the winters of 2010 and 2011. The MRC did not sample during summer 2010 and will suspend further summer sampling until the utility and cost of continuing summer sampling can be assessed. 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 contracted 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 and 2011.

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 local 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 Washington Department of Fish and Wildlife (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 using citizen scientists for mussel collections. Citizen scientists from local volunteer groups and WDFW successfully sampled mussels at over 25 sites across Western Washington.

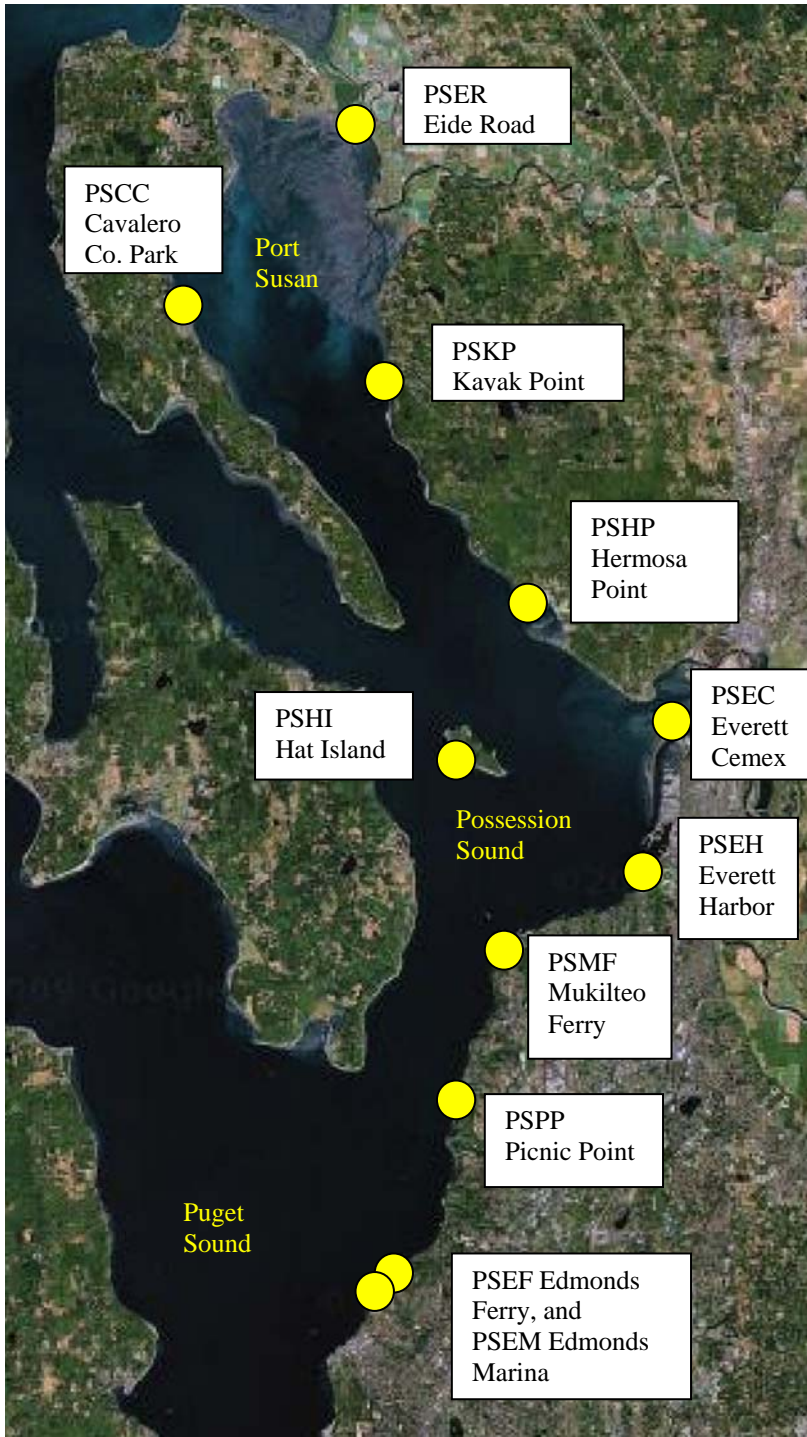
More than 65 volunteers contributed over 500 hours to sampling mussels in this statewide project, with a value of more than \$10,000. Volunteers significantly reduced the amount of time professional staff were needed in the field, provided staff scientists with valuable local knowledge and natural history, 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>.

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.
- Additionally, Dr. 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 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 Lytle 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.
- The Mussel Watch program was included as a part of an “MRC 101” presentation given by Mary Cunningham and Emily Whitney during the 2011 WSU Snohomish County Extension Beach Watchers training.
- The initial findings and trends of the Snohomish County Mussel Watch Program were presented by Lincoln Loehr at a WSU Snohomish County Extension Beach Watchers meeting on September 13, 2011.
- A poster abstract for Mussel Watch was submitted for the Salish Sea Ecosystem Conference October 2011.

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.

Puget Sound Cavalero

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

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.

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/Stillaguamish 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. Attachment C presents all of the Snohomish County, Stillaguamish Tribe and NOAA data arranged by station by NOAA.

In addition, to get some idea of the relative degree of contamination by these chemicals along the Snohomish Coast, we then, where possible, compared 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. Plots for a number of parameters for all the 2008 West Coast data, and for just the Washington State data are included in Attachment B and are incorporated into our discussion of PCBs and PAHs below.

Snohomish County Mussel Watch data have been received from TDI-Brooks for the 2007 dry season, the 2008 wet and dry seasons, and the 2009 wet and dry seasons.

Precipitation Data

We looked at precipitation data available on Snohomish County's web site 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, and the 2008 dry season averages are higher than the 2007 dry season averages. The 2008 30-day dry season average is higher than the wet season average. Much of the rainfall in the 30 days prior to the mussel collection occurred in the 10 days prior to the sampling.

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		
	7/9/07 - 9/6/07	1/11/08 - 3/11/08	06/29/08 - 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	1/17/10 - 3/17/10	11/19/10 - 1/17/11	11/27/10 - 1/25/11	12/24/10 - 2/21/11
Kayak Point County Park	2.14	4.05	2.59	5.01	1.66	.8	6.0	5.48	4.11	8.25	9.36	7.89
Soper Hill Road at SR 9	2.96	5.51	3.27	5.22	2.34	1.83	7.63	7.01	4.62	12.12	14.44	13.52
Average	2.55	4.78	2.93	5.12	2.0	1.32	6.82	6.25	4.37	10.19	11.9	10.71

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		
	8/9/07 - 9/6/07	2/10/08 - 3/11/08	06/29/08 - 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	2/16/10 - 3/17/10	12/19/10 - 1/17/11	12/27/10 - 1/25/11	1/23/11- 2/21/11
Kayak Point County Park	1.29	1.31	1.98	1.87	.57	.57	3.1	3.24	1.99	4.74	5.3	2.57
Soper Hill Road at SR 9	1.77	2.27	2.20	1.43	1.35	1.35	4.12	4.28	2.42	6.93	8.64	4.74
Average	1.53	1.79	2.09	1.65	.96	.96	3.61	3.76	2.21	5.84	6.97	3.66

07, 08, and 09 Wet Season - All samples collected on the same day

09 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

10 Wet Season

January 25 collections at Everett Cemex, Hat Island
 January 26 collections at Hermosa Point, Edmonds Ferry, Everett Harbor, Mukilteo Ferry
 March 18 collection at Picnic Point

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

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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	12.9(1.7)		NS	NS	NS	NS		
Kayak Point	Port Susan	NS	13.8(2.2)		12.4(1.3)	LS	10(1.2)	13.6(1.8)		
Cavalero	Port Susan		8.5(1.1)		4.7(0.7)	9.4(1.3)	8.6(0.8)	10.9(1.4)		
Hermosa Point	Port Susan	NS	NS	NS	NS	NS	NS	7.6(1.0)		
Hat Island	Possession Sound	NS	NS		10.4(1.5)	17.8(3.1)	9.7(1.9)	12.8(2.0)		
Cemex	Possession Sound	NS	NS	NS	NS	NS	NS	8.6(1.1)		
Everett Harbor	Possession Sound	NS	9.6(1.5)	13.2(2.1)		10.5(1.4)	5.6(0.7)	8.1(1.2)		
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)		
Picnic Point	Possession Sound	NS	NS	NS	NS	NS	NS	NS		
Edmonds Ferry	Main Basin Puget Sound	6.5(1.1)	10.9(1.9)	11.0(1.8)		13(2.4)	7.0 (0.9)	13.2(2.4)		
Edmonds Marina	Main Basin Puget Sound	NS	NS	NS	NS	NS	NS	12.1(1.9)		

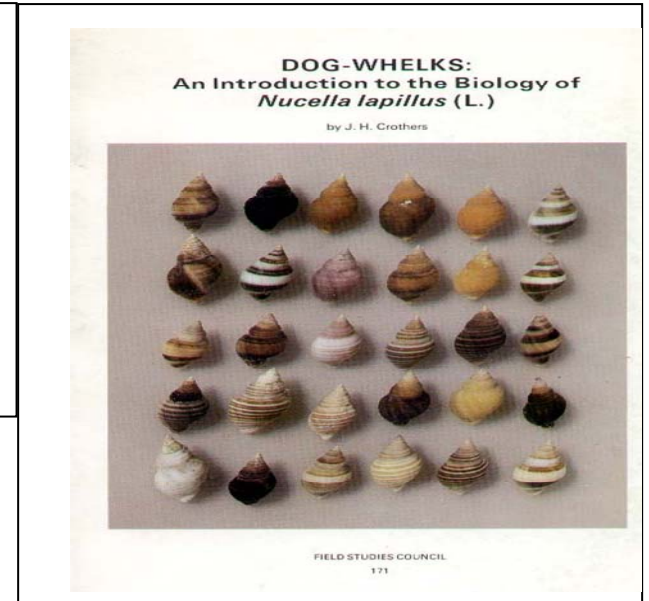
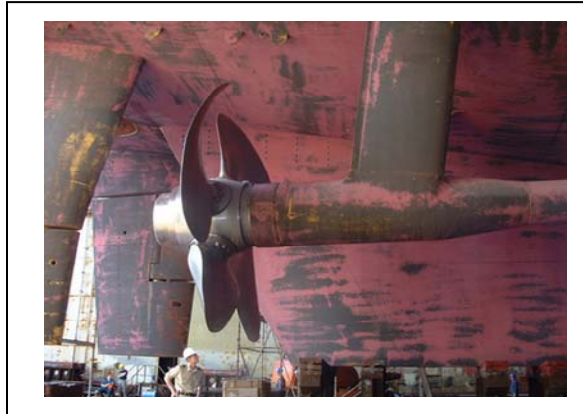
NS = no sample. LS = lost sample.

* Sampling occurred after about a ten-day period of winter type weather, significant rainfall and runoff and winds from the south, so we expected values higher than the 07 dry season sampling.

Organic Contaminants

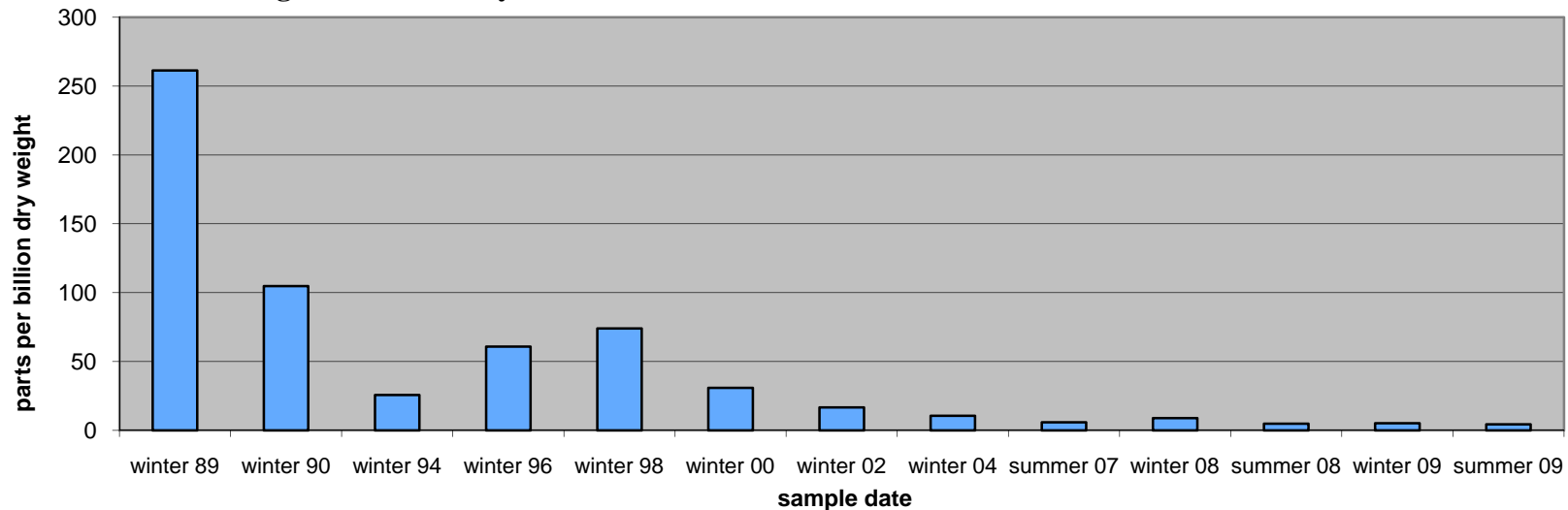
Total Butyltin (TBT)

Anti-fouling paints allow marine vessels smooth operation and fuel conservation. 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) data for the Everett Harbor station are presented in Figure 2 and show the sharp decline in TBT that resulted from the ban.

