Bioaccumulative Toxics in

Subsistence-Harvested Shellfish –

Contaminant Results and Risk Assessment

December 1, 2006

Prepared by the Swinomish Tribe, Office of Planning and Community Development, Water Resources Program, PO Box 817, La Conner, WA 98257 in cooperation with AESE Inc., P.O. Box 50392, Henderson NV 89016.

Swinomish Tribal Community

P.O. Box 817, 11404 Moorage Way
La Conner, WA 98257

Swinomish Water Resources Program

Office of Planning & Community Development

P.O. Box 817; 11430 Moorage Way - LaConner, WA 98257 - 360.466.7280 - 360.466.1615 fax

Report for EPA Grant R-829-467-01

We would like to express our great appreciation to the many Tribal members, elders, staff, and officials who provided advice, participated in the associated community events, and helped in many ways.

Executive Summary

The Swinomish Tribal Indian Community is located on Fidalgo Island on interior Puget Sound. The Swinomish people are a maritime people; as such, shellfish represent an abundant and reliable resource, and are a stable underpinning of Swinomish diet and culture.

For the Swinomish people, the close proximity of petrochemical industries to the shellfish beds, as well as the long standing and repeated violations of emission limit permits by those industries, pose a potential threat of health problems to members involved in subsistence gathering activities on or near the Swinomish Reservation. In addition, agricultural chemicals and metals are a concern. Several published reports indicate the presence of chemical contamination in areas where Swinomish citizens gather shellfish. Therefore, the Swinomish Tribe conducted a study, *Bioaccumulative Toxics in Native American Shellfish* (EPA Grant R-829-467-01), to evaluate contaminants and risks in clams and crabs gathered at traditional harvesting areas on and near the Reservation.

This report is the technical summary directed at Tribal staff and health care professionals. Outreach materials for the Tribal membership are summarized in the section on recommendations, but the actual outreach materials are not included in this report.

Muscle tissue was collected from two bivalve shellfish species: native little neck clams or "steamers" (*Prototheca staminea*), and butter clams (*Saxidomus giganteus*). Muscle and hepatopancreas tissue were collected from Dungeness crabs (*Cancer magister*). Tissues were analyzed for polychlorinated biphenyls (Aroclors and selected PCB congeners), polyaromatic hydrocarbons (PAHs), dioxins/furans (selected congeners), chlorinated pesticides, and heavy metals including organotins. Sediment samples from the shellfish bed sites were also collected and analyzed for the same substances. Risks were evaluated for individual samples as well as for a "seafood basket" of clams, crabs, and salmon.

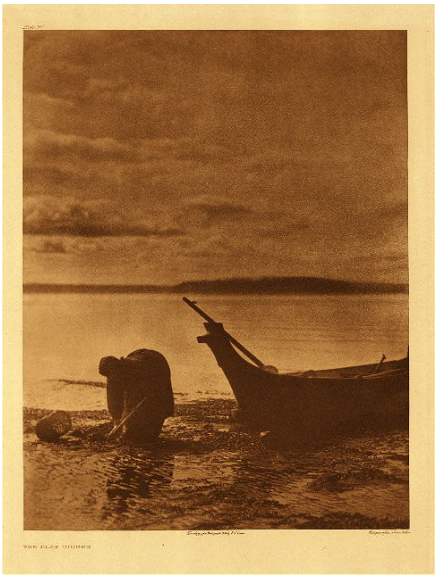
Risks can only be estimated if the amount of fish consumption is known. Several surveys of contemporary (i.e., suppressed) tribal consumption rates have been performed in the Pacific Northwest. However, the three studies used statistical methods that masked the true subsistence members, who tend to be more culturally conservative and less amenable to interviews. Because the Swinomish Tribe recognized that a more culturally appropriate survey method would result in more accurate data, an ethnographic-style survey, called seafood diet interviews, was performed to evaluate current consumption patterns. Data analysis is not complete, but ingestion rates reflective of mid-to-upper consumption patterns are used in the risk analysis.

The contaminants that contributed the most to human health risk were PCBs, arsenic, and dioxins/furans, with lesser contributions from mercury and other heavy metals, chlorinated pesticides, and PAHs. Risks from eating 100g (3.5 ounces) portions of each species daily (for a total of 300 grams per day) for life are in the range of concern because non-cancer risks for adults and children are above 1 (ranging from 3 to 20), and lifetime cancer risks are in the range of 1 in a 1000. Risks from a fully subsistent level consumption rate would be higher. Risks from eating less fish and shellfish might be

lower, depending on the quality of the replacement food, but would also adversely affect cultural practices and would lower the health benefits of fish and shellfish.

Recommendations for consuming numbers of meals from various locations are presented. The locations nearer the refineries are generally slightly more contaminated, with one location too contaminated to be used at all.

Subsequent projects are anticipated to include completion of the seafood diet interview data analysis, documentation of original subsistence rates, identification of the cleanest yet most culturally appropriate diet, and working with regulators to reduce or eliminate contamination of Tribal resources.



These photos of Coastal Salish people digging clams and mussels by Edward S. Curtis (c. 1900) are available online at Northwestern University and the Library of Congress' *American Memory*. http://curtis.library.northwestern.edu/weblinks.html; http://curtis.library.northwestern.edu/toc.cgi?sec=&psec=nai.09,#nai.09.book).

Project Management

This project was conducted by the Swinomish Tribal Community under EPA grant number R-829-467-01. The project involved many people, organized into project personnel and two types of advisors. The Tribal Advisory Board included technical and cultural staff, and the Technical Advisory Board included academic and regulatory staff.

Key Personnel	***Tribal Advisory Board***	***Technical Advisory Board***
Tony Basabe, PhD, Principal Investigator	Tamara Gage, Shellfish Biologist, Port Gamble S'Klallam Tribe	Pat Cirone, PhD, EPA Region 10
Barbara Harper, PhD, DABT, Toxicologist	Jennifer Hagen, Northwest Indian Fish Commission	Catherine O'Neill, JD, Seattle University, legal advisor
Charles O'Hara, M.A., Grant Administrator	David Winfry, Shellfish Biologist, Puyallup Tribe	Gary Palcisko, WA Dept of Health
Jamie Donatuto, PhD(c), Project Manager	Andy Dalton, Shellfish Biologist, Muckleshoot Tribe	Chetana Acharya, University of Washington, Outreach and Education
Todd Mitchell, M.S., Water Resources Coordinator/ SEL Manager	Ian Kanair, Natural Resources Director, Snoqualmie Tribe	Bill Griffith, PhD, University of Washington, Bio-statistician
Corey Contreras, Frank Dunn and Lane Fernando, Videographers	Christine Woodward, Envr Specialist, Samish Tribe	Nancy Judd, MS, University of Washington (position at time of Board appointment)
Kaia Smith, Environmental Outreach and Education	Michelle Myers, Biologist, Upper Skagit Tribe	Jim Gibson, Skagit River Systems Cooperative, Shellfish Biologist
Susan Clark and Leslie Bobb, Interviewers	Kelly Toy, Envr Specialist, Jamestown S'Klallam Tribe	Roseanne Lorenzana, PhD, EPA Region 10
Dr. Barbara Clure, Swinomish Primary Care Physician	Ray Ives, Water Quality Technician, Suquamish Tribe	Donald Vespar, MPH, Environmental Health Specialist
Scott Andrews, J.D., Swinomish QA Officer	Vince Cooke, Makah Tribe	Andy Ross, Skagit County Shellfish program
Elizabeth Moore, PhD, Project Evaluator	Terry Williams or designee, Tulalip Tribe	

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1.0 INTRODUCTION AND BACKGROUND

The *Bioaccumulative Toxics in Native American Shellfish* (BTNAS) project represents the logical continuation of research into contamination in water bodies that surround the Swinomish Reservation (**Figure 1)**. Several published reports indicate the presence of chemical contamination in those areas on or near the Reservation where Swinomish citizens gather shellfish. The overall goal of this project is to ascertain whether Swinomish citizens are exposed to bioaccumulative toxics when gathering and consuming local shellfish, and if so, to formulate and implement a community-based education strategy incorporating cultural learning preferences.

This document summarizes one phase of the overall project - - the contaminant data and estimates of health risk. It does not evaluate health statistics nor make any causal inferences between contaminant exposure and health conditions.

This report addresses Aim 1 of the overall BTNAS project. Aims 2-4 are described below but are not addressed in this report.

AIM 1: Contaminant Sampling and Risk Assessment

Muscle tissue was collected from two bivalve shellfish species: native little neck clams or "steamers" (*Prototheca staminea*), and butter clams (*Saxidomus giganteus*). Muscle and hepatopancreas tissue were collected from Dungeness crabs (*Cancer magister*). Tissues were analyzed for PCBs (Aroclors and selected congeners), PAHs, dioxins/furans (selected congeners), chlorinated pesticides, and heavy metals including organotins. Sediment samples from the shellfish bed sites were also collected and analyzed for the same substances.

Risks to people consuming the shellfish are evaluated based on the amount of shellfish consumed. Shellfish consumption rates were determined two ways. First, a fish consumption survey of Swinomish members, including subsistence users and/or harvesters, determined the ***current*** rates for men, women, youth, and children under the age of six. A future phase will determine the ***original*** subsistence rates because it is the rate that people are entitled to under the Treaty of Point Elliott. The original subsistence rate is higher than current suppressed rates. Most people understand the original ingestion rate to be the most healthful and most culturally appropriate ingestion rate.

For this report, health risks are estimated for the Swinomish people eating current amounts of shellfish with and without salmon.

AIM 2: Education

The second aim is to communicate the identified risk to community leaders and members in a culturally appropriate manner. Initial recommendations are included in this report.

AIM 3: Mitigation Options

The community and the project team will discuss strategies for lowering the amount of bioaccumulative toxics consumed. Possibilities include changing shellfish collection regulations, reevaluating industry effluent permits, and third party monitoring of the currently self-monitoring industries. It may also include

identifying the cleanest sources of seafood and the cleanest sources of terrestrial plant and animal food.

AIM 4: Health and Rights Evaluation

Aim 4 will identify the most prevalent health issues affecting the Swinomish people and determine whether any associations exist between the contaminants found in the shellfish sampled and any of the predominant health problems experienced on the Reservation. Violation of the Treaty right to consume amounts promised to them in perpetuity will be described, as well as the associated health consequences of lost natural foods and the health consequences of lost rights and heritage.

1.1 TRIBAL IMPORTANCE OF SHELLFISH

The citizens of the Swinomish Indian Tribal Community are descendants of the tribes and bands once known as the Lower Skagit, Kikiallus, Swinamish, and Samish. Today, there are approximately 1,000 Swinomish citizens. The Tribe is federally recognized and operates under the Constitution and Bylaws adopted in 1936 pursuant to the Indian Reorganization Act of 1934.

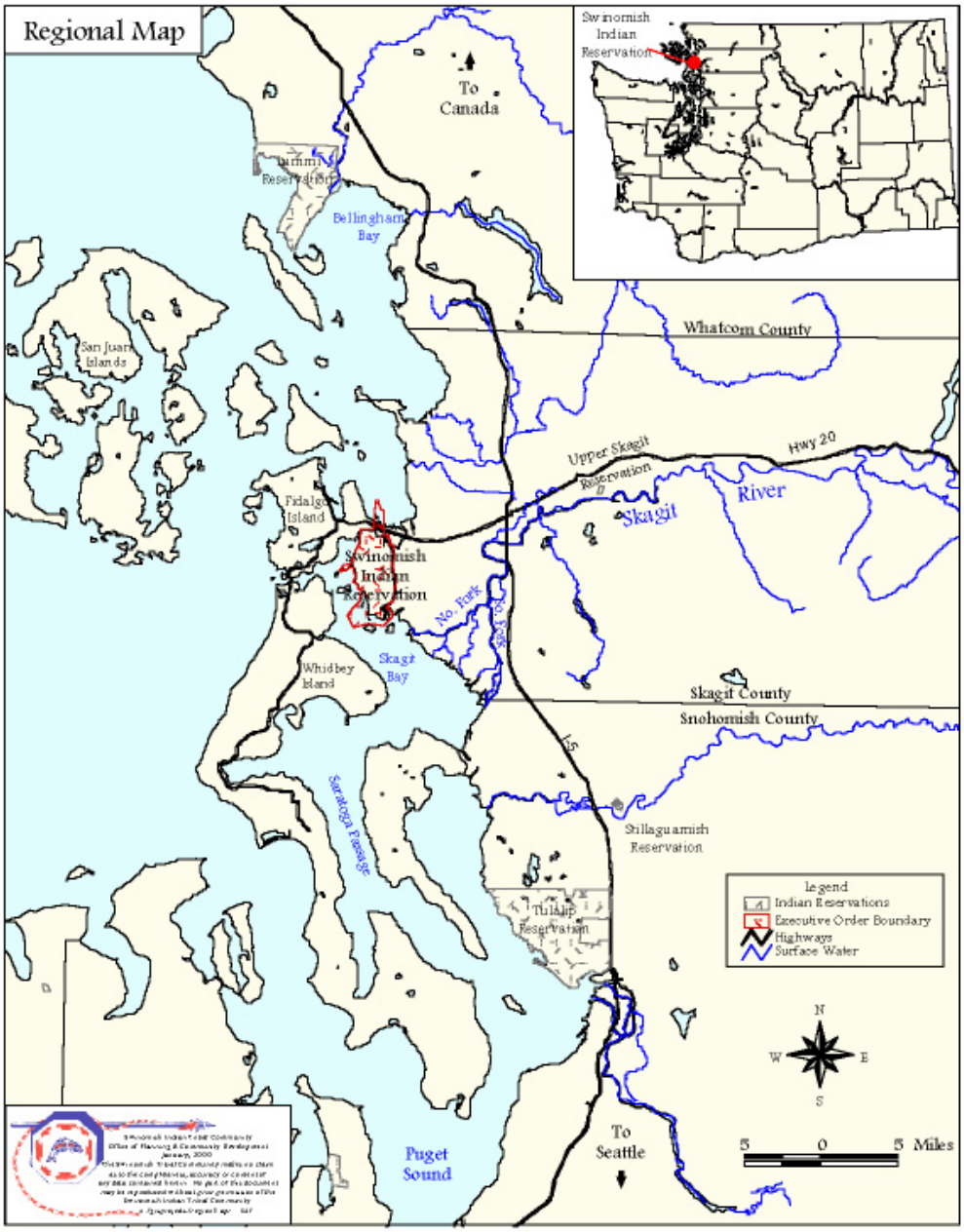
The Treaty of Point Elliott established the Swinomish Indian Reservation, located near La Conner, Washington, in 1855. From the millions of acres ceded by the Indian signatories to the Treaty, including Swinomish ancestors, the Treaty set aside the peninsula at the southern end of Fidalgo Island, formally called Shais-quihl, as a permanent homeland for the peoples of the Skagit River Valley. A subsequent Executive Order in 1873 moved the northwest boundary of the Reservation from the head of Turner's Bay to the Swinomish Channel, taking away the land at March Point, which was originally designated within the boundaries of the Reservation. Today, the Reservation encompasses approximately 7,344 acres of land area and approximately 2,900 acres of tribally owned tidelands.

Up to and since the time of the 1855 Point Elliott Treaty, the Swinomish were, and remain, a maritime people who had developed a set schedule of movement between unique environments that were seasonally abundant in fish, waterfowl, mammals, and flora (Roberts 1975). Many Swinomish villages were located near biologically rich shellfish beds, while additional settlements were located near other resources, such as deer meadows or root fields.

Shellfish are an abundant and reliable resource, located in known ecological niches, and are therefore a stable underpinning of Swinomish diet and culture. Since time immemorial, Swinomish people have harvested the shellfish beds surrounding the Reservation. These beds, however, comprise only a portion of the beds traditionally harvested by the Tribe as was recognized by the federal court in *United States v. Washington* when a much larger area was identified as Swinomish's usual and accustomed (U/A) fishing areas.[1]

[1] *United States v. Washington*, 459 F. Supp. 1020, 1049 (W.D. Wash. 1979)("The usual and accustomed fishing places of the Swinomish Tribal Community include the Skagit River and its tributaries, the Samish River and its tributaries and the marine areas of northern Puget Sound from the Fraser River south to and

Figure 1. Swinomish Indian Reservation



including Whidbey, Camano, Fidalgo, Guemes, Samish, Cypress, and the San Juan Islands, and including Bellingham Bay and Hale Passage adjacent to Lummi Island.")

The Swinomish Comprehensive Plan (1996) includes a policy statement that "*promotion of shellfish aquaculture shall be encouraged, emphasizing subsistence harvest practices*." The Comprehensive Plan expresses the significance of the land and resources, particularly shellfish, as follows:

> "To the Swinomish people, the Swinomish Indian Reservation is a homeland. It is a finite resource which binds its history, culture, traditions, and identity. As a finite resource, the Tribe acknowledges the irreplaceability of the reservation homeland. The cultural traditions which value the gathering of shellfish from the reservation tidelands have become impeded due to water quality degradation. This has resulted in the closing of beaches to shellfish harvesting. The culture and economy of the inhabitants of the Skagit region was centered around natural resources, including salmon, shellfish, and other marine life, as well as upland resources such as cedar, camas, berries, and wildlife. Shellfish are important subsistent and commercial resources for the Tribe."

1.2 PREVIOUS ENVIRONMENTAL DATA RELEVANT TO THE SAMPLING AREAS

The environmental contaminant information that triggered this project is described in this section. The shellfish beds in Fidalgo and Padilla Bays are not used much at present due to concerns about contamination, so they were included in order to determine if it would be safe to use them as they were used historically. Existing information about known or suspected contaminant locations was combined with information about traditional fish and shellfish information to select the sampling locations. Although existing information leads to concerns about health and risks, additional sampling conducted in this study was needed to fill data gaps and provide a sound basis for making recommendations about which shellfish beds to use more and which less, as well as overall recommendations about how much local seafood it is safe to consume over a lifetime.

For the Swinomish people, the close proximity of industries to the shellfish beds on or near the Reservation, as well as the long standing and repeated violations of emission limit permits by those industries, particularly of air emissions, pose a potential threat of health problems to members involved in subsistence gathering activities in those areas.

Of the five oil refineries in the State of Washington, two Title V oil refineries are located at March Point and have been in operation for almost 50 years. A concentrated cluster of petrochemical and cogeneration industries sits between Padilla Bay and Fidalgo Bay at March Point. Together, the two oil refineries on March Point process about 150,000 barrels of crude oil every day. Two additional oil refineries and an aluminum reduction plant are located 20 miles north of the reservation at Cherry Point and have also been in operation for almost half a century.

South Fidalgo Bay was heavily oiled in a 1991 oil spill, and oil or oil derivatives can still be seen in the marsh. The Padilla and Fidalgo Bay shellfish harvest areas also sit directly under industrial sewer outfalls. The refining process utilizes or produces many toxic metals, organic solvents, acids, and other chemicals. Millions of gallons of water are used in the refining process and although the facilities are required to treat the water, small amounts of the oil and chemicals remain in the effluent discharged on a daily basis

to Fidalgo Bay. There have been numerous past violations of the National Pollutant Discharge Elimination System permits by the petro-chemical industries. Monthly discharge monitoring reports and quarterly waste water characterizations reported cyanide, copper, mercury, ammonia, cadmium, chlorine, lead, nickel, selenium, and zinc all exceeded water quality standards in the final effluent reported in at least one of the waste water reports.

Information about recent environmental releases under various permits are available from www.scorecard.com, which presents Toxics Reporting Inventory (TRI) data for a range of Standard Industrial Codes. However, information on emissions of some chemicals and their concentrations is not available. Pesticide use is not included, nor is information from public owned treatment works, landfills, Superfund sites, or other waste sites. Tables 1-4 are taken from the Scorecard web page.

Table 1. TRI Facilities in Skagit County, WA

Zip Code: **98257**			
Community: **Skagit County**			
Reported Environmental Releases from TRI Sources in 2002			
Rank in Community	***Facility***	***City***	***Pounds***
1	Tesoro Refining & Marketing Co.	Anacortes	696,040
2	Shell Oil Products Puget Sound Refinery	Anacortes	320,318
3	General Chemical	Anacortes	12,955
4	Nordic Tug, Inc.	Burlington	11,492
5	Fibrex Corp.	Burlington	6,507
6	March Point Cogeneration Co.	Anacortes	6,377
7	Janicki Industries, Inc.	Sedro Woolley	3,229

Table 2. Chemicals Released from TRI Facilities in Skagit County, WA

Zip Code: **98257**		
Community: **Skagit County**		
Total pounds of reportable chemicals released from TRI Facilities in 2002		
Rank in Community	***Chemical Name***	***Pounds***
1	Sulfuric Acid	633.707
2	Ammonia	74,070
3	Toluene	52, 158
4	Xylene	51,368
5	Hydrochloric Acid	44,o1o
6	n-Hexane	37,106
7	Propylene	24,955
8	Styrene	21,062
9	Benzene	20,221
10	Cyclohexane	17,461
11	Cyanide Compounds	16,120
12	Hydrogen Cyanide	16,120
13	Ethylene	13,520
14	Ethylbenzene	10,244
15	Tetrachloroethylene	6,580
16	Chlorine	4,005
17	1,2,4-Trimethylbenzene	2,954
18	Carbon sulfide	2,642
19	Naphthalene	2,211
20	Diethanolamine	1,353

Table 3. Tesoro Refinery TRI Information

2002 Rankings: Major Chemical Releases or Waste Generation at This Facility								
Facility: TESORO REFINING & MARKETING CO., ANACORTES, WA								
Percentile								
Cleanest/Best Facilities in US						Dirtiest/Worst Facilities in US		
1-10%	20%	30%	40%	50%	60%	70%	80%	90% - 100%
Total environmental releases:								
								x
Cancer risk score (air and water releases):								
						x		
Noncancer risk score (air and water releases):								
							x	
Air releases of recognized carcinogens:								
							x	
Air releases of recognized developmental toxicants:								
								x
Air releases of recognized reproductive toxicants:								
								x

Table 4. Shell Refinery TRI Information

2002 Rankings: Major Chemical Releases or Waste Generation at This Facility								
Facility: SHELL OIL PRODS. U.S. PUGET SOUND REFY., ANACORTES, WA								
Percentile								
Comparison to the Cleanest/Best Facilities in US						Comparison to the Dirtiest/Worst Facilities in US		
1-10%	20%	30%	40%	50%	60%	70%	80%	90% - 100%
Total environmental releases:								
								x
Cancer risk score (air and water releases):								
						x		
Noncancer risk score (air and water releases):								
								x
Air releases of recognized carcinogens:								
							x	
Air releases of recognized developmental toxicants:								
							x	
Air releases of recognized reproductive toxicants:								
								x

Figure 2. Shell and Tesoro Refineries, March Point

Credit: Paul Joseph Brown/Seattle Post-Intelligencer

The shellfish beds within the Swinomish Reservation (as well as many of those within the Tribe's usual and accustomed fishing areas) are also within the air deposition zone from the defunct Asarco Tacoma smelter, which began operating in 1890 as a lead smelter, and converted to a copper smelter in 1912. The smelter specialized in processing ores with high arsenic concentrations and recovered arsenic trioxide and metallic arsenic as byproducts. Operation of the Asarco smelter for over 95 years resulted in contamination, primarily arsenic and lead, of the surrounding area. That contamination was the result of airborne emissions from smelting operations.[2] The air plume footprint for arsenic, lead, and cadmium attributable primarily to the smelter, including wet and dry deposition onto land as well as deposition onto water and subsequent distribution by currents, extends to and beyond Anacortes Island.[3]

The Whitmarsh Municipal landfill, a former mill, and a former petroleum waste disposal site are also situated near the petrochemical facilities and Padilla Bay Lagoon.

