Health Consultation

Port Angeles Harbor,
Evaluation of Chemical Contaminants in Dungeness Crab, Coonstripe Shrimp, and Mussels

Port Angeles, Clallam County, Washington

August 20, 2015

Prepared by

The Washington State Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

DOH 334-375

Foreword

The Washington State Department of Health prepared this health consultation in accordance with the Agency for Toxic Substances and Disease Registry (ATSDR) methodologies and guidelines. Health consultations are initiated in response to health concerns raised by community members or agencies about exposure to hazardous substances released into the environment. The health consultation summarizes our health findings and if needed, provides steps or actions to protect public health.

The findings in this report are relevant to conditions at the site during the time the report was written. It should not be relied upon if site conditions or land use changes in the future.

This report was supported by funds provided through a cooperative agreement with the ATSDR, U.S. Department of Health and Human Services. The findings and conclusions in these reports are those of the author(s) and do not necessarily represent the views of the ATSDR or the U.S. Department of Health and Human Services. This document has not been revised or edited to conform to agency standards.

Use of trade names is for identification only and does not imply endorsement by state or federal health agencies.

For additional information, please contact us at 1-877-485-7316 or visit our web site at **www.doh.wa.gov/consults**.

For persons with disabilities, this document is available on request in other formats. To submit a request, please call 1-800-525-0127 (TDD/TTY call 711).
For more information about ATSDR, contact the CDC Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's web site at **www.atsdr.cdc.gov**.

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Summary

Introduction

The purpose of this health consultation is to evaluate health risks that may be associated with consumption of chemicals found in crab, shrimp, or mussels collected from Port Angeles Harbor. Clallam County Environmental Health requested that the Washington State Department of Health evaluate whether consuming crab, shrimp, or mussels from Port Angeles Harbor would pose health threats. We conduct health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).[a] This health consultation features

- Dungeness crab, mussels, and coonstripe shrimp as species evaluated for both non-cancer health effects and cancer risk,
- risk assessment based on a state resident seafood consumption rate of 175 g/day[b] (for details, see Appendix B – Exposure Assumptions),
- supplementary risk assessment using a higher seafood consumption rate from the Lower Elwha Klallam Tribe (LEKT), and
- recommended meal limits for identified contaminants of concern in crab.

This evaluation is limited to the chemical contaminants found in these species from 2002 to 2012. It does not include the evaluation of biological hazards or other hazards nor does it consider any seasonal harvesting restrictions in consumption rates. Some harmful health hazards were found from the evaluation of existing chemical contaminant data from these species. More sampling data is needed for any future health consultation regarding consumption from this harbor. Due to many uncertainties, we currently recommend that people avoid harvesting from Port Angeles Harbor, or any other urban bay, for their main source of seafood.

Conclusion 1 – Dungeness Crab

Consuming Dungeness crab meat or hepatopancreas from Port Angeles Harbor at a state resident seafood consumption rate could significantly increase the risk of cancer over a lifetime.

Basis for Decision

- Lifetime excess cancer risk from consuming crab muscle is 3 in 10,000 from arsenic, PCBs and dioxin.
- Lifetime excess cancer risk from consuming hepatopancreas is 1 in 100 from arsenic, PCBs, dioxin, and DDT.
- Persistent chemicals found in crab data demonstrated the need for a crab advisory. Eating more than the calculated consumption limit (in Appendix G – Recommended Meal) may increase a person's risk of developing health problems.

[a] ATSDR's health consultation process, which is used by DOH, differs in scope and purpose from the risk assessment used by regulatory agencies, such as Washington State Department of Ecology (Ecology). While a risk assessment conducted under Ecology is used to support the selection of a remedial measure at a site, the health consultation is a mechanism used to provide the impacted community with information on the public health implications of a specific site, identifying those populations for which further health actions or studies are needed.
[b] This rate is under consideration for adoption within the Washington State Water Quality Standards. Currently, Water Quality Standards are based on a rate of 6.5 g/day, while the Model Toxics Control Act uses 54 g/day.

Conclusion 2 – Mussels and Coonstripe Shrimp

Consuming mussels or coonstripe shrimp from Port Angeles Harbor at a state resident seafood consumption rate is not expected to harm human health based on the available chemical data.

Basis for Decision:

- Mussels: Lifetime excess cancer risk is 1 in 100,000 from arsenic. No non-cancer health hazards were identified at this consumption rate. Note that mussels were not analyzed for dioxin and were sampled from just one area off Ediz Hook.
- Shrimp: Lifetime excess cancer risk is 1 in 100,000 from arsenic. No non-cancer health hazards were identified at this consumption rate. Note that data is more than 10 years old and is limited to three small samples.

Conclusion 3 – Tribal Consumption Scenario

Consuming Dungeness crab meat or hepatopancreas from Port Angeles Harbor at a Lower Elwha Klallam Tribe (LEKT) seafood consumption rate could significantly increase the risk of cancer over a lifetime. Eating crab hepatopancreas at this rate could additionally result in non-cancer health effects. This is a supplementary assessment; there are no indications that tribal members are exclusively consuming seafood from the harbor at the LEKT rate. Consuming mussels and shrimp from Port Angeles Harbor at the LEKT seafood consumption rate is not expected to harm human health based on the available chemical data.

Basis for Decision:

- Crab muscle: Lifetime excess cancer risk is 1 in 1,000 from arsenic, PCBs, and dioxin.
- Crab hepatopancreas: There are potential non-cancer health effects from PCBs and copper. Lifetime excess cancer risk is about 4 in 100 from PCBs, dioxin, and DDT.
- Mussels: Lifetime excess cancer risk is 7 in 100,000 from arsenic, PCBs, and PAHs.
- Coonstripe shrimp: Lifetime excess cancer risk is 8 in 100,000 from arsenic, PCBs, and dioxin.

Limitations

This health consultation is limited to chemical contaminants analyzed in Dungeness crab, coonstripe shrimp, and mussels from 2002 to 2012. It is uncertain how well the available data reflect current site conditions due to the age and limited quantity of these data. This health consultation does not evaluate biological hazards or other hazards, nor does it consider any seasonal harvesting restrictions in consumption rates. The health evaluation process uses maximum contaminant concentrations as a conservative approach to evaluate risks for potential health effects. As a result, this method may overestimate health risk and may not reflect a person's exposure over time; average concentrations are often preferred values to use for calculating long-term risk.

Next Steps

Recommendations

- Do not eat any crab hepatopancreas (crab butter) harvested from Port Angeles Harbor.
- We recommend eating no more than four (4) servings of crab meat each month from this harbor. Health risk can increase significantly if consuming more than 4 servings per month, or if other seafood is consumed in addition to the crab.
    - See Appendix G – Recommended Meal for details and serving sizes by body weight.
- Do not harvest any shellfish[c] from Port Angeles Harbor. This area is and has been permanently closed to shellfish harvesting due to pollution and ongoing biological hazards from sewage overflows. See website for map of closures: **www.doh.wa.gov/shellfishsafety**.
- Due to the age and limited quantity of data, we recommend more sampling of Port Angeles Harbor seafood in the future. We will work with stakeholders to ensure that future samples collected will be appropriate for health assessment purposes.

General Advice

The Washington State Department of Health encourages all Washingtonians to eat at least two seafood meals per week as part of a heart-healthy diet in accordance with American Heart Association recommendations. People may eat seafood more than two times weekly, but such frequent consumers should take the following advice to reduce exposure to contaminants in the seafood that they eat:

- Collect and eat seafood from a variety of locations away from urban bays, such as Port Angeles Harbor.
- Consider eating a variety of fish and shellfish that are low in contaminants according to guidance provided on our website at **www.doh.wa.gov/fish**.
- Consider eating an average serving size (about 8 oz. meat per meal for adults).
- Prepare proportionally smaller meals for young children.

Public Health Action Plan

1) We will develop a fact sheet for Port Angeles Harbor vicinity residents and visitors, and will work with Clallam County to distribute the fact sheets.
2) We will assist Clallam County in developing additional educational outreach materials (such as online resources or signage) as needed.
3) We will meet with stakeholders to discuss future sampling, and will assist in reviewing sampling plans to ensure that future samples are adequate for health assessment purposes.

[c] Shellfish means, for the purposes of chapter 246-280 WAC, all varieties of oysters, clams, mussels, and scallops. Washington State Department of Fish & Wildlife has also closed the harbor to clams and mussels year-round (WAC 220-56-350).

For More Information

If you have any questions about this health consultation contact Amy Leang at 360-236-3357 or 1-877-485-7316 at Washington State Department of Health. For more information about ATSDR, contact the Center for Disease Control and Prevention (CDC) Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's web site at **www.atsdr.cdc.gov**.

Purpose and Statement of Issues

The purpose of this health consultation is to evaluate health risks associated with consumption of contaminants in crab, shrimp, and mussels collected from Port Angeles Harbor. Clallam County Environmental Health requested that the Washington State Department of Health evaluate whether consumption of crab, shrimp and mussels from Port Angeles Harbor would pose health threats. This health consultation features

- Dungeness crab, mussels, and coonstripe shrimp as species evaluated for both non-cancer health effects and cancer risk,
- health assessment based on a state resident seafood consumption rate of 175 g/day[d] (for details, see Appendix B – Exposure Assumptions),
- supplementary health assessment using a higher seafood consumption rate from the Lower Elwha Klallam Tribe (LEKT), and
- recommended meal limits for identified contaminants of concern in crab.

Health consultations differs in scope and purpose from ongoing studies associated with hazardous waste cleanup sites in Port Angeles Harbor. A risk assessment conducted under the Washington State Department of Ecology (Ecology) Remedial Investigation/Feasibility Study (RI/FS) process is used to support the selection of a remedial measure at a site. However, the health consultation is a mechanism used to provide the impacted community with information on the public health implications of a specific site, identifying those populations for which further health actions or studies are needed. This evaluation is limited to chemical contaminants analyzed in these species sampled from 2002 to 2012.(1-3) It does not include the evaluation of biological hazards or other hazards nor does it consider seasonal harvesting restrictions.

Site Background

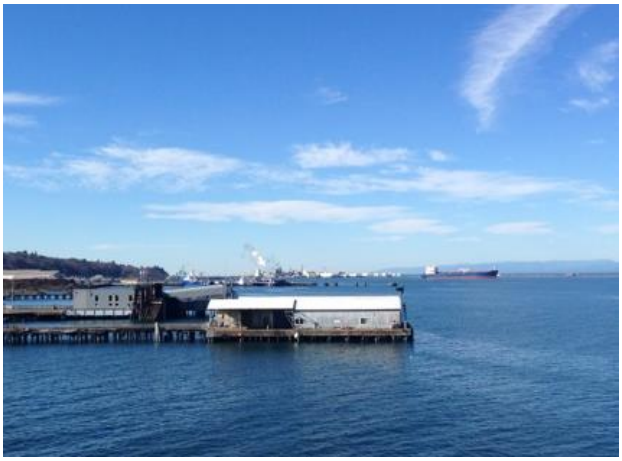
Site Description

Port Angeles Harbor is located in Clallam County, Washington. Port Angeles Harbor was identified by Ecology, under the Toxics Cleanup Program's Puget Sound Initiative, for focused sediment cleanup and source control. Past and current commercial and industrial activities in Port Angeles Harbor include cargo handling, boat manufacturing, marina operations, plywood manufacturing, pulp and paper mills, fishing enterprises, and ferry services.