Figure 2 Total Butyltins at Everett Harbor site 1989-2009



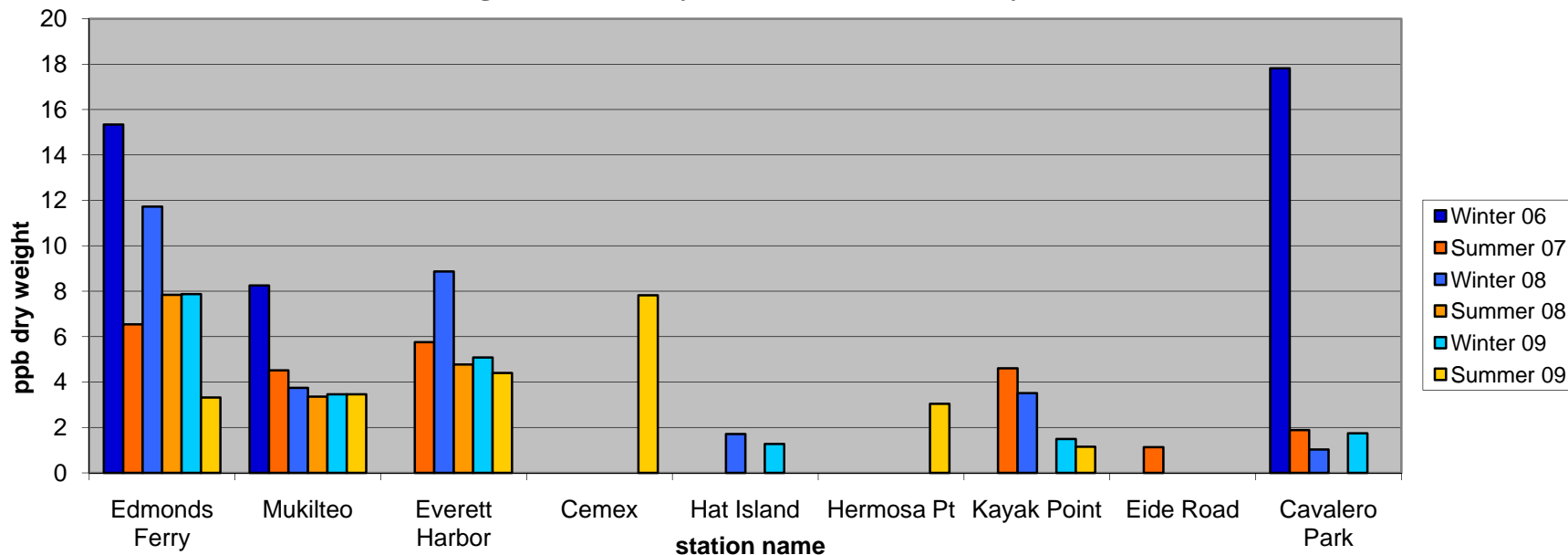
Concentrations of TBT in Snohomish and Island County (Cavalero Co. Park) samples in 2006 through 2009 samples ranged from 0.00 ppb dw (non-detect) at several Port Susan stations to 15.34 ppb dw at Edmonds Ferry and 17.82 ppb dw at Cavalero Park. The high values occurred in 2006. Concentrations appeared to decrease from south (Edmonds) to north (Cavalero). 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. We have no idea of a possible source for the Cavalero Park site. 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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	1.13		NS	NS	NS	NS		
Kayak Point	Port Susan	NS	4.61		3.54	LS	1.49	1.15		
Cavalero	Port Susan	17.82	1.88		1.0	0 U	1.74	0 U		
Hermosa Point	Port Susan							3.04		
Hat Island	Possession Sound	NS	NS		1.7	0 U	1.27	0 U		
Cemex	Possession Sound							7.82		
Everett Harbor	Possession Sound	NS	5.76	8.9		4.8	5.08	4.40		
Mukilteo Ferry	Possession Sound	8.25	4.51	3.8		3.4	3.46	3.46		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	15.34	6.54	11.7		7.8	7.87	3.32		
Edmonds Marina	Main Basin Puget Sound							0 U		

NS = no sample. LS = lost sample. "J" qualified data below method detection level. *10 day rainy period occurred before sampling. 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 made no sense. 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. 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. When the MRC does not find mussels at a site, then the site is simply not sampled. Another lesson learned is that mussels come and go and there are gaps in the data set to reflect that.

Polychlorinated Biphenyls (PCBs)

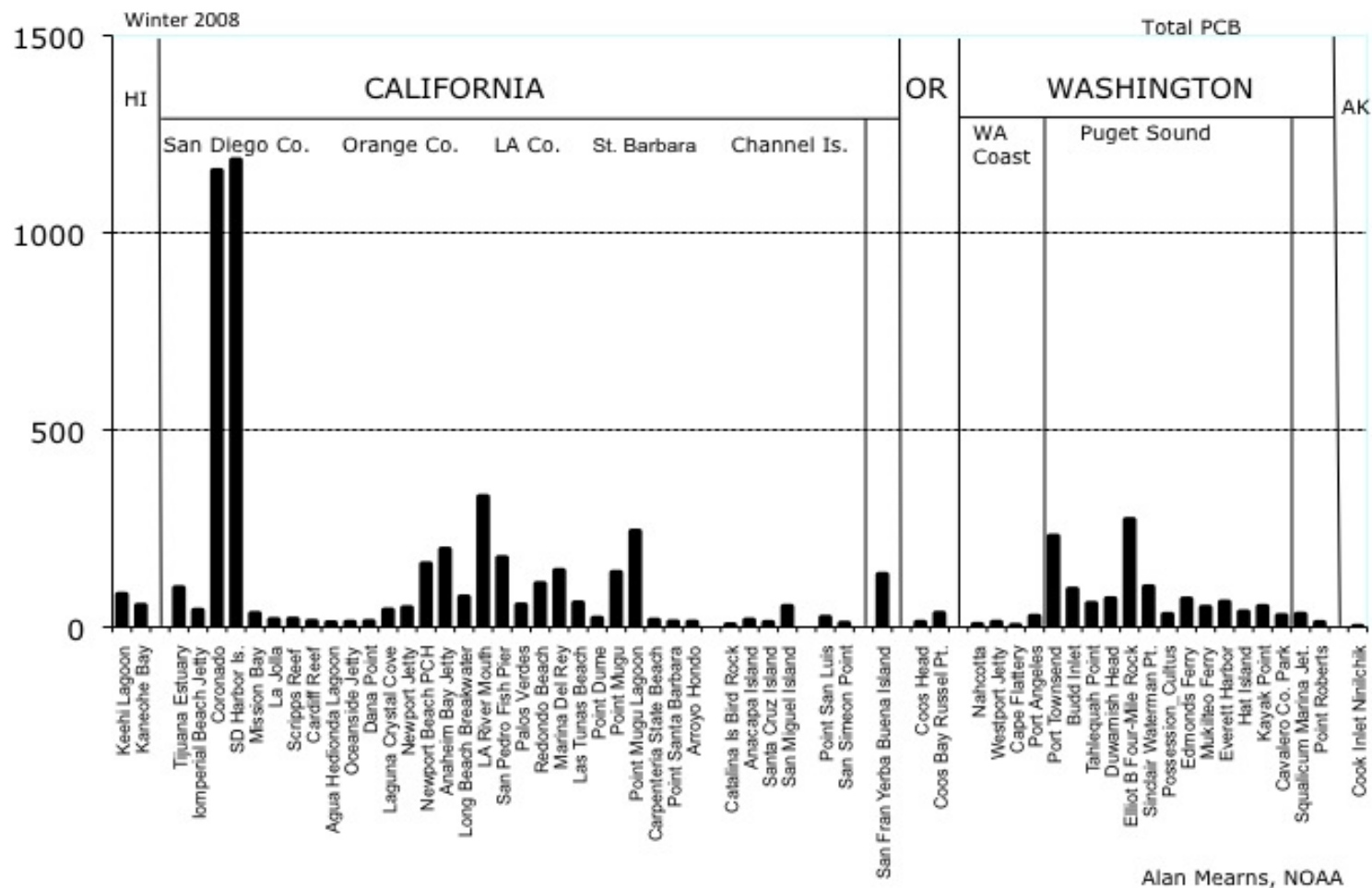


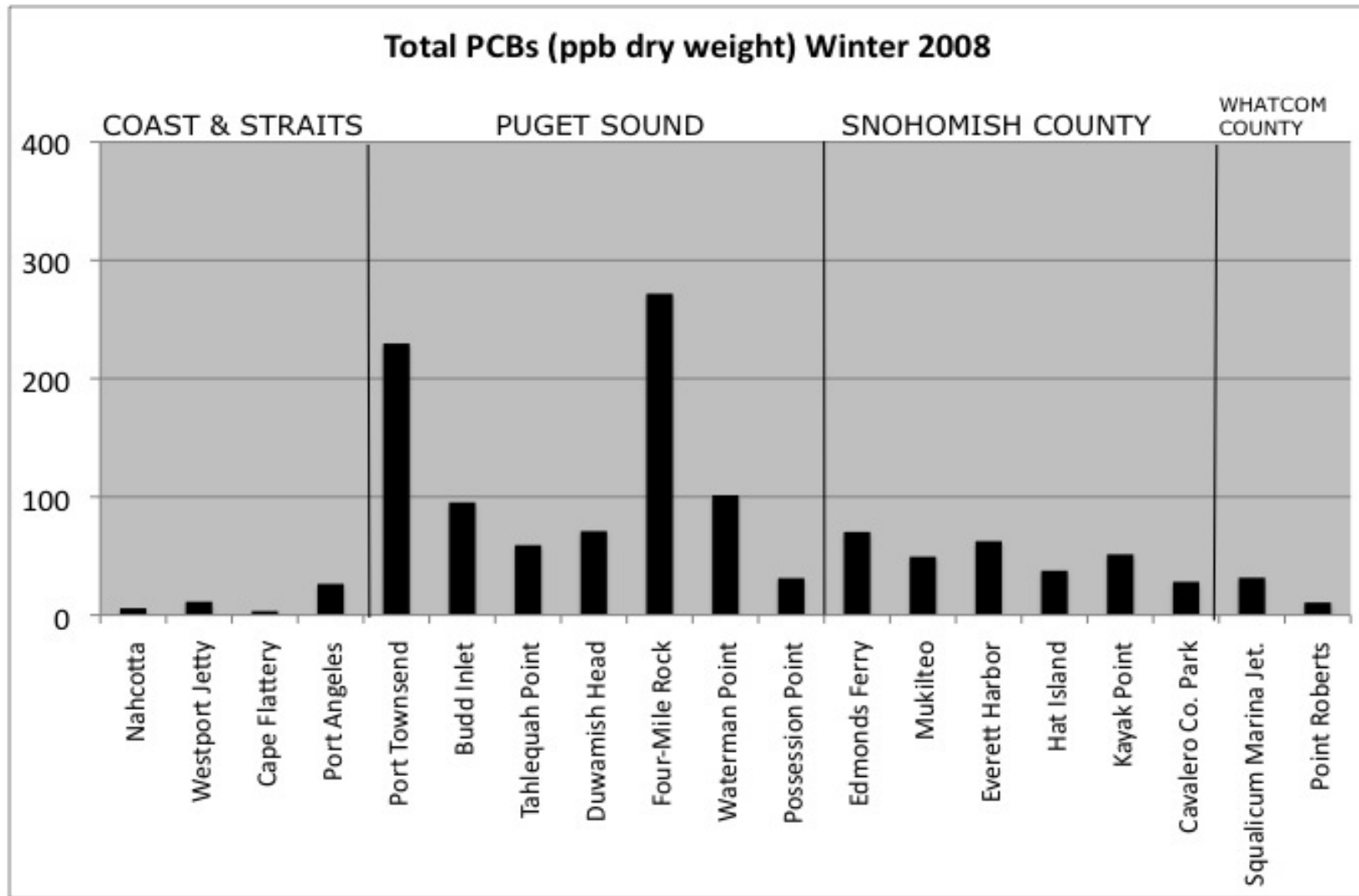
Polychlorinated biphenyls (PCBs) were used as fire retardants in electrical components and paints from the 1940s until they were banned in 1976 (Kimbrough, et. al., 2010). They biomagnify through marine food webs and remain among the most ubiquitous and problematic pollutants in Puget Sound marine life. 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 used in a formula to calculate a total Aroclor value¹. Total PCB 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 PCBs 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.

¹ The formula is Total PCB = (Sum of (18 PCB congeners – Interferences) x 2.19) + 2.19. The congeners are 8, 18, 28, 44, 52, 66, 101, 105, 118, 128, 138, 153, 170, 180, 187, 195, 206, and 209.

Figure 4 NOAA West Coast Winter 2008 Total PCBs.





TPCBs 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 13 ppb dw in mussels from Hat Island in summer 2009 to 199 ppb dw in mussels from Edmonds Ferry in Winter 2006. NOAA established low, medium and high ranges for PCBs from the National Mussel Watch Data (Kimbrough et. al., 2008).

Of the 27 samples, 26 were in the low range and 1 was in the medium range. 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. Perhaps this could be explained by stormwater. However, it might also be associated with differences in TPCB concentrations in surface and deep waters in Puget Sound. Gries and Osterberg (2011) showed that deep water had higher concentrations of TPCB than surface waters in Puget Sound and in the Strait of Juan de Fuca. Perhaps the density stratification in the water column is weaker in the winter months allowing more entrainment of deeper water into the surface water.

The following table and graphs present the total PCB data. The graphs illustrate how there is a significant difference between summer dry season and winter wet season concentrations. Figure 5 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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	2020.4		NS	NS		NS		
Kayak Point	Port Susan	NS	2424.3		5050.5	LS	1919.2	20.7		
Cavalero	Port Susan	42.99	1414.7		2828.2	23.66	626.0	15.2		
Hermosa Point	Port Susan							20.7		
Hat Island	Possession Sound	NS	NS		3737.4	24.00	29.3	13.3		
Cemex	Possession Sound							44.4		
Everett Harbor	Possession Sound	67.55	49.88	96.55		4848.8	43.00	42.5		
Mukilteo Ferry	Possession Sound	103.66	24.77	79.8		34.4	48.99	79.7		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	198.88#	6666.7	1131 13.2		5757	8787.7	40.5		
Edmonds Marina	Main Basin Puget Sound							37.2		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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

The seasonal differences as well as the north-south differences are evident in Figure 5.