In the state of Washington, most air and water permitting and monitoring functions are delegated from EPA to the Washington Department of Ecology. The current impacts of

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[2] EPA (2000). First Five-Year Report for Ruston/Tacoma Superfund Site. http://yosemite.epa.gov/r10/CLEANUP.NSF/6ea33b02338c3a5e882567ca005d382f/c73c106fd187e1b6882569150064ad86!OpenDocument&Highlight=0,ruston.

[3] Glass, G.L. (2003). Tacoma Smelter Plume Site Credible Evidence Report: The ASARCO Tacoma Smelter and Regional Soil Contamination in Puget Sound. http://www.ecy.wa.gov/programs/tcp/sites/Tacoma_smelter/Sources/Credible_Evidence/web%20pieces/Credfinl.pdf#search=%22asarco%20seattle%20air%20plume%22

air particulates that deposit onto soil and water are difficult to evaluate. The Puget Sound Clean Air Agency (www.pscleanair.org) regulates air quality under the state and federal clean air acts, and registers large stationary emission sources, issues construction permits, regulates open burning, conducts some monitoring (including some organics and several metals), and conducts education and outreach. In addition, reports detailing the industrial effluents released into the air are required by the Northwest Air Pollution Authority (NWAPA), as determined by standards set forth by the federal Clean Air Act. However, disclosure of several chemicals not specifically listed by NWAPA is voluntary, so public information is difficult to find.

The Skagit River is the largest river emptying into Puget Sound, and drains an area of 3000 square miles. Originally, the Skagit River had several outflows, including both Padilla and Skagit Bays, before water flow was changed by diking and draining in the late 1800s. Padilla Bay now drains 23,000 acres, which are agricultural and urban, and most of the freshwater comes from agricultural watercourses. Padilla Bay is now almost entirely intertidal (flooded at high tide and emptied at low tide). It supports large meadows of eelgrass, and was designated in 1980 as the only Natural Estuarine Research Reserve in the state of Washington. The Swinomish Channel connects Padilla Bay to Skagit Bay.

The Skagit River now empties only into Skagit Bay just south of the Reservation. All of its delta lands, including the land that now drains into Padilla Bay, are now agriculturally rich as many of the delta wetlands have been lost to diking. However, there are several efforts underway to remove dikes and restore wetlands and tidelands.

More than 20 streams within the Skagit River watershed are on Washington State's 303(d) list of water quality threatened or impaired water bodies. A water quality study was conducted by the Washington Department of Ecology in the lower Skagit River basin that included the mainstem downstream of Sedro-Woolley and the North and South Forks near Skagit Bay. That study focused on the effects of point and nonpoint pollutant loading on fecal coliform bacteria and dissolved oxygen levels in the lower Skagit River. Total Maximum Daily Loads have been proposed for fecal coliform bacteria, carbonaceous biological oxygen demand, and ammonia.[4]

1.2.1 *Existing Data on Water and Sediment Quality and Biological Resources*

Contamination from now-banned pesticides and PCBs in the Skagit River has declined over the past 20 years, according to Washington Department of Ecology.[5] The Department of Ecology sampled the river in Burlington and Mount Vernon for DDT and other chlorinated pesticides banned nationwide in the 1970s. The study of fish tissue samples collected in 2004 repeated similar research from 1984. PCB contamination was significantly lower than in 1984, but still above criteria. The pesticides heptachlor epoxide, benzene hexachloride, and the DDT complex were also still above the criteria.

[4] http://www.ecy.wa.gov/biblio/97326a.html;
[5] Department of Ecology News Release - June 30, 2005 http://www.ecy.wa.gov/news/2005news/2005-161.html; Verification of 303(d) Listings for Fish Tissue in the Skagit and Pend Oreille Rivers Publication No. 05-03-017 http://www.ecy.wa.gov/pubs/0503017.pdf

Padilla and Fidalgo Bays have been extensively studied. Studies by the Washington Department of Ecology (WDOE), the Puget Sound Water Quality Action Team (PSWQAT), other governmental agencies, and independent investigations have analyzed water quality and sediment contamination in the Padilla and Fidalgo Bay area. Over the years, findings have included, but are not limited to, polyaromatic hydrocarbons (PAHs), arsenic, lead, cadmium, polychlorinated biphenyls (PCBs), dioxins/furans, and a number of pesticides. Not unexpectedly, specific sources contribute to localized contamination. For example, Anacortes marina sediments are known to contain tributyltin (TBT), cadmium (Cd), and lead (Pb). The shoreline at an old Scott Paper mill has traces of dioxin and PCBs in sediment.

Johnson (1997) summarized 15 previous studies and also took new samples in Padilla and Fidalgo Bays. Total petroleum hydrocarbons (TPH) were measured in all samples. Because high molecular weight PAHs were predominant, the pattern was interpreted as combustion in origin (possibly from the refinery flare towers) rather than the lower molecular weight PAHs seen in gasoline fractions. Western Fidalgo Bay is known to have widespread low levels of metals. Johnson also identified retene and 4-methylphenol, which are associated with coal fragments, wood waste and pulp mill discharges, and refinery discharges. Several unusual chemicals were also found, including 4-nitrophenol (which may be a breakdown product of parathion), bis(2-chloroethyl)ether (which has many industrial uses), and coprostanol (an indicator of animal or human fecal contamination).

Johnson (1999) also responded to the Tribe's concern about the Whitmarsh Landfill, an abandoned landfill that operated as an unregulated public dump from the 1950s until 1973, located at the southern end of Padilla Bay on tidelands at the west end of a small lagoon. Johnson found that the seepage contained low levels of iron, diesel, benzene, 4 chlorinated benzenes, 3 xylenes, toluene, ethylbenzene, 14 PAHs, 4 phenols and methylphenols, diethylphthalate, nitrosodiphenylamine, dibenzofuran, carbazole, Aroclor 1242, and carbaryl (Sevin). The adjacent sediment also contained dioxin. Remediation was recommended. It is now in the initial investigation stage by the Washington Department of Ecology. A nearby site, Whitmarsh Siding (Washington site ID = 2683) is ranked 1, the highest level of concern, and is also awaiting a remedial action.

SHELLFISH

In May 2000, WDOE published a preliminary screening report on the presence of bioaccumulative toxics in shellfish in Padilla Bay at the request of the Swinomish Tribe (Johnson, 2000). The water column in Padilla Bay sloughs has been found to contain pesticides, herbicides, and their breakdown products. Johnson analyzed 14 composite samples of crabs, clams, oysters, and mussels for 130 metals and organic compounds. There were "slight" elevations in 30 chemicals compared to the rest of Puget Sound and Samish Island (used as a reference site), including lead, tributyltin, DDT compounds, and PAHs. The largest number of PAHs was in the Swinomish Channel and in March Point mussels. The report noted that sediments near the refinery outfalls exceeded sediment quality standards for cadmium, phenanthrene, and fluoranthene. Whitmarsh Landfill was still leaching methylphenols and some PCDD/DF, and caused toxicity in several bioassays. There were some extremely high petroleum hotspots in the Whitmarsh Lagoon. Some of the tissue concentrations were as follows:

Crab muscle contained arsenic (5230-8390 ppb or ug/Kg), selenium (496-692 ppb), mercury (41-75 ppb), lead (11-33 ppb), DDE (up to 0.2 ppb), Aroclor 1248 (up to 1.4 ppb), and TCDF (0.5 ng/kg or ppt).

Clams and oysters were lower for metals but higher for organics: arsenic (1360-2600 ppb), cadmium (211-1460 ppb), lead (43-128), mercury (11-26 ppb), DDT (1.2 ppb), Aroclors (2.7 ppb), two other pesticides, sixteen PAHs, and tributyltin tin (7.9 ppb).

"*Although arsenic and 2,3,7,8-TCDD concentrations appeared to be at background levels for Puget Sound, the concentrations in the shellfish samples exceeded human health screening levels*." This statement from Johnson (2000) underlines the need to evaluate cumulative risks, rather than simply comparing concentrations to individual contaminant screening levels. The screening-level risk evaluation was made for individual compounds and individual species (Johnson 2000) but cumulative risk was not evaluated, so the Tribe remained concerned.

SALMON

A review of existing contaminant data in Puget Sound salmon is included here because salmon are an important part of the Swinomish diet and are considered in some of the risk evaluations later in this report. The Puget Sound Ambient Monitoring Program[6] provides the following summary:

> "Pacific salmon from all areas of Puget Sound also accumulated PCBs. PCBs in chinook salmon were generally higher than Coho salmon, and marine-caught salmon of both species were higher than in-river salmon. PCBs in adult Coho salmon returning to spawn in Central and South Puget Sound watersheds had higher muscle PCBs than those returning to Northern Puget Sound watersheds. PCBs in chinook and Coho salmon also correlated positively with tissue lipid concentration. Unlike English sole, PCB accumulation in adult Pacific salmon, a pelagic migratory species, was not directly linked to contaminated sediments. The majority of PCB body burden in salmon is thought to be taken on in the marine phase but total residence time in Puget Sound probably has a strong influence on PCB exposure in Pacific salmon."

[6] http://wdfw.wa.gov/fish/psamp/findings.htm

The Puget Sound Action Team summarized 2001 data from West et al.[7] (Table 5).

Table 5. Salmon contaminant data

Contaminant	*Coho Salmon Concentration (average; range)*	*Chinook Salmon Concentration (average; range)*
Total Aroclors (ug/kg)	33 (6-130)	54 (12-220)
Total DDTs (ug/kg)	12 (3-39)	21 (4-59)
Mercury (mg/kg)	0.05 (0.025-0.110)	0.093 (0.051-0.16)
Arsenic (mg/kg)	0.64 (0.09-1.6)	0.7 (0.09-1.8)
Lead (mg/kg)	0.03 (0.02-0.04)	0.03 (0.02-0.04)

Resident fish in the Skagit River were sampled by the Washington Department of Ecology.[8] Levels have greatly declined over the 20 years, but are still detectable (Table 6).

Table 6. Skagit River fish contaminants

	1984		*2004*	
Species	*Total DDT*	*Total Aroclors*	*Total DDT*	*Total Aroclors*
Sucker	111 ug/kg	36 ug/kg	2.0 and 1.9	10.3 and 18.3
Whitefish	52 ug/kg	28 ug/kg	3.6 and 6.1	6.6

[7] http://www.psat.wa.gov/Publications/Pub_Master.htm. Pollution Status, Effects of Toxic Contaminants in the Puget Sound Environment (Table 4-17).
[8] Verification of 303(d) Listings for Fish Tissue in the Skagit and Pend Oreille Rivers. Publication No. 05-03-017 http://www.ecy.wa.gov/pubs/0503017.pdf

2.0 SAMPLING

2.1 RATIONALE FOR SELECTING SPECIES

A wide range of marine species is eaten. Fish include predominantly salmon and other anadromous species, as well as resident species such as flounder. Shellfish species known to be part of the Swinomish diet are shown in Table 7.

Table 7. Species eaten

Common name	Scientific name
Heart cockle	*Clinocardium nuttallii*
Butter clam	*Saxidomus giganteus*
Native littleneck	*Prototheca staminea*
Fat horse clam, or gaper	*Tresus capax*
Manila clam	*Venrupis philipinarum*
Geoduck clam	*Panopea abrupta*
Pacific Horse clam	*Tresus nuttali*
Razor clam	*Siliqua patula*
Red sea urchin	*Strongylocentrous franciscanus*
Green sea urchin	*Strongylocentrous droebachiensis*
Dungeness crab	*Cancer magister*
Blue mussels	*Mytilus edulis*
Northern horse mussel	*Modiolus modiolus*
Olympia oyster	*Ostrea luridea*
Spiny pink scallop	*Chlamys hastata*
Rock scallop	*Crassadoma gigantea*

Native little neck clams (steamer clams), butter clams, and Dungeness crabs were chosen for sampling for several reasons.

(1) they are abundant, so their populations would not be affected by sampling;.
(2) they are important to the tribe for subsistence and traditional purposes;
(3) there is easy access to the sites on or near the reservation where they are located;
(4) shellfish are not mobile and therefore more likely to indicate local pollution sources;
(5) little sampling data is available on these culturally important species.

2.2 SAMPLING LOCATIONS

For sediment and both species of clams, fifteen locations (with duplication of one site) were sampled in Padilla Bay, Fidalgo Bay, Turner's Bay, Similk Bay, and Kiket Bay. For Dungeness crab, a total of nine areas were sampled, with several crab pots pulled from each of the nine sample areas for a total of 21 crab pots. The sites were located in the above mentioned areas and also in Skagit Bay and in Crescent Harbor near Poinell Point.

Some of the sampling sites are in the same general location as sites used by previous investigators. The shellfish sample sites to the south and west of the Reservation have not been included in previous studies; however, prevailing winds often switch direction during stagnant wind periods, such as in an inversion, and the diminished air flow, coupled with the change in flow direction, may lead to deposition at these sites.

The Samish Island sites, historically used as reference sites, were sampled under the hypothesis that the target chemicals in question contaminate the area to a degree that does not allow for use as reference sites. Prevailing winds blow in a northerly direction, so air effluents from the petrochemical facilities would be carried directly over Samish Island, which is located far enough away from the facilities to allow deposition from the tall air stacks. Currents originating from March Point may flow in a counter clockwise direction, depositing water-borne contaminants on the south side of Samish Island as well.

The additional sites where the crab samples were collected (Crescent Harbor and Skagit Bay) were included in the sampling event because these areas are frequently visited for crabbing by the tribe. However, because of the focus of this study and the breadth of Swinomish's usual and accustomed fishing areas, not all sites accessed by Swinomish were sampled.

Figure 3. Sampling Locations

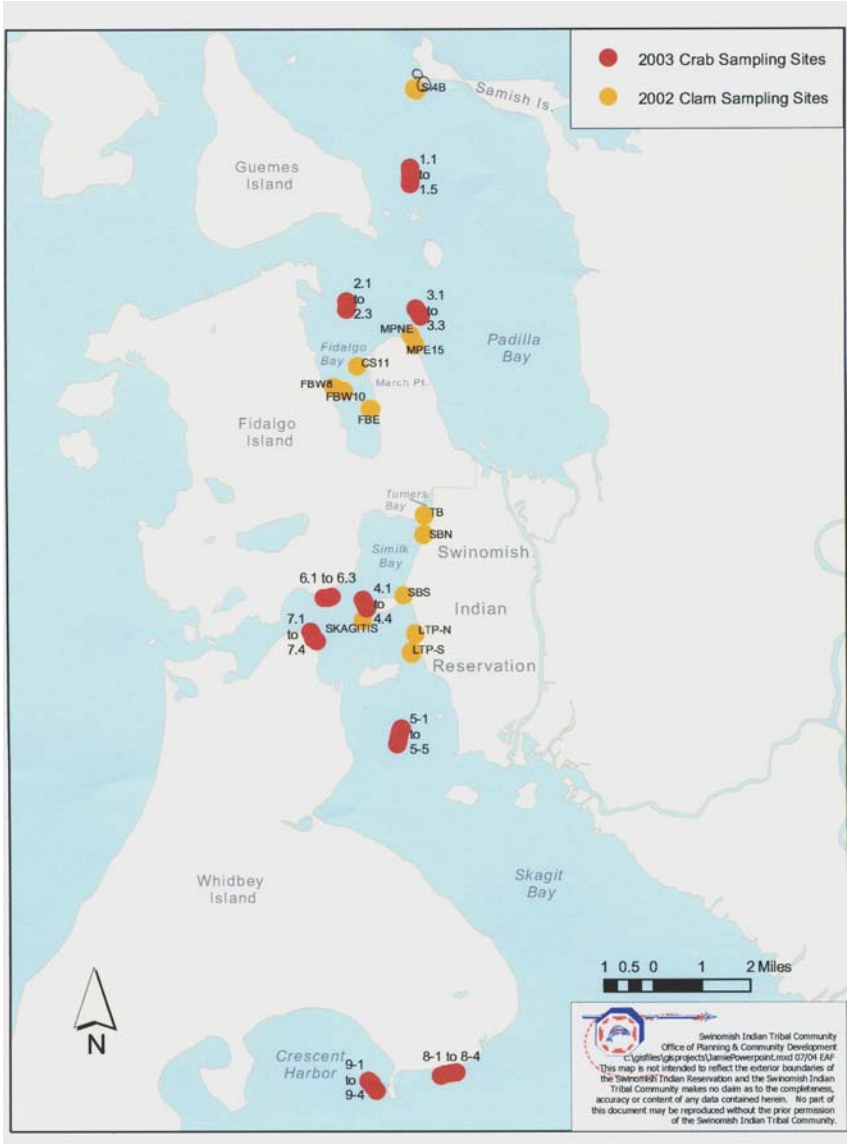


Table 8. Sampling Location Descriptions

General Location	*Characteristics and Rationale*
Fidalgo Bay	Historically an important harvest site, it is now impacted by contamination and thus not used for harvest in recent years. Access to the tidelands has been restricted by the March Point industries. Fidalgo Bay, much like Padilla Bay, may be subjected to chemical contamination from adjacent industries on March Point. In addition, contamination occurs from the high volume use by tanker traffic.
Padilla Bay	Selected for current and historical subsistence shellfish harvest use. Access to the March Point tidelands has been restricted by the industries residing there. Prevailing winds blow from the south toward the north in this area, so air effluents from the petrochemical facilities would be carried directly over Padilla Bay and Samish Island, which is located far enough away from the facilities to allow for deposition from the air stacks. Additionally, currents within Padilla Bay enter from the north, then generally flow in a counter-clockwise direction before exiting through the same passage as the entrance. These currents may potentially deposit water-borne pollutants from origins such as the March Point industrial facilities on the eastern shoreline of Padilla Bay and on the sand bar at Samish Island before leaving the basin. Other potential sources of contamination include pesticide runoff from the heavy agricultural use in Skagit Valley, several commercial marinas, and tanker traffic.
Samish Island	In previous studies, Samish Island was used as a reference site, and thought to represent background Puget Sound levels. This project sampled clams and sediment at Samish Island under the hypothesis that the target chemicals in question contaminate the site to a degree that does not allow for its continued use as a reference site.
North Skagit Bay (including Similk, Turner's and Kiket Bays))	West of the Reservation. Popular current and historical subsistence shellfish harvest use; highest quality and the most frequently visited. This area has not been previously sampled. Contaminated air deposition may occur here during high-pressure weather patterns, when winds originate from the north. During these high pressure systems, the surface winds are generally weaker compared to the prevailing southerlies resulting in less mixing, and deposition closer to the sources. Water-borne contamination may originate from non-point sources such as high volume boat use and potential contaminants carried in Skagit River outflow, e.g., from agriculture.
South Skagit bay (including Crescent Harbor)	South of the Reservation. Popular current and historical subsistence shellfish harvest use; highest quality and the most frequently visited. This area has not been previously sampled. Contaminated air deposition may occur here during high-pressure weather patterns, when winds originate from the north. During these high pressure systems, the surface winds are generally weaker compared to the prevailing southerlies resulting in less mixing, and deposition closer to the sources. Water-borne contamination may originate from non-point sources such as high volume boat use, potential contaminants carried in Skagit River outflow and from naval base operations on Whidbey Island.

Table 9. Comparison of sampling stations.

In some of the analyses, the data are clustered according to the following table. This is also the general grouping used by Tribal members when referring to gathering locations.

CLAM & SED Sites			***CRAB Sites***	
North Skagit Bay				
1, 1A	North beach Lone Tree Point, Kiket Bay		4	Similk Bay, NW of Kiket Island
2	Reef on Lone Tree Pt, Kiket Bay		5	North end Skagit Bay, west of SIR
3	South beach on Lone Tree Pt, Kiket Bay		6	West Similk Bay
4	Turner's Bay, Similk Bay		7	Coronet Bay
5	Similk Bay North			
6	Similk Bay South			
7	Skagit Island in Kiket Bay			
Padilla and Fidalgo Bays, March Point				
8	Fidalgo Bay west side, north of RV park		2	Fidalgo Bay, north of Crandell Spit
9	Fidalgo Bay east side, north of RR tracks		3	Padilla Bay, NE of March Point
10	Fidalgo Bay west side, north side of spit			
11	North side of Crandall Spit			
12	North end of March Point			
15	Eastside March Point			
North Padilla Bay/Samish Island				
13	Westside Samish Island,		1	Padilla Bay, east of Guemes Island
14	Eastside Samish Island			
South Skagit Bay & Crescent Harbor (crab only)				
			8	East side Poinell Pt., Crescent Bay, South Skagit Bay
			9	West side Poinell Pt., Crescent Bay, South Skagit Bay

2.3 COLLECTION METHODS

All sampling followed an EPA approved Quality Assurance Project Plan. All clam sampling procedures were performed in accordance with Puget Sound Water Quality Action Team's 1997 publication, "Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound.[9] Sampling site coordinates were recorded using a hand-held global positioning system (GPS) receiver.

Butter and Steamer Clam sampling	summer 2002
Sediment sampling	summer 2002
Dungeness Crab sampling	summer 2003

2.3.1 *Clams*

Subsistence harvesters commonly collect shellfish with pitchforks and store the specimens in buckets during collection and for transport back to their homes. This project used new stainless steel pitchforks, and clean buckets to minimize contamination during sampling and transport in the field. All sampling gear was decomtaminated according to protocol outlined in the QAQC plan. Sampling site coordinates were recorded using a mapping-grade Trimble ProXR GPS with sub-meter accuracy at post-processing. Sampling site descriptions were recorded in the sample logbook and included general site description, substrate description, location of any visible nearby pollution point sources, shellfish size, and an approximation of the dig area needed to yield the required 50 to 60 individual clams. Samples were wrapped in aluminum foil, double bagged in plastic Ziplok bags, and transported from the field to the Swinomish Environmental Laboratory in coolers with sealed icepacks.

Clams and sediment were collected at low tide from individual digs within a 100-foot stretch of beach. The uppermost ten centimeters of sediment in three ten-centimeter by ten-centimeter areas within each clam sample site were collected., resulting in a composite sample of no less than one liter of sediment for each site. Clams were greater than 3.81 cm, the minimum legal size limit. Only intact, live specimens from each species were collected, i.e., a tightly closed, unbroken shell.

The tissues analyzed generally matched the parts actually eaten by people. Small clams usually are eaten whole. For large clams, sometimes the tip of the siphon is removed and often (but not always) the stomach is removed. For this chemical analysis, the whole clam was homogenized for small clams (steamer clams). For large clams (butter clams), the siphon was removed.

The amount of field washing also matched actual methods when clams are eaten personally. Most harvesters rinse their clams in the local water before placing them in a bucket filled with local water for up to 2 days so that sand and sediment can be purged. However, clams are also eaten immediately after being brought home, so the wait time is highly variable. For this analysis, the clams were rinsed in *in situ* water in the field

[9] http://www.psat.wa.gov/Publications/protocols/protocol_pdfs/organics.pdf#search=%22pswqat%20qapp%22

before being wrapped in the aluminum foil. Therefore, the sand and sediment load might be somewhat higher, on average, in the analyzed samples than in the as-eaten condition.