In May 2007, the Clallam County Department of Health and Human Services issued an interim advisory on crab.(4) In June 2014, the Washington State Department of Health's Office of Shellfish and Water Protection (OSWP) was contacted by U.S. Environmental Protection Agency (EPA) about concerns from LEKT. The tribe was concerned that there were no signs posted around Port Angeles Harbor to warn people of chemical contamination hazards. OSWP then contacted Clallam County and provided signs to post.(5) The signs were not posted, however, because Clallam County expressed that the interim advisory in 2007 was influenced by

[d] This rate is under consideration for adoption within the Washington State Water Quality Standards. Currently, Water Quality Standards are based on a rate of 6.5 g/day, while the Model Toxics Control Act uses 54 g/day.

limited data analysis, there was little known about harvesting practices, and the City of Port Angeles did not want to unnecessarily alarm visitors to the harbor area.(5;6) Currently, Port Angeles Harbor is closed to shellfish harvesting primarily due to biological hazards, and the City of Port Angeles has signs installed to warn people of sewage overflow events (Figure 1b).



(a) (b)

Figure 1: (a) View of Port Angeles Harbor from waterfront with Nippon Industries in the background; (b) Sign installed by City of Port Angeles to warn about sewage overflow events. Port Angeles, Clallam County, Washington (2/17/2015).

Biota Samples

Although an interim advisory was issued by Clallam County to restrict harvesting from Port Angeles Harbor, some people are still crabbing and shrimping. People also occasionally pick up mussels while taking walks around the harbor.(6) Due to the available data on biota from this harbor and relevance of crab, shrimp, and mussels to the surrounding community, these three species were evaluated in this health consultation.(7) Other species that have been sampled in the past from the harbor include lingcod, horse clam, geoduck, and rock sole. These other species were not evaluated in this health consultation because there were not enough samples and/or samples were too dated (significantly greater than 10 years old) or not representative of the site to make health conclusions from.(7) Aside from various data gaps in biota sampling, this health consultation aims to address the main concerns of Port Angeles Harbor: crab, shrimp, and mussels.(6) Figure 2, below, shows the locations of where crab, shrimp, and mussels were sampled from, and the year(s) where sampling for these species occurred.

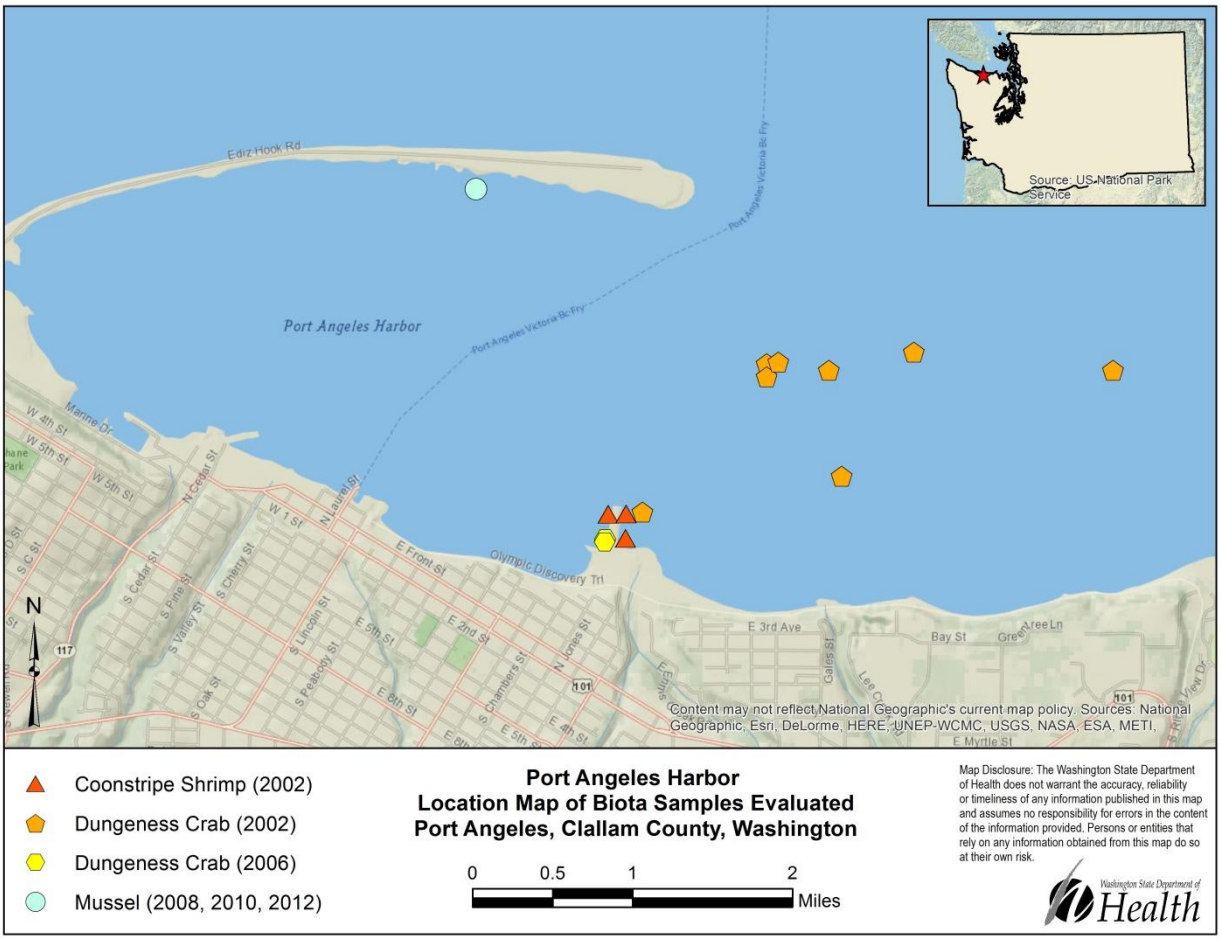


Figure 2: Locations of Crab, Shrimp and Mussel Samples Evaluated for Port Angeles Harbor Health Consultation, Port Angeles, Clallam County, Washington.

In 2002, whole coonstripe shrimp were sampled from the Rayonier Mill site dock while the Dungeness crab were mostly comprised of samples from over a mile away from the Rayonier Mill dock.(1) Later in 2006, individual crabs were sampled closer to the dock.(2) The mussels were sampled out by the salmon pens, west of the Coast Guard station on Ediz Hook.(8) Details on the numbers and types of chemicals analyzed for each of the species evaluated in this report can be viewed in Table 1, below.

Table 1: Summary Descriptions of Crab, Shrimp, and Mussel Samples Evaluated for Port Angeles Harbor Health Consultation, Port Angeles, Clallam County, Washington.

Species	Year(s) Collected	Study	Chemicals Analyzed	Tissue Type	Sample Type	Number of Samples	Number per Composite Sample
Coonstripe Shrimp	2002	Rayonier Marine RI (1)	Metals, PAHS, other SVOCs, PCBs, pesticides, dioxins and furans	Whole Body	Composite	3	7
Dungeness Crab	2002	Rayonier Marine RI (1)	Metals, PAHs, other SVOCs, PCBs, pesticides, dioxins and furans	Hepato-pancreas	Composite	3	5 to 8
				Muscle	Composite	3	5 to 8
	2006	Rayonier Phase 2 RI addendum (2)	PCBs, dioxins and furans	Hepato-pancreas	Individual	8	-
				Muscle	Individual	8	-
(*Mytilus* spp.)	2008, 2010, 2012	NOAA Mussel Watch* (3)	Metals, PAHS, other SVOCs, PCBs, pesticides	Tissue	Composite	3	60+

+ A minimum of 60 mussels were collected for tissue analysis.(8)
* Dioxin analysis was not included in NOAA Mussel Watch data because it is not a regularly analyzed contaminant in this monitoring program.(9)

Demographics

There is a population of about 15,000 people living within a mile of Port Angeles Harbor. Within this population, there are significant numbers of sensitive people: the young, older adults, pregnant, and immunocompromised (YOPI). Based on 2010 census data, this population includes

- 1,088 children aged six and younger,
- 2,841 seniors, and
- 2,592 women of child-bearing age.

Many Washington residents consume some local seafood. Native Americans, Asians, and Pacific Islanders are known to consume the highest amounts of seafood in Washington State. The population around Port Angeles Harbor is mostly white (about 90%). There was some growth in the numbers of Asians, Blacks, Other race(s), Pacific Islanders, and Hispanics/Latinos between 2000 and 2010. During that decade, there was little change in the Native American population, which was approximately 425 people. See Figure 3, below, for a general site profile from ATSDR.

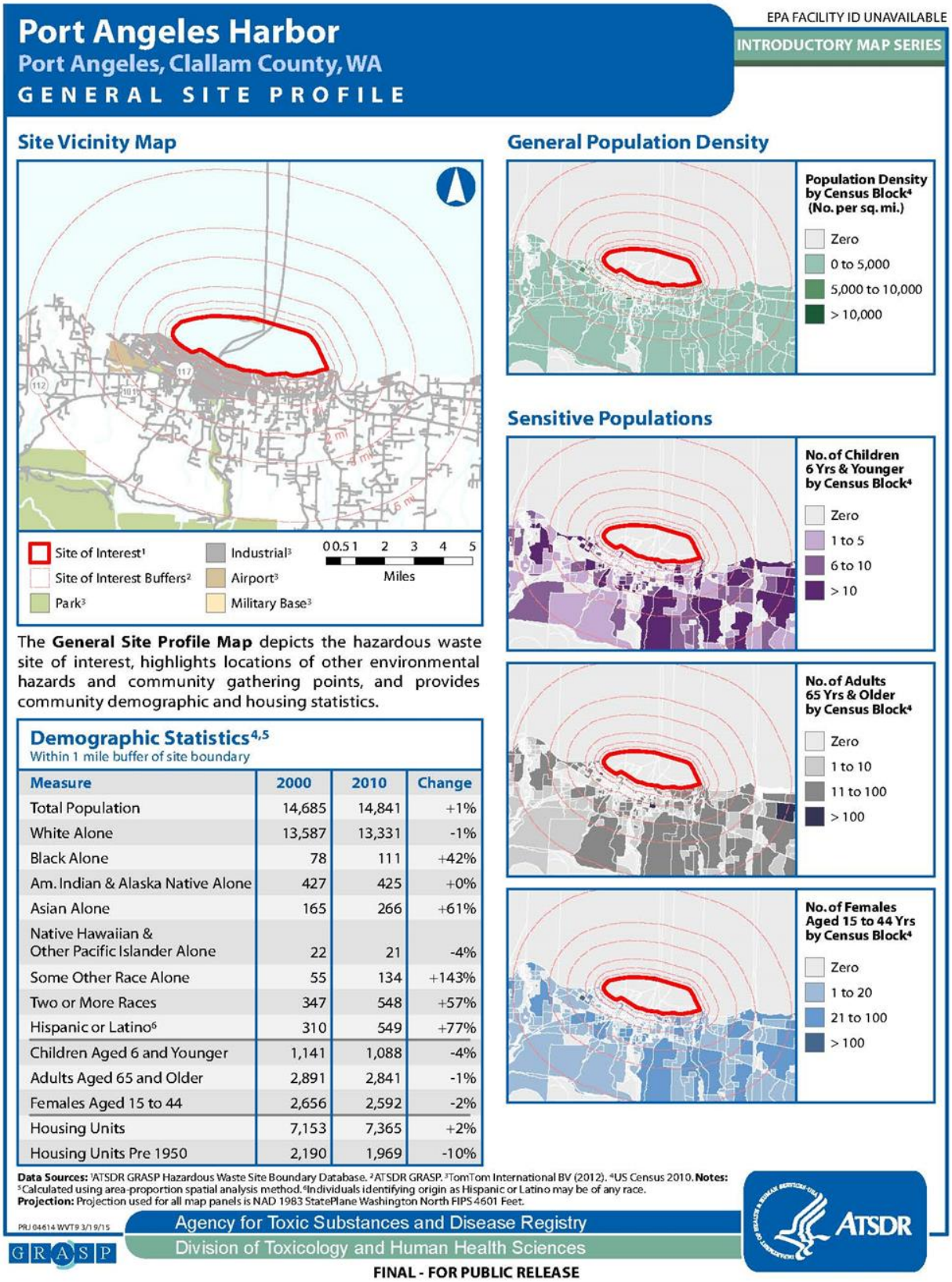


Figure 3: Demographic Statistics Map of the Port Angeles Harbor Vicinity, Port Angeles, Clallam County, Washington.