Figure 5 Total PCBs in Snohomish County mussels

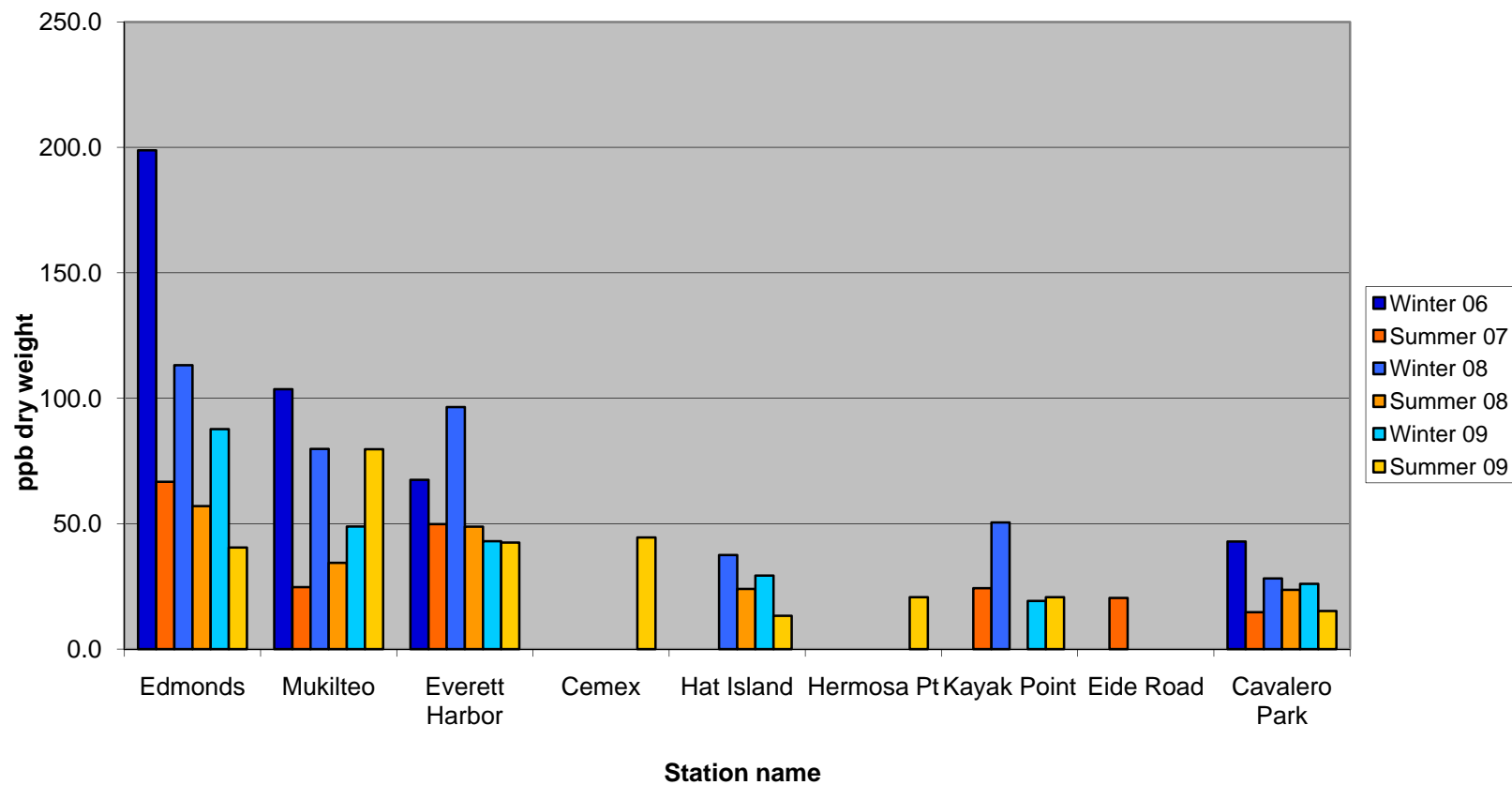
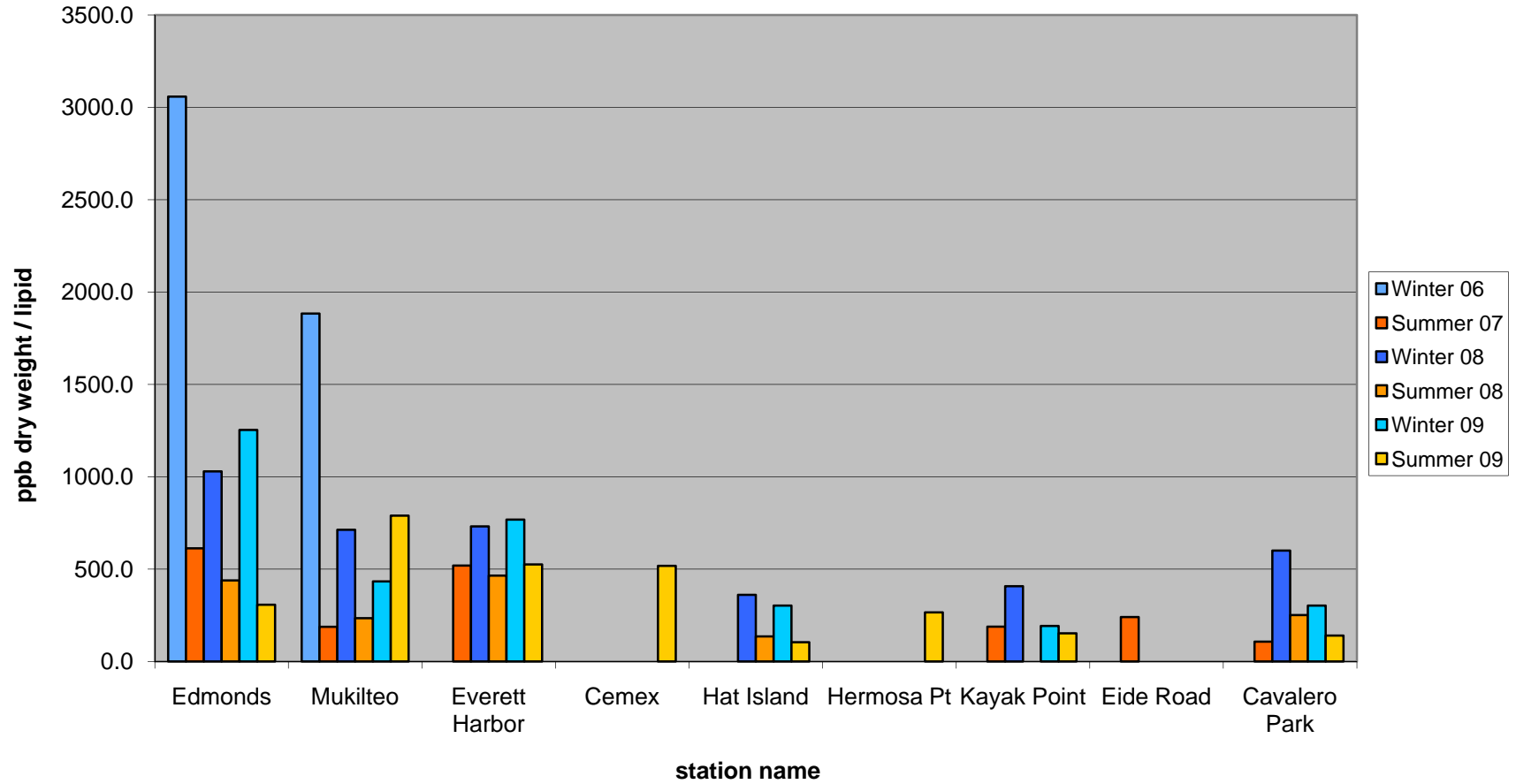
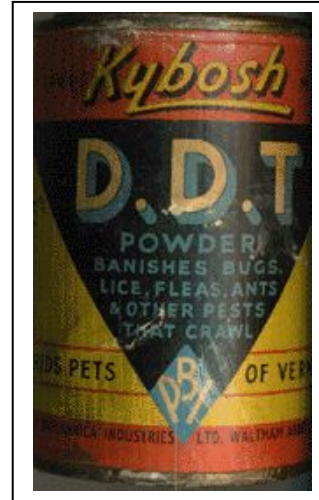


Figure 6 Lipid Normalized Total PCBs in Snohomish County mussels



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 13.73 ppb dw at Edmonds in December 2005. 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, indicating that stormwater is a source of TDDT.

NOAA established low, medium and high 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.

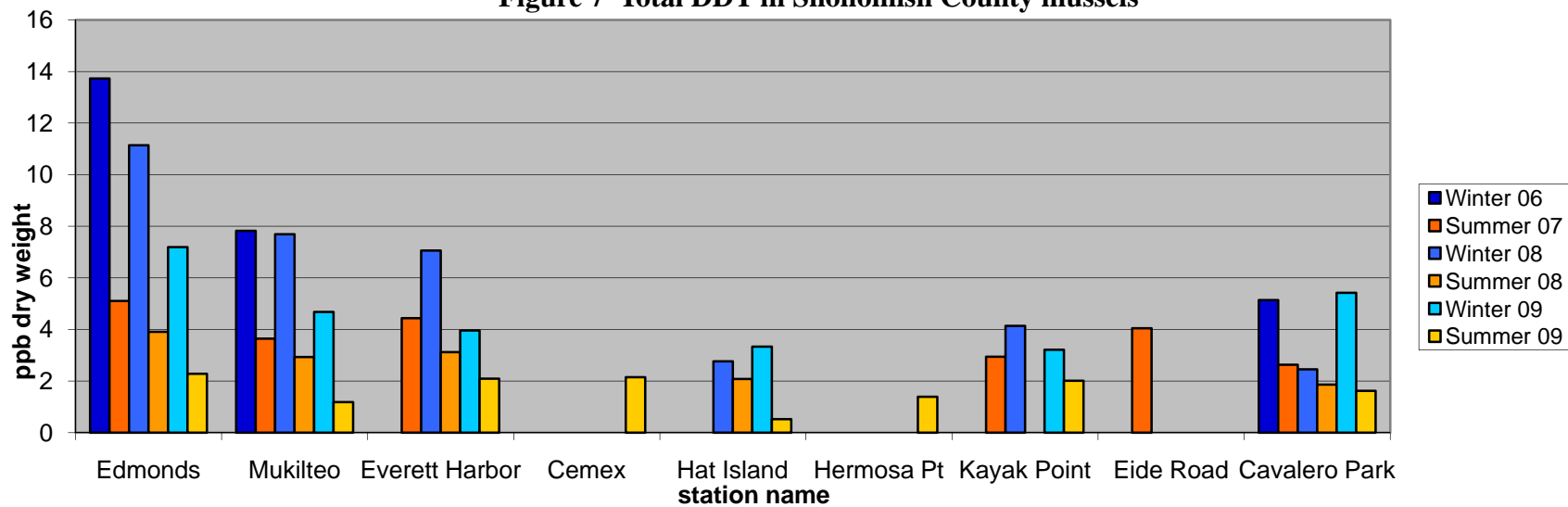
Table 6 Total DDT data in parts per billion (dry weight) from Snohomish County Mussel Watch

	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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	4.04		NS	NS		NS		
Kayak Point	Port Susan	NS	2.94		4.14	LS	3.21	2.01		
Cavalero	Port Susan	5.14	2.63		2.45	1.86	5.42	1.62		
Hermosa Point	Port Susan							1.39		
Hat Island	Possession Sound	NS	NS		2.76	2.08	3.33	0.52		
Cemex	Possession Sound							2.15		
Everett Harbor	Possession Sound	NS	4.44	7.06		3.12	3.96	2.09		
Mukilteo Ferry	Possession Sound	7.82	3.64	7.69		2.93	4.68	1.18		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	13.73	5.10	11.14		3.91	7.19	2.28		
Edmonds Marina	Main Basin Puget Sound							1.94		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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

Figure 7 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 five Snohomish and Island County mussel samples, once at each of five sites. All concentrations were very low, at or below 0.4 ppb. The highest three concentrations were at Mukilteo, Hat Island and Everett Harbor. Chlorpyrifos was not detected in any of the six sites sampled in summer 2007, winter 2009 and summer 2009, but was detected at two sites in March 2008 and three sites in August 2008. 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.

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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	0.00 U		NS	NS		NS		
Kayak Point	Port Susan	NS	0.00 U		0.11	LS	0.00U	0.00U		
Cavalero	Port Susan	0.00 U	0.00 U		0.17	0.00 U	0.00U	0.00U		
Hermosa Point	Port Susan							0.00U		
Hat Island	Possession Sound	NS	NS		0.00 U	0.30	0.00U	0.00U		
Cemex	Possession Sound							0.00U		
Everett Harbor	Possession Sound	NS	0.00 U	0.00 U		0.22	0.00U	0.00U		
Mukilteo Ferry	Possession Sound	0.00 U	0.00 U	0.00 U		0.40	0.00U	0.00U		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	0.00 U	0.00 U	0.00 U		0.00 U	0.00U	0.00U		
Edmonds Marina	Main Basin Puget Sound							0.00U		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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 Kayak Point in September 2009 to 13.18 ppb dw at Edmonds in September 2007. The 13.18 ppb dw value at Edmonds is an outlier, as the next highest concentration at Edmonds was less than 5 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. The data indicate some elevations in the wet season compared to the dry season.

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.