2.3.2 *Crabs*

Eight to ten Dungeness crabs (*Cancer magister*) were collected from each of the crab pots at the sampling sites using new, stainless steel, decontaminated crab pots baited with squid and set overnight. There were two to five crab pots at each sampling site to ensure adequate tissue samples for the analyses. Only male crabs with carapace widths greater than 15.88 cm, the legal limit, were taken. Sampling site descriptions were recorded in the sample logbook and included general site description, substrate description, location of any visible nearby pollution point sources, shellfish size, and water depth. Sampling site coordinates were recorded using a mapping-grade Trimble ProXR GPS with sub-meter accuracy at post-processing. The crabs were killed with a blow to the ventral nerve cord, which did not break the carapace or rupture the organs, then wrapped in aluminum foil, double bagged in Ziplok bags and stored in a cooler with sealed ice packs for transport from the field to the Swinomish Environmental Laboratory.

3.0 CHEMICAL ANALYSIS

The shellfish samples were shipped whole to AXYS Analytical Laboratory (Sydney, BC). AXYS employees removed the desired shellfish body tissue from each specimen, homogenized the samples, and sent a portion to the Washington Department of Ecology Manchester Laboratory, while retaining the rest for the AXYS analyses.

All sediment examples were analyzed and reported as dry weight. All clam and crab samples were analyzed and reported as wet weight.

3.1 WDOE MANCHESTER LABORATORY

The Washington Department of Ecology Manchester Laboratory performed many of the analyses.

Table 10. Parameters, Methods and Matrixes analyzed at The Washington Department of Ecology Manchester Laboratory

Parameter	Matrix	Method
Organotins	Sediment, tissue	GC/AED NOAATBT
PAHs	Sediment, tissue	GC/SIM-MS EPA 8270m isotopic dilution
PCB aroclors	Sediment, tissue	GC/ECD EPA 8082
Mercury	Sediment, tissue	CVAA EPA 245.5
Lead, copper, cadmium, nickel, zinc, arsenic, selenium	Sediment, tissue	ICP-MS EPA 6020
Chlorinated pesticides	Sediment, tissue	GC/ECD EPA 8081
Percent solids	Sediment, tissue	Gravimetric EPA 160.3m
Total organic carbon	Sediment	Combustion/ CO^2 measurement PSEP
Grain size	Sediment	Sieve and pipet ASTM D422
Percent lipids	tissue	Gravimetric MeCl2 extraction

Pesticide detection limits are shown in Table 10. For a number of pesticides all results were rejected or were blank.

Table 11. Chlorinated Pesticide Analysis

Chlorinated Pesticides	*Reported Detection Limit*	*Method*
Aldrin, chlorpyrifos, cis-nonaclor, dieldrin, lindane, trans-nonaclor	0.5 to 10 ug/kg dw & ww	GC/ECD EPA 8081
Alpha-BHC, beta BHC, delta-BHC	0.5 ug/kg dw & ww	GC/ECD EPA 8081
Alpha-, gamma chlordane, oxychlordane	0.5 ug/kg dw & ww	GC/ECD EPA 8081
Chlordane (sum of targeted compounds)	All R or no data	GC/ECD EPA 8081
Endosulfan I, II, sulfate	All R or no data	GC/ECD EPA 8081
Endrin, Endrin ketone, Endrin aldehyde	All R or no data	GC/ECD EPA 8081
Heptaclor, Heptaclor epoxide	0.5 ug/kg dw & ww	GC/ECD EPA 8081
Hexachlorobenzene	Clam, Sed = All R	GC/ECD EPA 8081

	Crab = 0.5 ug/kg dw & ww	
o,p'-DDT, o,p'-DDE, o,p'-DDD, p,p'-DDT, p,p'-DDE, p,p'-DDD	0.5 ug/kg dw & ww	GC/ECD EPA 8081
Mirex	All R or no data	GC/ECD EPA 8081
Methoxyclor, pentachloroanisol,	Clam, Sed = 0.5 to 10 ug/kg dw & ww Crab = All R	GC/ECD EPA 8081
Toxaphene	Clam, Sed = 11 ug/kg dw & ww Crab = All R	GC/ECD EPA 8081
PCB Aroclors	4-5 ug/kg dw or ww	GC/ECD EPA 8082
Note: Results are reported as wet weight (ww) or dry weight (dw); R indicates rejected data; no data indicates blanks in the received data without other qualifiers.		

Metals and their detection limits are shown in Table 12.

Table 12. Metals and Organotin Analysis

Metals and Organotins	***Reported Detection Limits***	***Method***
Arsenic, Cadmium, Copper, Lead, Nickel	0.1-0.2 mg/kg dw or ww	ICP-MS EPA 6020
Mercury	0.003 mg/kg dw SED, 3 ug/kg ww	EPA 245.5
Selenium	0.5 mg/kg dw or ww	ICP-MS EPA 6020
Zinc	5 mg/kg dw or ww	ICP-MS EPA 6020
Dibutyltin dichloride, Monobutyltin trichloride, Terabutyltin, Tributyltin chloride	1.0-1.4 ug/kg dw or ww	GC/AED NOAATBT

PAHs were analyzed using isotopic dilution technology, EPA Method 8270, as modified by Manchester.. Extended PAHs were also analyzed for potential use in fingerprinting petroleum product sources. Detection limits ranged from 0.1 to >400 ug/kg. Table 13 lists the PAHs that were analyzed.

Table 13. Polyaromatic Hydrocarbons

Polyaromatic Hydrocarbons		
1,1'-Biphenyl	C1-Chrysenes	C4-Phenanthrenes/Anthracenes
1,6,7-Trimethylnaphthalene	C1-Dibenzothiophenes	Carbazole
1-Methylphenanthrene	C1-Fluoranthrene/Pyrene	Chrysene
2,6-Dimethylnaphthalene	C1-Fluorenes	Chrysene, 5-methyl-
2-Chloronaphthalene	C1-Naphthalenes	Dibenz[a,h]anthracene
2-Methylfluoranthene	C1-Phenanthrenes/Anthracenes	Dibenzofuran
2-Methylphenanthrene	C2-Chrysenes	Dibenzothiophene
4,6-Dimethyldibenzothiophene	C2-Dibenzothiophenes	Fluoranthene
9H-Fluorene, 1-methyl-	C2-Fluorenes	Fluorene
Acenaphthene	C2-Naphthalenes	Indeno(1,2,3-cd)pyrene
Acenaphthylene	C2-Phenanthrenes/Anthracenes	Naphthalene
Anthracene	C3-Chrysenes	Naphthalene, 1-methyl-
Benzo(a)anthracene	C3-Dibenzothiophenes	Naphthalene, 2-methyl-
Benzo(a)pyrene	C3-Fluorenes	Perylene
Benzo(g,h,i)perylene	C3-Naphthalenes	Phenanthrene
Benzo[b]Fluoranthene	C3-Phenanthrenes/Anthracenes	Phenanthrene, 3,6-dimethyl-
Benzo[e]pyrene	C4-Chrysenes	Pyrene
Benzo[k]fluoranthene	C4-Naphthalenes	Retene

3.2 AXYS LABORATORY

The AXYS Laboratory performed PCB and dioxin/furan congener analysis using high resolution gas chromatography-mass spectroscopy.

Table 14. Dioxins-Furan-PCB Analysis

	Approx. DL	***Method***
dioxin-furan congeners (tetra through octa)	0.05 pg/g ww or dw	GC-MS EPA 1613B/ 8290
dioxin-furan homologue classes	0.05 pg/g ww or dw	GC-MS EPA 1613B/ 8290
PCB congeners	<0.2 pg/g ww or dw	EPA 1668a

3.3 EPA MANCHESTER LABORATORY

The speciated arsenic analyses were conducted on butter clams (*Saxidomis giganteus)* collected at fifteen different sites during in May and June 2002. The WDOE Manchester Lab gave freeze-dried sub-samples to the EPA Manchester Lab for speciated and total arsenic analyses.

> "The experimental method for arsenic speciation is a procedure for extracting different forms, or species, of arsenic from seafood using tetramethyl ammonium hydroxide (TMAOH). The extract is then analyzed using ion chromatography (IC) to separate the species prior to detection by inductively coupled plasma – mass spectrometry (ICP-MS). The types of seafood for which this method has been developed are seaweed, finfish, and shellfish. The species separated and analyzed by this method are: arseneous acid (As^{3+}), arsenic acid (As^{5+}), monomethylarsonic acid (MMA), dimethylarsinic acid (DMA), arsenobetaine (AsB), arsenocholine (AsC), trimethylarsine oxide (TMAO), tetramethylarsonium ion (TMA) and arsenosugars [As(328), As(392), As(408), etc.]."[10]

[10] Roseanne Lorenzana (EPA Region 10), personal communication

3.4 DATA VALIDATION

Data validation was performed by the Technical Support Unit, OEA, USEPA Region 10. The definitions of qualifiers from the two laboratories are shown in Table 15.

Table 15. Data Qualification Definitions

U -the analyte was not detected at or above the reported result
J - the analyte was positively identified. The numerical result is an estimate.
UJ - The analyte was not detected at or above the estimated result.
R or REJ - The data are unusable for all purposes.
N - For organic analytes there is evidence that the analyte is present in this sample.
NJ - There is evidence that the analyte is present. The numerical result is an estimate.

The Reported Detection Limit (RDL) is defined by EPA as 2.623 times the Method Detection Limit (MDL).[11] The MDL is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is above zero (i.e. that the analyte is present). The MDL is determined from analysis of a sample in a specific matrix type containing the analyte and is considered the lowest limit at which a compound can be reliably detected. The Practical Quantitation Limit (PQL) is typically 5 to 10 times the MDL.

There were apparently some problems with the analysis and/or the data qualification and validation process from the WDOE Manchester Laboratory. Some results were accepted as unqualified or J when they were below the RDL, while others were labeled U although they were 2 or more times higher than the RDL, and in some cases 100 times higher than the RDL. In other cases some results were labeled as U even though results appeared identical to other unqualified results of the same analyte.

[11] CFR, July 1, 2003, Definition and Procedure for the Determination of the Method Detection Limit – Revision 1.11. Title 40, Part 136, Appendix B.

4.0 DETECTION FREQUENCIES AND PATTERNS

Overall Observations

Sediment contamination shows a clear spike at Station 9 (in Fidalgo Bay, just north of the railroad track) often 10x higher than other stations, including the other stations in Fidalgo Bay (Stations 8, 10, and 11). This difference is not as visible in the clams, which have much more uniform concentrations.

Other than Clam Station 9 on March Point, there were some differences between stations, but no spatial pattern of contaminants stood out, except that concentrations in Fidalgo and Padilla Bays were slightly higher than in the Skagit Bay sites.

4.1 PCBs

Aroclors. Aroclors were never detected in sediment or clams, generally at a detection limit of 5 ug/kg ww. However, Aroclor 1254 was detected in most crab samples, and Aroclor 1260 was detected in approximately one-third of the crab samples.

Congeners. Unlike Aroclors, several PCB congeners were detected in every clam sample, except for PCB 81, which was never detected. Congener 126, by far the most toxic congener, was detected in 6 clam samples and all crab samples except 2 crab muscle tissue samples. Most of the clams with congener 126 were from clam sites 10-13 (in Padilla and Fidalgo Bays). Congener 126 was also detected in many sediment samples, with clam Station 9 (March Point) being markedly higher than any other sediment site. Concentrations in crabs were clearly lower at Skagit Bay sites than the Padilla-Fidalgo Bay sites.

Total PCB congener concentrations in crabs were roughly an order of magnitude higher than in clams, although much of this difference disappears when converting to TEQ for the risk assessment because the congeners have different toxicities. In crabs, concentrations in muscle were always lower than in the hepatopancreas. Dioxin patterns generally followed the PCB patterns.

Table 16 shows congener concentrations (not converted to TEQ). Clam and sediment stations are indicated as BC (butter clams), SC (steamer clams) or sediment, followed by the station number. Crab data is shown by station number and tissue type (M = muscle; P = hepatopancreas).

Table 16. PCB congener concentrations

CONGENER	MATRIX	MIN CONC	MIN Station ID	MAX CONC	MAX Station ID	UNITS
PCB 77	ClamTissue	0.2	SC13	0.8	BC10	pg/g wet
	Sediment	0.2	Sed2	5.6	Sed9	pg/g dry
	Crab	3	1 to 4 (M)	29	9 (P)	pg/g wet
PCB 105	Tissue	1.8	SC13	11.2	BC10	pg/g wet
	Sediment	1.2	Sed2	73	Sed9	pg/g dry
	Crab	42	1 to 4 (M)	761	6 (P)	pg/g wet
PCB 114	Tissue	0.15	SC13	0.4	BC10	pg/g wet
	Sediment	0.07	Sed 13	4.4	Sed9	pg/g dry
	Crab	2	1 to 4 (M)	44	6 (P)	pg/g wet
PCB 118	Tissue	5.0	SC13	17	BC8	pg/g wet
	Sediment	2.5	Sed2	176	Sed9	pg/g dry
	Crab	120	1 to 4 (M)	2090	6 (P)	pg/g wet
PCB 123	Tissue	0.1	SC13	0.75	BC8	pg/g wet
	Sediment	0.05	Sed2	2.4	Sed9	pg/g dry
	Crab	2	1 to 4 (M)	49	8,9 (P)	pg/g wet
PCB 126	Tissue	0.06	SC12	0.2	BC12	pg/g wet
	Sediment	0.07	Sed1, 14	0.7	Sed9	pg/g dry
	Crab	0.4	2,4 (M)	6	4 (P)	pg/g wet
PCB 156	Tissue	0.44	SC14	2.56	BC10	pg/g wet
	Sediment	0.2	Sed3, 13	23	Sed9	pg/g dry
	Crab	12	4 (M)	233	6 (P)	pg/g wet
PCB 157	Tissue	0.14	SC13	2.3	BC10	pg/g wet
	Sediment	0.1	most	5	Sed9	pg/g dry
	Crab	4	1 to 4 (M)	68	6 (P)	pg/g wet
PCB 167	Tissue	0.42	SC14	1.68	BC10	pg/g wet
	Sediment	0.1	several	10	Sed9	pg/g dry
	Crab	7	1 to 4 (M)	134	6 & 9	pg/g wet
PCB 169	Tissue	0.04	SC5	0.515	BC15	pg/g wet
	Sediment	0.03	several	0.3	Sed9	pg/g dry
	Crab	0.09	1 to 4 (M)	0.8	several	pg/g wet
PCB 189	Tissue	0.1	SC14	0.382	BC10	pg/g wet
	Sediment	0.03	Sed2	0.9	Sed9	pg/g dry
	Crab	1	1 to 4 (M)	21	6 (P)	pg/g wet

4.2 METALS AND ORGANOTINS

Dibutyltin dichloride, tetrabutyltin and monobutyltin trichloride were never detected in clams, crabs, or sediment (DL = 1.4 ug/kg). Tributyltin chloride was not detected above the detection limit in sediment (all qualified as U or UJ), but was detected in all clams, and in all crab hepatopancreas but never in crab muscle tissue.

Mercury and arsenic were uniformly detected. Although there was a 6-fold difference between the highest and lowest tissue samples, there was no discernable distribution pattern for mercury between Bays. For mercury in crabs, concentrations were uniformly higher in muscle than in the hepatopancreas of each sample, and all crab samples were higher than squid bait, which was higher than every clam sample. In clams, most butter clams were slightly higher than steamer clams from the same site.

For total arsenic, crab muscle was, on average, somewhat higher than the hepatopancreas concentration from the same crab. Crab samples were uniformly higher than both types of clams, and butter clams were generally somewhat higher than steamer clams from the same site. Squid bait was lower than all clam and all crab samples.

Table 17 shows the detection frequency of each metal, along with an indication of the range of results.

Table 17. Metals results

Metal	n detected in Sediment (dry weight; 16 sites)	n detected in Butter Clams (wet weight, 16 sites)	n detected in Steamer Clams (wet weight, 16 sites)	n detected in crabs out of 21 each M and P; M = muscle P = hepatopancreas (wet weight, 21 sites)
Arsenic	all (<5 mg/kg)	all (~2 mg/kg)	all (~2.5 mg/kg)	M – all (5.2-12.8 mg/kg) P – all (4.5-9.7 mg/kg)
Cadmium	10 (<0.5 mg/kg)	1 (0.2 mg/kg)	all (~.25 mg/kg)	M - 1 (0.12 mg/kg) P - all (<1.25 mg/kg)
Copper	all (<15 mg/kg)	all (1-5 mg/kg)	all (1-4 mg/kg)	M – all (5.6-8.5 mg/kg) P – all (18-60 mg/kg)
Lead	all (<5 mg/kg)	2 (<0.13 mg/kg)	0	M – 2 (<0.3mg/kg) P – 10 (<0.3mg/kg)
Mercury	all (<0.04 mg/kg)	all (~0.02 mg/kg)	all (~0.02 mg/kg)	M – all (0.04-0.07mg/kg) P – all (0.03-0.04 mg/kg)
Nickel	all (<60 mg/kg)	all (<3 mg/kg)	all (<2 mg/kg)	M – 2 (<.2 mg/kg) P – all (0.2-0.6 mg/kg)
Selenium	1 (0.6 mg/kg)	9 (~0.5 mg/kg)	all (<1 mg/kg)	M – all (0.7-1.7 mg/kg) P – all (1.5-3.3 mg/kg)
Zinc	all (<44 mg/kg)	all (<20 mg/kg)	all (<20 mg/kg)	M – all (31-43 mg/kg) P – all (13-19 mg/kg)
Organotins (TBT only)	none (d.l. = 1.4 mg/kg)	all (<0.005 mg/kg)	all (<0.002 mg/kg)	M – not detected P – 0.001-0.003 mg/kg

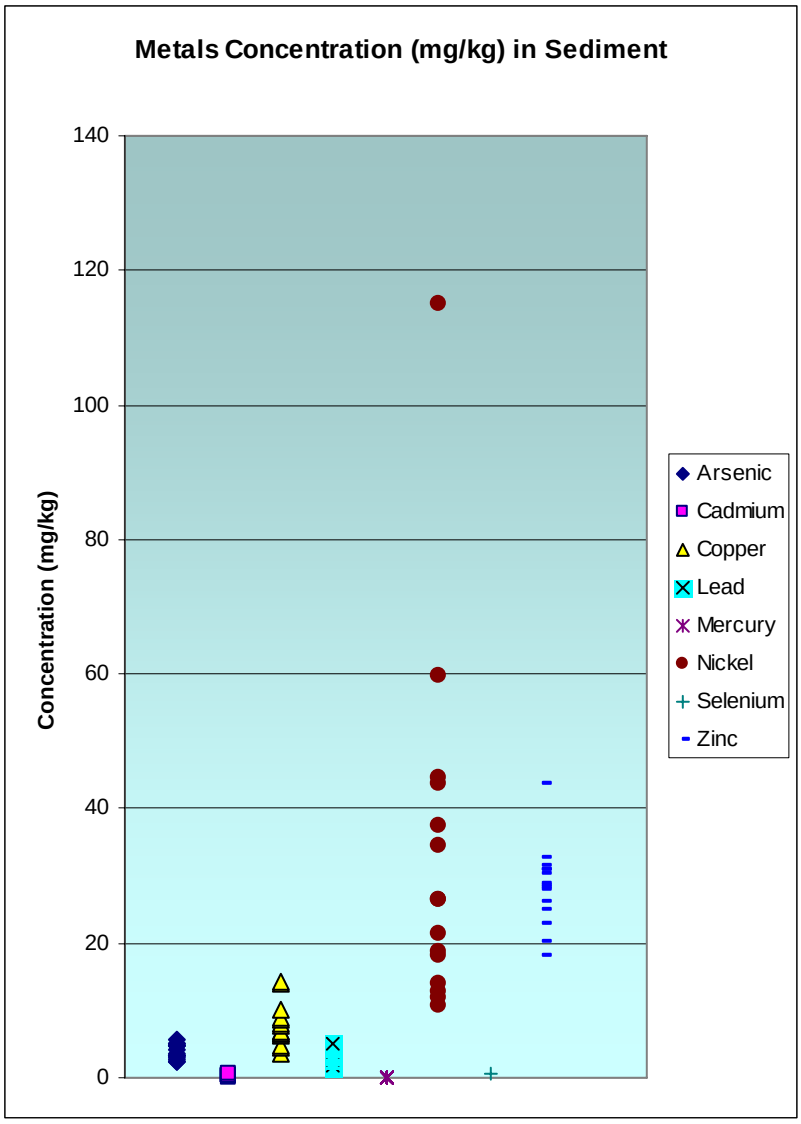


Figure 4. Metals concentration in sediment

Figure 4 shows how concentrations of metals were distributed among sediment stations. Nickel and zinc show the greatest variability. Figure 5 presents the same information without nickel or zinc to show the distribution of each of the remaining metals.

Figure 5. Sediment concentrations without Ni or Zn

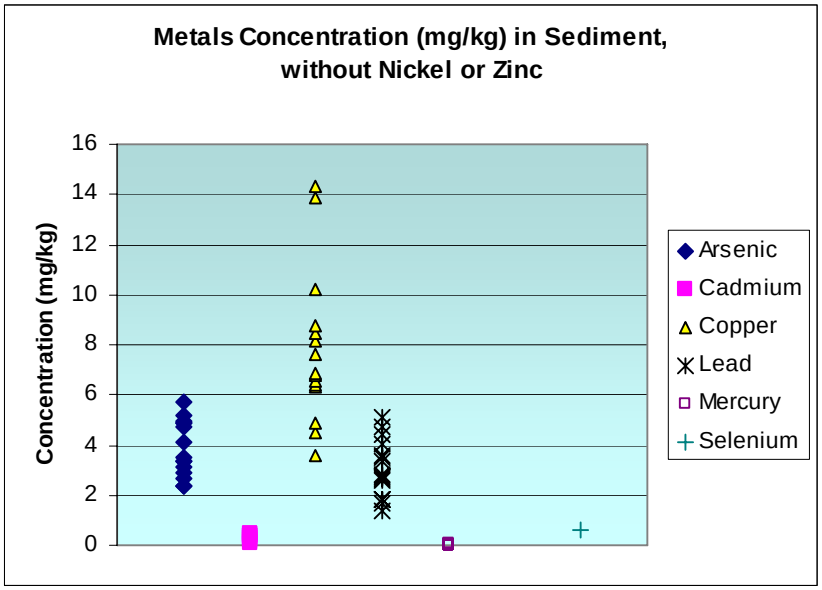
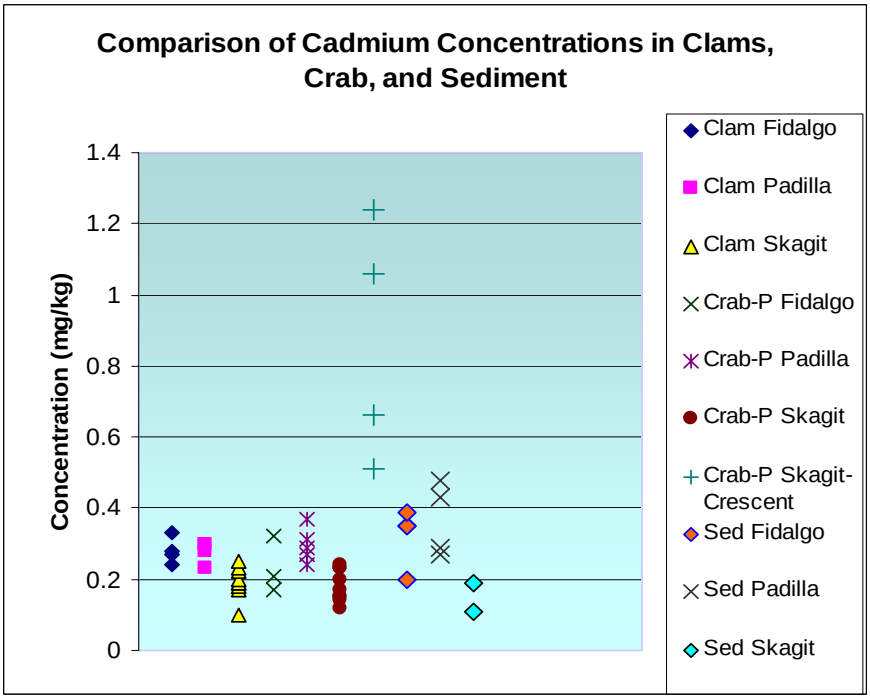


Figure 6 presents a comparison of cadmium among matrix and locations. The Crescent Bay sites for crabs were markedly higher, but no sediment samples were taken from Crescent Bay.

