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Ecological Condition of the Estuaries of Oregon and Washington

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Ecological Condition of the Estuaries of Oregon and Washington

an Environmental Monitoring and Assessment Program (EMAP) Report

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Photo: Harold W. Streeter, NOAA/NMFS vessel used by Washington Department of Ecology in 2000.

I. INTRODUCTION

Estuaries are bodies of water that receive freshwater and sediment from rivers and saltwater from the oceans. They are transition zones between the fresh water of a river and the salty environment of the sea. This interaction produces a unique environment that supports wildlife and fisheries and contributes substantially to the ecology and economy of coastal areas.

Recent studies have shown that growth of the human population is concentrated in the coastal areas (Culliton, 1990). This population growth in the coastal areas of the west is a principal driver for many stresses to the ecosystem such as habitat loss, pollution, and nutrient enhancement. These stressors can affect the sustainability of coastal ecological resources (Copping and Bryant, 1993). Increased globalization of the economy is a major influence in the introduction of exotic species into port and harbors. Major environmental policy decisions at local, state and federal levels will determine the future for estuarine conditions of the western U.S. Information on the ecological condition of estuaries is essential to these policy decisions.

The overall quality of estuaries in Oregon and Washington is described in this report using data collected as part of the Western Environmental Monitoring and Assessment Program (EMAP). In EPA Region 10, Western EMAP is a cooperative effort between the Environmental Protection Agency (EPA) Office of Research and Development (ORD), EPA Region 10, the Washington Department of Ecology (Ecology), the Oregon Department of Environmental Quality (ODEQ), the National Oceanographic and Atmospheric Administration (NOAA) and others. Much of this report is based on work by ODEQ (Sigmon, 2004), Ecology (Wilson and Partridge, 2005) and EPA ORD (Nelson, 2005 and U.S. EPA, 2004).

A. Background

EMAP (Environmental Monitoring and Assessment Program) was initiated by EPA's Office of Research and Development (ORD) to estimate the current status and trends in the condition of nation's ecological resources. EMAP also examines associations between these indicators and natural and human caused stressors. This information will assist the EPA and States/Tribes as the Clean Water Act (CWA) directs them to develop programs that evaluate, restore and maintain the chemical, physical and biological integrity of the Nation's waters. The data collected during this survey can also be used to examine the relationships between environmental stressors and the condition of ecological resources

The coastal component of Western EMAP applies EMAP’s monitoring and assessment tools to create an integrated and comprehensive coastal monitoring program along the west coast. Water column measurements are combined with information about sediment characteristics and chemistry, benthic organisms, and fish to describe the current estuarine condition. Sampling began during the summer of 1999, with small estuaries of Oregon and Washington.

In 2000, sampling continued with the larger estuaries of Oregon and Washington (Puget Sound and the Columbia River estuary). The boundary for the Columbia River estuary was head of tidal influence, so there were some freshwater components of this sampling effort. This report provides a summary of the data from 1999-2000 sampling for the small and large estuarine systems of the states of Washington and Oregon.

B. Objectives

The overall objectives of this project are:

- to describe the current ecological condition of estuaries in Washington and Oregon based on a range of indicators of environmental quality using a statistically based survey design;
- to establish a baseline for evaluating how the conditions of the estuarine resources change in the future;
- to develop and validate improved methods for use in future coastal monitoring and assessment efforts in the western coastal states;
- to transfer the technical approaches and methods for designing, conducting and analyzing data from statistically based environmental assessments to the states and others;
- to work with the states and others to build a strong program of water monitoring which will lead to better management and protection of western estuaries.

II. METHODS

The Washington Department of Ecology (Ecology), and the Oregon Department of Environmental Quality (ODEQ) conducted all field sampling for this project in 1999-2000 with assistance from EPA Region 10 and the National Marine Fisheries Service (NMFS).

The goal of EMAP is to develop ecological monitoring and assessment methods that advance the science of measuring environmental resources to determine if they are in an acceptable or unacceptable condition. Two major features of EMAP are:

- the probability-based selection of sample sites and
- the use of ecological indicators.