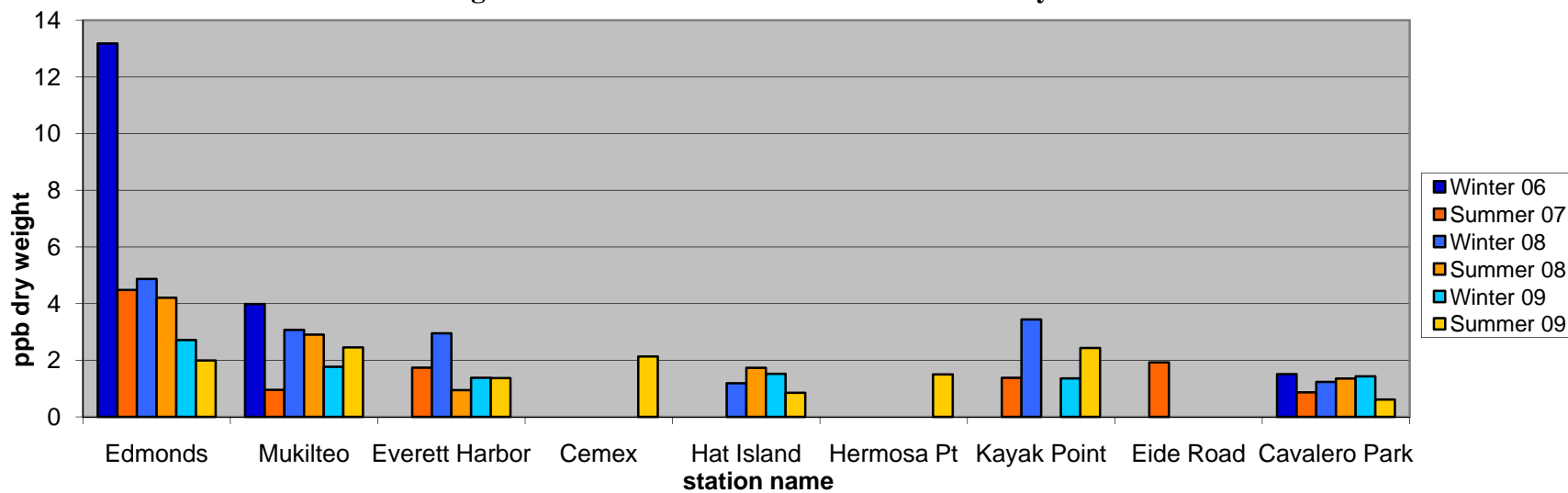
Table 8 Total Chlordane data in parts per billion (dry weight) from Snohomish County Mussel Watch

	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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	1.92		NS	NS	NS	NS		
Kayak Point	Port Susan	NS	1.38		3.44	LS	1.36	2.43		
Cavalero	Port Susan	1.51	0.87		1.23	1.35	1.43	0.61		
Hermosa Point	Port Susan							1.50		
Hat Island	Possession Sound	NS	NS		1.19	1.73	1.52	0.85		
Cemex	Possession Sound							2.13		
Everett Harbor	Possession Sound	NS	1.73	2.95		0.94	1.38	1.37		
Mukilteo Ferry	Possession Sound	3.98	0.95	3.07		2.90	1.77	2.45		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	13.18#	4.48	4.87		4.20	2.71	1.99		
Edmonds Marina	Main Basin Puget Sound							3.27		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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

Figure 8 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 from China as well as North Africa, to North America; Canada and China conducted a joint transport study in 2005 to 2008.

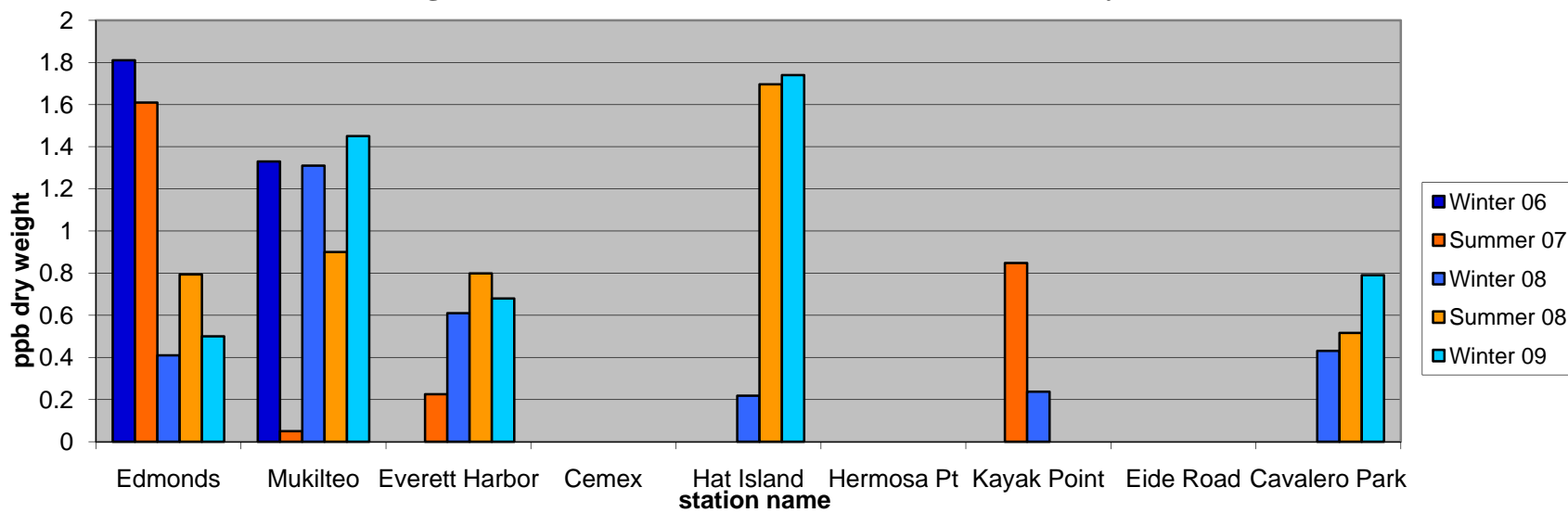
Concentrations of Total HCH in Snohomish and Island County mussels ranged from 0 ppb dw at three sites in 2007 to 1.81 ppb dw at Edmonds in Winter 2006 and 1.74 ppb dw at Hat Island in Winter 2009. Mearns (2001) reported that HCHs were common in mussels along the entire Pacific Coast including Alaska.

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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	0.00 U		NS	NS	NS	NS		
Kayak Point	Port Susan	NS	0.85		0.24	LS	0.00U	0.00U		
Cavalero	Port Susan	0.00 U	0.00 U		0.43	0.52	0.79	0.00U		
Hermosa Point	Port Susan							0.00U		
Hat Island	Possession Sound	NS	NS		0.22	1.70	1.74	0.00U		
Cemex	Possession Sound							0.00U		
Everett Harbor	Possession Sound	NS	0.23	0.61		0.80	0.68	0.00U		
Mukilteo Ferry	Possession Sound	1.33	0.00 U	1.31		0.90	1.45	0.00U		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	1.81	1.61	0.41		0.79	0.50	0.00U		
Edmonds Marina	Main Basin Puget Sound							0.00U		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

Figure 9 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 mussels between 2005 and 2009, 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 be 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. Aldrin was not detected in any Snohomish Co. MRC mussels.

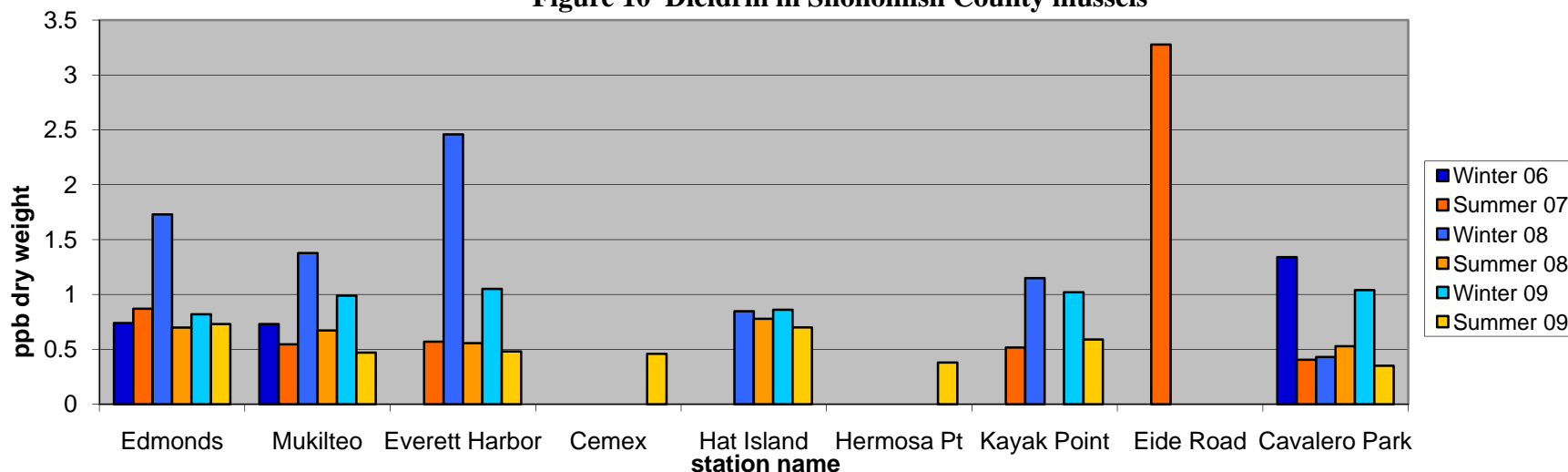
Table 10 Dieldrin data in parts per billion (dry weight) from Snohomish County Mussel Watch

	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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	3.28		NS	NS		NS		
Kayak Point	Port Susan	NS	0.52		1.15	LS	1.02	0.59		
Cavalero	Port Susan	1.34	0.40		0.43	0.53	1.04	0.35		
Hermosa Point	Port Susan							0.38		
Hat Island	Possession Sound	NS	NS		0.85	0.78	0.86	0.70		
Cemex	Possession Sound							0.46		
Everett Harbor	Possession Sound	NS	0.57	2.46		0.56	1.05	0.48		
Mukilteo Ferry	Possession Sound	0.73	0.55	1.38		0.67	0.99	0.47		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	0.74	0.87	1.73		0.70	0.82	0.73		
Edmonds Marina	Main Basin Puget Sound							0.47		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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.

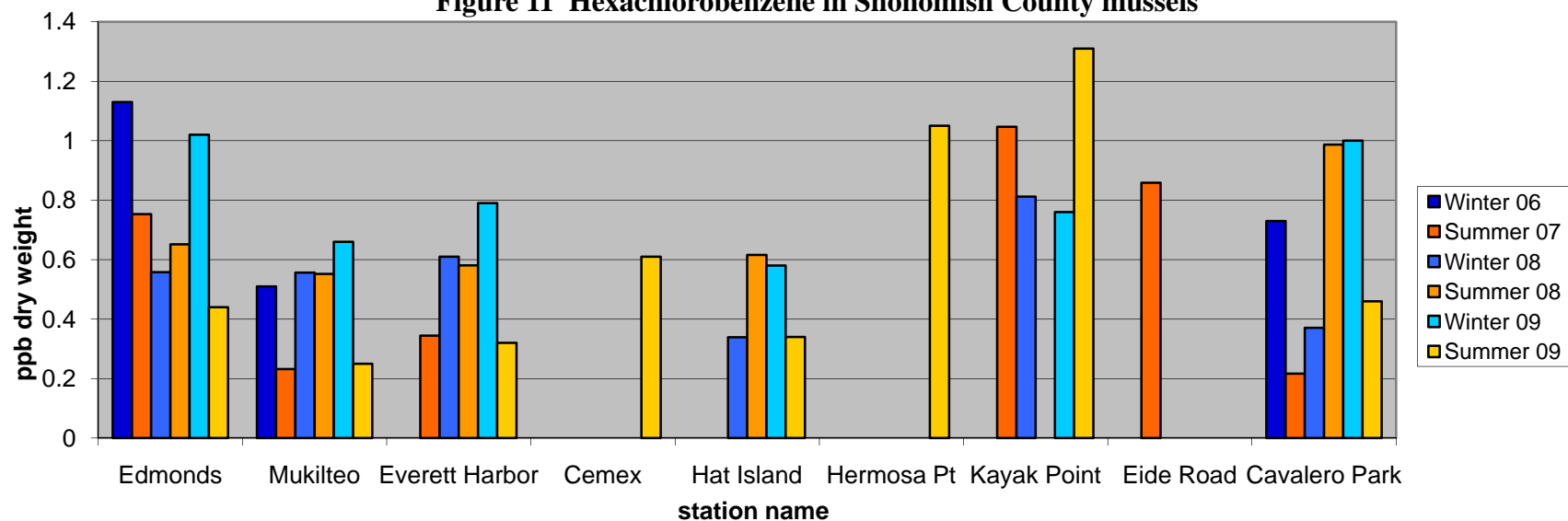
HCB was detected in all but three of the 2005 through 2009 Snohomish County MRC mussel samples. Concentrations did not vary greatly, ranging from 0 (undetected) at three stations in the 2007 dry season sampling to 1.61 ppb dw at Edmonds, also in the 2007 dry season sampling. HCB has been a low-level 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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	0 U		NS	NS		NS		
Kayak Point	Port Susan	NS	0.85		0.24	LS	0.76	1.31		
Cavalero	Port Susan	0.73	0 U		0.93	0.99	1.00	0.46		
Hermosa Point	Port Susan							1.05		
Hat Island	Possession Sound	NS	NS		0.22	0.62	0.58	0.34		
Cemex	Possession Sound							0.61		
Everett Harbor	Possession Sound	NS	0.23 JJ	0.61		0.58	0.79	0.32		
Mukilteo Ferry	Possession Sound	0.51	0 U	1.31		0.55	0.66	0.25		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	1.13	1.61	0.41		0.65	1.02	0.44		
Edmonds Marina	Main Basin Puget Sound							0.25		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

Figure 11 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.