Figure 6. Comparison of Cd results among media



4.3 TOTAL AND SPECIATED ARSENIC

Total arsenic was analyzed as part of the metals analysis in all samples. Speciated arsenic was analyzed in Butter clams only.

Total arsenic estimated by the conventional method (EPA 6020) was compared to total arsenic estimated by summing all the speciated arsenic concentrations. Arsenic concentrations resulting from summing all the individual arsenic species were roughly 2 to 5 times higher than results from EPA 6020. [Note: divide ng/g (ppb) by 1000 to get mg/kg (ppm).]

Table 18. Total and Speciated Arsenic Results in Butter Clams

Arsenic Species	Average	Range	Average percent of total Arsenic
As328	2163 ng/g	1200-3900 ng/g	20%
As392	199 ng/g	130-370 ng/g	2%
As408	104 ng/g	25-250 ng/g	1%
As482	4725 ng/g	3100-7700 ng/g	44%
AsB	2103 ng/g	852-1950 ng/g	20%
AsC	164 ng/g	32-300 ng/g	2%
DMA	891 ng/g	473-1700 ng/g	8%
Inorganic As	174 ng/g	19-364 ng/g	2%
MMA	18 ng/g	6-29 ng/g	<1%
TMA	153 ng/g	10-386 ng/g	1%
TMAO	51 ng/g	20-83 ng/g	<1%
Total average	*10.7 mg/kg*		
Method 6020 Results, Butter Clams			
Total Arsenic	4.3 mg/kg	0.9-3.3 mg/kg	10% inorganic (assumed)

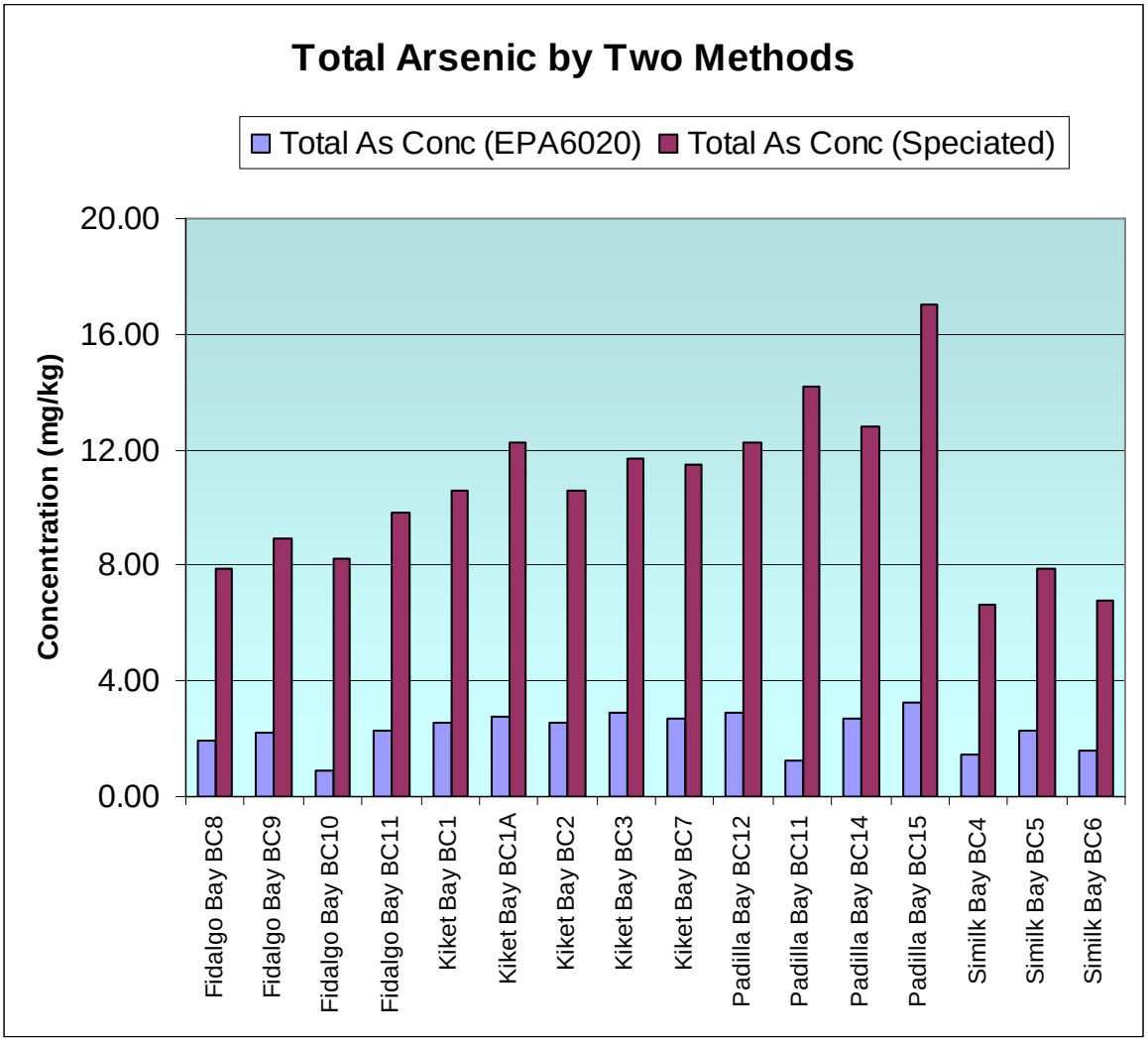


Figure 7. Graphical representation of total arsenic by two methods

Figure 7 compares the total arsenic estimated by the two methods in Butter clams, and Table 8 compares the inorganic arsenic by the two methods..

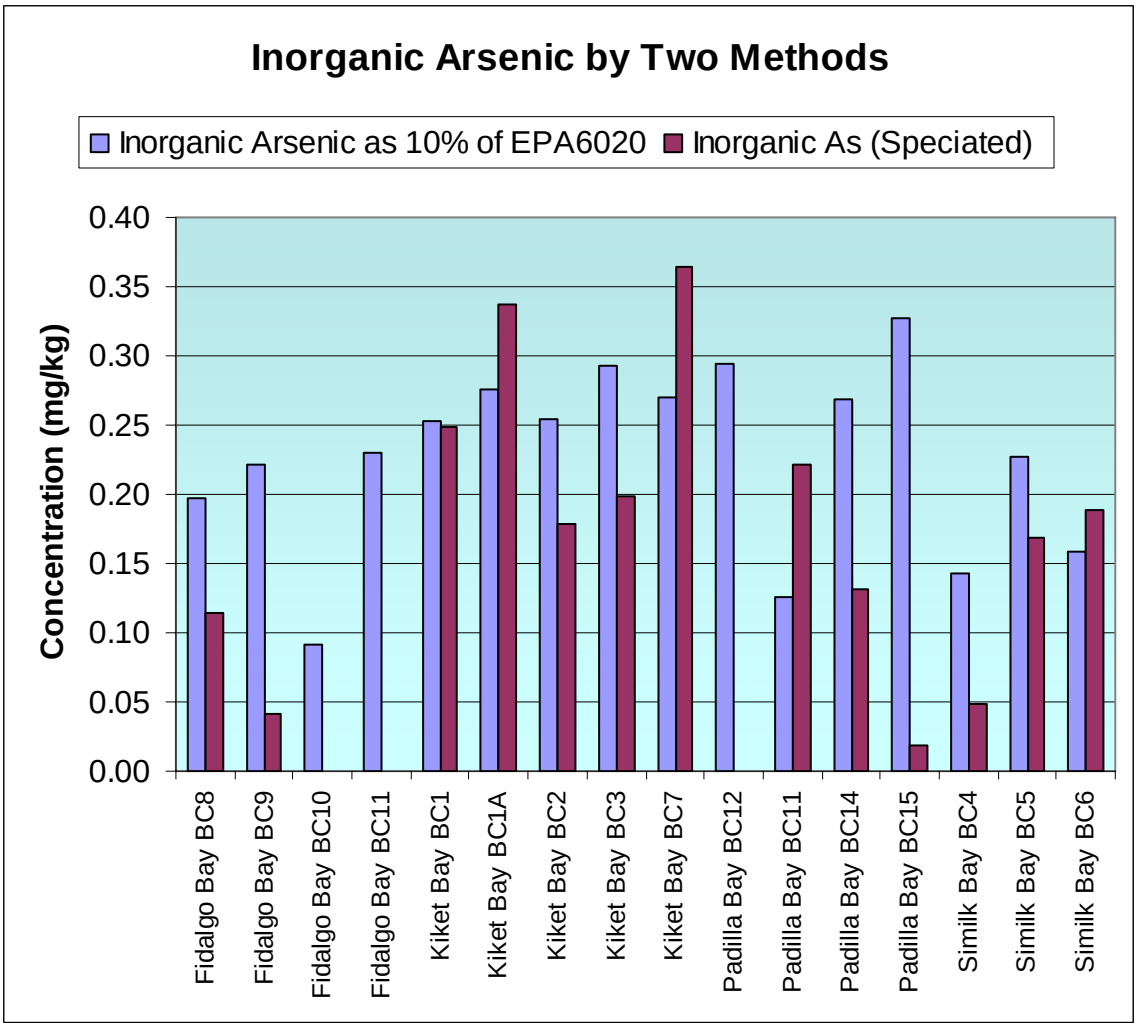


Figure 8. Graphical representation of total inorganic arsenic by two methods

The conventional assumption used in risk assessment is that 10% of total arsenic from EPA 6020 is inorganic. Inorganic arsenic was measured as an average of approximately 2% of the total speciated arsenic. The risk analysis in this report used 10% of total arsenic (method 6020), which may slightly overestimate inorganic arsenic concentrations.

4.3 CHLORINATED PESTICIDES

No pesticides were detected in any sediment or clam samples, at detection limits of 0.046 to 0.86 ug/kg for clams, and data were received as a mix of U, UJ, R or not reported (blank). Chlordane and toxaphene were never detected, but had higher detection limits (chlordane DL = 9.1 ug/kg; toxaphene DL = 11 ug/kg). The detection limit for many results was 5 ug/kg. Almost none of the duplicate samples had reported results. Several chlorinated pesticides were detected in crabs, mostly in the hepatopancreas (designated as "P" in Table 19).

Table 19. Chlorinated Pesticides in Crabs

Detected Pesticide	***Frequency***	***Reported Concentrations***
2,4'DDE	one sample (8 P)	0.5 ug/kg
4,4'DDD	8 samples, all 'P'	0.2 to 0.6
4,4'DDE	most samples	0.25 to 14 ug/kg
Alpha-BHC	most samples	0.15 to 1
Beta BHC	approx 50% of samples	up to 3 ug/kg
Hexachlorobenzene	approx 15 samples	0.6 to 0.9 ug/kg

4.5 POLYAROMATIC HYDROCARBONS

Most PAHs were minimal in clams and crabs, although they were uniformly reported at 3-fold to 10-fold higher than the RDL. Station 9 typically was tremendously higher for PAHs in sediment. For some data in clams, station 9 appeared slightly but consistently higher than the rest of the sites. Crabs were essentially negative for all PAHs. As expected, a comparison between sediment and co-located clam concentration indicates that PAHs are not bioaccumulative.

Table 20. PAH results in sediment, clams, and crabs

PAH	**Sediment**	**Clams**	**Crabs**
	(How many positive sites; Max conc; (Max site))	***same as sediment***	***(Number of positive samples; Max conc.; P = hepatopancreas; M = muscle)***
1,1'-Biphenyl	3 sites; up to 38 ug/kg (SED9)	All; up to 4 ug/kg	4 samples; up to 1.2; P only
1,6,7-Trimethylnaphthalene	12 sites; up to 7.4 ug/kg	All; up to 1 ug/kg	0
1-Methylphenanthrene	2 sites: SED12 = 24; SED9 = 747	All, up to 2 ug/kg	Several; up to 26 ug/kg
2,6-Dimethylnaphthalene	All sites, up to 36 ug/kg (SED9)	All, up to 4 ug/kg	Most; up to 32 ug/kg
2-Methylfluoranthene	1 site; 565 ug/kg (SED9)	All; up to 1 ug/kg	0
2-Methylphenanthrene	All; up to 2450 ug/kg (SED9)	4 clam sites; up to 6 ug/kg	Most; up to 4.9 ug/kg
4,6-Dimethyldibenzothiophene	Most; up to 57 ug/kg (SED9)	All; up to 1 ug/kg	0

9H-Fluorene, 1-methyl-	Most; up to 161 ug/kg (SED9)	All; up to 1 ug/kg	0
Acenaphthene	Most; up to 430 ug/kg (SED9)	All, up to 2 ug/kg	2 samples; up to 1.7 ug/kg
Acenaphthylene	Most; up to 234 ug/kg (SED9)	All; up to 1 ug/kg	0
Anthracene	All; up to 427 ug/kg (SED9)	All, up to 2 ug/kg	1 sample; 0.5 ug/kg
Benzo(a)anthracene	All; up to 965 ug/kg (SED9)	All; up to 1 ug/kg	0
Benzo(a)pyrene	All; up to 498 ug/kg (SED9)	All; up to 1 ug/kg	1 sample; 1.1 ug/kg
Benzo(g,h,i)perylene	All; up to 179 ug/kg (SED9)	All; up to 1 ug/kg	0
Benzo[b]Fluoranthene	All; up to 2200 ug/kg (SED9)	All; up to 1 ug/kg	0
Benzo[e]pyrene	All; up to 2564 ug/kg (SED9)	All; up to 1 ug/kg	0
Benzo[k]fluoranthene	All; up to 1540 ug/kg (SED9)	All; up to 1 ug/kg	0
C1-Chrysenes	All; up to 720 ug/kg (SED9)	All, up to 4 ug/kg	0
C1-Dibenzothiophenes	All; up to 400 ug/kg (SED9)	All, up to 4 ug/kg	0
C1-Fluoranthrene/Pyrene	All; up to 2820 ug/kg (SED9)	2 sites; 6.8 and 7.7 ug/kg	1 sample; 0.8 ug/kg
C1-Fluorenes	All; up to 610 ug/kg (SED9)	All, up to 4 ug/kg	1 sample; 0.8 ug/kg
C1-Naphthalenes	All; up to 149 ug/kg (SED9)	All, up to 4 ug/kg	Several; up to 3.8 ug/kg
C1-Phenanthrenes/Anthracenes	All; up to 7800 ug/kg (SED9)	All, up to 18 ug/kg	Most; up to 24 ug/kg
C2-Dibenzothiophenes	All; up to 400 ug/kg (SED9)	All, up to 4 ug/kg	0
C2-Naphthalenes	All; up to 148 ug/kg (SED9)	All, up to 4 ug/kg	0
C2-Phenanthrenes/Anthracenes	All; up to 2440 ug/kg (SED9)	All, up to 8.6 ug/kg	0
C3-Naphthalenes	All; up to 380 ug/kg (SED9)	All, up to 4 ug/kg	2 samples; up to 1.3 ug/kg
C3-Phenanthrenes/Anthracenes	All; up to 590 ug/kg (SED9)	All, up to 4 ug/kg	0
C4-Phenanthrenes/Anthracenes	All; up to 40 ug/kg (SED1)	All, up to 4 ug/kg	5 samples; up to 4.3 ug/kg
Carbazole	All; up to 260 ug/kg (SED9)	All; up to 1 ug/kg	Several; up to 25 ug/kg
Chrysene	All; up to 4340 ug/kg (SED9)	All, up to 7.4 ug/kg	0
Chrysene, 5-methyl-	All; up to 218 ug/kg (SED9)	All; up to 1 ug/kg	0
Dibenz[a,h]anthracene	All; up to 54 ug/kg (SED9)	All; up to 1 ug/kg	0
Dibenzofuran	All; up to 509 ug/kg (SED9)	All; up to 3.3 ug/kg	Several; up to 1.5 ug/kg
Dibenzothiophene	All; up to 846 ug/kg (SED9)	All; up to 1.9 ug/kg	0
Fluoranthene	All; up to 19,000 ug/kg (SED9)	All; up to 60 ug/kg	Several; up to 2 ug/kg
Fluorene	All; up to 835 ug/kg (SED9)	All; up to 4.1 ug/kg	Several; up to 1.2 ug/kg
Indeno(1,2,3-cd)pyrene	All; up to 192 ug/kg (SED9)	All; up to 1 ug/kg	1 sample; 0.9 ug/kg
Naphthalene	Most; up to 112 ug/kg (SED9)	4 sites; up to 2.4 ug/kg	Several; up to 3.2 ug/kg
Naphthalene, 1-methyl-	All; up to 55 ug/kg (SED9)	All; up to 1 ug/kg	1 site 0.56 ug/kg; P
Naphthalene, 2-methyl-	Most; up to 82 ug/kg (SED9)	All; up to 1.6 ug/kg	Several; up to 1.1 ug/kg
Perylene	Most; up to 88 ug/kg (SED9)	All; up to 1 ug/kg	0
Phenanthrene	All; up to 12,000 ug/kg (SED9)	All; up to 24 ug/kg	Several; up to 4.7 ug/kg
Phenanthrene, 3,6-dimethyl-	Most; up to 308 ug/kg (SED9)	All; up to 1 ug/kg	1 sample; 1.2 ug/kg
Pyrene	All; up to 12,900 ug/kg (SED9)	All; up to 38 ug/kg	4 samples; up to 1.5 ug/kg
Retene	Most; up to 9.7 ug/kg	1 site at 3.2 ug/kg	7 samples; up to 2.7 ug/kg

The spatial distribution of all PAHs among sediment sampling location (station number) is similar to the pattern shown in Figure 9 for benzo(a)pyrene.

Figure 9. Benzo(a)pyrene concentration in each sediment location

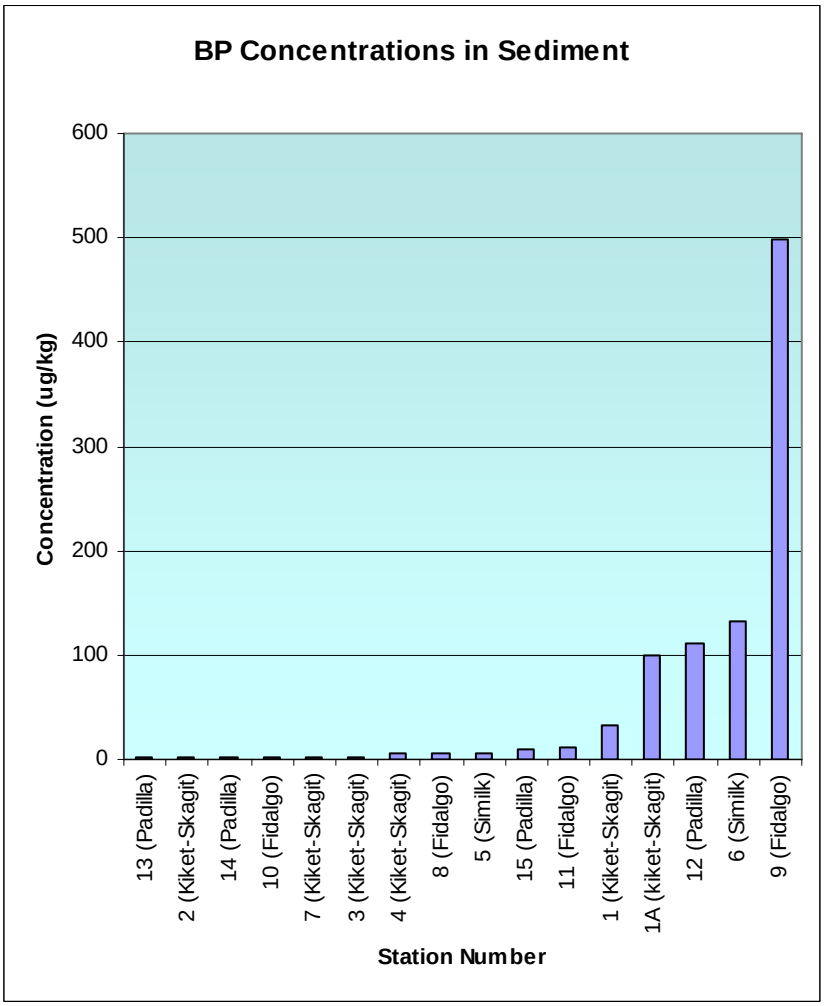
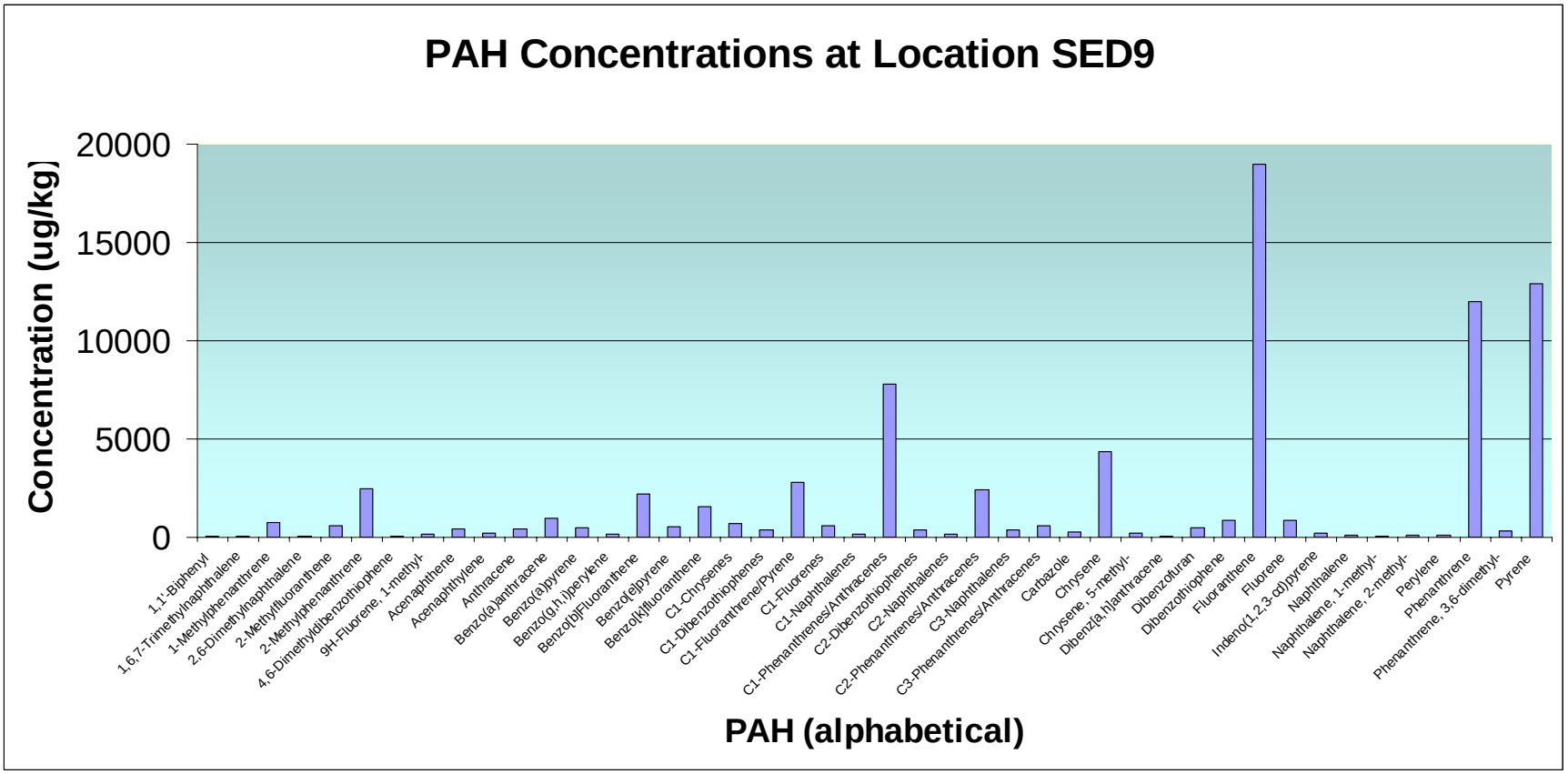


Figure 10. PAH pattern at sediment Station 9

Station 9 is located on March Point. PAHs are listed alphabetically (not by molecular weight). The lowest concentration was 36 ug/kg.