Community Health Concerns

There have been a number of community health concerns about high chemical contaminant levels in biota harvested from Port Angeles Harbor. In particular, the Lower Elwha Klallam Tribe (LEKT) had concerns about consuming dioxin and high levels of other carcinogenic contaminants that would bioaccumulate and result in high risk of cancer. LEKT also observed that some local residents who knew about Clallam County's interim advisory were still eating crab from Port Angeles Harbor because they did not feel sick immediately afterwards.(10) The Department of Health recognizes that there are many people who use this rationale when deciding to continue to eat seafood from contaminated waterbodies. It is a common misconception for many sites in Washington, especially in areas where subsistence harvesting is common. We continue to work on providing educational resources and communication to the public about the long-term consequences of exposures to chemicals and cumulative health risks. The evaluation of crab from this health consultation may be of particular interest to the community since crabbing is still popular in Port Angeles Harbor.(6;10)

Discussion

Exposure Pathways

To begin assessing possible health risks, exposure pathways need to be identified. An exposure pathway has five parts:

- Source of contamination (e.g. hazardous waste site);
- Environmental Media and Transport Mechanism (e.g. waterbodies);
- Point of Exposure (e.g. Port Angeles harbor docks);
- Route of Exposure (e.g. eating); and
- Receptor Population (e.g. harvesters).

An exposure pathway is complete when all five parts are present and when the source of contamination has reached the receptor population.(11) The receptor population includes anyone who eats crab, shrimp, or mussels harvested from Port Angeles Harbor. There is sufficient evidence that some people are consuming contaminated species, potentially at a state resident seafood consumption rate. This is no indication that tribal members are consuming seafood exclusively from this harbor at an LEKT consumption rate.

For this health consultation, we assumed that there is a completed exposure pathway at the state resident seafood consumption rate only. Therefore, any public health recommendations made in this health consultation will be based on significant findings at the state resident seafood consumption rate – not at the LEKT rate. The health screening and assessment carried out at the LEKT consumption rate is provided in Appendices E – F as supplementary information.

Contaminants of Concern Screening

Contaminants of concern (COC) were determined by employing a screening process. Screening values (SVs) were developed according to EPA guidance and are used to narrow the focus of evaluation to contaminants that are present at potential levels of public health concern.(11) We screened the highest levels detected of each contaminant with individual screening values for non-cancer health effects. Similarly, the highest levels of each carcinogenic compound detected were compared against screening values for cancer risk (see Appendices B and E).

With the exception of lead, SVs for chemicals that do not cause cancer represent levels that are not expected to cause any health problems (see Appendix D). For lead, SVs are primarily based on the goal of keeping children's blood lead levels below 5 micrograms per deciliter (µg/dL). These types of SVs often form the basis for cleanup goals.

If a contaminant is present but does not exceed the health comparison value, no further evaluation of that contaminant is necessary since we do not expect that it will pose a health threat. Also, no further evaluation is necessary if a contaminant was undetected in samples and not expected to be present in the area. When a contaminant is found to be above a health screening value, further evaluation of that contaminant is required. However, a contaminant found above the screening value does not necessarily mean that people are likely to become sick if they are exposed. All COCs were further evaluated in an exposure assessment.

Table 2: Contaminants of Concern found in Dungeness Crab, Shrimp, and Mussels from Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Species	Contaminants of Concern at WA State Consumption Rate		Contaminants of Concern at LEKT Consumption Rate	
	Non-cancer	Cancer	Non-cancer	Cancer
Dungeness Crab (muscle)	PCBs	arsenic, PCBs, dioxin	PCBs, dioxin, copper	arsenic, PCBs, dioxin
Dungeness Crab (hepatopancreas)	PCBs, dioxin, cadmium, copper	arsenic, PCBs, dioxin, DDT	PCBs, dioxin, cadmium, copper, arsenic, mercury, selenium	arsenic, PCBs, dioxin, DDT
Mussels		Arsenic		arsenic, PCBs, PAHs
Coonstripe Shrimp		Arsenic		arsenic, PCBs, dioxin

Chemical Specific Toxicity

Background information about some contaminants of concern, including those contaminants that were significant in the health assessment, is summarized below.

Arsenic

Arsenic is a naturally-occurring element in the Earth's crust. It is often referred to as a metal, although technically, it is a metalloid since it has properties of both metals and nonmetals. Arsenic is used in a variety of industrial applications. The most common application for arsenic is in wood preservation. Arsenic compounds are colorless, tasteless, and odorless, so it is difficult to tell whether arsenic is present in food, water, or air. Arsenic does not degrade, and can travel through the environment into different media including soil, sediment, surface water, groundwater, air, and also shellfish. Arsenic comes in two forms: organic and inorganic. Organic arsenic, often present in shellfish, is much less harmful to human health than inorganic arsenic. Inorganic arsenic is generally found in soil or sediment, and as a small portion of the arsenic in fish.(12) The form of arsenic assessed in this health consultation was inorganic arsenic.

All people are exposed to some levels of arsenic by eating food, drinking water, and breathing air. The most distinctive effect from exposure to elevated levels of arsenic is seen in the skin. Patches of darkened skin, corns, and other abnormal skin growth may appear on the palms, soles, and torso.(12) Arsenic is a known carcinogen (EPA Cancer Class A) and may cause skin cancer to develop, as well as liver, bladder, and lung cancer. Other common health effects include fatigue, abnormal heart rhythm, and nerve function impairment that cause "pins and needles" sensations in the hands and feet. It is unknown whether arsenic causes birth defects.

We evaluated the highest concentration of arsenic detected in crab, shrimp, and mussels. At the state resident seafood consumption rate used in the evaluation process, no non-cancer health effects are expected from arsenic. As shown in Table 2, above, arsenic contributes to the lifetime excess cancer risks calculated for consumption of crab, mussels, and shrimp. In particular, there are significant excess cancer risks expected from the consumption of crab. To view individual contributions of arsenic to cancer risk to each of the species evaluated, see Appendices C and F.

Cadmium

Cadmium is a naturally-occurring metal in the earth's crust, and is associated with zinc, lead, and copper ores. It can spread through the environment through mining and refining as well as through fossil fuel combustion and waste incineration processes. Consuming very high levels of cadmium may cause stomach irritation, leading to vomiting and diarrhea, and sometimes death. Ingesting lower levels of cadmium over a long period of time can be toxic to the kidneys, and may cause bones to become fragile. Health effects from dermal exposure have not been well characterized, and carcinogenic effects from cadmium have only been found from inhaling cadmium.(13)

The health effect level used in this assessment was based on the reference dose established by EPA for cadmium contamination in food. This reference dose was based on data from various

human studies. A symptom of excess cadmium exposure includes low molecular weight proteinuria, which results in increased secretion of proteins like enzymes and hormones in urine; this is an early sign of cadmium-induced kidney damage.(13) Later symptoms of kidney damage caused by cadmium include kidney stone formation and slower filtration rates. Depending on individual health and nutritional intake, long-term exposure to cadmium may also cause bone fractures or other skeletal problems like osteoporosis or decreased bone density.(13)

We evaluated the highest concentration of cadmium detected in crab, shrimp, and mussels. No adverse health effects are expected to occur at the consumption rates evaluated. See appendices for health comparison levels and estimated cadmium doses in crab hepatopancreas (appendices C and F).

Copper

Copper is a metal that naturally occurs in the earth's crust, and is also found naturally in all plants and animals. Organisms need a low level intake of copper for living. At higher levels, however, copper can produce toxic effects. Copper is commonly found is electrical wiring, water pipes, and other metal products. Copper compounds are also used in preserving wood, leather, and fabrics, and treating plant diseases. In addition to natural sources, high amounts of copper are commonly released into the environment in mines, smelters, landfills, and industrial settings through the incineration of fuels and wastes, wood production, and fertilizer production. Copper is not classifiable as a carcinogen, since there are no adequate human or animal studies. However, at high levels it can cause gastrointestinal distress, including nausea, vomiting, and diarrhea.(14)

Excess copper exposure is an additional health concern only in the supplementary evaluation of the LEKT consumption scenario. Gastrointestinal upset could occur shortly after consuming Dungeness crab hepatopancreas at the LEKT crab consumption rate. See Table F1 in Appendix F – Lower Elwha Klallam Tribe Cancer and Non-Cancer Exposure Assessment for health comparison level and estimated dose.

Dioxin

Dioxins are a group of many different compounds that have varying harmful human health effects. They are produced both naturally and through human activity. Naturally, dioxins are found in areas of high organic matter, such as ash, soil, or plants, and also by forest fires or active volcanoes. It is thought that most of the dioxins found in the environment are produced by human activity as a byproduct of incineration and combustion processes.(15) Industrial areas that involve these processes are likely to have dioxin contamination, such as Rayonier Mills. When dioxins enter the food chain, bioaccumulation is expected to occur since the molecules are hard for organisms to break down and don't readily dissolve in water.

The dioxin molecule called 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is one of the most toxic and often serves as a basis for quantifying mixtures of dioxin compounds. Most datasets, like the ones used in this health consultation, report dioxins as TCDD TEQs (toxic equivalents), which provides a meaningful way of quantifying the many different kinds of dioxins. In this report,

TCDD TEQs are referred to in general as “dioxins.”

Dioxins have also been found in all samples of human blood and fat tissues, even from people with no known exposures to dioxins. All people are exposed to very low levels of dioxins every day. The majority of dioxin for an average person comes from eating food, especially meats (including seafood) and dairy products. Infants are exposed to dioxins as well, since dioxins have been measured in human breast milk and infant formula. It can take over a decade for humans to eliminate half the amount of TCDD that has accumulated in the body. However, occupational exposures to high levels of dioxins have been significantly reduced over time since it has been recognized as a human health hazard.(15)

Very high levels of dioxin can cause health effects like chloracne, which can disfigure the face and upper body. Non-cancer health effects of dioxin can be severe but are reversible, and are expected to happen only after an accidental exposure to a very high level of dioxin.(16) For Port Angeles Harbor, repeated chronic, low-level exposures are more likely to happen. Dioxin is currently classified by EPA as Cancer Class B2, “a probable carcinogen,” due to evidence from animal studies. In general, chronic, low-level exposure in humans is not well-characterized in comparison to acute, high level acute exposures. Dioxins contribute significantly to the total cancer risk calculated for Dungeness crab tissues at the state resident consumption rate. At the LEKT consumption rate, dioxins contribute to cancer risk in shrimp as well as crab. The mussel dataset does not include data on dioxin to evaluate because dioxins are not regularly analyzed as part of the NOAA Mussel Watch program.(9) To view individual contributions of dioxin to lifetime excess cancer risk in crab and shrimp, see Appendices C and F.

DDT

DDT is a synthetic chemical that was once widely used as a pesticide to control the spread of vector borne diseases and to protect crops. DDT was banned in the United States in 1972 due to both environmental and human health concerns, and can no longer be used except in cases of public health emergencies. It is still manufactured and used in some other countries, primarily for the control of malaria. DDT does not readily break down, can travel long distances, and lasts in soil for many years. As with dioxin, DDT bioaccumulates in the food chain. The majority of DDT for an average person comes from eating food, especially meats (including seafood) and dairy products. Infants may be exposed to DDT through drinking breast milk. (17)

Acute effects from ingesting high levels of DDT include nervous system problems; people can experience tremors and seizures, sweating headache, nausea, vomiting, and dizziness. DDT exposure could also adversely the liver, adrenal glands, and reproductive processes although chronic, low-level exposures are not well-characterized in humans. Some studies have found that elevated DDE (a common breakdown product of DDT) serum levels measured in pregnant women is associated with shortened lactation time, increased chance of having a pre-term baby, and decreased height and delayed mental development in their young children.(18) DDT is currently classified as an EPA Class B2 probable carcinogen due to evidence from animal studies. DDT contributes to some of the lifetime excess cancer risk in crab hepatopancreas, the tissue that could cause a considerable increase in cancer risk at a state resident consumption rate as well as at the LEKT consumption rate. See Appendix C and F for details.