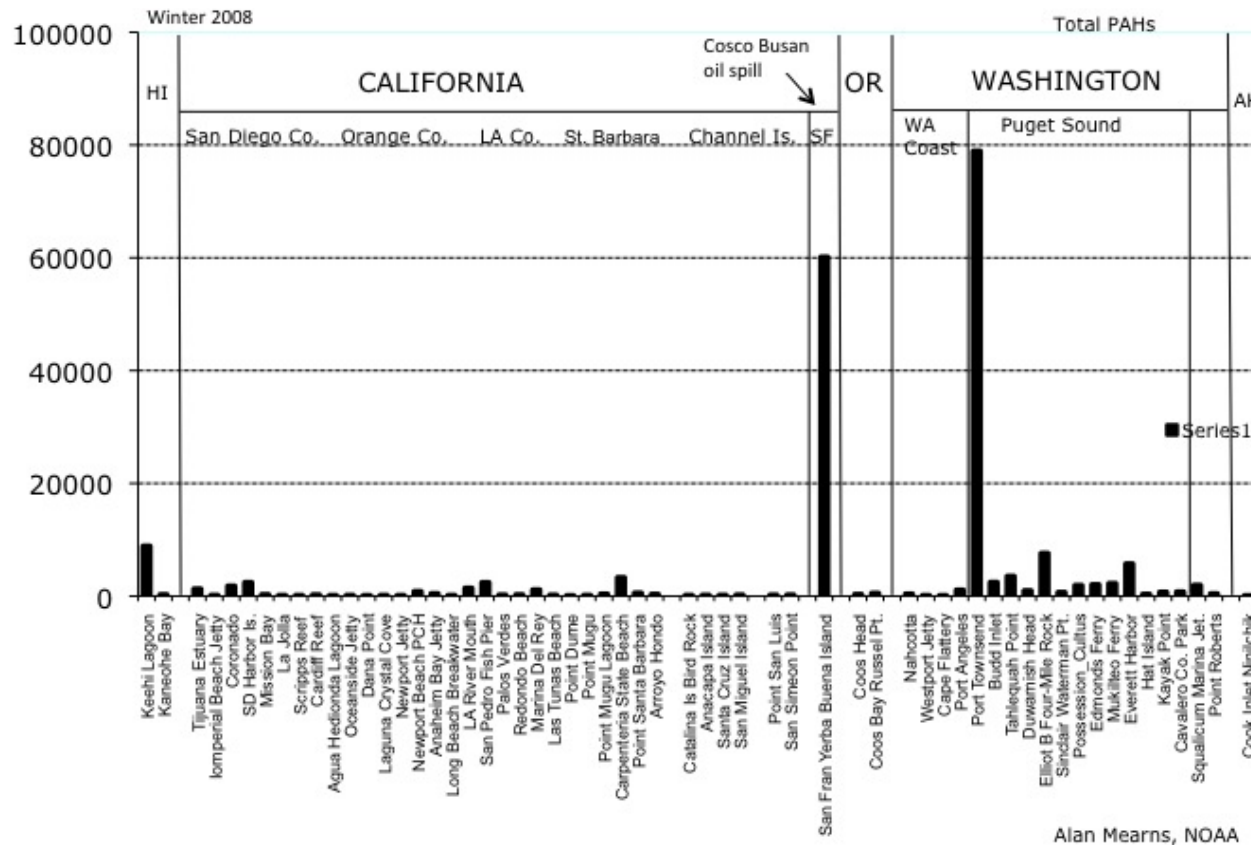
The NOAA Mussel Watch Program now analyzes over 50 different PAH compounds, and presents the concentration of total PAHs. Over time, the Mussel Watch program has come to include more and more PAHs in their analysis, which means comparisons of total PAHs over time is not a straightforward comparison. For all practical purposes though, comparison of total PAH data over the last 5 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 fires 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 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 12 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 marina related. There was also a smaller spike at Everett Harbor. The figures help put the Snohomish County data in context.

Figure 12 2008 Winter PAH Data for the West Coast



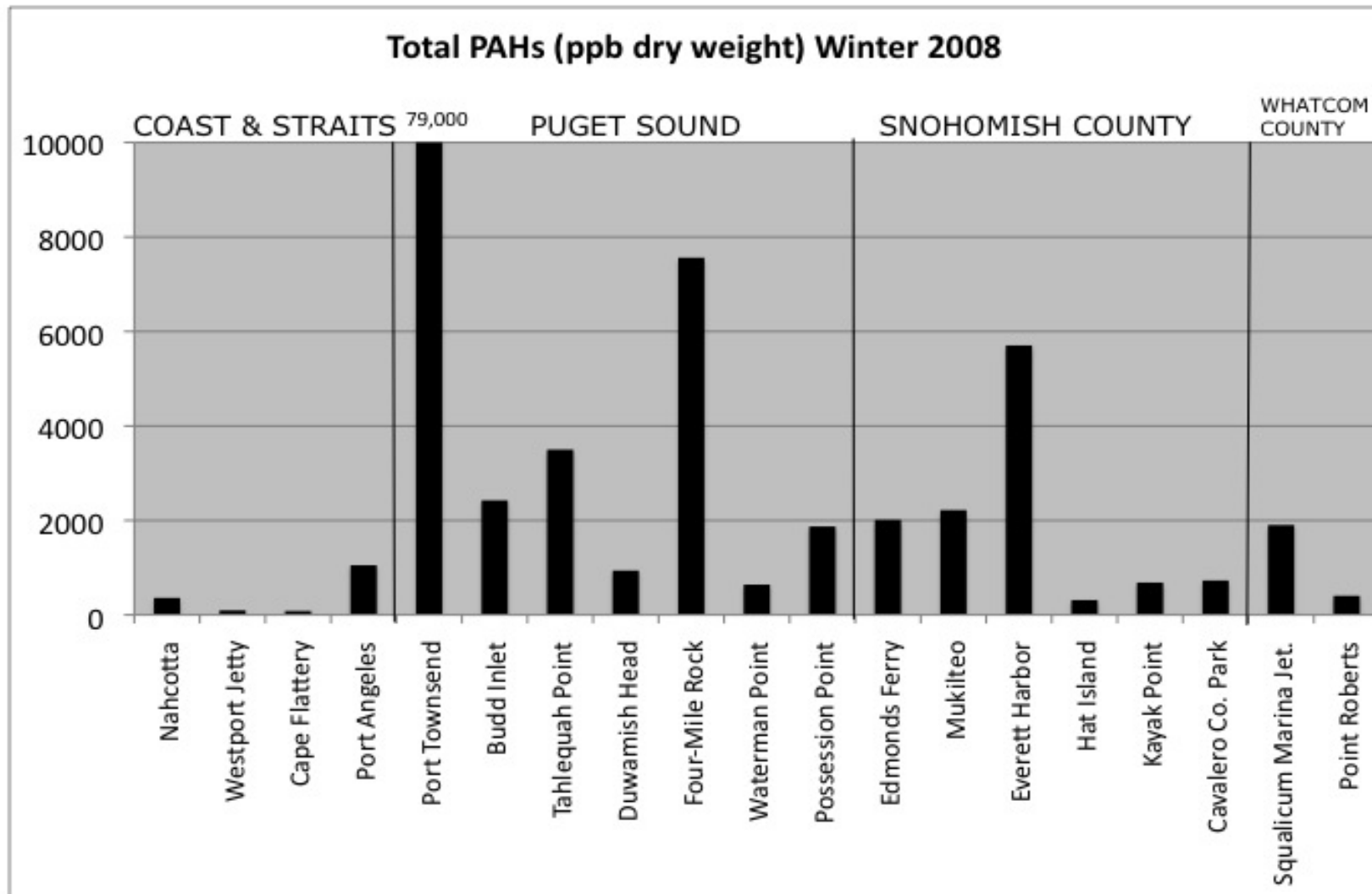


Table 12 presents Total PAH data for the Mussel Watch stations in Snohomish County. Two patterns are evident. PAHs are lower in Port Susan than in the Possession Sound and Puget Sound stations to the south. PAHs also vary significantly with the season,

indicating that stormwater runoff is 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 34 samples, 23 were in the low range, 10 were in the medium range, and 1 was in the high range.

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

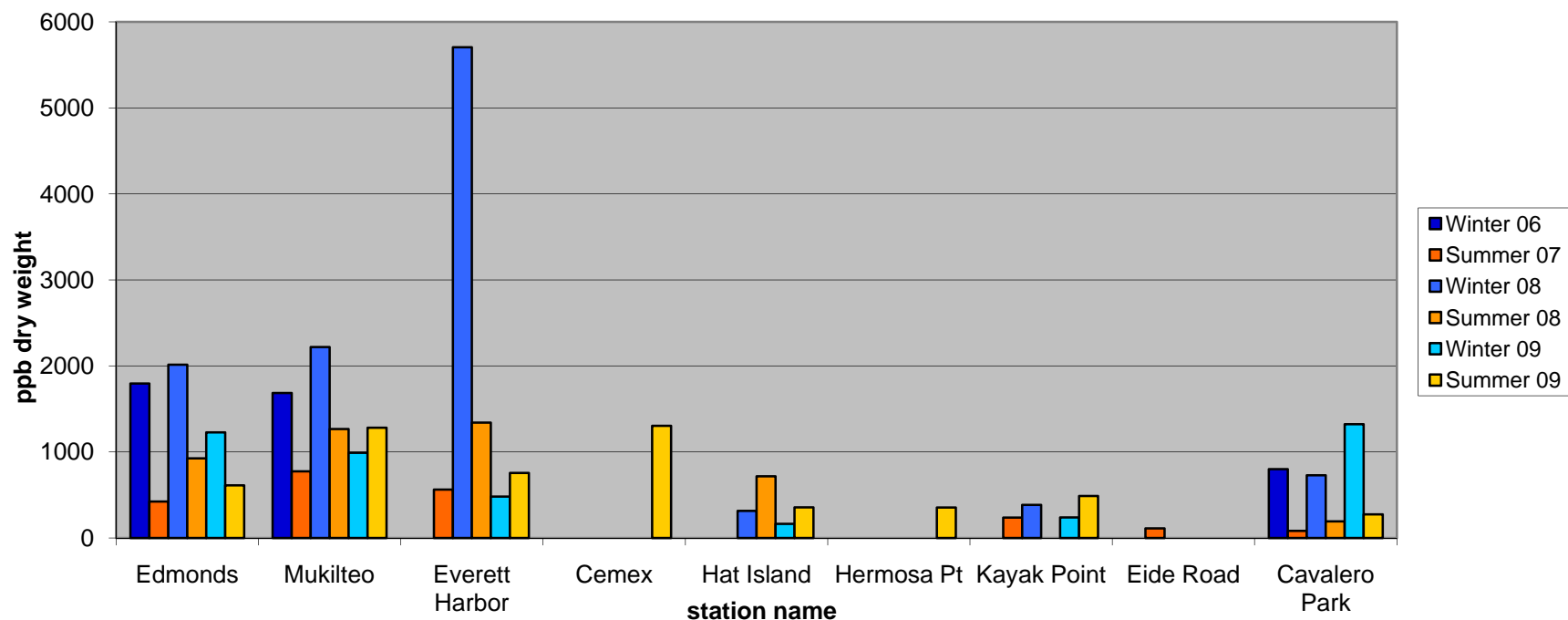
	Water body	06 wet season	07 dry season	08 wet season		08 “dry” season*	09 wet season	09 dry season	10 wet season	11 wet season
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	128		NS	NS		NS		
Kayak Point	Port Susan	NS	292		745	LS	257	487		
Cavalero	Port Susan	840	147		919	245	1387#	275		
Hermosa Point	Port Susan							354		
Hat Island	Possession Sound	NS	NS		355	791	177	356		
Cemex	Possession Sound							1303#		
Everett Harbor	Possession Sound	NS	635	7037##		1440#	555	755		
Mukilteo Ferry	Possession Sound	1716#	830	2353#		1346#	1041	1281#		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	1879#	477	2114#		989	1305#	612		
Edmonds Marina	Main Basin Puget Sound							695		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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.