5.0 RISK ASSESSMENT METHODS

5.1 SCREENING AND TREATMENT OF NON-DETECTS

Once the data validation step was complete, the data were examined for detection patterns. If a contaminant was never detected, it was removed from the database. All other analytes were retained.

The risk results are presented for "ZERO" detection limit, meaning that non-detects were carried through as if they were truly not present, rather than assuming that concentrations were ½ the detection limit or at the upper 95th percentile. This is more conservative (less protective) than an alternative approach that was considered but not used, namely, to set non-detect concentrations at zero for contaminants that were rarely detected, while setting non-detect concentrations for contaminants that were detected at some higher frequency at ½ of the detection limit. As discussed in the section on uncertainty, this is a source of potentially underestimating risks.

5.2 TOXICITY EVALUATION – PCBS AND DIOXINS

The risk evaluation for PCBs and dioxins used the WHO98 Toxicity Equivalency Factor for each PCB congener or dioxin-furan class, along with the TCDD cancer slope factor (1E+6) and the MRL[12] (1E-9 mg/kg-d) for non-cancer potency. The TEQ methods are based on three citations (WHO98[13], WHO 2005[14], and Dioxin Reassessment[15]).

Table 21. TEF values used for dioxins and PCBs

Chlorination Homologue Class	TEF
2,3,7,8-TCDD	1
1,2,3,7,8-PentaCDD	1 (WHO97 and DR Table 9-2)
M1 (monochloro) CDD and CDF	0.0001
D2 (dichloro) CDD	0.001
T3 (trichloro) CDD	0.01
T4 (tetrachloro) CDD (except 2,3,7,8-TCDD)	0.01
P5 (pentachloro) CDD (except 1,2,3,7,8-PeCDD)	***0.3***
H6 (hexachloro) CDD	0.1
H7 (heptachloro) CDD	0.01
O8 (octachloro) CDD	***0.0003***
M1 (monochloro) CDF	0.0001

[12] http://www.epa.gov/ttn/atw/hlthef/dioxin.html.

[13] WHO98. Van den Berg, 1998 EHP 106 (12): 775-792

[14] WHO 2005. Martin van den Berg, L Birnbaum, M Denison, M De Vito, W Farland, M Feeley, H Fiedler, H Hakansson, A Hanberg, L Haws, M Rose, S Safe, D Schrenk, C Tohyama, A Tritscher, J Tuomisto, M Tysklind, N Walker, and R Peterson (2006) *"The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds."* ToxSci Advance Access published online on July 7, 2006; **(Final version:** Toxicological Sciences 2006 93(2):223-241). For PentachloroCDD, OctachloroCDD, OctachloroCDF, and PCB congener 169 the TEF has increased 3-fold. http://toxsci.oxfordjournals.org/cgi/content/abstract/kfl055v1

[15] http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55264; http://www.epa.gov/ncea/pdfs/dioxin/part2/drich9.pdf.

D2 (dichloro) CDF	0.0001
T3 (trichloro) CDF	0.01
T4 (tetrachloro) CDF	0.5
P5 (pentachloro) CDF	0.5
H6 (hexachloro) CDF	0.1
H7 (heptachloro) CDF	0.01
O8 (octachloro) CDF	***0.0003***
PCB Congener 77	0.0001
PCB Congener 81	0.0001
PCB Congener 105	0.0001
PCB Congener 114	0.0005
PCB Congener 118	0.0001
PCB Congener 123	0.0001
PCB Congener 126	0.1
PCB Congener 156	0.0005
PCB Congener 157	0.0005
PCB Congener 167	0.00001
PCB Congener 169	***0.03***
PCB Congener 189	0.0001

5.3 TOXICITY EVALUATION - OTHER CONTAMINANTS

Mercury. The risk analysis used a Reference Dose of 0.05E-5 mg/kg-d. This is 2-fold more protective than the EPA RfD (1.0E-04). This considers other endpoints, new information since the RfD was developed in 1995 and confirmed in 2001, and the recommendation of the EPA Science Advisory Board to consider an additional safety factor.[16]

Lead. Lead is not normally evaluated with other contaminants. In most assessments, lead is removed from the database and evaluated using the IEUBK model rather than adding it to other metals with the same health endpoints. For this analysis lead was evaluated using the mercury RfD (assuming that they are roughly equal in toxicity) and the California CSF for Lead (a B2 carcinogen). Until the All Ages Lead Model is released, this is a place holder for lead, which allows it to be evaluated within the cumulative assessment.

Arsenic. This risk assessment followed the convention that considers only 10% of the total arsenic to be toxic (assuming that 90% is in the organic forms, AsBetaine and AsCholine, arsenosugars, and metabolites, and that these are non- toxic). However, for this assessment we assumed that arsenic is 5 times more toxic than indicated in IRIS to reflect the new toxicity data and the lowering of the drinking water standard by 5-fold. Inorganic arsenic was, in actuality, only 2% of the total arsenic according to the butter clam sample results that were analyzed for speciated arsenic, which might overestimate

[16] http://www.ncseonline.org/NLE/CRSreports/05Jan/RL32420.pdf; http://www.epa.gov/sab/pdf/ehc9801.pdf; and Testimony by William Farland (1998), http://epw.senate.gov/105th/epab10-1.htm

arsenic risks. However, organic arsenic forms do have some toxicity, which could underestimate risk.

Organotins. Traces of tributyltin chloride were found from scattered locations in crabs, but the other organotins were not detected. The EPA and ATSDR RfD for tributyltin is 0.0003 mg/kg-d[17]. Although IRIS does not list a RfD for other butyltins, the ATSDR Toxicology Profile (2005) for tin lists a MRL for dibutyltin of 0.0005 mg/kg-d. Some assessments treat all organotins as tributyltin.[18] For this assessment, the ATSDR-EPA RfD was used.

5.4 RISK CALCULATIONS

Risks were calculated using conventional equations. The Average Daily Dose (ADD) was calculated using the following equation:

$$ADD = \frac{C \; x \; IR \; x \; EF \; x \; ED}{AT \; x \; BW \; CF}$$

where:

- C = concentration of chemical in the sample (mg/kg)
- IR = Ingestion rate of each sample
- EF = Exposure frequency (children and adults = 365 days per year)
- ED = Exposure duration for non-carcinogens (Adults = 70 years; Children = 6 years); ED for carcinogens = 70 years.
- BW = Body weight (Adults = 70 kg; Children = 15 kg)
- AT = Averaging time (days)
- CF = Unit conversion factor (1000 g/kg)

Non-cancer risks are estimated by comparing the dose for each chemical to the chemical-specific reference dose (RfD). The RfD is an estimate of a daily dose, developed by USEPA and published in the IRIS database), that is generally recognized as sage for human exposure, with possible exceptions for the seriously ill, people with certain genetic makeup, and fetuses and infants. The ratio of the average daily dose for each chemical to its RfD is called the hazard quotient (HQ).

$$HQ = \frac{ADD}{RfD}$$

In order to evaluate the risks from chemical mixtures, the sum of individual hazard quotients is calculated, called the hazard index (HI). The goal of most health actions is to keep the HQ and HI below 1.

[17] http://www.epa.gov/iris/toxreviews/0349-tr.pdf#page=48
[18] http://www.dtsc.ca.gov/ScienceTechnology/ftp/econote4.pdf; http://www.atsdr.cdc.gov/HAC/PHA/clearlake/cle_p1.html#T1A.

$$HI = HQ_1 + HQ_2 + ...HQ_n$$

Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as the result of exposure to carcinogenic chemicals, or excess lifetime cancer risk. Cancer risks are estimated by multiplying the ADD for each carcinogen by the cancer slope factor (CSF) for that carcinogen, which is the numerical description of the upper 95th percent confidence limit of the carcinogenic potency. As with non-cancer risks, cancer risks are summed for all carcinogenic chemicals.

$$Cancer\ Risk = Intake\left(\frac{mg}{kg \cdot day}\right)\ x\ CSF\left(\frac{mg}{kg \cdot day}\right)^{-1}$$

A previous study that included Padilla Bay samples (Johnson 2000) included a qualitative health assessment that compared concentrations of individual contaminants to screening values by using the above equations, by solving the above equation for concentrations that result in predetermined risk levels (1E-5 for cancer and HQ = 1 for non-cancer risks) at unknown ingestion rates for individual shellfish species. The screening concentrations developed by the WA DOH (see Johnson 2000 appendix) were not used for several reasons:

1. cumulative risks cannot be estimated by this method;
2. the cancer target level of 1E-5 may or may not be the Swinomish Tribe's target cancer level;
3. the ingestion rate used to develop the WA DOH levels was not indicated.

6.0 RISK RESULTS

6.1 INGESTION RATES

Risks can only be estimated if the amount of fish consumption is known. Several surveys of current (i.e., suppressed) consumption rates have been performed in the Columbia Basin and Puget Sound (Suquamish 1996; Toy et al., 1996; CRITFC 1994). For all three studies, several observations can be made that indicate that caution should be used when using these consumption rates. In particular, the higher consumers are of interest because they represent a subset of more subsistence diets. Each study population had a group of high consumers, and each of the three studies used a different approach to using high-end consumption data (one study omitted its high-end data, one study recoded the high-consumption data, and one study used its high end data without recoding it but did not evaluate it separately). These statistical treatments mask the true subsistence members, who tend to be more culturally conservative and less amenable to interviews.

Because the Swinomish Tribe recognized that a more culturally appropriate survey method would result in more accurate data, an ethnographic-style survey was performed to evaluate current consumption patterns. The data analysis is not complete, but based on a preliminary analysis of the consumption data, we used **260 grams per day** (8 ounces) for assessing risks for individual samples. This value is in the mid to upper range of ingestion for all seafood combined. This value was used for both adults and children – the difference between children's and adult non-cancer risk is due solely to the body weight and exposure duration factors. This may result in overestimating doses for younger children, but will not necessarily underestimate risks because children are more sensitive to the contaminants in question since their nervous systems are still developing. Therefore, for the "seafood basket" cumulative risk, a total of 300 grams per day (100 grams each of clams, crab, and salmon) was used for all evaluations.

Several other studies have specifically studied true subsistence consumers among Columbia Plateau Tribes, and estimated much higher consumption rates. Many earlier studies were cited in the "Boldt decision" (the February 12, 1974 decision in *United States v. Washington*) at 500 pounds per capita per year (620 gpd)[19]. More recent studies (Harper and Harris, 1997; Walker, 1967; Walker and Pritchard, 1999; Hunn, 1990; Ray, 1977) showed that true subsistence consumption persists among a subset of tribal members to this day.

6.2 OVERALL RISK OBSERVATIONS

The overall risk drivers were PCBs, arsenic, and dioxins, and to a lesser extent lead, mercury and other heavy metals, tributyltin (crabs only), chlorinated pesticides (crabs only), and polyaromatic hydrocarbons.

- Risk was fairly uniform over all sites. Risks at the Padilla-Fidalgo sites was slightly higher. Concentrations were strikingly higher at Station 9 (March Point),

[19] *United States v. Washington,* 384 F. Supp. 312, 380 (W.D. Wash. 1974); *aff'd* 520 F.2d 676 (9th Cir. 1976), *cert. denied*, 423 U.S. 1086 (1976).

but this is not reflected in risks as much because the contaminants (especially PAHs) bioaccumulate less, are less toxic than the primary risk driving contaminants, and/or do not have toxicity values available for inclusion in risk assessments.

- In clams, non-cancer risk is driven overwhelmingly and uniformly by PCBs and arsenic, followed by dioxins and mercury. Cancer risk is driven by PAHs, followed by arsenic, and PCBs. Tributyltin is also a concern in some locations. Steamer clams were generally slightly cleaner than butter clams. Butter clams are bigger and may filter more water volume than the smaller steamer clams.
- In crabs, non-cancer risks were driven by arsenic, followed by heavy metals (mercury, lead, selenium, copper), dioxins, and chlorinated pesticides, PCBs, and PAHs. Cancer risk was driven by arsenic, followed by dioxins, PCBs, and chlorinated pesticides.
- Crabs seem to bioaccumulate more contaminants, especially arsenic. Crabs are exposed to thicker and older sediment from deeper waters. Crab hepatopancreas was uniformly higher than crab muscle in contaminant concentrations.
- No chlorinated pesticides were detected in clams or sediment, but several were uniformly detected in crabs (i.e., DDE, hexachlorobenzene). There may have been some problems with the low level detection of pesticides in the analyses.
- Samish Island does not seem to be a good reference site, nor does Crescent Harbor.

6.3 RISKS FROM SEDIMENT INGESTION

People harvesting clams can be exposed to the co-located sediments during collection and to some residual sediment in the clams if they are not held in water before eating. Because tide flats tend to be silty or muddy, and because there may be residual sediment in the clams as eaten, the ingestion rate of 100 mg per daily visit is used as a reasonable upper bound. It should be noted that the method for developing soil and sediment ingestion rates considers an entire day rather than a single event or single location. However, digging clams is a muddy activity and could actually be a “1-gram event,” and therefore an ingestion rate of 100 mg per day seems reasonable (Table 22).

Table 22. Risks from daily sediment ingestion

SEDIMENT – Daily Visits			
	HQ Child ZERO DL 100 mg/d	HQ Adult ZERO DL 100 mg/d	Lifetime CA Risk at 100 mg/d
SED1	0.3	0.1	6.E-06
SED1A	0.4	0.1	6.E-06
SED2	0.3	0.1	2.E-06
SED3	0.2	0.1	4.E-06
SED4	0.2	0.1	5.E-06
SED5	0.3	0.1	6.E-06
SED6	0.3	0.1	4.E-06
SED7	0.4	0.1	7.E-06
SED8	0.3	0.1	3.E-05
SED9	0.7	0.2	7.E-05
SED10	0.2	0.1	1.E-05
SED11	0.3	0.1	1.E-05
SED12	0.4	0.1	2.E-05
SED13	0.1	0.1	3.E-06
SED14	0.2	0.1	4.E-06
SED15	0.3	0.1	1.E-05

Risks for a single visit to each site are shown below (Table 23); this information is used when discussing cumulative risks.

Table 23. Sediment risks from single visits

SEDIMENT - Single Visit			
	HQ Child ZERO DL 100 mg	HQ Adult ZERO DL 100 mg	Lifetime CA Risk at 100 mg
SED1	2.E-04	3.E-06	2.E-10
SED1A	2.E-04	3.E-06	2.E-10
SED2	1.E-04	2.E-06	8.E-11
SED3	1.E-04	2.E-06	2.E-10
SED4	8.E-05	1.E-06	2.E-10
SED5	1.E-04	2.E-06	2.E-10
SED6	1.E-04	2.E-06	2.E-10
SED7	2.E-04	3.E-06	3.E-10
SED8	1.E-04	3.E-06	1.E-09
SED9	3.E-04	6.E-06	3.E-09
SED10	8.E-05	1.E-06	4.E-10
SED11	1.E-04	2.E-06	4.E-10
SED12	2.E-04	3.E-06	8.E-10
SED13	5.E-05	1.E-06	1.E-10
SED14	7.E-05	1.E-06	2.E-10
SED15	1.E-04	2.E-06	4.E-10

6.4 CLAM RISKS

Risks from contaminants in clams are based on a 70 kg person eating 260 grams of an individual sample daily for 70 years from a particular site. Risks from Butter clams were uniformly greater than for the smaller Steamer clams by a 1.5 to 2-fold margin. For the purpose of risk assessment, however, risks were averaged across both species for each site. This assumes that a person does not choose only one of the species, but gathers a mix of the two species (Table 24) as available.

Table 24. Risks from daily clam consumption

CLAMS – Lifetime Daily meals of 260g (Butter and Steamer combined)			
Station	HQ Child ZERO DL (6 yrs exposure duration)	HQ Adult; ZERO DL	Lifetime Cancer Risk
1	10	3	2E-03
10	21	3	2E-03
11	13	3	2E-03
12	13	3	1E-02
13	8	3	8E-03
14	8	3	1E-03
15	13	3	2E-03
1A	10	3	2E-03
2	10	3	2E-03
3	10	3	2E-03
4	10	3	2E-03
5	13	3	2E-03
6	10	3	2E-03
7	10	3	2E-03
8	21	3	1E-02
9	13	3	1E-02

Risks for a single meal of 100 grams (3.5 ounces) is used as the basic unit used in the seafood basket evaluations of cumulative risks (Table 25).

Table 25. Clam risks from single meals

CLAMS - Single Meal of 100g (Butter and Steamer combined)			
Station	HQ Child ZERO DL; 100 g	HQ Adult; ZERO DL; 100 g	Lifetime Cancer Risk, 100 g
1	2.E-03	4.E-05	3.E-08
10	5.E-03	5.E-05	4.E-08
11	5.E-03	4.E-05	3.E-08
12	5.E-03	4.E-05	1.E-07
13	2.E-03	2.E-05	1.E-07
14	2.E-03	3.E-05	2.E-08
15	2.E-03	4.E-05	3.E-08
1A	2.E-03	4.E-05	3.E-08
2	2.E-03	3.E-05	3.E-08
3	1.E-03	4.E-05	2.E-08
4	2.E-03	3.E-05	3.E-08
5	2.E-03	4.E-05	3.E-08
6	3.E-03	3.E-05	3.E-08
7	3.E-03	3.E-05	2.E-08
8	4.E-03	5.E-05	2.E-07
9	4.E-03	5.E-05	2.E-07

6.5 CRAB RISKS

Crab risks are shown in Tables 25 and 26.

Table 26. Risks from daily crab ingestion

CRABS – Lifetime Daily meals of 260g (M = muscle; P = hepatopancreas)			
Station	HQ Child ZERO DL (6 yrs exposure duration)	HQ Adult; ZERO DL	Lifetime Cancer Risk
1-M	6	2	2E-04
1-P	6	2	3E-04
2-M	5	1	2E-04
2-P	10	2	3E-04
3-1M	10	2	3E-04
3-1P	10	2	3E-04
4-M	8	2	2E-04
4-P	8	2	2E-04
5-M	8	2	2E-04
5-P	8	2	2E-04
6-M	8	2	2E-04
6-P	8	2	2E-04
7-M	8	2	2E-04
7-P	8	2	2E-04
8-M	8	2	2E-04
8-P	10	3	2E-04
9-M	10	3	3E-04
9-P	15	3	3E-04
Squid bait	3	0.5	3E-05

Table 27. Crab risks from single meals

CRABS – Single meal of 100g (M = muscle; P = hepatopancreas)			
Station	**HQ Child ZERO DL**	**HQ Adult; ZERO DL**	**Lifetime Cancer Risk**
1-M	2.E-03	3.E-05	4.E-09
1-P	2.E-03	4.E-05	4.E-09
2-M	9.E-04	3.E-05	3.E-09
2-P	2.E-03	3.E-05	4.E-09
3-1M	2.E-03	3.E-05	4.E-09
3-1P	2.E-03	3.E-05	4.E-09
4-M	1.E-03	2.E-05	2.E-09
4-P	1.E-03	2.E-05	3.E-09
5-M	1.E-03	3.E-05	3.E-09
5-P	1.E-03	3.E-05	3.E-09
6-M	1.E-03	3.E-05	3.E-09
6-P	1.E-03	2.E-05	3.E-09
7-M	1.E-03	2.E-05	3.E-09
7-P	1.E-03	2.E-05	3.E-09
8-M	1.E-03	3.E-05	3.E-09
8-P	2.E-03	4.E-05	3.E-09
9-M	2.E-03	4.E-05	4.E-09
9-P	3.E-03	4.E-05	4.E-09
Squid bait	4.E-04	8.E-06	4.E-10

6.6 TYPICAL RISK DRIVERS

Risks for each site, summed by chemical class are presented in the Appendix. Representative samples/locations are shown in the following figures; the pattern was similar across all locations.