PAHs

Polycyclic aromatic hydrocarbons (PAHs) are a group of more than100 different chemicals formed from incomplete combustion of organic substances, like petroleum products, charbroiled meats, wood, and garbage. PAHs can be produced from both natural and industrial processes, and are often found in mixtures throughout the environment and in foods people eat every day. For example, PAHs are found in tobacco and wood smoke, cereals, bread, grains, fruits, meats, and dairy products. PAHs can also be found near forest fires, volcanoes, and hazardous waste sites where wood, petroleum, or any organic materials have been burned.(19)

The health effects of PAHs vary between each chemical; some chemicals are considered carcinogenic and more harmful than others. Benzo(a)pyrene and some other carcinogenic PAHs (cPAHs) are currently classified by EPA as Cancer Class B2 – "probable carcinogen" based on animal studies. In animal studies, ingesting PAHs can cause cancer and also some reproductive effects, such as reduced birth weight and birth defects. Other animal studies demonstrate that PAHs can also harm the immune system and skin. Human studies show that inhaling or touching PAHs and other chemicals in combination with PAHs may lead to cancer. The effects of consuming PAHs in humans are not well-characterized.(19)

In this assessment, toxic equivalency factors were determined for cPAHs based on the toxicity of benzo(a)pyrene in order to provide a means to quantify and assess cancer risk for mixtures of cPAHs. There is some cancer risk attributable to PAHs in mussels consumed in the LEKT consumption rate scenario. See Appendix F – Lower Elwha Klallam Tribe Cancer and Non-Cancer Exposure Assessment for details.

PCBs

Polychlorinated biphenyls (PCBs) are a group of synthetic chemicals that were once widely used as coolants and lubricants in electrical equipment. They are usually found as oily liquids or solids that are either clear or yellow in color. PCBs were also often mixed in with building materials, such as caulking, for good insulating properties. In 1977, the manufacturing of PCBs stopped because of evidence that PCBs were causing environmental and human health problems. PCBs don't readily break down in the environment and can bioaccumulate in the food chain. Although the manufacture of PCBs has stopped in the United States, PCBs can be released into the environment from hazardous waste sites, electrical transformers, burning of wastes in incinerators, and older buildings built before 1977.(20) People can still be exposed to PCBs regularly through using older transformers and capacitors (or any electrical device made before 1977), and also by accidentally ingesting particles from caulking with PCBs and PCB-contaminated dust from older buildings.

PCBs can travel long distances and are found all over the world. People are exposed to PCBs primarily through the consumption of food – especially seafood, meat, and dairy. Since contaminants like dioxin, DDT, and PCBs tend to be stored in fatty tissues in humans, infants may also be exposed to PCBs through drinking breast milk. The health effects of PCBs are not well-characterized in humans but based on animal studies, the immune system and cognitive function could be impacted with exposure to PCBs. There is also some evidence that some PCBs

can interfere with reproductive development in humans.(21) PCBs are classified as an EPA Cancer Class B2 probable carcinogen due to evidence from animal studies. PCBs contribute to the lifetime excess cancer risks calculated from Dungeness crab tissue samples. The chemicals also are a non-cancer health concern in hepatopancreas consumed at the LEKT crab consumption rate. See Appendices C and F for details.

Evaluating Non-cancer Hazards

Estimated doses for Washington State and the LEKT were calculated and shown in Appendices C and E. To calculate risk of non-cancer health effects, an estimated dose of each chemical is calculated using consumption rates specific to each species in which that chemical was analyzed. The state resident seafood consumption rate is based on a total seafood consumption rate of 175 grams per day. Doses calculated for LEKT were based on the tribe's reported consumption rates in a 2009 letter to Ecology.(22) See Appendix B for equations used for non-cancer health evaluation. For a conservative approach, all concentrations used in estimating chemical doses were maximum concentration levels of each chemical found in each species.

Estimated doses were then compared to oral MRLs (or RfDs). These MRLs are an estimate of the daily ingested dosages for humans that are likely to be without risk of adverse health effects for a specific duration of exposure. If MRLs are not available for certain chemicals, RfDs are used. RfDs are doses below which non-cancer adverse health effects are not expected to occur. Both MRLs and RfDs are derived from documented health effect levels observed in studies with either humans or animals.

Hazard quotients (HQs) are ratios between estimated doses and MRLs (or RfDs). See Appendix B for more on calculating HQs. When HQs are equal to or below 1, no adverse health effects are expected and additional evaluation of that chemical is unnecessary. However, when HQs exceed 1 for a contaminant, the estimated exposure dose is compared to a documented health effect dose for that chemical. These health levels are often documented as the no-observed-adverse-effect level (NOAEL[e]) or lowest-observed-adverse-effect level (LOAEL[f]). When an estimated dose for a chemical exceeds its documented health effect level, chemical-specific non-cancer health effects could occur.

HQ calculations and subsequent health comparison levels for COCs can be viewed in Appendices C and F. In the LEKT consumption scenario, eating crab hepatopancreas could cause non-cancer health effects from PCBs and copper; gastrointestinal irritation from copper could occur within 1-14 days of consumption, and decreased immune function and/or neurobehavioral problems from PCBs could occur after an intermediate duration (15 – 364 days). Eating crab at a state resident seafood consumption rate is unlikely to result in adverse non-cancer health effects. However, due to elevated HQs and potential non-cancer health risk from crab tissues, recommended meal limits are calculated for crab (see Appendix G – Recommended Meal).

[e] NOAEL: The highest exposure level at which there are no biologically significant increases in the frequency or severity of adverse effect between the exposed population and its appropriate control; some effects may be produced at this level, but they are not considered adverse or precursors of adverse effects (U.S. Environmental Protection Agency).
[f] LOAEL: The lowest exposure level at which there are biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group (U.S. Environmental Protection Agency).

Evaluating Exposure to Lead

The biokinetics of lead are different from most other chemicals because it is stored in bones and remains in the body long after it is ingested. Therefore, a different approach was used to assess the potential non-cancer health effects associated with exposure to lead because there are no MRLs or RfDs.[g] Instead, we used EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model. The IEUBK model predicts blood lead levels in a distribution of exposed children (ages 0 – 7) based on the amount of lead in environmental media, such as fish.

Based on these data, no public health action is necessary to address lead. See Appendix D – Lead Exposure Assessment for details on IEUBK model inputs and results.

Evaluating Cancer Risk

Cancer is a common illness that increases in susceptibility with age. There are many different forms of cancer resulting from a variety of causes, and not all are fatal. About 1 in 3 to 1 in 2 people living in the United States will develop cancer at some point in their lives.(23) Current regulatory practice assumes that there is no "safe" dose of a carcinogen, and that any dose of a carcinogenic chemical will result in some additional cancer risk. Cancer risk estimates are therefore measures of chance (probability). These measures, however uncertain, are useful in determining the magnitude of a cancer threat because any level of a carcinogenic contaminant carries an associated risk.

All contaminants that are possible carcinogens were evaluated further with cancer SVs, except for cadmium. Cadmium was not screened for cancer because it is only known to cause cancer through inhalation and not ingestion. For chemicals that are known to cause cancer through ingestion, excess lifetime cancer risk was estimated using calculated doses and chemical-specific cancer slope factors (CSF). See Appendix B for cancer risk calculations.

In this health consultation, cancer risk is considered significant to public health when exposure causes an excess lifetime cancer risk of 1 in 10,000 (1E-04) or higher. Therefore, in addition to the background risk of developing cancer (about 1 in 3 to 1 in 2), any given exposure predicted to cause one additional case of cancer among 10,000 similarly-exposed people during a lifetime is considered a public health hazard. Cancer risk was calculated for carcinogenic COC(s) found in each tissue type. Calculated cancer risks can be viewed in Appendices C and F. The tissue of most significant concern is crab hepatopancreas. If eaten at a state resident seafood consumption rate (as 30% of all seafood consumed), crab hepatopancreas from Port Angeles Harbor can cause a 1-in-100 excess lifetime cancer risk. Crab muscle was also a concern. If crab muscle is eaten at the same consumption rate, as 30% of all seafood consumed, it could cause a 3-in-10,000 excess lifetime cancer risk. Eating crab from Port Angeles Harbor at the evaluated consumption rates is a public health concern due to the excess lifetime cancer risks it presents.

[g] In 1988, the EPA decided against developing an RfD for lead due to the relatively high certainty of predicting its health effects with low levels in blood.

Children's Health Considerations

Children's health requires special attention in communities when there is contamination found in the environment. Children may be more vulnerable to exposure to environmental contaminants than adults; exposures and subsequent adverse health effects are often exacerbated for younger children compared to older children or adults. The following factors contribute to the increased vulnerability of children:

- Children are smaller and receive higher doses of chemical exposure per body weight.
- Children's developing bodies or systems are more vulnerable to toxic exposures especially during critical growth stages in which permanent damage may occur.

Children's health was considered in this health consultation, as well as more sensitive people that include the young, older adults, pregnant, and immunocompromised.

Conclusions

1) Consuming Dungeness crab meat or hepatopancreas from Port Angeles Harbor at a state resident seafood consumption rate could significantly increase the risk of cancer over a lifetime. However, the interim advisory for crabs issued by Clallam County can be updated to eat no more than four meals per month of crab muscle. Crab hepatopancreas should not be eaten.

2) Consuming mussels or coonstripe shrimp from Port Angeles Harbor at a state resident seafood consumption rate is not expected to harm human health based on the available chemical data.

3) Consuming Dungeness crab meat or hepatopancreas from Port Angeles Harbor at a Lower Elwha Klallam Tribe (LEKT) seafood consumption rate could significantly increase the risk of cancer over a lifetime. Eating hepatopancreas at this rate could additionally result in non-cancer health effects. This is a supplementary assessment; there are no indications that tribal members are exclusively consuming seafood from the harbor at the LEKT rate. Consuming mussels and shrimp from Port Angeles Harbor at the LEKT consumption rate is not expected to harm human health based on the available chemical data.

Limitations

This health consultation is limited to chemical contaminants analyzed in Dungeness crab, coonstripe shrimp, and mussels from 2002 to 2012. It is uncertain how well the available data reflect current site conditions due to the age and limited quantity of these data. This health consultation does not evaluate biological hazards or other hazards, nor does it consider any seasonal harvesting restrictions in consumption rates. The health evaluation process uses maximum contaminant concentrations as a conservative approach to evaluate risks for potential health effects. As a result, this method may overestimate health risk and may not reflect a person's exposure over time; average concentrations are often preferred values to use for calculating long-term risk.

Recommendations

- Do not eat any crab hepatopancreas (crab butter) harvested from Port Angeles Harbor.
- We recommend eating no more than four (4) servings of crab meat each month from this harbor. Health risk can increase significantly if consuming more than 4 servings per month, or if other seafood is consumed in addition to the crab.
    - See Appendix G – Recommended Meal for details and serving sizes by body weight.
- Do not harvest any shellfish[h] from Port Angeles Harbor. This area is and has been permanently closed to shellfish harvesting due to pollution and ongoing biological hazards from sewage overflows. See website for map of closures: **www.doh.wa.gov/shellfishsafety**.
- Due to the age and limited quantity of data, we recommend more sampling of Port Angeles Harbor seafood in the future. We will work with stakeholders to ensure that future samples collected will be appropriate for health assessment purposes.