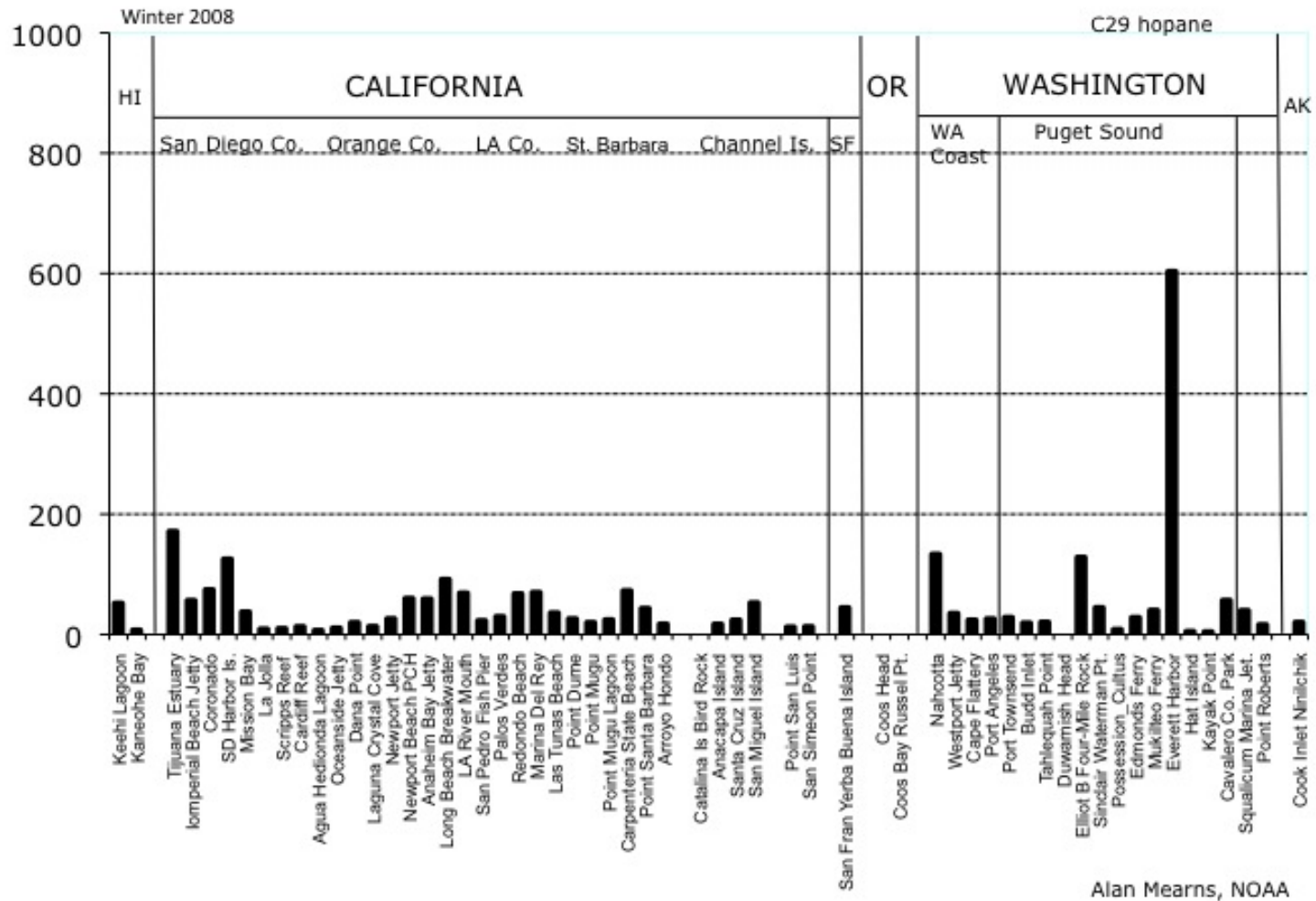
Figure 13 Total PAHs in Snohomish County mussels



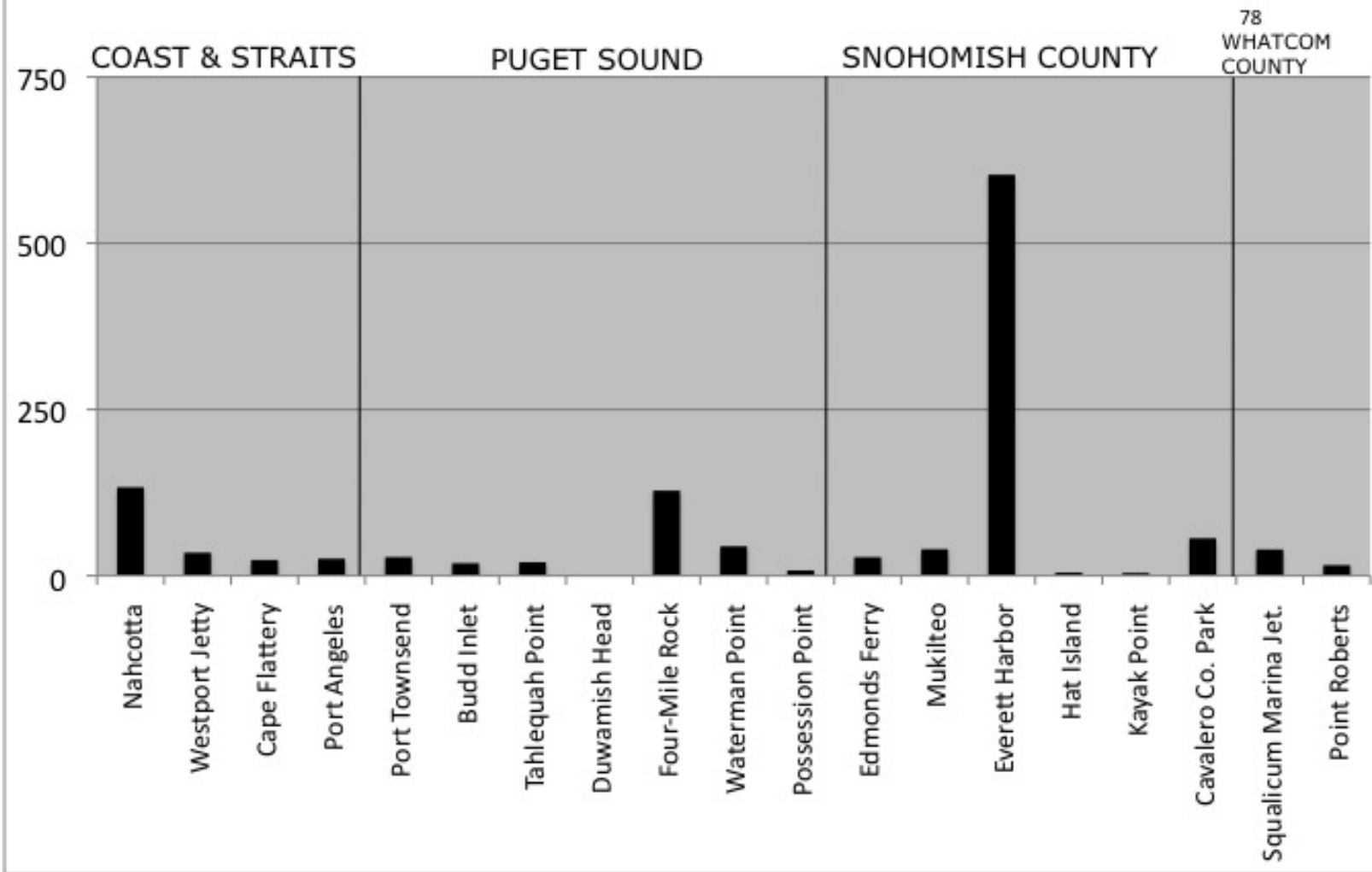
The winter 2008 Everett Harbor Total PAH values were quite elevated compared to other sites and other sample periods.

Although not a PAH, hopane is considered to be a useful petroleum marker that does not degrade over time. 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 14 Winter 2008 NOAA C29 Hopane Data



C29 Hopane (ppb dry weight) Winter 2008



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 and total HPAH concentrations from the Mussel Watch data simply as another way to examine the data.

Note 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.

The HPAHs show a very strong difference between winter and summer seasons at all stations except Hat Island. The Hat Island samples from the 2008 wet season to the 2009 wet season were all samples taken from creosote treated pilings. Creosote is a significant source of HPAHs, which may explain the anomaly with the Hat Island HPAH data. Beginning with the 2010 wet season, all samples from Hat Island have been sampled from an old concrete structure. The MRC is awaiting data from mussels collected from the concrete structure.

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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	28	NS		NS	NS	NS		
Kayak Point	Port Susan		44		112	LS	77	55		
Cavalero	Port Susan	149	17		134	43	314	35		
Hermosa Point	Port Susan							51		
Hat Island	Possession Sound	NS	NS		49	209	46	59		
Cemex	Possession Sound							209		
Everett Harbor	Possession Sound	NS	89	325		268	87	117		
Mukilteo Ferry	Possession Sound	176	146	293		216	224	204		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	130	61	216		158	163	98		
Edmonds Marina	Main Basin Puget Sound							103		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

Figure 15 Total Low Molecular Weight PAHs (LPAHs) in Snohomish County mussels

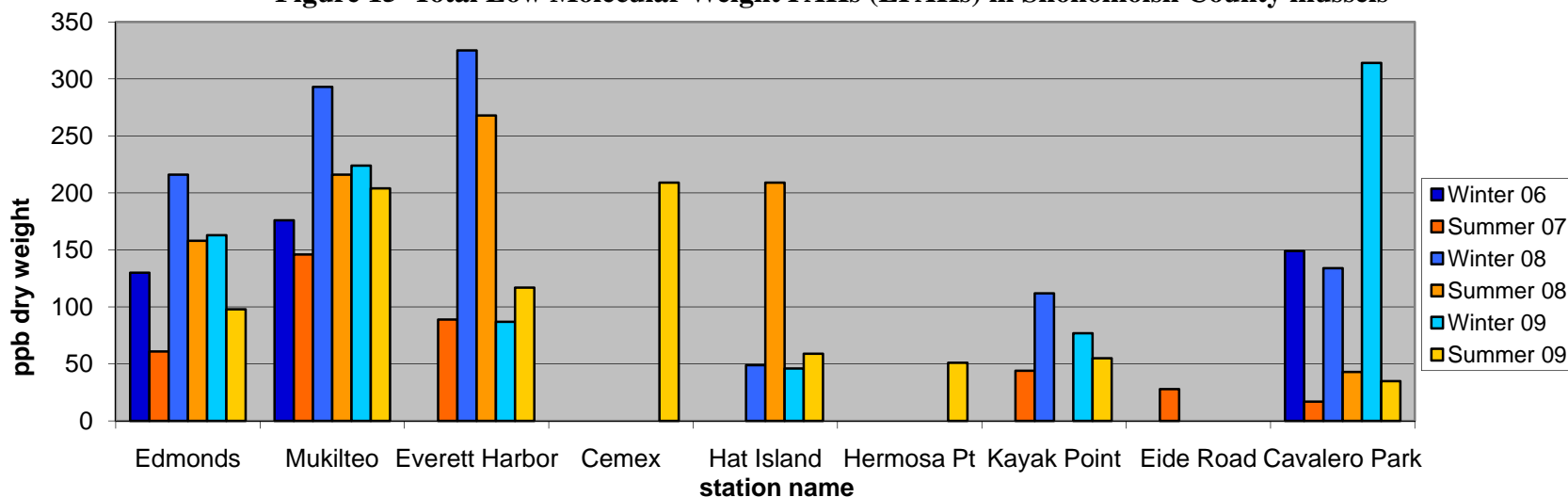
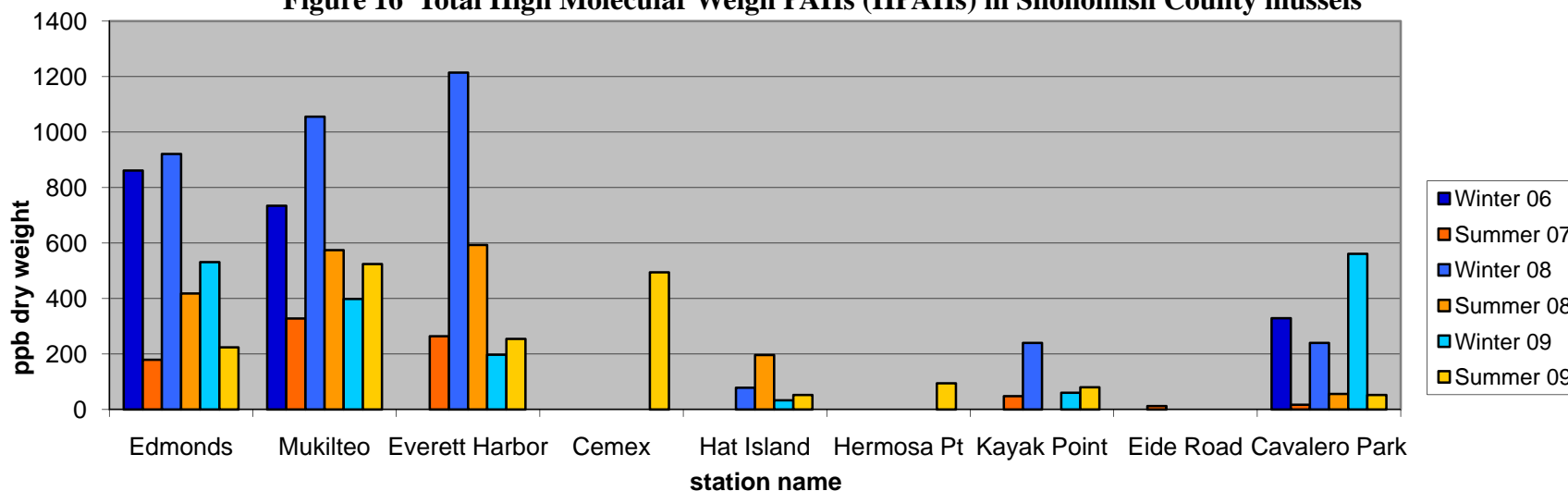


Table 14 Total High Molecular Weight PAHs (HPAH) data in parts per billion (dry weight) from Snohomish County Mussel Watch

	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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	12	NS		NS	NS	NS		
Kayak Point	Port Susan		48		240	LS	60			
Cavalero	Port Susan	329	17		240	56	561	52	-	-
Hermosa Point	Port Susan							94	-	-
Hat Island	Possession Sound				78	593	33	52	-	-
Cemex	Possession Sound							494	-	
Everett Harbor	Possession Sound	NS	264	1214		574	197	254	-	-
Mukilteo Ferry	Possession Sound	734	328	1055		196	398	524	-	
Picnic Point	Possession Sound								-	
Edmonds Ferry	Main Basin Puget Sound	861	179	921		418	531	224	-	-
Edmonds Marina	Main Basin Puget Sound							267		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

Figure 16 Total High Molecular Weigh PAHs (HPAHs) in Snohomish County mussels



Trace Metals

The NOAA Mussel Watch metals data for Puget Sound has been non-remarkable. Essentially, the metals show little difference with the open ocean stations with the exception that some data are counterintuitive. Arsenic and Cadmium are highest at Cape Flattery by the entrance to the Strait of Juan de Fuca. (See figures in Attachment B) The elevated values are associated 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 baseflow 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 the highest values thus far are in mussels from the Port Susan sites and the lowest are from the Hat Island, Edmonds Ferry and Mukilteo Ferry sites. NOAA established low, medium and high ranges for Copper from the National Mussel Watch Data (Kimbrough, et. al., 2008). Of the 26 samples, 20 were in the low range and 6 were in the medium range. The MRC is still waiting for the data from the winters of 2009, 2010, and 2011. Until more data are in, we are hesitant to comment on whether there are seasonal trends.