Figure 11. Cancer risk drivers from a representative clam sample

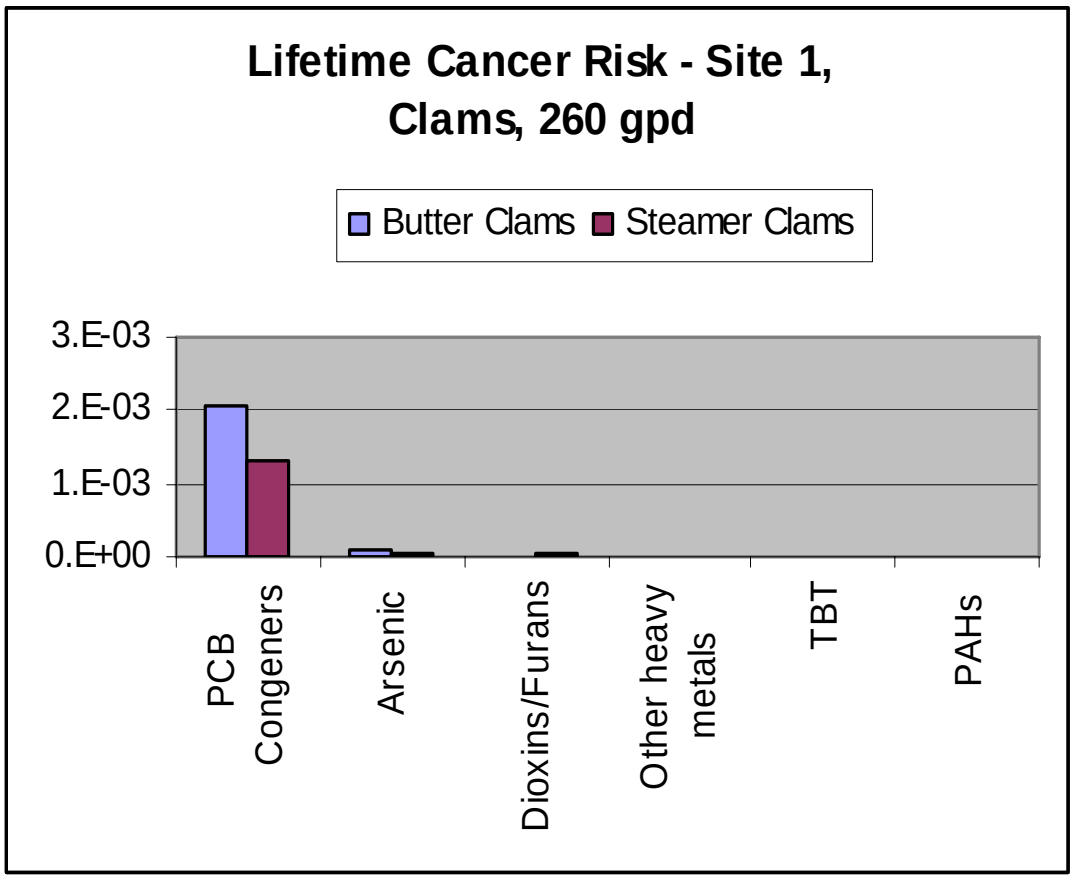


Figure 12. Non-cancer risk drivers from a representative clam sample

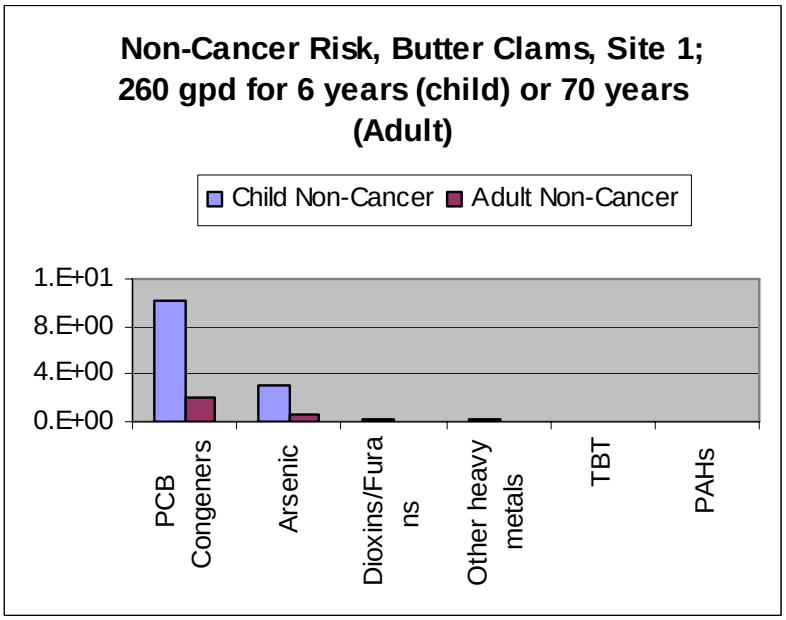


Figure 13. Cancer risk drivers from a representative crab sample

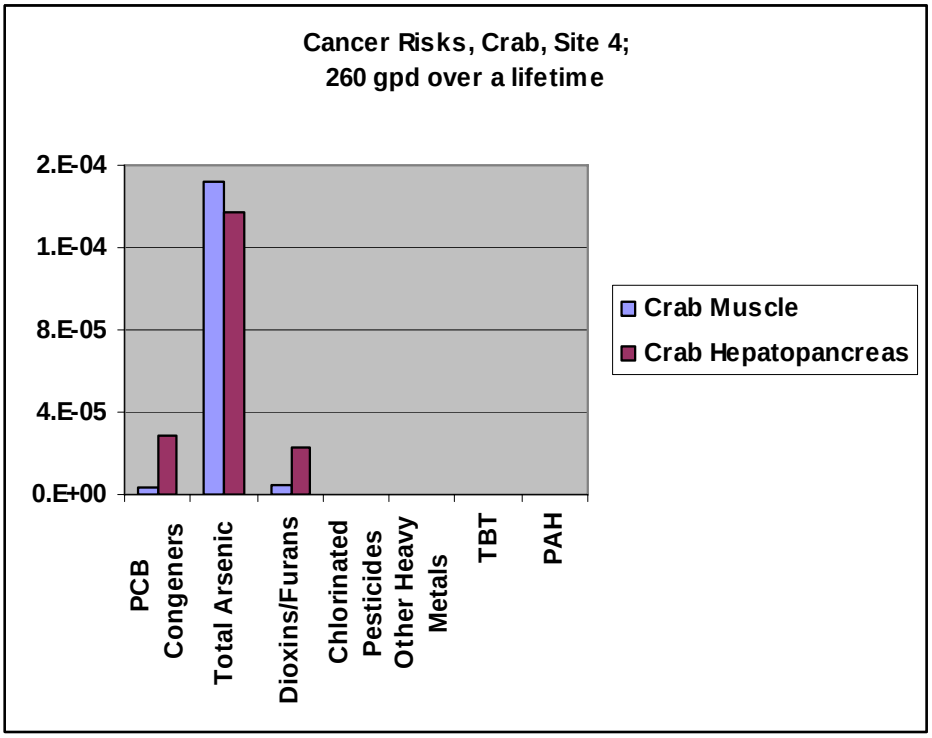


Figure 14. Non-cancer risk drivers from a representative crab sample

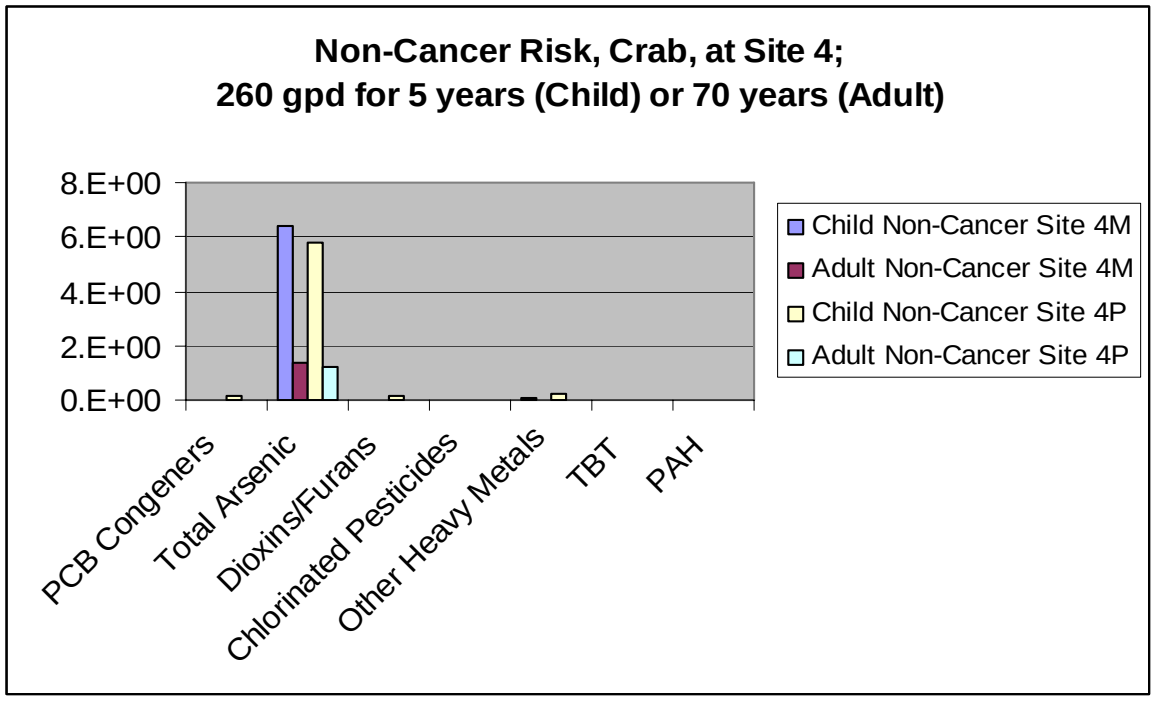
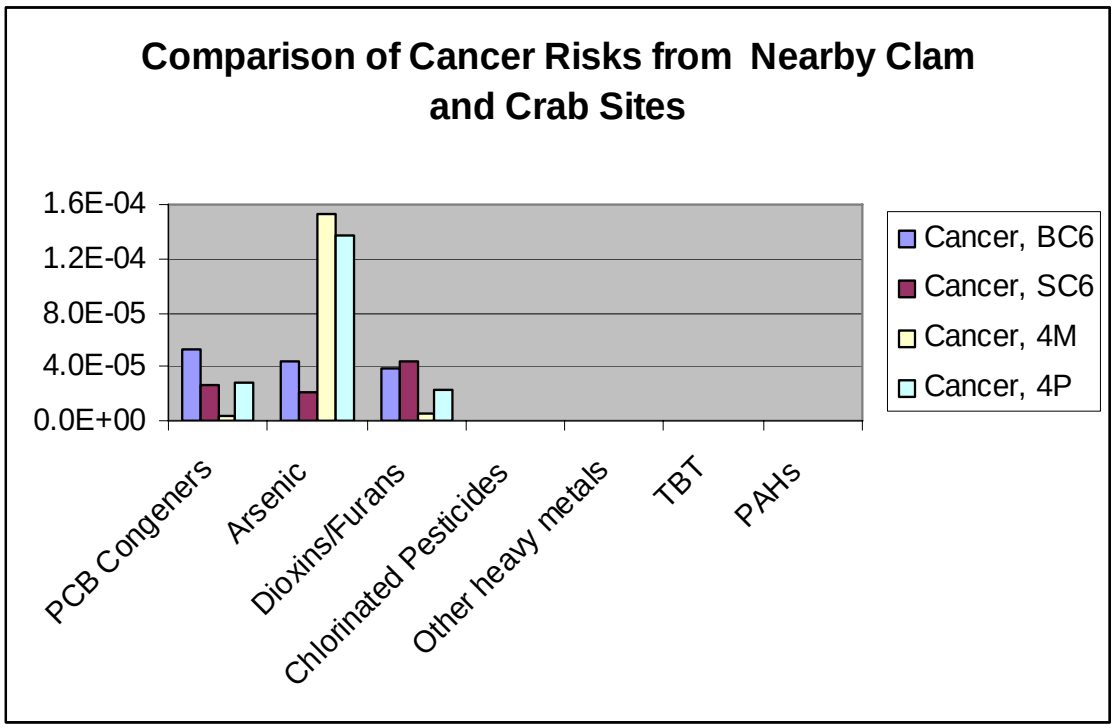


Figure 15 shows a comparison in concentrations in clams and nearby crabs. Arsenic was noticeably higher in crabs, both crab muscle (4M) and hepatopancreas (4P), compared to nearby clams (Butter clams, BC6; Steamer clams; SC6).

Figure 15. Comparison of cancer risks in clams and crabs



As a comparison to clams and crabs, salmon non-cancer risks are driven by PCBs (Aroclors), DDT, and mercury, along with lead and arsenic. Cancer risks are driven by PCBs and DDT.

Figure 16. Non-cancer risk drivers in Puget Sound salmon

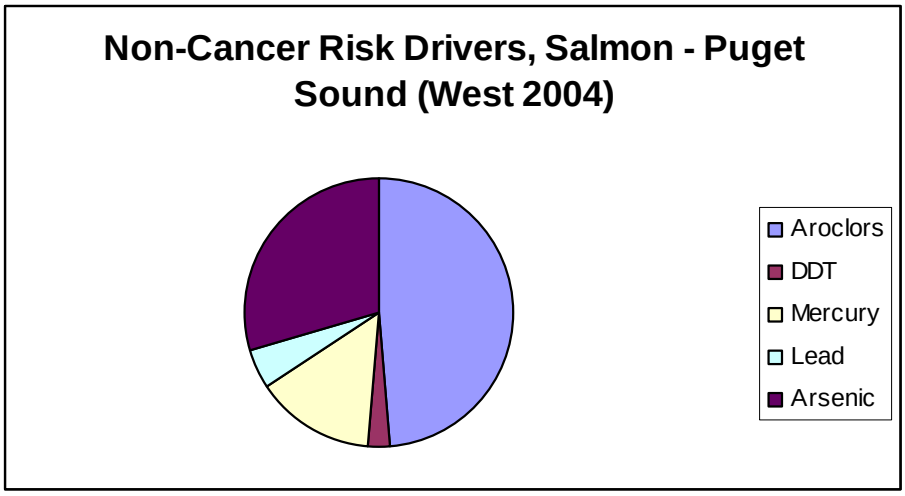


Figure 17. Cancer risk drivers in Puget Sound salmon

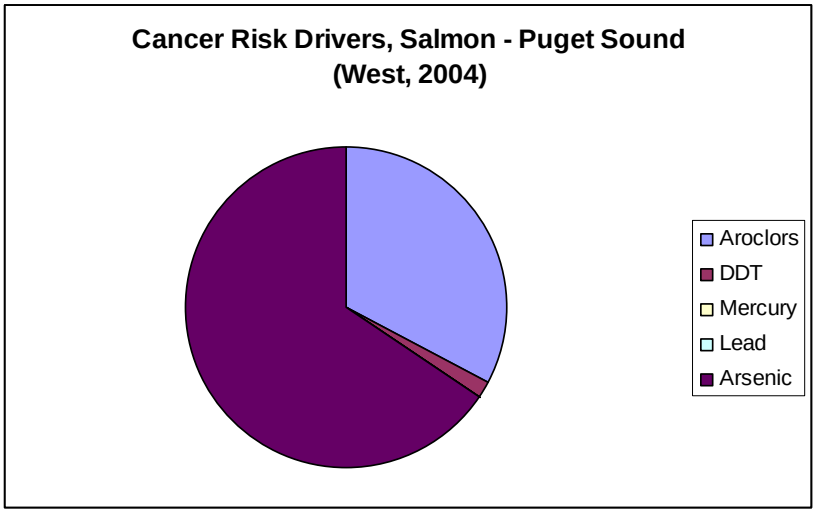
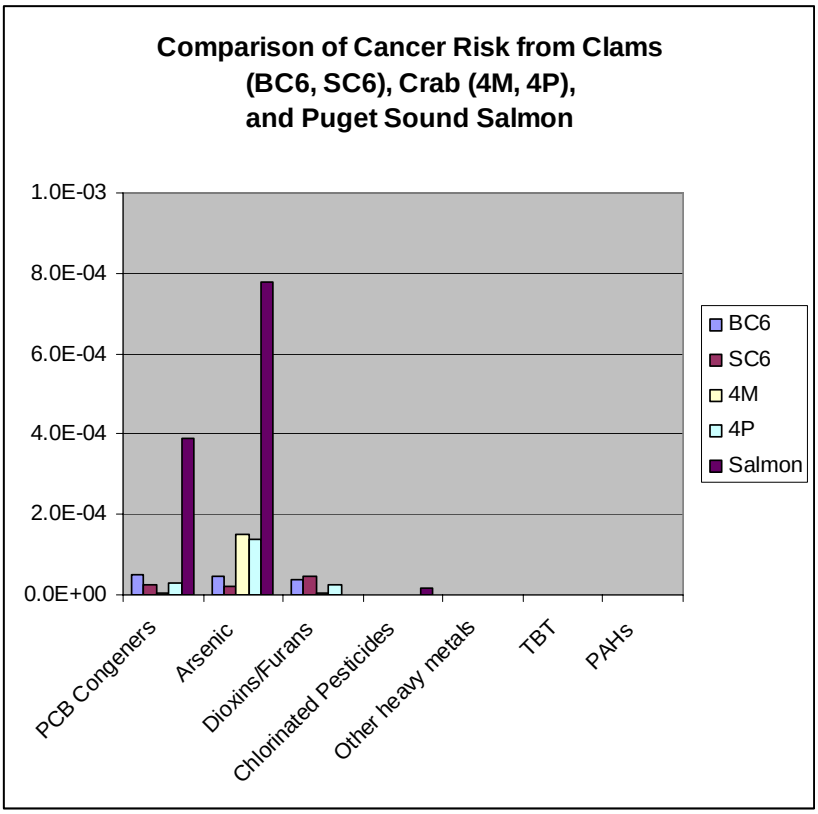


Figure 18. Comparison of cancer risks from clams, crabs, and salmon.



Comparison of risks from clams, crabs, and salmon at 260 gpd each indicates that salmon risks are higher than for clams or crabs.

7.0 RISK CHARACTERIZATION AND RECOMMENDATIONS

Risk characterization refers to the interpretation of the risk results, and the community context of total risks. Several considerations are discussed in this section:

(a) What health effects can be caused by the primary contaminants;
(b) Whether to assume simple additivity across all contaminants in the evaluation of cumulative risks;
(c) How much total seafood is eaten as a reasonable basis for estimating cumulative risks;
(d) What risks could occur across a range of ingestion rates.

7.1 POTENTIAL HEALTH IMPACTS

Health risks are typically presented either as simple cumulative (additive) risks, or as risks specific to individual organ systems (the 'target tissue" or primary health effect) and/or to individual contaminants. The considerations include whether there is similarity in the health effects caused by different contaminants, and whether there is evidence of interactions between contaminants (synergism or antagonism) so that one contaminate potentiates or reduces the effects of another contaminant. Generally speaking, antagonism is rare because, while there are experimental laboratory dose sequences that can reduce toxicity, environmental exposures can rarely be assumed to occur in precisely the right order and amount. Synergism is much more likely because organ systems all work together to produce human health, so adversely affecting one organ is likely to stress other organs. This is also common sense – when a contaminant is ingested, most tissues are exposed even if some tissues are more sensitive to the molecular toxic mechanism, and all contaminants have multiple health effects even if one or two occur more commonly than others.

Health effects caused by the primary contaminants are shown in Table 29. Many of these observations were made in humans; however, not all of the individual chemicals have been studied in people after confirmable exposure durations and pathways. Of all the health effects noted in Table 29, the human health toxic potency factor used in regulations and risk assessments is typically based on one of the more serious health effects noted in animals or people, as well as on cancer potency where applicable. In all cases, the contaminant or contaminant class affects many organ systems, even if one organ system is identified as the 'target tissue' on which the potency factor is based. The following table presents information taken from ATSDR Toxicity Profiles for the individual chemicals where health effects can be traced to single contaminants in the laboratory (for animal data) or the environment (animals and humans).

Table 28. Health Effects for the Primary Contaminants (from ATSDR)

Organ System	*Arsenic*	*Mercury*	*PCBs-Dioxins*	*DDT Complex*	*PAH*
Cardiovascular	X		X		
Gastrointestinal (Stomach, intestine)	X	X	X	X	X
Hematological (Blood)	X	X	X		X
Hepatic (Liver)	X		X	X	X
Renal (Kidney)	X	X	X	X	X
Ocular (Eyes)	X		X		
Dermal (Skin)	X		X		X
Neurological (Nervous system, Brain)	X	X	X	X	
Endocrine	X		X	X	
Immunological			X	X	
Reproductive and Developmental		X	X	X	X
Cancer	X	X	X	X	X

Two ATSDR Interactive Profiles are relevant to this risk assessment, and the conclusions support the assumption of additivity for tissues that are affected in common. In addition, both cancer and non-cancer risks are incurred simultaneously, further supporting additivity.

ATSDR Interactive Profile for PBTs in Fish (dioxins, hexachlorobenzene, methylmercury, DDE, PCBs)

Several studies have been designed to examine whether or not consumption of Great Lakes or Baltic Sea fish containing biopersistent chemicals may be associated with detrimental effects on the health and/or development of humans or animals. For example, a prospective study of children whose mothers consumed 3 meals per month of Lake Michigan fish before and during pregnancy found small, but statistically significant, changes in neurological endpoints at several stages of development compared with children of non-fish-eating mothers. Differences in neurological function are seen between adults as well. Based on these and other studies, ATSDR concluded that *"additive joint action at shared targets of toxicity is either supported by data (for a few pairs) or is recommended as a public health protective assumption."*

ATSDR Interactive Profile for Metals (As, Cr, Cd, Pb)

Lead, arsenic, cadmium, and chromium are frequently found together in the soil of hazardous waste sites. The primary route of concern for a mixture of these chemicals in soil or food is likely to be oral, and the duration intermediate to chronic. Chronic exposure is of particular concern because of the cumulative nature of cadmium injury to the kidney, and the association of chronic oral exposure to arsenic with dermal lesions and cancer. ATSDR suggests that "health assessment approach that deals with each metal separately may underestimate the potential for mixtures of these metals to cause effects." "The recommendations for assessing the potential hazard to public health of the joint toxic action of lead, arsenic, cadmium, and chromium(VI) is to use the hazard index and

> TTDs to estimate endpoint-specific hazard indexes for neurological, renal, cardiovascular, hematological, and testicular toxicity of the mixture. This approach is appropriate when hazard quotients of at least two of the components equal or exceed 0.1"

Brief summaries of the primary health effects from the risk drivers is taken from ATSDR Toxicology Profiles.[20] ATSDR Toxicology summarize the toxicological and adverse health effects for the specific hazardous substances. The health effects described below may appear after various chronic exposure regimes, but this depends on the dose level and the susceptibility of the individual. Thus, these are potential health effects, although making a causal association (i.e., attributing a human symptom to a particular contaminant) is statistically difficult in small populations or in individuals.

7.2.1 Arsenic

> There are a large number of studies in humans and animals on the toxic effects of ingested arsenic. The diet is usually the predominant source of exposure for the general population. The effects most likely to be of human health concern from ingestion of arsenic are gastrointestinal irritation, peripheral neuropathy, vascular lesions, anemia, a group of skin diseases, including skin cancer, and other cancers of the internal organs including bladder, kidney, liver, and lung cancer. Anemia and leukopenia are common effects of arsenic poisoning in humans, and have been reported following acute, intermediate, and chronic oral exposures. One of the most common and characteristic effects of arsenic ingestion is a pattern of skin changes that include generalized hyperkeratosis and formation of hyperkeratotic warts or corns on the palms and soles, along with areas of hyperpigmentation interspersed with small areas of hypopigmentation on the face, neck, and back. These and other dermal effects have been noted in a large majority of human studies involving repeated oral exposure. In cases of low-level chronic exposure (usually from water), these skin lesions appear to be the most sensitive indication of effect, so this end point is considered to be the most appropriate basis for establishing a chronic oral MRL. This is supported by the finding that other effects (hepatic injury, vascular disease, neurological effects) also appear to have similar thresholds. A large number of epidemiological studies and case reports indicate that ingestion of inorganic arsenic can cause injury to the nervous system, but neurological effects were not generally found in populations chronically exposed to arsenic. The drinking water standard for arsenic has been lowered five-fold due to recognition of recent data showing health effects at lower doses.

7.2.2 PCBs and Dioxins

> A tremendous number of studies have been done on PCBs and dioxins/furans. These compounds are lipophilic and accumulate most in fatty tissue, but affect every tissue in the body, causing both cancer and non-cancer effects. A great deal of concern exists that even low levels of PCBs transferred to the fetus across the placenta may induce long-lasting neurological damage. Because PCBs are lipophilic substances, there is also concern that significant amounts might be transferred to nursing infants via breast milk. Studies in women who

[20] Agency for Toxic Substances and Disease Registry (2005) ToxProfiles2005 CD.

consumed 2 or 3 salmon or lake trout/month of Great Lakes fish contaminated with environmentally persistent chemicals, including PCBs, have provided evidence that PCBs are important contributors to subtle neurobehavioral alterations observed in newborn children and that some of these alterations persist during childhood. Some consistent observations at birth have been motor immaturity and hyporeflexia and lower psychomotor scores between 6 months and 2 years old. Highly chlorinated PCB congeners, which accumulate in certain fish, are associated with neurobehavioral alterations seen in some newborn children. Subtle neurobehavioral alterations have also been observed in children born to mothers in the general population with the highest PCB body burdens. The evidence continues to accumulate.