General Advice

The Washington State Department of Health encourages all Washingtonians to eat at least two seafood meals per week as part of a heart-healthy diet in accordance with American Heart Association recommendations. People may eat seafood more than two times weekly, but such frequent consumers should take the following advice to reduce exposure to contaminants in the seafood that they eat:

- Collect and eat seafood from a variety of locations away from urban bays, such as Port Angeles Harbor.
- Consider eating a variety of fish and shellfish that are low in contaminants according to guidance provided on our website at **www.doh.wa.gov/fish**.
- Consider eating an average serving size (about 8 oz. meat per meal for adults).
- Prepare proportionally smaller meals for young children.

Public Health Action Plan

1) We will develop a fact sheet for Port Angeles Harbor vicinity residents and visitors, and will work with Clallam County to distribute the fact sheets.
2) We will assist Clallam County in developing additional educational outreach materials (such as online resources or signage) as needed.
3) We will meet with stakeholders to discuss future sampling, and will assist in reviewing sampling plans to ensure that future samples are adequate for health assessment purposes.

[h] Shellfish means, for the purposes of chapter 246-280 WAC, all varieties of oysters, clams, mussels, and scallops. Washington State Department of Fish & Wildlife has also closed the harbor to clams and mussels year-round (WAC 220-56-350).

Report Preparation

This health consultation for the Port Angeles Harbor Site was prepared by the Washington State Department of Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. This report was supported by funds from a cooperative agreement with ATSDR, U.S. Department of Health and Human Services. This document has not been reviewed and cleared by ATSDR.

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Appendix A – Glossary

Acute	Occurring over a short time (1 – 14 days) [compare with **chronic**].
Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Cancer Slope Factor (CSF)	A number assigned to a cancer causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Chronic	Occurring over a long time (more than 1 year) [compare with **acute**].
Screening Value (SV)	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The SV is used during the public health assessment process. Substances found in amounts greater than their SVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dose (for chemicals that are not radioactive)	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts Per Billion (ppb)/Parts Per Million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.

Appendix B – Exposure Assumptions and Preliminary Screening

Equations used in Health Risk Assessment

Non-cancer Health Effects	Cancer Health Effects
$SV = \frac{[(MRL\ or\ RfD) \times BW]}{CR}$ $Dose = (C \times CR)/BW$ $HQ = \frac{Dose}{MRL\ or\ RfD}$	$SV = \frac{\left[\left(\frac{RL}{CSF}\right) \times BW\right]}{CR}$ $Risk = Dose\ \times CSF$

SV = Screening value (mg/kg or ppm)
Dose (mg/kg/day)
Risk (unitless)
HQ = Hazard Quotient (unitless)
C = Concentration (mg/kg or ppm)
MRL = Minimal risk level (mg/kg/day)
RfD = Reference dose (mg/kg/day)
BW = Default mean body weight (kg) = 80 kg
RL = Risk level (unitless) = $1x10^{-5}$
CSF = Oral cancer slope factor $(mg/kg/day)^{-1}$, contaminant-specific
CR = Consumption Rate (kg/day) = 0.175 kg/day = 175 g/day (*total* seafood consumption)[i]

Individual Species CR for state resident, apportioned according to LEKT Shellfish CR (22):

- Dungeness crab: 52.5 g/day (30% of CR)
- Mussels: 17.5 g/day (10% of CR)
- Coonstripe Shrimp: 17.5 g/day (10% of CR)

Individual Species CR used in supplementary LEKT assessment (22):

- Dungeness crab: 149.4 g/day
- Mussels: 49.8 g/day, assumed
- Coonstripe Shrimp: 49.8 g/day

See Appendix E and F for LEKT assessment.

[i] This rate is under consideration for adoption within the Washington State Water Quality Standards. Currently, Water Quality Standards are based on a rate of 6.5 g/day, while the Model Toxics Control Act uses 54 g/day.

Table B1: Non-Cancer Screening of Maximum Concentrations Contaminants in Dungeness Crab at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Organic Compounds	Muscle Tissue (ppb)	Hepato-pancreas (ppb)	MRL (mg/kg/day)	Screening Value (ppb)	Reference
Total PCBs	**178.81**	**5799.52**	0.00002	30	Chronic Oral MRL Aroclor 1254
Total TCDD TEQ	6.6E-04	**3.8E-02**	1.00E-09	1.5E-03	Chronic Oral MRL 2,3,7,8-TCDD
4,4-DDE	0.80	13.00	0.0005	762	Intermediate Oral MRL p,p-DDT
4,4'-DDT	4.7	110	0.0005	762	Intermediate Oral MRL
alpha-BHC	NA	2	0.008	12190	Chronic Oral MRL
beta-BHC	NA	2.1	0.0006	914	Intermediate Oral MRL
delta-BHC	NA	0.82	0.00001	15	Intermediate Oral MRL gamma-BHC
2-Methylnaphthalene	0.56 U	0.56 U	0.04	60952	Chronic Oral MRL
Acenaphthene	0.08 U	0.79	0.6	914286	Intermediate Oral MRL
Acenaphthylene	0.12 U	0.95	0.03	45714	Pyrene RfD surrogate
Anthracene	0.12 U	0.95	10	15238095	Intermediate Oral MRL
Fluorene	0.37 U	0.48	0.04	60952	RfD, Chronic Oral
Naphthalene	0.55 U	0.87	0.6	914286	Intermediate Oral MRL
Phenanthrene	0.24	1.2	0.3	457143	Anthracene RfD surrogate
Benzo(a)anthracene	0.17 U	0.73	0.03	45714	Pyrene RfD surrogate
Benzo(a)pyrene	0.10 U	0.1 U	0.03	45714	Pyrene RfD surrogate
Benzo(b)fluoranthene	0.15 U	0.38	0.04	60952	Fluoranthene RfD surrogate
Benzo(k)fluoranthene	0.17 U	0.35	0.04	60952	Fluoranthene RfD surrogate
Benzo(g,h,i)perylene	0.20 U	0.34	0.03	45714	Pyrene RfD surrogate
Chrysene	0.17 U	0.66	0.03	45714	Pyrene RfD surrogate
Dibenz(a,h)anthracene	0.15 U	0.39	0.03	45714	Pyrene RfD surrogate
Fluoranthene	0.37 U	1.3	0.04	60952	RfD, Chronic Oral
Indeno(1,2,3-cd)pyrene	0.18 U	0.33	0.04	60952	Fluoranthene RfD surrogate
Pyrene	0.39 U	1.2	0.03	45714	Oral RfD
Pyridine	18 U	18 U	0.001	1524	Oral RfD

Table B1 continued

Inorganics	Muscle Tissue (ppm)	Hepato-pancreas (ppm)	MRL or RfD (mg/kg/day)	Screening Value (ppm)	Reference
Arsenic (Inorganic)	0.01	0.23	0.0003	0.5	Chronic Oral MRL
Cadmium	0.02	**3.66**	0.001	1.5	Chronic Oral MRL
Copper	5.64	**99.8**	0.01	15.2	Intermediate Oral MRL
Lead	0.01	0.05	NA	NA	See Appendix D
Mercury	0.11	0.22	0.0003	0.5	Chronic Oral MRL methylmercury
Selenium	0.9	2.8	0.005	7.6	Chronic Oral MRL
Zinc	50.2	25.3	0.3	457.1	Chronic Oral MRL

ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U – Undetected; J – Estimated; NA – Not Analyzed
MRL: Chronic Oral Minimal Risk Level from Agency for Toxic Substances and Disease Registry
RfD: Reference Dose from Environmental Protection Agency
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Table B2: Cancer Screening of Contaminants in Dungeness Crab at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Inorganics	EPA Cancer Class	Muscle Tissue (ppm)	Hepatopancreas (ppm)	Cancer Slope Factor $(mg/kg/day)^{-1}$	Screening Value (ppm)
Arsenic (Inorganic)	A	**0.01**	**0.23**	5.7	0.00267
Organohalogens	**EPA Cancer Class**	**Muscle Tissue (ppb)**	**Hepatopancreas (ppb)**	**Cancer Slope Factor $(mg/kg/day)^{-1}$**	**Screening Value (ppb)**
Total PCBs	B2	**178.81**	**5799.52**	2	8
Total TCDD TEQ	B2	**6.60E-04**	**3.80E-02**	1.50E+05	1.00E-04
4,4-DDE	B2	0.8	13	0.34	45
4,4'-DDT	B2	4.7	**110**	0.34	45

Table B2 continued

cPAHs	EPA Cancer Class	TEF	Muscle Tissue TEF (ppb)	Hepato-pancreas TEF (ppb)	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Screening Value (ppb)
benz(a)anthracene	B2	0.1	0.017 U	0.073	7.3	2.1
chrysene		0.01	0.0017 U	0.0066		
benzo(b)fluoranthene		0.1	0.015 U	0.038		
benzo(k)fluoranthene		0.1	0.017 U	0.035		
benzo(a)pyrene		1	0.1 U	0.1 U		
indeno(1,2,3-c,d)pyrene		0.1	0.018 U	0.033		
dibenz(a,h)anthracene		0.1	0.015 U	0.039		
Total cPAH TEQ			0.18	0.32		

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U: not detected, reporting limit
cPAHS: carcinogenic polycyclic aromatic hydrocarbons; TEQ: toxic equivalent; TEF: Toxic Equivalency Factor
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Table B3: Non-Cancer Screening of Contaminants in Mussels and Coonstripe Shrimp at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Organic Compounds	Mussels (ppb)	Coonstripe Shrimp (ppb)	MRL (mg/kg/day)	Screening Value (ppb)	Reference
Total PCBs	12 J	17 U	0.00002	91	Chronic Oral MRL Aroclor 1254
Total TCDD TEQ	NA	2.11E-04	1.00E-09	0.005	Chronic Oral MRL 2,3,7,8-TCDD
1,6,7-Trimethylnaphthalene	2	NA	0.6	2742857	Intermediate Oral MRL, Naphthalene surrogate
18a-Oleanane	6.6	NA	0.03	137143	Pyrene RfD surrogate
1-Methylnaphthalene	2.1	NA	0.07	320000	Chronic Oral MRL
1-Methylphenanthrene	3.2	NA	0.3	1371429	Anthracene RfD surrogate
2,6-Dimethylnaphthalene	1.8	NA	0.04	182857	Chronic Oral MRL
2-Methylnaphthalene	3.2	1.8	0.04	182857	Chronic Oral MRL
Acenaphthene	12	4.8	0.6	2742857	Intermediate Oral MRL
Acenaphthylene	0.66	0.55	0.03	137143	Pyrene RfD surrogate
Anthracene	2.3	0.32	10	45714286	Intermediate Oral MRL
Benz[a]anthracene	2.8	0.43	0.03	137143	Pyrene RfD surrogate
Benzo[a]pyrene	1.2	0.10 U	0.03	137143	Pyrene RfD surrogate
Benzo[b]fluoranthene	5.6	0.32	0.04	182857	Fluoranthene RfD surrogate
Benzo[e]pyrene	3.7	NA	0.03	137143	Pyrene RfD surrogate
Benzo[g,h,i]perylene	0.84	0.20 U	0.03	137143	Pyrene RfD surrogate
Benzo[k]fluoranthene	3.4	0.17 U	0.04	182857	Fluoranthene RfD surrogate
Benzothiophene	0.17 J	NA	0.6	2742857	Intermediate Oral MRL
Biphenyl	2.1	NA	0.5	2285714	Oral RfD for Biphenyl, 1,1'-
C29-Hopane	9.9	NA	-	-	NA
Carbazole	0.31 J	NA	-	-	NA
Chrysene	7.7	0.55	0.03	137143	Pyrene RfD surrogate
Dibenzo[a,h]anthracene	0.17 J	0.15 U	0.03	137143	Pyrene RfD surrogate
Dibenzofuran	3.4	NA	0.001	4571	Provisional Peer-reviewed Toxicity Value, EPA