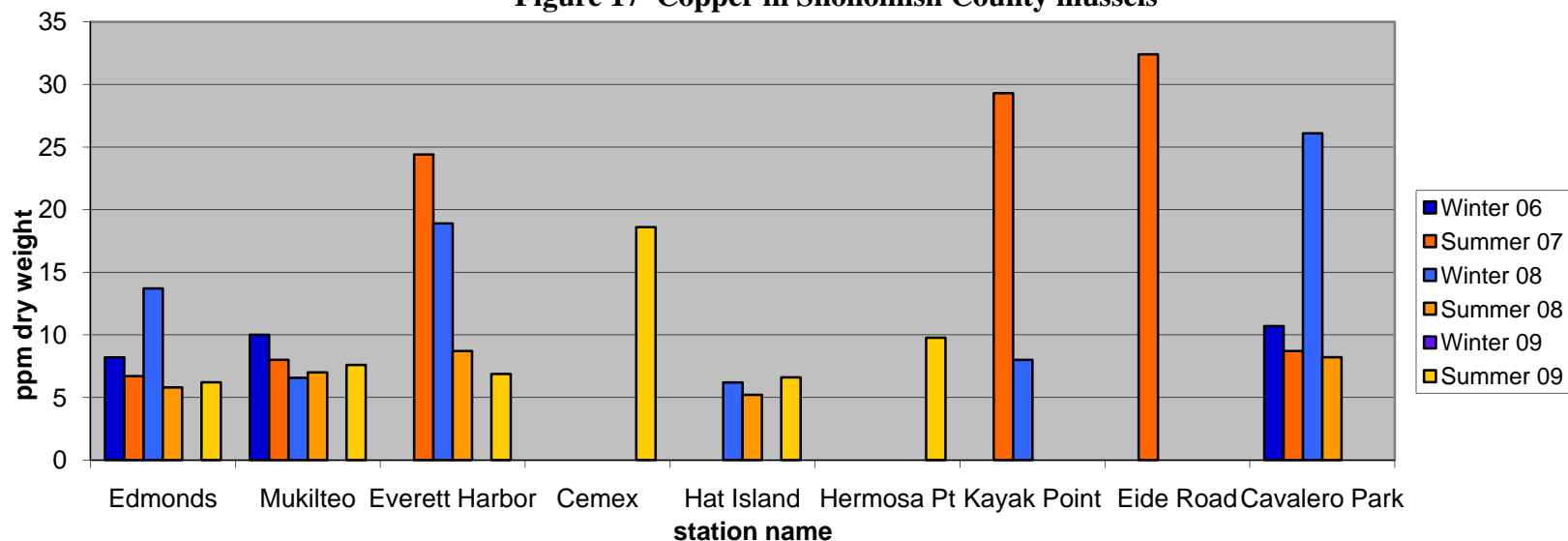
Table 15 Total Copper data in parts per million (dry weight) from Snohomish County Mussel Watch

	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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	32.4#	NS		NS	NS	NS		
Kayak Point	Port Susan		29.3#		8.0	LS				
Cavalero	Port Susan	10.7	8.7		26.1#					
Hermosa Point	Port Susan							9.77		
Hat Island	Possession Sound				6.2	5.2		6.6		
Cemex	Possession Sound							18.6#		
Everett Harbor	Possession Sound		24.4#	18.9#		8.7		6.87		
Mukilteo Ferry	Possession Sound	10	8.0	6.6		7.0		7.59		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	8.2	6.7	13.7		5.8		6.21		
Edmonds Marina	Main Basin Puget Sound							10.9		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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

Figure 17 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, and the other 25 samples were in the low range. As with copper, the stations in Port Susan have higher mercury than the stations in Possession Sound.

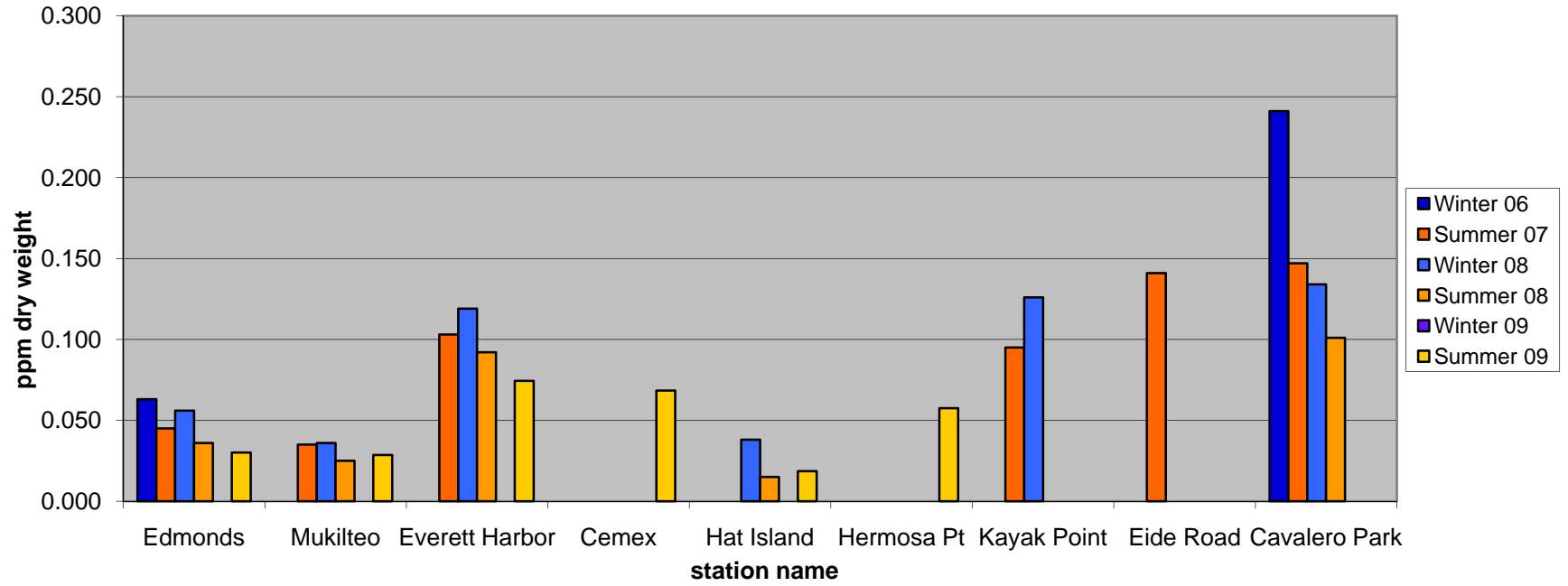
Table 16 Total Mercury data in parts per million (dry weight) from Snohomish County Mussel Watch.

	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
		12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	0.141	NS		NS	NS	NS		
Kayak Point	Port Susan		0.095		0.126	LS				
Cavalero	Port Susan	0.241#	0.147		0.134	0.101				
Hermosa Point	Port Susan							0.058		
Hat Island	Possession Sound				0.038	.015		0.019		
Cemex	Possession Sound							0.068		
Everett Harbor	Possession Sound		0.103	0.119		.092		0.074		
Mukilteo Ferry	Possession Sound		0.035	0.036		.025		0.029		
Picnic Point	Possession Sound									
Edmonds Ferry	Main Basin Puget Sound	0.063	0.045	0.056		.036		0.030		
Edmonds Marina	Main Basin Puget Sound							0.024		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.

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

Figure 18 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. We are still awaiting the NOAA metals lab data from the most recent three wet seasons.

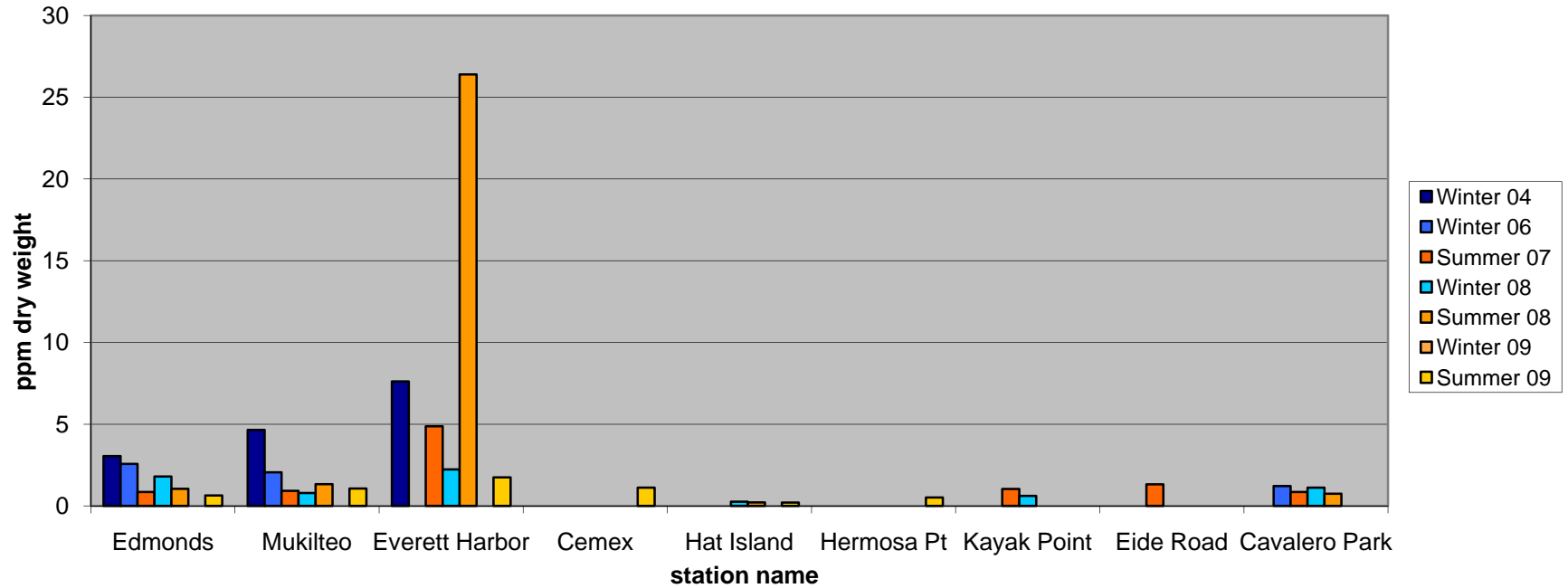
The sparse data show that the 2006 wet season had low range levels of lead for Mukilteo Ferry and Edmonds Ferry, and no data were obtained for Everett Harbor. The data also show that lead levels in the 2007 dry season were lower than prior wet seasons for the stations, with Everett Harbor still in NOAA's 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. The 2009 dry season had low lead levels. The MRC looks forward to receiving the lab delayed metals data to evaluate further the trends.

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
			12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	NS	1.32		NS	NS	NS	NS		
Kayak Point	Port Susan	NS	NS	1.04		0.61	LS				
Cavalero	Port Susan	NS	1.22	0.85		1.12	0.75				
Hermosa Point	Port Susan								0.51		
Hat Island	Possession Sound	NS	NS	NS		0.26	0.22		0.20		
Cemex	Possession Sound								1.12		
Everett Harbor	Possession Sound	7.62##	NS	4.87#	2.23		26.4##		1.75		
Mukilteo Ferry	Possession Sound	4.65#	2.06	0.92	0.79		1.33		1.07		
Picnic Point	Possession Sound										
Edmonds Ferry	Main Basin Puget Sound	3.05#	2.57	0.85	1.8		1.05		0.64		
Edmonds Marina	Main Basin Puget Sound								0.42		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.
 # 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

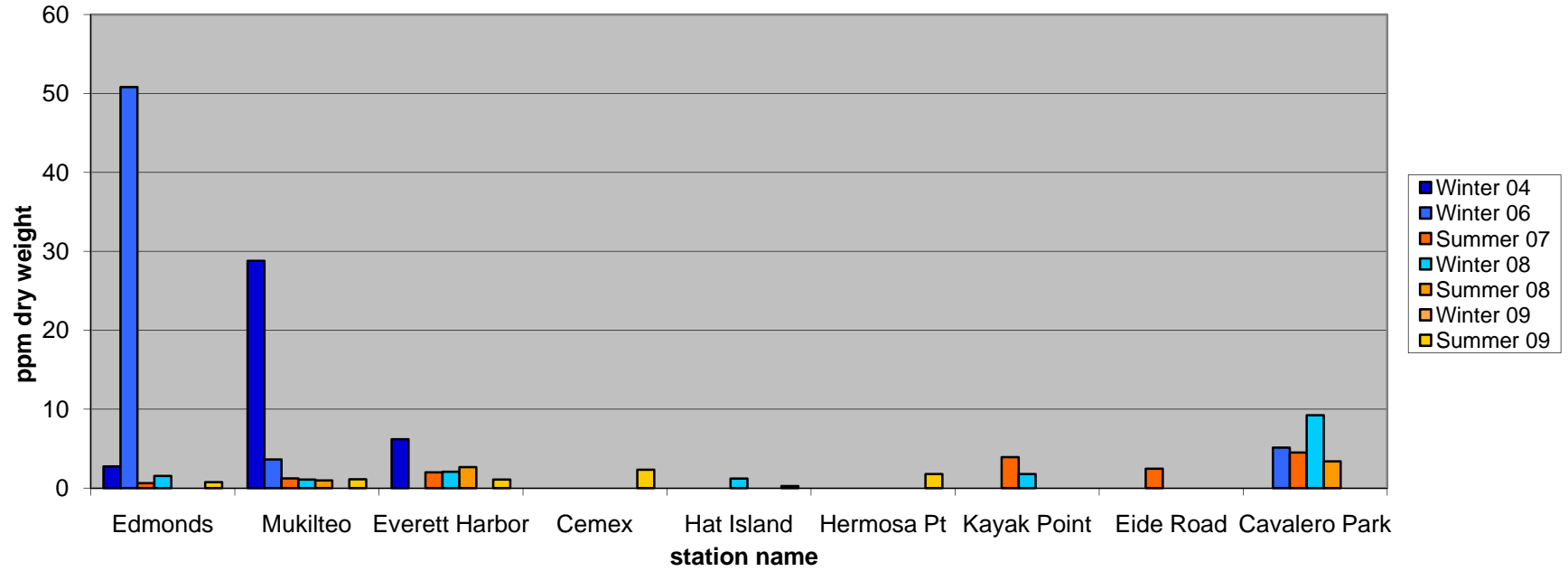
NOAA did not present chromium data or describe low, medium and high ranges for the National Mussel Watch Data (Kimbrough, et. al., 2008). In response to a request by the Tulalip Tribe, the MRC selected chromium as a metal to include in this report. (Note that the data set includes lots more metals than 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.