7.2.3 Mercury and Lead

In the environment, inorganic mercury can be methylated by microorganisms to methylmercury. Methylmercury will accumulate in the tissues of organisms. The animals at the top of the food chain tend to accumulate the most methylmercury in their bodies. Any source of mercury release to the environment may, therefore, lead to increased levels of methylmercury in tissues of large fish and mammals. The literature on the health effects of mercury is extensive. Most of the information concerning neurotoxicity in humans following oral exposure to organic mercury comes from reports describing the effects of ingesting contaminated fish or fungicide-treated grains (or meat from animals fed such grains). The major effects that are seen across the studies include motor disturbances, such as ataxia and tremors, as well as signs of sensory dysfunction, such as impaired vision. The predominant neuropathological feature is degenerative changes in the cerebellum, which is likely to be the mechanism involved in many of the motor dysfunctions. In humans, disruptions of higher brain functions have also been noted. The effects on brain function associated with prenatal methylmercury exposure appear diverse, with early dysfunction in the Faroe Island population detectable at exposure levels currently considered to be safe.

7.2.4 DDT and other Chlorinated Pesticides

Typically, people are not exposed to DDT, DDE, or DDD individually, but rather to a mixture of all three compounds since DDE and DDD are degradation and metabolic products of DDT. In animals and probably in humans, the liver appears to be a sensitive target for DDT. Exposure to DDT and DDT-related compounds, particularly during development, can adversely affect the development and function of the reproductive system of both female and male animals. This is due primarily to the ability of some of these compounds to disrupt the action of natural steroids and bind to receptors for estrogens and androgens. Evidence of DDT-induced compromises in immune function has been obtained from studies conducted in animals. The nervous system appears to be one of the primary target systems for DDT toxicity in humans. DDT is an animal carcinogen and a probably human carcinogen.

7.2.5 Polyaromatic Hydrocarbons

Although a large toxicity database exists on complex mixtures that contain PAHs (such as crude oils, various high boiling point distillates, complex petroleum products, cigarette smoke, coal tars, creosote, and the products of coal liquefaction processes), reliable health-based and environmental information exists on only a few individual PAHs. The primary concern is DNA damage, anemia and other blood effects, liver effects, and cancer.

7.2 FISH BASKET RISKS

This section discusses situations where people eat a mixture of crabs, clams, and finfish gathered from a variety of locations. The goal is to gain a sense of average multi-species and multi-location risks. For the purposes of risk assessment, the "fish basket" is assumed to be comprised of equal daily amounts (100 gpd) of clams, crabs, and salmon, for a total of 300 gpd (or 11 ounces). The ingestion rate of a total of 300 gpd is assumed for children as well as adults, which may overestimate intake for younger children. However, children are more sensitive to health effects, so assuming a higher per capita intake more accurately represents risks for younger children than simply scaling down the intake rate but not correcting for children's increased sensitivity.

Table 29. Cumulative Fish Basket (Total Seafood) Risks

Daily Seafood Meals of 300 g (100 g of Each Species)			
Location	**HQ Child (6 years)**	**HQ Adult (70 years)**	**Cancer Risk (70 years lifetime)**
Clams -Skagit Bays average	4	1	7E-4
Clams - Fidalgo-Padilla average	5	1	9E-4
Crab - Skagit Bays average	3	0.7	8E-5
Crab - Fidalgo-Padilla average	3	0.8	1E-4
Puget Sound Salmon	11	2	5E-04
Total Ranges of Risk	17 to 21	3-5	1E-3 to 2E-3

Cumulative risks from daily ingestion are in the range of concern because non-cancer risks for adults and children are above 1, and lifetime cancer risks are above 1E-6 and even over 1E-4. As with most risk assessments, these estimates assume a continual daily ingestion of a constant amount of clams, crabs, and fish, and simple additivity of chemical impacts on health. This information is used to make recommendations for different groups of people such as adult males, women, or children, and for general locations and species mixtures.

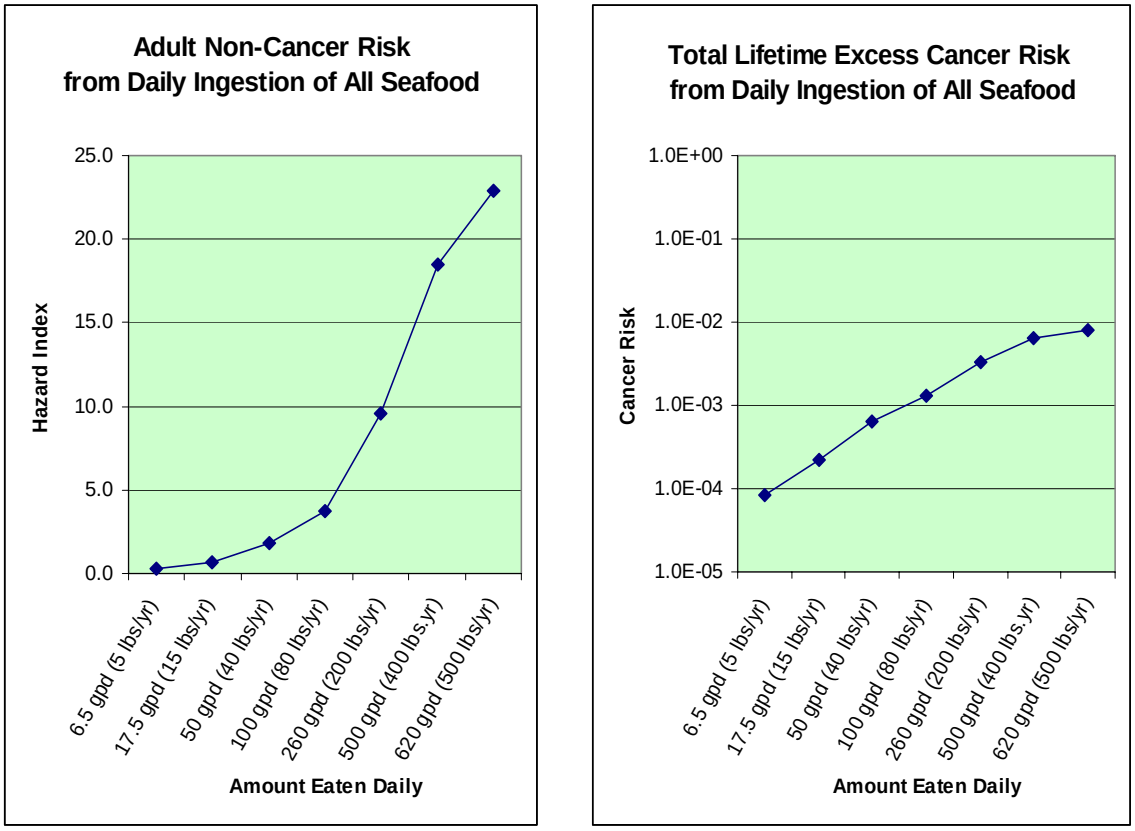


Figure 19. Cumulative Risks – Range of Ingestion Rates

Figure 19 depicts the cumulative risks from ingestion of all seafood (clams, crab, and fish) at constant daily rates. This type of illustration allows an individual to base their daily ingestion on cancer and non-cancer risk levels. Note that both types of risk are incurred simultaneously. Conversion information is shown in Table 30 (454 grams per pound; 16 ounces per pound). Column A shows the conversions for 6.5 gpd into ounces per day, meals per week, and so on.

Table 30. Conversion of Ingestion Rates

	A	B	C	D	E	F	G
gpd	6.5	17.5	50	100	260	500	620
oz/d	0.2	0.6	2	3.5	10	18	22
How many 8 oz meals/wk	0.2	0.5	1.5	3	8	15	17
Frequency of 8-oz meals	Less than one 8-oz meal per month	One 8-oz meal per month	One to two 8-oz meals/wk	Three 8-oz meals/wk	Every day or 1/2 lb/day	Twice per day or 1 lb/d	1 lb/d plus other forms and uses
Pounds per year	5	15	40	80	200	400	500

7.3 OVERALL RECOMMENDATIONS

The overall recommendations are primarily location-based, rather than species-based. Although there are some differences between butter clams, steamer clams, and crabs, they are not different enough to make species-specific recommendations. Finfish are indicated separately since their contaminant burdens appear to be consistently higher.

- Station 9 on March Point should not be used at all – it is clearly contaminated.
- Skagit Bay sites are somewhat more preferable to Fidalgo and Padilla Bays.
- Heavy-use areas around marinas, ferry docks, and industrial areas should be avoided.
- The crab hepatopancreas should always be removed before eating.

The following information is posted on the Tribal web page[21] and refers to the maps shown in Figures 20 and 21.

> Puget Sound finfish such as salmon should be limited to one meal per week, including the different types of fish caught in different seasons. Risk drivers are PCBs, mercury, and arsenic.
>
> Women of child-bearing age (14 - 49 years old) may be able to eat two meals per week (one salmon and one clam or crab, preferably from yellow sites).
>
> Children can also eat two meals a week (one salmon and one clam or crab only from yellow sites), assuming a smaller portion size.
>
> Adult males and women past child-bearing age can add another meal per week, for example two salmon meals and one of either clam or crab from yellow or orange sites, or vice versa. Three seafood meals is the upper limit for everyone.
>
> Preferably no tuna for anyone because it has high levels of mercury, which is extremely toxic.
>
> For serving size, an average serving is considered to be an 8-ounce meal. Two 8-ounce meals per week are equal to one pound of seafood per week.
>
> MAP KEY:
>
> - There are no green sites (unlimited) anywhere
> - Orange sites mean one meal per week (alone or in combination)
> - Yellow sites mean two meals per week
> - Red sites mean that it is recommended not to eat or harvest there

---

* These recommendations are based on calculations for people who live at Swinomish and harvest and/or eat shellfish from these locations for their entire lives. Their recommendations are not intended for use in commercial harvests.

[21] http://www.swinomish.org/planning/environmental_science/water_resources/tidelands/btnas/tidelands.btnas1.html

Figure 20. Map of recommendations for clam sites

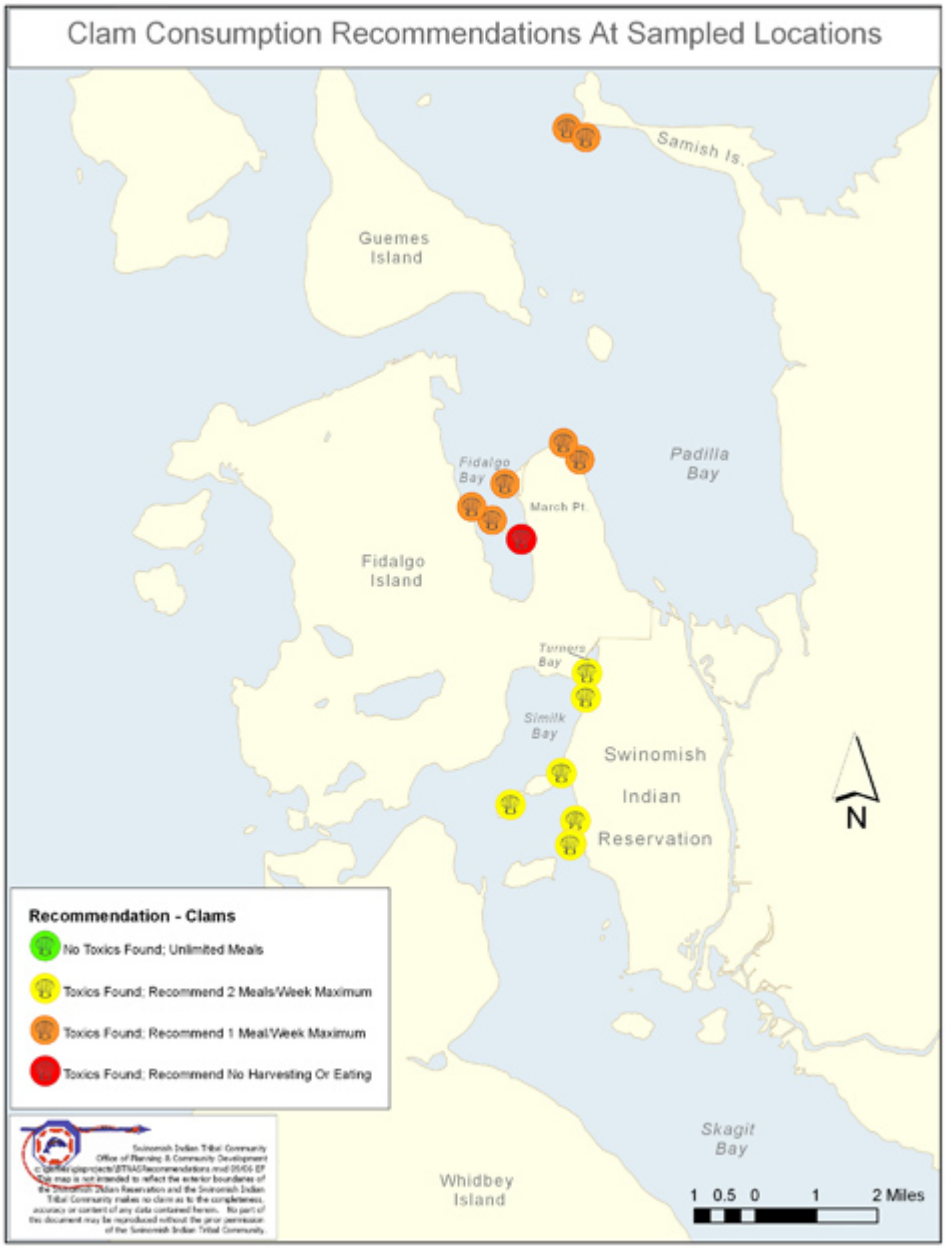
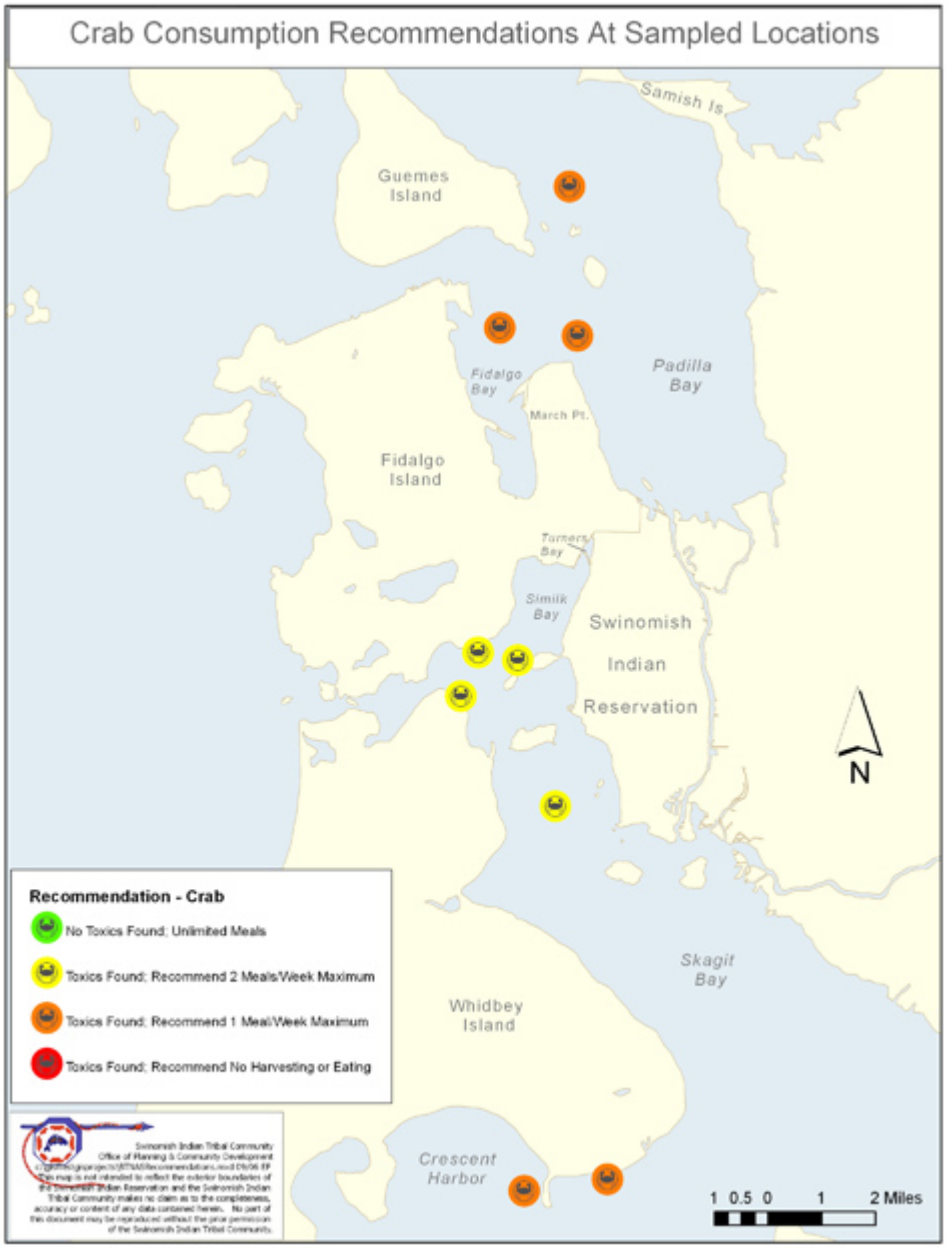


Figure 21. Map of recommendations for crab sites



8.0 SOURCES OF UNCERTAINTY; DATA GAPS

This section presents a discussion of the assumptions and procedures that introduce the greatest amount of uncertainty in the HHRA, as well as their effect on the estimates of potential risk. The discussion of their effect is qualitative because in many instances not enough information exists to quantify the magnitude of these uncertainties.

8.1 LOCATIONS, SPECIES, OTHER EXPOSURES

Not all harvest areas were tested for contaminants. Some areas not tested may be higher or lower in contamination than the areas tested; therefore contaminant data may not be truly reflective of the types or concentrations to which Swinomish citizens may be exposed.

The species that were selected are surrogates for many other fish and shellfish eaten. In addition, contaminant burdens in other parts of the food supply, both wild-harvested and commercial, are incompletely known. The recommendations consider the benefits as well as the risks of seafood, and also consider the information, or lack thereof, about the rest of the diet. However, this remains a significant data gap.

8.2 TOXICITY

The primary source of uncertainty for toxicity considerations is the fact that the Reference Doses and Cancer Slope Factors published in IRIS are in some case a decade or more behind the state of the data. Since now data generally shows increasing potency (or occasionally less potency), there is a perennial issue with using the most current toxicity information.

Cumulative risks assume simple additivity of health effects, which may underestimate any synergism between chemicals.

Dioxins and PCBs

There is some non-Ah toxicity that is not included in the TEF factors, and therefore not included in the risk assessment. For example, the lower chlorinated congeners, which are not entirely without toxicity, were not analyzed. There is also toxicity that is not mediated by the Ah receptor, and therefore also not included in the TEF approach. Overall, dioxin and PCB risks could be underestimated. In fact, EPA considers dioxin to be so toxic that no Reference Dose (i.e., no presumably safe level) has been published. However, ATSDR has published a Minimum Risk Level, which was used in this assessment.

Arsenic

Information indicating that arsenic is more toxic than previously thought is slowly accumulating. This has been taken into account in this assessment by adjusting the IRIS toxicity factors.

Lead and Mercury

Lead and mercury are two metals often considered to be so toxic as to have no threshold (i.e., no dose is without some risk) for neurological effects, particularly for the developing nervous system before birth and throughout adolescence. The mercury Reference Dose was adjusted 2-fold to account for new data. In addition, this assessment treated lead and mercury the same, rather than removing lead and evaluating it separately as if no other neurotoxins were present.

Other contaminants

Many of the analyzed contaminants, particularly extended PAHs, do not have toxicity information. While toxicity is likely minimal, the lack of information remains a source of uncertainty. Other contaminants such as agriceuticals and pharmaceuticals were not analyzed.

Because chlorinated pesticides were always detected in crabs but never in clams or sediments, there remains a question about the quality of the analysis in clams and sediment.

Non-detects were treated as if they were truly not present, even if they were present in nearby samples. This may underestimate risks.

8.3 INGESTION RATES

Data analysis of current consumption rate data is incomplete. Risks for various percentiles of Swinomish citizens may be somewhat higher or lower than estimated in this report. Further, traditional subsistence rates have not been determined, although they will be higher than current consumption rates.

Seasonally-higher rates are likely higher than the annual averages used in this report; seasonal data were collected as part of the seafood diet interviews to be analyzed for use in future assessments.

8.4 CO-RISK FACTORS

Clusters of factors that could increase vulnerability (poverty, housing conditions, etc) may cluster in Tribal communities. Therefore, in addition to increased exposure, there may be increased vulnerability that magnify cumulative risks. For example, poverty alone may increase sensitivity aside from correlated quality of housing, health care, and nutrition. These and other factors were not used to adjust the risk characterization.