Table B3 continued

Dibenzothiophene	1.4	NA	0.01	45714	Provisional Peer-reviewed Toxicity Value, EPA
Fluoranthene	26	2.7	0.04	182857	RfD, Chronic Oral
Fluorene	4.3	0.77	0.04	182857	RfD, Chronic Oral
Indeno[1,2,3-c,d]pyrene	0.67	0.18 U	0.04	182857	Fluoranthene RfD surrogate
Naphthalene	3.9	5.2	0.6	2742857	Intermediate Oral MRL
Naphthobenzothiophene	2	NA	-	-	
Perylene	1.1	NA	0.03	137143	Pyrene RfD surrogate
Phenanthrene	24	3.2	0.3	1371429	Anthracene RfD surrogate
Pyrene	15	1.7	0.03	137143	Oral RfD
Pyridine	NA	280	0.001	4571	
2,4'-DDT	0.091	NA	0.0005	2286	Intermediate Oral MRL p,p-DDT
4,4'-DDD	0.17	NA	0.0005	2286	Intermediate Oral MRL p,p-DDT
4,4'-DDE	1.1	NA	0.0005	2286	Intermediate Oral MRL p,p-DDT
4,4'-DDT	0.067	1.3	0.0005	2286	Intermediate Oral MRL
Alpha-Chlordane	0.16	NA	0.0006	2743	Chronic Oral MRL Chlordane
alpha-Hexachlorocyclohexane	NA	0.64	8.00E-03	36571	Chronic Oral MRL
Beta-Hexachlorocyclohexane	0.94	6	0.0006	2743	Intermediate Oral MRL
Cis-Nonachlor	0.1	NA	0.0006	2743	Chronic Oral MRL Chlordane
Dieldrin	0.16	NA	0.00005	229	Chronic Oral MRL
Endosulfan I	0.054	NA	0.005	22857	Chronic Oral MRL
Endosulfan II	0.11	NA	0.005	22857	Chronic Oral MRL
Endosulfan Sulfate	0.05	NA	0.005	22857	Chronic Oral MRL Endosulfan
Endrin	0.019 J	NA	0.0003	1371	Chronic Oral MRL
Gamma-Chlordane	0.062	NA	0.0006	2743	Chronic Oral MRL Chlordane
Gamma-Hexachlorocyclohexane	0.074	NA	0.00001	46	Intermediate Oral MRL
Hexachlorobenzene	0.28	NA	0.00007	320	Chronic Oral MRL

Table B3 continued

Pentachloroanisole	0.21	NA	0.001	4571	Chronic Oral MRL Pentachlorophenol
Trans-Nonachlor	0.18	NA	0.0006	2743	Chronic Oral MRL Chlordane
Dibutyltin	0.32 J	NA	0.005	22857	Intermediate Oral MRL
Monobutyltin	0.12 J	NA	0.005	22857	Intermediate Oral MRL Dibutyltin
Tributyltin	0.66	NA	0.0003	1371	Chronic Oral MRL
Inorganics	**Mussels (ppm)**	**Coonstripe Shrimp (ppm)**	**MRL or RfD (mg/kg/day)**	**Screening Value (ppm)**	**Reference**
Aluminum	32	NA	1	4571	Chronic Oral MRL
Arsenic (inorganic)	0.011	0.01	0.0003	1.4	Chronic Oral MRL
Cadmium	0.65	0.04	0.001	4.6	Chronic Oral MRL
Chromium	0.12	NA	0.0009	4.1	Chronic Oral MRL
Copper	1.6	5.14	0.01	46	Intermediate Oral MRL
Iron	82	NA	3600	16457143	Tolerable Upper adult intake level, NIH
Lead	0.054	0.01	NA	NA	See Appendix D
Manganese	1.6	NA	0.14	640	Oral RfD
Mercury	0.0075	0.03	0.0003	1.4	Chronic Oral MRL methylmercury
Nickel	0.15	NA	0.02	91	Oral RfD
Selenium	0.64	0.20 U	0.005	23	Chronic Oral MRL
Silver	0.0027	NA	0.005	23	Oral RfD
Tin	0.0075	NA	0.3	1371	Intermediate Oral MRL
Zinc	24	12.6	0.3	1371	Chronic Oral MRL

ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U – Undetected; J – Estimated; NA – Not Analyzed
MRL: Chronic Oral Minimal Risk Level from Agency for Toxic Substances and Disease Registry
RfD: Reference Dose from Environmental Protection Agency
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Table B4: Cancer Screening of Contaminants in Mussels and Coonstripe Shrimp at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Inorganics	**EPA Cancer Class**	**Mussels (ppm)**	**Coonstripe Shrimp (ppm)**	**Oral Cancer Slope Factor $(mg/kg/day)^{-1}$**	**Screening Value (ppm)**
Arsenic (Inorganic)	A	**0.0112**	**0.01**	5.7	0.00802
Organic Compounds	**EPA Cancer Class**	**Mussels (ppb)**	**Coonstripe Shrimp (ppb)**	**Oral Cancer Slope Factor $(mg/kg/day)^{-1}$**	**Screening Value (ppb)**
Total PCBs	B2	12 J	17 U	2	23
Total TCDD TEQ	B2	NA	2.11E-04	1.50E+05	3.00E-04
4,4'-DDD	B2	0.1666	NA	0.24	190
4,4'-DDE	B2	1.1088	NA	0.34	134
4,4'-DDT	B2	0.0672	1.3	0.34	134
Alpha-Chlordane	B2	0.1596	NA	0.35	131
Dieldrin	B2	0.1568	NA	16	3
Gamma-Chlordane	B2	0.0616	NA	0.35	131
Hexachlorobenzene	B2	0.2805	NA	1.6	29
alpha-BHC	B2	NA	0.64	6.3	7
beta-BHC	C	NA	6	1.8	25

Table continued below

Table B4 continued

cPAHs	EPA Cancer Class	TEF	Mussels TEF (ppb)	Shrimp TEF (ppb)	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Screening Value (ppb)
benz(a)anthracene	B2	0.1	0.28	0.043	7.3	6.3
chrysene		0.01	0.077	0.0055		
benzo(b)fluoranthene		0.1	0.56	0.032		
benzo(k)fluoranthene		0.1	0.34	0.017		
benzo(a)pyrene		1	1.2	0.1		
indeno(1,2,3-c,d)pyrene		0.1	0.067	0.018		
dibenzo(a,h)anthracene		0.1	0.017	0.015		
Total cPAH TEQ			2.5	0.23		

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U: not detected, reporting limit
cPAHS: carcinogenic polycyclic aromatic hydrocarbons; TEQ: toxic equivalent; TEF: Toxic Equivalency Factor
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Appendix C – Cancer and Non-cancer Exposure Assessment

Table C1: Hazard Quotients and Health Assessment of Contaminants of Concern in Dungeness Crab at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Contaminant of Concern	MRL or RfD (mg/kg/day)	Crab Tissue Type	Maximum Concentration (ppm)	Estimated Dose (mg/kg/day)	Hazard Quotient (Dose/MRL)	NOAEL or LOAEL (mg/kg/day)
Total PCBS	0.00002	Muscle	0.18	1.2E-04	6	5.00E-03
		Hepatopancreas	5.8	3.8E-03	190	5.00E-03
TCDD TEQ	1.00E-09	Hepatopancreas	3.80E-05	2.5E-08	25	1.20E-07
Cadmium	0.001	Hepatopancreas	3.66	2.4E-03	2.4	1.0E-02
Copper	0.01	Hepatopancreas	99.8	6.5E-02	7	9.10E-02

MRL: Chronic Oral Minimal Risk Level from Agency for Toxic Substances and Disease Registry (ATSDR)
RfD: Reference Dose from Environmental Protection Agency (EPA); ppm: parts per million; mg: milligram; kg: kilogram body weight;
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
PCBs, TCDD TEQ, and Copper Comparison Doses: LOAEL: Lowest Observed Adverse Effect Level, ATSDR
Cadmium Comparison Dose: NOAEL: No Observed Adverse Effect Level, EPA

No estimated dose exceeds NOAEL/LOAEL, so adverse health effects are unlikely to occur at this consumption rate. However, recommended meal limits will be calculated for this tissue due to the presence of very high hazard quotients.

Table C2: Cancer Risk of Contaminants of Concern in Crab Muscle at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.01	6.60E-06	4.0E-05
Total PCBs	B2	2	0.17881	1.20E-04	2.3E-04
Total TCDD TEQ	B2	1.50E+05	6.60E-07	4.30E-10	6.5E-05
Lifetime Cancer Risk from Crab Muscle					**3.4E-04**

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen; Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent; ppm: parts per million; mg: milligram; kg: kilogram body weight

Table C3: Cancer Risk of Contaminants of Concern in Crab Hepatopancreas at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.23	1.50E-04	8.6E-04
Total PCBs	B2	2	5.79952	3.80E-03	7.6E-03
Total TCDD TEQ	B2	1.50E+05	3.80E-05	2.50E-08	3.8E-03
4,4'- DDT	B2	3.40E-01	1.10E-01	7.20E-05	2.5E-05
Lifetime Cancer Risk from Crab Hepatopancreas					**1.2E-02**

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen; Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
ppm: parts per million; mg: milligram; kg: kilogram body weight

Table C4: Cancer Risk of Contaminants of Concern in Mussels at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.0112	2.5E-06	1.4E-05

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen
ppm: parts per million; mg: milligram; kg: kilogram body weight

Table C5: Cancer Risk of Contaminants of Concern in Coonstripe Shrimp at a State Resident Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.01	2.2E-06	1.2E-05

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen
ppm: parts per million; mg: milligram; kg: kilogram body weight

Appendix D – Lead Exposure Assessment

Table D1: Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Results, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Tissue	Meat Diet Fraction (%)	Maximum Concentration (ppm)	Results (%≥ 5 µg/dL BLL*)	Lead [Pb] Public Health Hazard
Mussels	10	0.054	0.009	No
Shrimp	10	0.01	0.007	No
Crab muscle	30	0.01	0.007	No
Crab hepatopancreas	30	0.05	0.015	No

*Blood lead level (BLL) reference level at which the CDC recommends public health action.
%: percent; ppm: parts per million, µg/dL: micrograms per deciliter.

In this statistical model, it was conservatively assumed that all meats consumed in a child's diet are seafood. The meat diet fractions listed for each tissue type are consistent with fish diet fractions used throughout this health consultation. IEUBK model has set parameters for total meat intake ranging from 29.6 g/day to 121 g/day for children ages 0 – 7 years. On average, the amounts of mussels, shrimp, and crab consumed in this model would exceed that of the 90th percentile Suquamish Tribe child. Based on existing consumption survey studies, the Suquamish are the high-end tribal consumers of seafood in Washington State.(24)

Less than 5% of young children are predicted to have elevated blood lead levels (≥ 5 µg/dL) from the consumption of mussels, shrimp, or crab from Port Angeles Harbor; therefore, no public health action is warranted regarding lead [Pb] in these species evaluated.