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
			12/05	9/07	12/07	3/08	8/08	3/09	8/09		
Eide Road	Port Susan	NS	NS	2.46		NS	NS		NS		
Kayak Point	Port Susan	NS	NS	3.93		1.78	LS				
Cavalero	Port Susan	NS	5.13	4.52		9.24	3.40				
Hermosa Point	Port Susan								1.78		
Hat Island	Possession Sound	NS	NS	NS		1.21	0.0		0.27		
Cemex	Possession Sound								2.33		
Everett Harbor	Possession Sound	6.19		2.00	2.07		2.66		1.09		
Mukilteo Ferry	Possession Sound	28.8	3.64	1.24	1.09		0.98		1.13		
Picnic Point	Possession Sound										
Edmonds Ferry	Main Basin Puget Sound	2.75	50.8	0.64	1.55		0.0		0.75		
Edmonds Marina	Main Basin Puget Sound								1.13		

NS = no sample. LS = lost sample. *10 day rainy period occurred before sampling.
Unusually high values are highlighted in red.

Figure 20 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. 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.

If we think of PAHs, recognize that most of the PAHs we see in mussels are high molecular weight, which come from combustion 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 therefore, makes sense then 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. 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). Emissions from trains would be a year round source, much like the ferries. Hence, trains may contribute to a base level of PAHs, but they do not explain the winter peaks. Creosote treated railroad ties could be a winter time source of PAHs, and railroad beds are very permeable and close to mussels in Edmonds, Mukilteo and Everett Harbor.

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. There are high molecular weight PAHs found in creosote pilings. The Hat Island (PSHI) station samples in our current database were collected from creosote pilings. Samples are now collected from a concrete structure, but we do not have data yet from the new location at Hat Island. The PAH levels for Hat Island, however, are still lower than levels for the southern part of the Snohomish County coast. Perhaps, the creosote has only a small effect.

We are aware of a PCB remediation 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 from the work at Boeing to PCBs in mussels at our stations, but if so, it is not strongly evident.

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. The 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. Was there a change in fuel related PAHs from this action? Probably, but we do not have the data to say. 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.

As citizen scientists, we are in position to observe and consider possible contamination sources during mussel collection. Volunteer Chris Betchley observed an application of Roundup, at the Eide Road site in 2007. The active ingredient in the herbicide Roundup is glyphosphate, which was not tested for in the mussels. It is an interesting observation, however, considering mussels were collected there that year, but they have been missing since then.

The Everett Harbor data are intriguing, as the site has occasional onetime spikes for parameters such as lead 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. It is also near a combined storm sewer overflow outfall of the City of Everett. These are possible sources. 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.

Sometimes the data lead to more questions than answers. To try to evaluate whether the similar general concentrations of PAHs and PCBs for the Everett Harbor, Mukilteo Ferry and Edmonds Ferry sites represent a regional signal, or instead represent close proximity to sources for each of those sites, we added a site at Picnic Point. It has only been sampled once in the 2010 wet season and we still do not have the data. If it is similar to the Edmonds Ferry and Mukilteo Ferry sites, then we might infer a regional signal. If it is less, then we might infer locally derived sources affecting each site.

We look forward to obtaining more data and considering the trends further.

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.

Our surface water quality criteria are found in Chapter 173-201A WAC, and we include criteria to protect aquatic life from acute or chronic conditions. We also have human health surface water quality criteria adopted for our state by EPA at 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 human health criteria are based on people consuming 6.5 grams a day of the organisms that live in the water. This consumption rate of 6.5 grams a day 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 lifetime cancer risk 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 criteria based surface water quality standard of 0.031 ug/L is established 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. (Smoked salmon data from two split samples were analyzed by NOAA in 1990 (Varanasi et al., 1990).

Relation to On-going Puget Sound Cleanup 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. We anticipate that on-going monitoring may also show reductions in copper, PAHs, PCBs, and other contaminants based on recent laws and on-going clean-up activities. Mussel Watch monitoring data can be used to see if concentrations in marine waters are actually falling over time. Some of the recent laws and planned clean-up 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

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

³ *Id.* §2402(4).

⁴ *Id.* §2403(b).

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 Clean-up 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.

In December 2005, Boeing Commercial Airplanes, Everett Plant removed PCB-containing joint compound material from the flightline 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 flightline 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 in 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 in catch basin solids 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 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.

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 is expected to begin in 2012 at 2 sites, 2014 at one site, with the timing at the other sites to be determined. 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, xylene, tributyltin, petroleum, vinyl chloride, benzoic acid, copper, cadmium, chromium, zinc, lead, arsenic and other metals. (Ecology PSI Website, 2011)

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 21 PSI Sites



Figure 22 City of Everett CSOs

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

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,

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 22 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

As evident in the data tables, the MRC is still waiting for data from winter 2010 through winter 2011. There have been significant delays at the Mussel Watch contract lab, TDI-Brooks International. In part, these delays are due to the large influx of high priority samples at the lab from the Deepwater Horizon Oil Spill in the Gulf of Mexico. While frustrating, the data delays do serve to reinforce the value of the Mussel Watch Program. Mussel Watch data in the Gulf of Mexico provide a baseline against which samples collected after the oil spill can be compared. At this time, we do not know when we will receive these data.

Contractual difficulties have also complicated the project. Due to data delays, TDI-Brooks did not send an invoice for winter 2010 lab services and our contract with TDI-Brooks expired. Without a contract, the MRC was unable to pay TDI-Brooks. This issue was resolved in November 2010, when lab manager Juan Ramirez graciously agreed to waive the cost of approximately \$7,000 for analysis of the winter 2010 samples. Further challenges arose in 2010, due to difficulties and delays in arranging a contract between TDI-Brooks and Snohomish County. The delays limited the MRC to a Sole Source Contract with TDI-Brooks for analysis of winter 2011 samples. Sole Source Contract restrictions limited lab services to \$10,000 and thus in turn limited the MRC to four sampling sites.

The four-site limit imposed by the Sole Source Contract, however, was not the only limiting factor. Several Mussel Watch sites in Snohomish County had mussel populations insufficient for sampling. Throughout the project interannual variations 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 23). 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.

Recommendations

NRDA (Natural Resources Damage Assessment) in Port Gardner

NRDAs are conducted to calculate the monetary cost of restoring injuries to natural resources that result from releases of hazardous substances or discharges of oil. Damages to natural resources are evaluated by identifying the functions or 'services' provided by the resources, determining the baseline level of the services provided by the injured resource(s), and quantifying the reduction in service levels as a result of the contamination. Regulations for assessing NRD have been promulgated under both the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund and the Oil Pollution Act of 1990 (OPA). The NRDA process is conducted by Natural Resource Trustees on behalf of the public. Trustees include the United States, States, Indian Tribes, and foreign governments. NRDA involves a Preliminary Assessment, Injury Assessment/Restoration Planning, and Restoration Implementation.

The Snohomish County Marine Resources Committee is considering alternative funding mechanisms should our regular base grant be reduced. At this time, the Tulalip Tribes are working with the state to submit Port Gardner for a Natural Resource Damages Assessment (NRDA). The Tribes are aware of the important role that the MRC plays in local marine conservation, and should funding be obtained through this mechanism, the MRC will be considered to receive funding. MRC staff submitted Mussel Watch data to the Tulalip Tribes per their request.

Continue Education/outreach Efforts

In our next 2-year grant cycle, the MRC will offer to provide presentations to a variety of community groups and agencies on the mussel watch program, where we plan to ask the public about possible contaminant sources. We will also complete targeted interviews with people knowledgeable about business practices to address potential sources.

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.

Continue Mussel Watch Monitoring

The long-term goal of the MRC is to continue the expanded Mussel Watch program in Snohomish County. However, due to budget limitations, in our next grant cycle, the MRC plans to continue mussel collections at the NOAA sites only. The MRC and volunteers will collect the mussels and mail them to the labs for processing. NOAA would continue to pay for the lab analysis.

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. Potential funding sources include the Tulalip Tribes, grant funding, and a possible expansion of the program throughout Puget Sound by the Puget Sound Partnership and local jurisdictions to address stormwater runoff.

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”.

The MRC will work with SWM to continue to evaluate the possibility of meeting the CWD request. Initial inquiries have found that the mussel watch data can be used for consumption risk assessment with help of a health official. This assessment may require hiring a professional consultant. Additional MRC funding would be needed to facilitate this effort.

NOAA scientist, Alan Mearns agrees that there is great opportunity for seafood risk assessment for mussels and other filter feeders in Puget Sound. He states that

Health agencies have well-proven methods and criteria for evaluating PAH health risks to seafood consumers during oil spills. It takes very high concentrations of PAH's in seafood to cause risk. In fact, only one of thousands of fish and crustacean samples from the Gulf Oil spill area had levels of PAH's that posed any risk at all because the PAHs did not biomagnify. Mussels and oysters could pose higher risks in some heavily contaminated situations.

The PAH seafood criteria used in recent oil spill risk assessments (Exxon Valdez to Deepwater Horizon) could be applied to existing Puget Sound mussel watch data. The same for several other contaminant groups such as PCB's, DDT, and probably the polybrominated diphenyl ethers (PBDEs, flame retardants). The criteria can be set for different types of consumers, including subsistence people.

I suspect the bottom line will be that, even though contaminants such as PAHs are higher in Puget Sound mussels than elsewhere (except during major oil spills), the mussels would pass the risk assessment.

Since the above discussion was put in this report, the Department of Ecology listed mussel watch sites throughout the state as impaired primarily due to the PAH levels in the tissue. We have discussed the listing earlier in this report and tried to put it in context. Perhaps mussels could pass one type of risk assessment and not pass another. One needs to also consider the benefits of consuming seafood and contrast that with the risks of other types of protein sources.

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). The rocks/rip-rap could be named after the volunteer.

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.

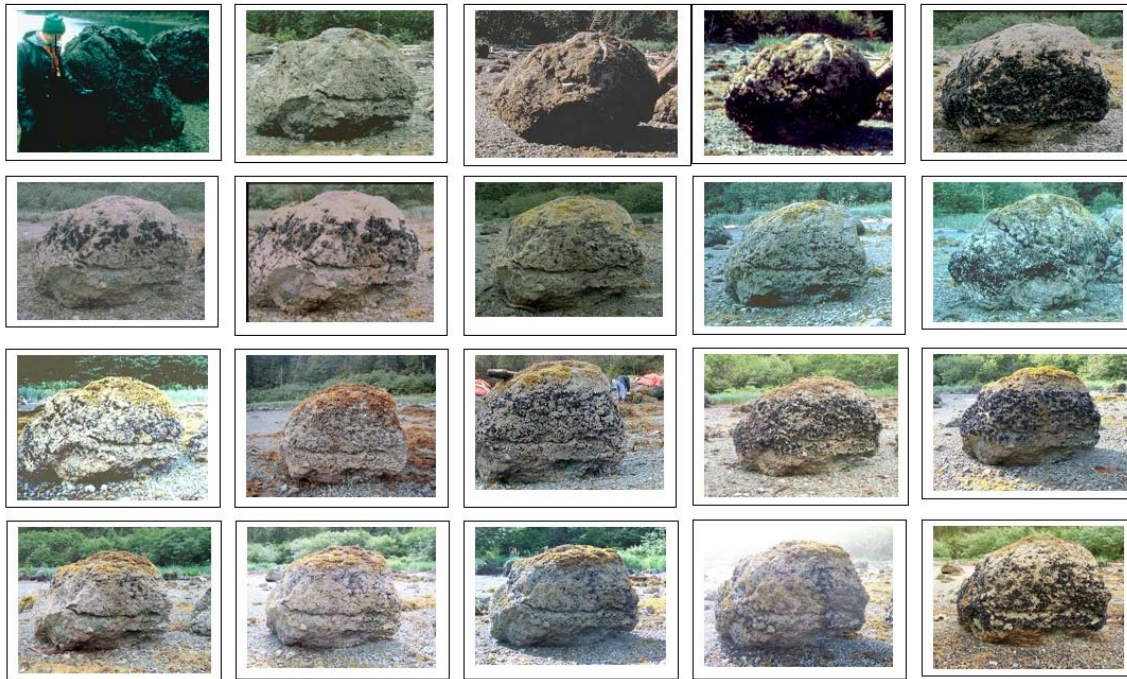


Figure 23 Interannual variation in mussel cover on previously oiled rock “Ernie” from Shelter Bay site, 1989 (upper left) to 2008 (lower right)

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 emphasize public outreach during our next grant cycle. 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 recently launched a new website with a page dedicated to the Mussel Watch Project. This report and data will be made available at the site.

Due to delays in receiving data from the laboratory, we have not completed as much public outreach as had we anticipated, including reporting to our volunteers on our findings. As we continue to receive data from the labs, we need to make sure our volunteers are briefed, so they know how they have contributed to the project.

We will continue to analyze available data from historic collections and data from our 2009-2011 collections as we receive it from the labs, and make the data and analysis available to the public.

CONCLUSION

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. This work has recently come to fruition as it may serve as a key funding source for the MRC as federal funding constraints lead the MRC to diversify its funding portfolio.

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.

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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