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APPENDIX

Risk Results for Individual Samples

Lifetime Site Risks at 260g per day

Child = ages 1-6; Adult = Lifetime

BC = butter clams; SC = steamer clams; M = crab muscle; P = crab hepatopancreas

CLAM sites - Skagit Bay (Turner, Similk, Kiket Bays)

		Child Non-Cancer	Adult Non-Cancer	Cancer				Child Non-Cancer	Adult Non-Cancer	Cancer
BC1	PCB Congeners	1.E+01	2.E+00	2.E-03		**SC1**	PCB Congeners	6.E+00	1.E+00	1.E-03
	Arsenic	3.E+00	6.E-01	7.E-05			Arsenic	3.E+00	5.E-01	6.E-05
	Dioxins/Furans	1.E-01	2.E-02	2.E-05			Dioxins/Furans	2.E-01	4.E-02	4.E-05
	Other heavy metals	1.E-01	3.E-02	0.E+00			Other heavy metals	1.E-01	2.E-02	0.E+00
	TBT	2.E-03	3.E-04	0.E+00			TBT	6.E-04	1.E-04	0.E+00
	PAHs	7.E-05	1.E-05	6.E-07			PAHs	1.E-04	2.E-05	5.E-07
	Totals	***1.E+01***	***3.E+00***	***2.E-03***			***Totals***	***9.07E+00***	***1.90E+00***	***1.40E-03***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC1A	PCB Congeners	1.E+01	2.E+00	1.E-04		**SC1A**	PCB Congeners	6.E+00	1.E+00	2.E-03
	Arsenic	3.E+00	6.E-01	7.E-05			Arsenic	2.E+00	5.E-01	6.E-05
	Dioxins/Furans	2.E-01	2.E-02	5.E-05			Dioxins/Furans	3.E-01	5.E-02	5.E-05
	Other heavy metals	1.E-01	3.E-02	0.E+00			Other heavy metals	1.E-01	2.E-02	0.E+00
	TBT	1.E-03	3.E-04	0.E+00			TBT	5.E-04	1.E-04	0.E+00
	PAHs	8.E-05	1.E-05	6.E-07			PAHs	8.E-05	2.E-05	5.E-07
	Totals	***1.E+01***	***3.E+00***	***2.E-04***			***Totals***	***9.E+00***	***2.E+00***	***2.E-03***
		Child Non-	**Adult Non-Cancer**	**Cancer**				**Child Non-**	**Adult Non-Cancer**	**Cancer**

		Cancer						Cancer		
BC2	PCB Congeners	8.E+00	2.E+00	2.E-03		**SC2**	PCB Congeners	7.E+00	1.E+00	2.E-03
	Arsenic	3.E+00	6.E-01	7.E-05			Arsenic	3.E+00	6.E-01	7.E-05
	Dioxins/Furans	2.E-01	3.E-02	4.E-05			Dioxins/Furans	2.E-01	5.E-02	4.E-05
	Other heavy metals	8.E-02	2.E-02	0.E+00			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	1.E-03	3.E-04	0.E+00			TBT	4.E-04	9.E-05	0.E+00
	PAHs	8.E-05	2.E-05	5.E-07			PAHs	8.E-05	1.E-05	5.E-07
	Totals	***1.E+01***	***2.E+00***	***2.E-03***			***Totals***	***1.E+01***	***2.E+00***	***2.E-03***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC3	PCB Congeners	7.E+00	1.E-01	2.E-04		**SC3**	PCB Congeners	6.E+00	1.E+00	1.E-03
	Arsenic	3.E+00	7.E-01	8.E-05			Arsenic	3.E+00	6.E-01	7.E-05
	Dioxins/Furans	1.E-01	2.E-02	5.E-05			Dioxins/Furans	1.E-01	3.E-02	3.E-05
	Other heavy metals	1.E+01	2.E+00	2.E-05			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	2.E-03	4.E-04	0.E+00			TBT	4.E-04	8.E-05	0.E+00
	PAHs	8.E-05	1.E-05	6.E-07			PAHs	8.E-05	1.E-05	6.E-07
	Totals	***2.E+01***	***3.E+00***	***3.E-04***			***Totals***	***9.E+00***	***2.E+00***	***1.E-03***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC4	PCB Congeners	9.E+00	2.E+00	2.E-03		**SC4**	PCB Congeners	7.E+00	2.E+00	2.E-03
	Arsenic	2.E+00	4.E-01	4.E-05			Arsenic	2.E+00	4.E-01	4.E-05
	Dioxins/Furans	3.E-01	8.E-02	7.E-05			Dioxins/Furans	2.E-01	5.E-02	4.E-05
	Other heavy metals	1.E-01	2.E-02	0.E+00			Other heavy metals	1.E-01	2.E-02	0.E+00
	TBT	8.E-04	2.E-04	0.E+00			TBT	3.E-04	6.E-05	0.E+00
	PAHs	8.E-05	2.E-05	4.E-07			PAHs	8.E-05	2.E-05	6.E-07
	Totals	***1.E+01***	***3.E+00***	***2.E-03***			***Totals***	***9.E+00***	***2.E+00***	***2.E-03***

		Child Non-Cancer	Adult Non-Cancer	Cancer				Child Non-Cancer	Adult Non-Cancer	Cancer
BC5	PCB Congeners	1.E+01	2.E+00	2.E-03		**SC5**	PCB Congeners	7.E+00	1.E+00	2.E-03
	Arsenic	3.E+00	6.E-01	4.E-08			Arsenic	4.E+00	8.E-01	9.E-05
	Dioxins/Furans	3.E-01	2.E-02	5.E-05			Dioxins/Furans	1.E-01	6.E-03	3.E-05
	Other heavy metals	1.E+01	2.E+00	6.E-05			Other heavy metals	6.E-02	1.E-02	0.E+00
	TBT	8.E-04	2.E-04	0.E+00			TBT	4.E-04	7.E-05	0.E+00
	PAHs	8.E-05	2.E-05	6.E-07			PAHs	8.E-05	2.E-05	6.E-07
	Totals	***2.E+01***	***5.E+00***	***2.E-03***			***Totals***	***1.E+01***	***2.E+00***	***2.E-03***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC6	PCB Congeners	9.E+00	2.E+00	5.E-05		**SC6**	PCB Congeners	8.E+00	2.E+00	3.E-05
	Arsenic	2.E+00	4.E-01	4.E-05			Arsenic	2.E+00	4.E-01	2.E-05
	Dioxins/Furans	2.E-01	5.E-02	4.E-05			Dioxins/Furans	1.E-01	3.E-02	4.E-05
	Other heavy metals	8.E-02	2.E-02	0.E+00			Other heavy metals	1.E-01	2.E-02	0.E+00
	TBT	1.E-03	2.E-04	0.E+00			TBT	4.E-04	9.E-05	0.E+00
	PAHs	8.E-05	2.E-05	6.E-07			PAHs	8.E-05	2.E-05	6.E-07
	Totals	***1.E+01***	***2.E+00***	***1.E-04***			***Totals***	***1.E+01***	***2.E+00***	***9.E-05***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC7	PCB Congeners	7.E+00	2.E+00	3.E-05		**SC7**	PCB Congeners	5.E+00	1.E+00	6.E-05
	Arsenic	1.E+00	1.E+00	1.E+00			Arsenic	3.E+00	6.E-01	7.E-05
	Dioxins/Furans	5.E-02	5.E-02	5.E-02			Dioxins/Furans	3.E-02	3.E-02	6.E-05
	Other heavy metals	4.E-02	4.E-02	4.E-02			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	6.E-04	6.E-04	6.E-04			TBT	5.E-04	1.E-04	0.E+00
	PAHs	3.E-05	3.E-05	3.E-05			PAHs	5.E-05	1.E-05	6.E-07
	Totals	***8.E+00***	***3.E+00***	***1.E+00***			***Totals***	***8.E+00***	***2.E+00***	***2.E-04***

CRAB Sites - Skagit Bay (north)										
		Q	2.E+00							
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
4M	PCB Congeners	2.E-02	4.E-03	4.E-06		**4P**	PCB Congeners	1.E-01	2.E-02	3.E-05
	Total Arsenic	6.E+00	1.E+00	2.E-04			Total Arsenic	6.E+00	1.E+00	1.E-04
	Dioxins/Furans	2.E-02	5.E-03	4.E-06			Dioxins/Furans	1.E-01	2.E-02	2.E-05
	Chlorinated Pesticides	2.E-04	5.E-05	9.E-09			Chlorinated Pesticides	3.E-03	5.E-04	3.E-07
	Other Heavy Metals	6.E-02	1.E-02	0.E+00			Other Heavy Metals	2.E-01	9.E-06	5.E-08
	TBT	0.E+00	0.E+00	0.E+00			TBT	6.E-04	1.E-04	0.E+00
	PAH	4.E-06	9.E-07	0.E+00			PAH	1.E-05	3.E-06	0.E+00
	Totals	***6.E+00***	***1.E+00***	***2.E-04***			***Totals***	***6.2E+00***	***1.3E+00***	***1.9E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
5M	PCB Congeners	2.E-02	5.E-03	5.E-06		**5P**	PCB Congeners	1.E-01	2.E-02	2.E-05
	Total Arsenic	8.E+00	2.E+00	2.E-04			Total Arsenic	7.E+00	2.E+00	2.E-04
	Dioxins/Furans	1.E-02	2.E-03	2.E-06			Dioxins/Furans	7.E-02	1.E-02	1.E-05
	Chlorinated Pesticides	3.E-04	6.E-05	2.E-08			Chlorinated Pesticides	2.E-03	3.E-04	2.E-07
	Other Heavy Metals	1.E-01	3.E-02	5.E-08			Other Heavy Metals	2.E-01	3.E-02	8.E-08
	TBT	0.E+00	0.E+00	0.E+00			TBT	1.E-03	3.E-04	0.E+00
	PAH	4.E-06	8.E-07	0.E+00			PAH	1.E-05	3.E-06	0.E+00
	Totals	***8.E+00***	***2.E+00***	***2.E-04***			***Totals***	***8.E+00***	***2.E+00***	***2.E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
6M	PCB Congeners	2.E-02	5.E-03	3.E-06		**6P**	PCB Congeners	1.E-01	3.E-02	3.E-05
	Total Arsenic	7.E+00	2.E+00	2.E-04			Total Arsenic	5.E+00	1.E+00	1.E-04
	Dioxins/Furans	3.E-02	7.E-03	6.E-06			Dioxins/Furans	1.E-01	3.E-02	3.E-05
	Chlorinated Pesticides	5.E-04	1.E-04	6.E-08			Chlorinated Pesticides	3.E-02	9.E-04	3.E-07

	Other Heavy Metals	2.E-01	5.E-02	8.E-08			Other Heavy Metals	2.E-01	4.E-02	8.E-08
	TBT	0.E+00	0.E+00	0.E+00			TBT	1.E-03	2.E-04	0.E+00
	PAH	2.E-05	3.E-06	0.E+00			PAH	7.E-05	1.E-05	2.E-08
	Totals	***8.E+00***	***2.E+00***	***2.E-04***			***Totals***	***5.8E+00***	***1.2E+00***	***1.8E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
7M	PCB Congeners	1.E-02	3.E-03	2.E-06		**7P**	PCB Congeners	1.E-01	9.E-03	9.E-06
	Total Arsenic	7.E+00	1.E+00	2.E-04			Total Arsenic	7.E+00	1.E+00	2.E-04
	Dioxins/Furans	4.E-02	7.E-03	3.E-05			Dioxins/Furans	1.E-01	2.E-02	1.E-05
	Chlorinated Pesticides	3.E-04	5.E-05	6.E-08			Chlorinated Pesticides	3.E-03	6.E-04	2.E-07
	Other Heavy Metals	7.E-02	1.E-02	0.E+00			Other Heavy Metals	7.E-02	1.E-02	0.E+00
	TBT	0.E+00	0.E+00	0.E+00			TBT	2.E-03	4.E-04	0.E+00
	PAH	5.E-05	1.E-05	0.E+00			PAH	8.E-05	2.E-05	3.E-07
	Totals	***7.E+00***	***1.E+00***	***2.E-04***			***Totals***	***7.E+00***	***2.E+00***	***2.E-04***
CLAM Sites - Padilla & Fidalgo Bays, March Point										
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC8	PCB Congeners	1.E+01	3.E-01	3.E-04		**SC8**	PCB Congeners	8.E+00	2.E+00	2.E-04
	Arsenic	2.E+00	5.E-01	5.E-05			Arsenic	2.E+00	4.E-01	4.E-05
	Dioxins/Furans	1.E+00	3.E-01	3.E-04			Dioxins/Furans	1.E+00	2.E-01	2.E-04
	Other heavy metals	1.E-01	2.E-02	0.E+00			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	2.E-03	4.E-04	0.E+00			TBT	9.E-04	2.E-04	0.E+00
	PAHs	8.E-05	2.E-05	5.E-07			PAHs	8.E-05	2.E-05	5.E-07
	Totals	***2.E+01***	***1.E+00***	***6.E-04***			***Totals***	***1.E+01***	***2.E+00***	***5.E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**

BC9	PCB Congeners	1.E+01	3.E+00	2.E-04		**SC9**	PCB Congeners	7.E+00	2.E+00	6.E-05
	Arsenic	3.E+00	5.E-01	6.E-05			Arsenic	2.E+00	5.E-01	6.E-05
	Dioxins/Furans	8.E-01	2.E-01	2.E-04			Dioxins/Furans	8.E-01	2.E+00	2.E-04
	Other heavy metals	1.E-01	3.E-02	0.E+00			Other heavy metals	2.E-01	3.E-02	0.E+00
	TBT	2.E-03	4.E-04	0.E+00			TBT	8.E-04	2.E-04	0.E+00
	PAHs	8.E-04	1.E-04	5.E-07			PAHs	5.E-04	1.E-04	5.E-07
	Totals	***2.E+01***	***3.E+00***	***4.E-04***			***Totals***	***1.E+01***	***4.E+00***	***3.E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC10	PCB Congeners	2.E+01	2.E+00	8.E-06		**SC10**	PCB Congeners	8.E+00	2.E+00	2.E-04
	Arsenic	1.E+00	6.E-01	7.E-05			Arsenic	2.E+00	4.E-01	5.E-05
	Dioxins/Furans	1.E+00	2.E-02	5.E-05			Dioxins/Furans	1.E+00	2.E-01	3.E-04
	Other heavy metals	8.E-02	3.E-02	0.E+00			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	2.E-03	3.E-04	0.E+00			TBT	1.E-03	2.E-04	0.E+00
	PAHs	1.E-04	1.E-05	6.E-07			PAHs	8.E-05	2.E-05	6.E-07
	Totals	***2.E+01***	***3.E+00***	***1.E-04***			***Totals***	***1.15E+01***	***2.50E+00***	***5.41E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC11	PCB Congeners	1.E+01	3.E+00	9.E-05		**SC11**	PCB Congeners	7.E+00	1.E+00	1.E-04
	Arsenic	3.E+00	6.E-01	6.E-05			Arsenic	2.E+00	5.E-01	5.E-05
	Dioxins/Furans	4.E-01	9.E-02	9.E-05			Dioxins/Furans	4.E-01	1.E-01	1.E-04
	Other heavy metals	1.E-01	3.E-02	0.E+00			Other heavy metals	2.E-01	3.E-02	0.E+00
	TBT	3.E-03	6.E-04	0.E+00			TBT	9.E-04	2.E-04	0.E+00
	PAHs	1.E-04	3.E-05	6.E-07			PAHs	1.E-04	2.E-05	6.E-07
	Totals	***2.E+01***	***3.E+00***	***2.E-04***			***Totals***	***9.E+00***	***2.E+00***	***2.E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**

BC12	PCB Congeners	1.E+01	3.E+00	8.E-05		**SC12**	PCB Congeners	7.E+00	1.E+00	1.E-04
	Arsenic	3.E+00	7.E-01	8.E-05			Arsenic	3.E+00	6.E-01	7.E-05
	Dioxins/Furans	4.E-01	9.E-02	9.E-05			Dioxins/Furans	5.E-01	1.E-01	1.E-04
	Other heavy metals	1.E-01	2.E-02	0.E+00			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	3.E-03	5.E-04	0.E+00			TBT	1.E-03	2.E-04	0.E+00
	PAHs	1.E-04	2.E-05	6.E-07			PAHs	1.E-04	2.E-05	6.E-07
	Totals	***2.E+01***	***3.E+00***	***3.E-04***			***Totals***	***1.E+01***	***2.E+00***	***3.E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC15	PCB Congeners	9.E+00	2.E+00	8.E-05		**SC15**	PCB Congeners	6.E+00	1.E+00	5.E-05
	Arsenic	4.E+00	8.E-01	9.E-05			Arsenic	3.E+00	6.E-01	7.E-05
	Dioxins/Furans	3.E-01	8.E-02	7.E-05			Dioxins/Furans	5.E-01	5.E-02	5.E-05
	Other heavy metals	1.E-01	3.E-02	0.E+00			Other heavy metals	2.E-01	4.E-02	0.E+00
	TBT	2.E-03	5.E-04	0.E+00			TBT	1.E-03	2.E-04	0.E+00
	PAHs	1.E-04	2.E-05	6.E-07			PAHs	8.E-05	2.E-05	6.E-07
	Totals	***1.E+01***	***3.E+00***	***2.E-04***			***Totals***	***9.E+00***	***2.E+00***	***2.E-04***
CRAB Sites - Padilla & Fidalgo Bays										
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
1M	PCB Congeners	2.E-02	4.E-03	4.E-06		**1P**	PCB Congeners	6.E-02	1.E-02	1.E-05
	Total Arsenic	9.E+00	2.E+00	2.E-04			Total Arsenic	1.E+01	2.E+00	2.E-04
	Dioxins/Furans	4.E-02	9.E-03	8.E-06			Dioxins/Furans	1.E-01	3.E-02	3.E-05
	Chlorinated Pesticides	3.E-04	7.E-05	5.E-08			Chlorinated Pesticides	4.E-01	8.E-02	2.E-07
	Other Heavy Metals	7.E-02	1.E-02	0.E+00			Other Heavy Metals	1.E-01	3.E-02	7.E-08
	TBT	0.E+00	0.E+00	0.E+00			TBT	1.E-03	3.E-04	0.E+00
	PAHs	1.E-05	2.E-06	0.E+00			PAH	1.E-04	2.E-05	0.E+00

	Totals	***1.E+01***	***2.E+00***	***2.E-04***			***Totals***	***1.E+01***	***2.E+00***	***3.E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
2M	PCB Congeners	2.E-02	4.E-03	4.E-06		**2P**	PCB Congeners	7.E-02	1.E-02	1.E-05
	Total Arsenic	8.E+00	2.E+00	2.E-04			Total Arsenic	0.E+00	0.E+00	0.E+00
	Dioxins/Furans	5.E-02	1.E-02	1.E-05			Dioxins/Furans	2.E-01	3.E-02	3.E-05
	Chlorinated Pesticides	0.E+00	0.E+00	4.E-08			Chlorinated Pesticides	1.E-03	3.E-04	2.E-07
	Other Heavy Metals	6.E-02	1.E-02	0.E+00			Other Heavy Metals	1.E+00	2.E-01	1.E-04
	TBT	0.E+00	0.E+00	0.E+00			TBT	1.E-03	3.E-04	0.E+00
	PAH	6.E-06	1.E-06	0.E+00			PAH	9.E-05	2.E-05	0.E+00
	Totals	***8.E+00***	***2.E+00***	***2.E-04***			***Totals***	***1.4E+00***	***2.9E-01***	***1.5E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
3M	PCB Congeners	2.E-02	4.E-03	4.E-06		**3P**	PCB Congeners	9.E-02	2.E-02	2.E-05
	Total Arsenic	9.E+00	2.E+00	2.E-04			Total Arsenic	8.E+00	2.E+00	2.E-04
	Dioxins/Furans	4.E-02	8.E-03	8.E-06			Dioxins/Furans	2.E-01	4.E-02	4.E-05
	Chlorinated Pesticides	2.E-04	5.E-05	8.E-09			Chlorinated Pesticides	2.E-03	4.E-04	2.E-07
	Other Heavy Metals	7.E-02	2.E-02	0.E+00			Other Heavy Metals	2.E-01	4.E-02	4.E-08
	TBT	0.E+00	0.E+00	0.E+00			TBT	1.E-03	2.E-04	0.E+00
	PAH	4.E-05	8.E-06	0.E+00			PAH	5.E-05	1.E-05	0.E+00
	Totals	***9.E+00***	***2.E+00***	***2.E-04***			***Totals***	***9.E+00***	***2.E+00***	***3.E-04***
CLAM Sites - Samish Island (north Padilla Bay)										
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**

BC13	PCB Congeners	6.E+00	1.E+00	3.E-05		**SC13**	PCB Congeners	3.E+00	2.E+00	8.E-06
	Arsenic	1.E+00	3.E-01	4.E-05			Arsenic	3.E+00	6.E-01	7.E-05
	Dioxins/Furans	1.E-01	3.E-02	3.E-05			Dioxins/Furans	1.E-01	2.E-02	5.E-05
	Other heavy metals	5.E-02	8.E-03	0.E+00			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	1.E-03	3.E-04	0.E+00			TBT	6.E-04	3.E-04	0.E+00
	PAHs	8.E-05	2.E-05	5.E-07			PAHs	5.E-05	1.E-05	5.E-07
	Totals	***7.E+00***	***2.E+00***	***9.E-05***			***Totals***	***6.E+00***	***3.E+00***	***1.E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
BC14	PCB Congeners	6.E+00	1.E+00	3.E-05		**SC14**	PCB Congeners	3.E+00	6.E-01	5.E-05
	Arsenic	3.E+00	7.E-01	7.E-05			Arsenic	3.E+00	5.E-01	6.E-05
	Dioxins/Furans	1.E-01	6.E-01	3.E-05			Dioxins/Furans	3.E-01	5.E-02	5.E-05
	Other heavy metals	1.E-01	2.E-02	0.E+00			Other heavy metals	1.E-01	3.E-02	0.E+00
	TBT	1.E-03	3.E-04	0.E+00			TBT	9.E-04	2.E-04	0.E+00
	PAHs	8.E-05	1.E-05	5.E-07			PAHs	5.E-05	1.E-05	5.E-04
	Totals	***9.E+00***	***3.E+00***	***1.E-04***			***Totals***	***6.E+00***	***1.E+00***	***7.E-04***
CRAB Sites - Guemes - Crescent Harbor										
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
8M	PCB Congeners	2.E-02	7.E-03	6.E-06		**8P**	PCB Congeners	1.E-01	4.E-02	3.E-05
	Total Arsenic	9.E+00	2.E+00	2.E-04			Total Arsenic	8.E+00	2.E+00	2.E-04
	Dioxins/Furans	3.E-02	8.E-03	7.E-06			Dioxins/Furans	1.E-01	2.E-02	2.E-05
	Chlorinated Pesticides	2.E-04	4.E-05	7.E-09			Chlorinated Pesticides	2.E-03	7.E-04	3.E-07
	Other Heavy Metals	6.E-02	1.E-02	0.E+00			Other Heavy Metals	1.E-01	2.E-02	0.E+00
	TBT	0.E+00	0.E+00	0.E+00			TBT	8.E-04	2.E-04	0.E+00
	PAH	1.E-05	2.E-06	0.E+00			PAH	1.E-05	3.E-06	0.E+00
	Totals	***9.E+00***	***2.E+00***	***2.E-04***			***Totals***	***8.6E+00***	***1.8E+00***	***2.5E-04***

		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**				**Child Non-Cancer**	**Adult Non-Cancer**	**Cancer**
9M	PCB Congeners	2.E-02	4.E-03	4.E-06		**9P**	PCB Congeners	2.E-01	3.E-02	3.E-05
	Total Arsenic	1.E+01	3.E+00	3.E-04			Total Arsenic	1.E+01	2.E+00	2.E-04
	Dioxins/Furans	2.E-02	4.E-03	4.E-06			Dioxins/Furans	1.E-01	2.E-02	2.E-05
	Chlorinated Pesticides	3.E-04	7.E-05	8.E-08			Chlorinated Pesticides	4.E-03	9.E-04	5.E-07
	Other Heavy Metals	5.E-02	1.E-02	0.E+00			Other Heavy Metals	2.E-01	4.E-02	5.E-08
	TBT	0.E+00	0.E+00	0.E+00			TBT	9.E-04	2.E-04	0.E+00
	PAH	4.E-06	8.E-07	0.E+00			PAH	9.E-05	2.E-05	0.E+00
	Totals	***1.E+01***	***3.E+00***	***3.E-04***			***Totals***	***1.0E+01***	***2.2E+00***	***2.9E-04***
		Child Non-Cancer	**Adult Non-Cancer**	**Cancer**						
Squid	PCB Congeners	3.E-02	8.E-03	8.E-06						
Bait	Total Arsenic	8.E-01	2.E-01	2.E-05						
	Dioxins/Furans	2.E-03	3.E-04	0.E+00						
	Chlorinated Pesticides	6.E-04	1.E-04	2.E-08						
	Other Heavy Metals	3.E-01	6.E-02	4.E-08						
	TBT	1.E-03	2.E-04	0.E+00						
	PAH	8.E-05	2.E-05	0.E+00						
	Totals	***1.E+00***	***2.E-01***	***3.E-05***						