Appendix E – Lower Elwha Klallam Tribe Preliminary Screening

Table E1: Non-Cancer Screening Results of Contaminants in Dungeness Crab at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Organic Compounds	Muscle Tissue (ppb)	Hepato-pancreas (ppb)	MRL (mg/kg/day)	Screening Value (ppb)	Reference
Total PCBs	**178.81**	**5799.52**	0.00002	11	Chronic Oral MRL Aroclor 1254
Total TCDD TEQ	**6.60E-04**	**3.80E-02**	1.00E-09	5.4E-04	Chronic Oral MRL 2,3,7,8-TCDD
4,4-DDE	0.8	13	0.0005	268	Intermediate Oral MRL p,p-DDT
4,4'-DDT	4.7	110	0.0005	268	Intermediate Oral MRL
alpha-BHC	NA	2	0.008	4284	Chronic Oral MRL
beta-BHC	NA	2.1	0.0006	321	Intermediate Oral MRL
delta-BHC	NA	0.82	0.00001	5	Intermediate Oral MRL gamma-BHC
2-Methylnaphthalene	0.56 U	0.56 U	0.04	21419	Chronic Oral MRL
Acenaphthene	0.08 U	0.79	0.6	321285	Intermediate Oral MRL
Acenaphthylene	0.12 U	0.95	0.03	16064	Pyrene RfD surrogate
Anthracene	0.12 U	0.95	10	5354752	Intermediate Oral MRL
Fluorene	0.37 U	0.48	0.04	21419	RfD, Chronic Oral
Naphthalene	0.55 U	0.87	0.6	321285	Intermediate Oral MRL
Phenanthrene	0.24	1.2	0.3	160643	Anthracene RfD surrogate
Benzo(a)anthracene	0.17 U	0.73	0.03	16064	Pyrene RfD surrogate
Benzo(a)pyrene	0.10 U	0.1 U	0.03	16064	Pyrene RfD surrogate
Benzo(b)fluoranthene	0.15 U	0.38	0.04	21419	Fluoranthene RfD surrogate
Benzo(k)fluoranthene	0.17 U	0.35	0.04	21419	Fluoranthene RfD surrogate
Benzo(g,h,i)perylene	0.20 U	0.34	0.03	16064	Pyrene RfD surrogate
Chrysene	0.17 U	0.66	0.03	16064	Pyrene RfD surrogate
Dibenz(a,h)anthracene	0.15 U	0.39	0.03	16064	Pyrene RfD surrogate
Fluoranthene	0.37 U	1.3	0.04	21419	RfD, Chronic Oral
Indeno(1,2,3-cd)pyrene	0.18 U	0.33	0.04	21419	Fluoranthene RfD surrogate

Table E1 continued

Pyrene	0.39 U	1.2	0.03	16064	Oral RfD
Pyridine	18 U	18 U	0.001	535	Oral RfD
Inorganics	**Muscle Tissue (ppm)**	**Hepato-pancreas (ppm)**	**MRL or RfD (mg/kg/day)**	**Screening Value (ppm)**	**Reference**
Arsenic (Inorganic)	0.01	**0.23**	0.0003	0.16	Chronic Oral MRL
Cadmium	0.02	**3.66**	0.001	0.54	Oral RfD
Copper	**5.64**	**99.8**	0.01	5.4	Intermediate Oral MRL
Lead	0.01	0.05	NA	NA	See Appendix D
Mercury	0.11	**0.22**	0.0003	0.16	Chronic Oral MRL methylmercury
Selenium	0.9	**2.8**	0.005	2.7	Chronic Oral MRL
Zinc	50.2	25.3	0.3	160.6	Chronic Oral MRL

ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U – Undetected; J – Estimated; NA – Not Analyzed
MRL: Chronic Oral Minimal Risk Level from Agency for Toxic Substances and Disease Registry
RfD: Reference Dose from Environmental Protection Agency
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Table E2: Cancer Screening of Contaminants in Dungeness Crab at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Inorganics	**EPA Cancer Class**	**Muscle Tissue (ppm)**	**Hepatopancreas (ppm)**	**Cancer Slope Factor (mg/kg/day)$^{-1}$**	**Screening Value (ppm)**
Arsenic (Inorganic)	A	**0.01**	**0.23**	5.7	0.00094
Organic Compounds	**EPA Cancer Class**	**Muscle Tissue (ppb)**	**Hepatopancreas (ppb)**	**Cancer Slope Factor (mg/kg/day)$^{-1}$**	**Screening Value (ppb)**
Total PCBs	B2	**178.81**	**5799.52**	2	3
Total TCDD TEQ	B2	**6.60E-04**	**3.80E-02**	1.50E+05	3.60E-05
4,4-DDE	B2	0.8	13	0.34	16
4,4'-DDT	B2	4.7	**110**	0.34	16

Table E2 continued

cPAHs	EPA Cancer Class	TEF	Muscle Tissue TEF (ppb)	Hepato-pancreas TEF (ppb)	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Screening Value (ppb)
benz(a)anthracene	B2	0.1	0.017	0.073	7.3	0.73
chrysene		0.01	0.0017	0.0066		
benzo(b)fluoranthene		0.1	0.015	0.038		
benzo(k)fluoranthene		0.1	0.017	0.035		
benzo(a)pyrene		1	0.1	0.1		
indeno(1,2,3-c,d)pyrene		0.1	0.018	0.033		
dibenz(a,h)anthracene		0.1	0.015	0.039		
Total cPAH TEQ			0.18	0.32		

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U: not detected, reporting limit
cPAHS: carcinogenic polycyclic aromatic hydrocarbons; TEQ: toxic equivalent; TEF: Toxic Equivalency Factor
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Table E3: Non-Cancer Screening Results of Contaminants in Mussels and Coonstripe Shrimp at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Organic Compounds	Musselx (ppb)	Coonstripe Shrimp (ppb)	MRL (mg/kg/day)	Screening Value (ppb)	Reference
Total PCBs	12 J	17 U	0.00002	32	Chronic Oral MRL Aroclor 1254
Total TCDD TEQ	NA	2.11E-04	1.00E-09	1.6E-03	Chronic Oral MRL 2,3,7,8-TCDD
1,6,7-Trimethylnaphthalene	2	NA	0.6	963855	Intermediate Oral MRL, Naphthalene surrogate
18a-Oleanane	6.6	NA	0.03	48193	Pyrene RfD surrogate
1-Methylnaphthalene	2.1	NA	0.07	112450	Chronic Oral MRL
1-Methylphenanthrene	3.2	NA	0.3	481928	Anthracene RfD surrogate
2,6-Dimethylnaphthalene	1.8	NA	0.04	64257	Chronic Oral MRL

Table E3 continued

2-Methylnaphthalene	3.2	1.8	0.04	64257	Chronic Oral MRL
Acenaphthene	12	4.8	0.6	963855	Intermediate Oral MRL
Acenaphthylene	0.66	0.55	0.03	48193	Pyrene RfD surrogate
Anthracene	2.3	0.32	10	16064257	Intermediate Oral MRL
Benz[a]anthracene	2.8	0.43	0.03	48193	Pyrene RfD surrogate
Benzo[a]pyrene	1.2	0.10 U	0.03	48193	Pyrene RfD surrogate
Benzo[b]fluoranthene	5.6	0.32	0.04	64257	Fluoranthene RfD surrogate
Benzo[e]pyrene	3.7	NA	0.03	48193	Pyrene RfD surrogate
Benzo[g,h,i]perylene	0.84	0.20 U	0.03	48193	Pyrene RfD surrogate
Benzo[k]fluoranthene	3.4	0.17 U	0.04	64257	Fluoranthene RfD surrogate
Benzothiophene	0.17 J	NA	0.6	963855	Intermediate Oral MRL
Biphenyl	2.1	NA	0.5	803213	Oral RfD for Biphenyl, 1,1'-
C29-Hopane	9.9	NA	-	-	NA
Carbazole	0.31 J	NA	-	-	NA
Chrysene	7.7	0.55	0.03	48193	Pyrene RfD surrogate
Dibenzo[a,h]anthracene	0.17 J	0.15 U	0.03	48193	Pyrene RfD surrogate
Dibenzofuran	3.4	NA	0.001	1606	Provisional Peer-reviewed Toxicity Value, EPA
Dibenzothiophene	1.4	NA	0.01	16064	Provisional Peer-reviewed Toxicity Value, EPA
Fluoranthene	26	2.7	0.04	64257	RfD, Chronic Oral
Fluorene	4.3	0.77	0.04	64257	RfD, Chronic Oral
Indeno[1,2,3-c,d]pyrene	0.67	0.18 U	0.04	64257	Fluoranthene RfD surrogate
Naphthalene	3.9	5.2	0.6	963855	Intermediate Oral MRL
Naphthobenzothiophene	2	NA	-	-	
Perylene	1.1	NA	0.03	48193	Pyrene RfD surrogate
Phenanthrene	24	3.2	0.3	481928	Anthracene RfD surrogate
Pyrene	15	1.7	0.03	48193	Oral RfD

Table E3 continued

Pyridine	NA	280	0.001	1606	
2,4'-DDT	0.091	NA	0.0005	803	Intermediate Oral MRL p,p-DDT
4,4'-DDD	0.17	NA	0.0005	803	Intermediate Oral MRL p,p-DDT
4,4'-DDE	1.1	NA	0.0005	803	Intermediate Oral MRL p,p-DDT
4,4'-DDT	0.067	1.3	0.0005	803	Intermediate Oral MRL
Alpha-Chlordane	0.16	NA	0.0006	964	Chronic Oral MRL Chlordane
alpha-Hexachlorocyclohexane	NA	0.64	8.00E-03	12851	Chronic Oral MRL
Beta-Hexachlorocyclohexane	0.94	6	0.0006	964	Intermediate Oral MRL
Cis-Nonachlor	0.1	NA	0.0006	964	Chronic Oral MRL Chlordane
Dieldrin	0.16	NA	0.00005	80	Chronic Oral MRL
Endosulfan I	0.054	NA	0.005	8032	Chronic Oral MRL
Endosulfan II	0.11	NA	0.005	8032	Chronic Oral MRL
Endosulfan Sulfate	0.05	NA	0.005	8032	Chronic Oral MRL Endosulfan
Endrin	0.019 J	NA	0.0003	482	Chronic Oral MRL
Gamma-Chlordane	0.062	NA	0.0006	964	Chronic Oral MRL Chlordane
Gamma-Hexachlorocyclohexane	0.074	NA	0.00001	16	Intermediate Oral MRL
Hexachlorobenzene	0.28	NA	0.00007	112	Chronic Oral MRL
Pentachloroanisole	0.21	NA	0.001	1606	Chronic Oral MRL Pentachlorophenol
Trans-Nonachlor	0.18	NA	0.0006	964	Chronic Oral MRL Chlordane
Dibutyltin	0.32 J	NA	0.005	8032	Intermediate Oral MRL
Monobutyltin	0.12 J	NA	0.005	8032	Intermediate Oral MRL Dibutyltin
Tributyltin	0.66	NA	0.0003	482	Chronic Oral MRL

Table E3 continued

Inorganics	Mussels (ppm)	Coonstripe Shrimp (ppm)	MRL or RfD (mg/kg/day)	Screening Value (ppm)	Reference
Aluminum	32	NA	1	1606	Chronic Oral MRL
Arsenic (inorganic)	0.011	0.01	0.0003	0.48	Chronic Oral MRL
Cadmium	0.65	0.04	0.001	1.6	Oral RfD
Chromium	0.12	NA	0.0009	1.4	Chronic Oral MRL
Copper	1.6	5.14	0.01	16.1	Intermediate Oral MRL
Iron	82	NA	3600	5783133	Tolerable Upper adult intake level, NIH
Lead	0.054	0.01	NA	NA	See Appendix D
Manganese	1.6	NA	0.14	225	Oral RfD
Mercury	0.0075	0.03	0.0003	0.5	Chronic Oral MRL methylmercury
Nickel	0.15	NA	0.02	32	Oral RfD
Selenium	0.64	0.20 U	0.005	8.0	Chronic Oral MRL
Silver	0.0027	NA	0.005	8.0	Oral RfD
Tin	0.0075	NA	0.3	482	Intermediate Oral MRL
Zinc	24	12.6	0.3	482	Chronic Oral MRL

ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U – Undetected; J – Estimated; NA – Not Analyzed
MRL: Chronic Oral Minimal Risk Level from Agency for Toxic Substances and Disease Registry
RfD: Reference Dose from Environmental Protection Agency
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Table E4: Cancer Screening of Contaminants in Mussels and Coonstripe Shrimp Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Inorganics	EPA Cancer Class	Mussels (ppm)	Coonstripe Shrimp (ppm)	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Screening Value (ppm)
Arsenic (Inorganic)	A	**0.0112**	**0.01**	5.7	0.00282
Organic Compounds	**EPA Cancer Class**	**Mussels (ppb)**	**Coonstripe Shrimp (ppb)**	**Oral Cancer Slope Factor $(mg/kg/day)^{-1}$**	**Screening Value (ppb)**
Total PCBs	B2	**12 J**	**17 U**	2	8
Total TCDD TEQ	B2	NA	**2.11E-04**	1.50E+05	1.10E-04
4,4'-DDD	B2	0.1666	NA	0.24	67
4,4'-DDE	B2	1.1088	NA	0.34	47
4,4'-DDT	B2	0.0672	1.3	0.34	47
Alpha-Chlordane	B2	0.1596	NA	0.35	46
Dieldrin	B2	0.1568	NA	16	1
Gamma-Chlordane	B2	0.0616	NA	0.35	46
Hexachlorobenzene	B2	0.2805	NA	1.6	10
alpha-BHC	B2	NA	0.64	6.3	3
beta-BHC	C	NA	6	1.8	9

Table continued below

Table E4 continued

cPAHs	EPA Cancer Class	TEF	Mussels TEF (ppb)	Shrimp TEF (ppb)	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Screening Value (ppb)
benz(a)anthracene	B2	0.1	0.28	0.043	7.3	2.2
chrysene		0.01	0.077	0.0055		
benzo(b)fluoranthene		0.1	0.56	0.032		
benzo(k)fluoranthene		0.1	0.34	0.017		
benzo(a)pyrene		1	1.2	0.1		
indeno(1,2,3-c,d)pyrene		0.1	0.067	0.018		
dibenz(a,h)anthracene		0.1	0.017	0.015		
Total cPAH TEQ			**2.5**	0.23		

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
ppb: parts per billion; ppm: parts per million; mg: milligram; kg: kilogram body weight; U: not detected, reporting limit
cPAHS: carcinogenic polycyclic aromatic hydrocarbons; TEQ: toxic equivalent; TEF: Toxic Equivalency Factor
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
Bold – chemical is a contaminant of concern and the value exceeds screening values

Appendix F – Lower Elwha Klallam Tribe Cancer and Non-Cancer Exposure Assessment

Table F1: Hazard Quotients and Health Assessment of Contaminants of Concern in Dungeness Crab at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Contaminant of Concern	MRL (mg/kg/day)	Crab Tissue Type	Maximum Concentration (ppm)	Estimated Dose (mg/kg/day)	Hazard Quotient (Dose/MRL)	NOAEL or LOAEL (mg/kg/day)
Total PCBS	0.00002	Muscle	0.18	3.4E-04	17	5.00E-03
		Hepatopancreas	5.8	**1.1E-02**	542	
TCDD TEQ	1.00E-09	Muscle	6.60E-07	1.2E-09	1	1.20E-07
		Hepatopancreas	3.80E-05	7.1E-08	71	
Arsenic	3.00E-04	Hepatopancreas	0.23	4.3E-04	1	8.00E-04
Cadmium	0.001	Hepatopancreas	3.66	6.8E-03	6.8	1.0E-02
Copper	0.01	Muscle	5.64	1.1E-02	1.1	9.10E-02
Copper	0.01	Hepatopancreas	99.8	**1.9E-01**	19	9.10E-02
Mercury	0.0003	Hepatopancreas	0.22	4.1E-04	1	1.30E-03
Selenium	0.005	Hepatopancreas	2.8	5.2E-03	1	1.50E-02

ppm: parts per million; mg: milligram; kg: kilogram body weight
MRL: Chronic Oral Minimal Risk Level from Agency for Toxic Substances and Disease Registry
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent
PCBs, TCDD TEQ Comparison Doses: LOAEL: Lowest Observed Adverse Effect Level, ATSDR
Arsenic, Mercury, and Selenium Comparison Doses: NOAEL: No Observed Adverse Effect Level, ATSDR
Cadmium Comparison Dose: NOAEL: No Observed Adverse Effect Level, EPA
Bold – estimated dose exceeds NOAEL/LOAEL, indicating potential for health effects

Eating crab hepatopancreas at the LEKT crab consumption rate could cause non-cancer health effects from PCBs and copper; gastrointestinal irritation from copper could occur within 1-14 days of consumption, and decreased immune function and/or neurobehavioral problems from PCBs could occur after an intermediate duration (15 – 364 days).

Table F2: Cancer Risk Calculations for Contaminants of Concern in Dungeness Crab Muscle at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.01	1.87E-05	1.1E-04
Total PCBs	B2	2	0.17881	3.34E-04	6.7E-04
Total TCDD TEQ	B2	1.50E+05	6.60E-07	1.23E-09	1.8E-04
Excess Lifetime Cancer Risk from Crab Muscle					**9.6E-04**

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
ppm: parts per million; mg: milligram; kg: kilogram body weight
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent

Table F3: Cancer Risk Calculations for Contaminants of Concern in Dungeness Crab Hepatopancreas at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.23	4.30E-04	2.4E-03
Total PCBs	B2	2	5.79952	1.10E-02	2.2E-02
Total TCDD TEQ	B2	1.50E+05	3.80E-05	7.20E-08	1.1E-02
4,4'- DDT	B2	3.40E-01	1.10E-01	2.10E-04	7.0E-05
Excess Lifetime Cancer Risk from Crab Hepatopancreas					**3.5E-02**

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
ppm: parts per million; mg: milligram; kg: kilogram body weight
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent

Table F4: Cancer Risk Calculations for Contaminants of Concern in Mussels at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.0112338	7.00E-06	4.0E-05
Total PCBs (estimate)	B2	2	1.20E-02	7.50E-06	1.5E-05
cPAH TEQ	B2	7.3	2.50E-03	1.56E-06	1.1E-05
				Lifetime Cancer Risk from Mussels	6.6E-05

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
cPAHS: carcinogenic polycyclic aromatic hydrocarbons; TEQ: toxic equivalent
ppm: parts per million; mg: milligram; kg: kilogram body weight

Table F5: Cancer Risk Calculations for Contaminants of Concern in Coonstripe Shrimp at a Lower Elwha Klallam Tribe Consumption Rate, Port Angeles Harbor, Port Angeles, Clallam County, Washington.

Chemical	EPA Cancer Class	Cancer Slope Factor $(mg/kg/day)^{-1}$	Concentration (ppm)	Dose (mg/kg/day)	Cancer Risk
Arsenic (Inorganic)	A	5.7	0.01	6.23E-06	3.5E-05
Total PCBs	B2	2	0.017	1.06E-05	2.1E-05
Total TCDD TEQ	B2	1.50E+05	2.11E-07	1.31E-10	2.0E-05
				Lifetime Cancer Risk from Coonstripe Shrimp	7.6E-05

EPA: Environmental Protection Agency; Cancer Class A: Human Carcinogen, Cancer Class B2: Probable human carcinogen (based on evidence from animal studies)
ppm: parts per million; mg: milligram; kg: kilogram body weight
TCDD TEQ: 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin toxic equivalent

Appendix G – Recommended Meal Limits

Meal Limit Calculations:

Meal limits were calculated for crab based on non-carcinogenic contaminants of concern along with other additional chemicals found in crab tissues. Additionally, meal limits were calculated based on additive effects of chemicals for developmental and immunologic health endpoints. Meal limits were calculated using the equation below in conjunction with the MRL or RfD as the target risk value and the exposure parameters provided in Table G1, below. The developmental and immunologic endpoints are based on the additive effects of dioxin and mercury as recommended in the ATSDR interaction profile for toxic contaminants found in fish.(25) Tables G2 and G3 provides meal limits that would be protective of women and children who eat crab from Port Angeles Harbor.

ML = [(RfD or MRL) × BW × DM]/C × MS
ML = recommended limit of meals per month
RfD = reference dose (EPA)
MRL = minimal risk level (ATSDR)

Many factors must be considered when one is recommending limits on the consumption of seafood, including the health benefits of eating shellfish, the quality and comprehensiveness of environmental data, and the availability of alternate sources of nutrition. In addition, these meal limit calculations do not consider a multi-species consumption scenario, which would require weighting of each species consumed.

Table G1. Exposure Parameters Used to Calculate Recommended Meal Limits for Crab from Port Angeles Harbor, Clallam County, Washington.

Chemical	**MRL or RfD**	**Health Endpoint**		**Units**
		Developmental RfD/MRL	**Immunological RfD/MRL**	
Arsenic	0.3	N/A		µg/kg/day
Cadmium	1			
Copper	10			
DDT	0.5			
DDE	2	2	2	
PCBs	0.03	0.03	0.02	
Dioxin	0.000001	0.000001	0.00002	
Mercury	0.1	0.1	0.3	
Exposure Parameter	**Value**			**Units**
Average Concentration (C)	*variable*			µg/kg
Days per month (DM)	30.4			days/month
Mean Body Weight (BW)	60			kg
Meal size (MS)	0.227			kg

RfD: EPA Reference Dose; MRL: Minimal Risk Level (ATSDR); µg: microgram; kg: kilogram

Table G2. Calculated Meal Limits Per Month for Dungeness Crab Muscle Tissue from Port Angeles Harbor, Clallam County, Washington.

Contaminant	Average Concentration (ppm)	Meals based on RfD/ MRL	Meals based on Developmental additive endpoint	Meals based on Immune additive endpoint	Lowest meals per month (rounded)
Arsenic	6.00E-03	402	NA	NA	**4**
Cadmium	1.43E-02	562			
Copper	5.24	15			
DDT	1.97E-03	2039			
DDE	5.63E-04	28544	3.8	3.0	
PCBs	0.0461	5.2			
Dioxin	2.26E-7	36			
Mercury	0.100	8.0			

Table G3. Calculated Meal Limits Per Month for Dungeness Crab Hepatopancreas from Port Angeles Harbor, Clallam County, Washington.

Contaminant	Average Concentration (ppm)	Meals based on RfD/ MRL	Meals based on Developmental additive endpoint	Meals based on Immune additive endpoint	Lowest meals per month (rounded)
Arsenic	0.20	12	NA	NA	**0**
Cadmium	3.01	2.6			
Copper	74.1	1.1			
DDT	4.70E-02	85			
DDE	1.08E-02	1488	0.068	0.053	
PCBs	2.984	0.081			
Dioxin	1.795E-5	0.45			
Mercury	0.169	4.8			

Note: An average legal-sized Dungeness crab weighs around 1.8 pounds, or 28.8 ounces. The estimated percentage that is edible meat (muscle tissue) is about 24%. Therefore, each Dungeness crab contains about 6.9 ounces of crab meat.(26)

28.8 ounces × 0.24 = 6.91 ounces of crab meat

Applying the Table G2 and G3 meal limits across the general population assumes that meal sizes decrease or increase proportionately with body weight. Such an assumption could result in underestimating exposure for consumers who eat proportionately more seafood per unit of body weight. Table G4 demonstrates how an eight-ounce meal for a 70-kilogram adult would change to remain proportional with body weight. Meal sizes are reported in both ounces and grams of uncooked meat.

Table G4. Adjustment of Seafood Meal Size Based on the Body Weight of the Consumer.

Body Weight		**Meal Size**	
Pounds	**Kilograms**	**Ounces**	**Grams**
19	9	1	28
39	18	2	57
58	26	3	85
77	35	4	113
96	44	5	142
116	53	6	170
135	61	7	199
154	70	8	227
173	79	9	255
193	88	10	284
212	96	11	312
231	105	12	340
250	113	13	369
270	123	14	397
289	131	15	425
308	140	16	454

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