A. Design - How to Select Estuarine Sites to Sample

Environmental monitoring and assessments are typically based on subjectively selected sampling sites. EMAP provides an alternative method of sample site selection for large scale monitoring. Peterson (1998; 1999) compared subjectively selected localized lake data with EMAP probability-based sample selection and showed the results for the same area to be substantially different. The primary reason for these differences was lack of regional sample representativeness of subjectively selected sites. Coastal studies have been plagued by the same problem. A more objective approach is needed to assess overall estuarine quality on a regional scale.

In addition, it is generally impossible to completely census an extensive resource, such as the set of all estuaries on the west coast. A more practical approach to evaluating resource condition is to sample selected portions of the resource using probability-based sampling.

Designing a probability-based survey begins with creating a list of all units of the target population from which to select the sample and selecting a random sample of units (places to collect data) from this list. The list or map that identifies every unit within the population of interest is termed the sampling frame.

Studies based on random samples of the resource rather than on a complete census are termed sample or probability-based surveys. Probability-based surveys offer the advantages of being affordable, and of allowing extrapolations to be made of the overall condition of the resource based on the random samples collected. These methodologies are widely used in national programs such as forest inventories, consumer price index, labor surveys, and such activities as voter opinion surveys.

A probability-based survey design provides the approach to selecting samples in such a way that they provide valid estimates for the entire resource of interest, in this case the estuaries of Oregon and Washington. Therefore, the results in this document will be reported in terms of the percent of estuarine area of Oregon and Washington. The sampling frame for the EMAP Western Coastal Program was developed from USGS 1:100,000 scale digital line graphs and stored as a GIS data layer in ARC/INFO program. Additional details are described in Diaz-Ramos (1996), Stevens (1997), and Stevens and Olsen (1999).

The assessment of condition of small estuaries conducted in 1999 was the first phase of a two-year comprehensive assessment of all estuaries of the states of Washington and Oregon. The complete assessment requires the integrated analysis of data collected from the small estuarine systems in 1999 and the larger estuarine systems in 2000 (**Map 1**). The intent of the design is to be able to combine data from all stations for analysis. The West Coast sampling

Map 1. Coastal EMAP Sampling Locations, 1999-2000 (Washington and Oregon).

frame was constructed as a GIS coverage that included the total area of the estuarine resource of interest. The estuarine area of Oregon and Washington represented by this report is 8670 square kilometers (or 3348 square miles).

For the state of Washington, the 1999 design included only small estuaries along the coastline outside of the Puget Sound system, and consisted of a total of 50 sites (Appendix 1). Tributary estuaries of the Columbia River located within Washington state were included in the 1999 sampling effort, while the main channel area was not sampled until 2000 (as part of the 2000 Oregon design).

The Washington 2000 sampling design included only the large "estuary" of Puget Sound and its tributaries. Site selection for this estuary used a combined approach in order to allow collaboration with a survey previously conducted by National Oceanographic and Atmospheric Administration (NOAA) under the NOAA National Status and Trends Program. The overall design combined the existing NOAA probability based monitoring design with the EMAP Western Coastal study design. The EMAP grid was extended to include Canadian waters at the north end of Puget Sound, and then was overlaid on the existing NOAA monitoring sites. There were 41 stations selected based on the NOAA sampling stations, in addition to 30 new EMAP stations, of which 10 were associated with the San Juan Islands (Appendix 1).

The Oregon 1999 design included only small estuaries of the state and consisted of 50 sites (Appendix 1). Tributary estuaries of the Columbia River located within Oregon were included in the 1999 sampling effort, while the main channel area was not sampled until 2000. An intensive sampling effort was designed for Tillamook Bay, where 30 sites were selected (Appendix 1).

The Oregon 2000 design included only the main channel area of the Columbia River. The Columbia River system was split into two subpopulations: the lower, saline portion and the upper, more freshwater portion, with a total of 20 and 30 sites, respectively (Appendix 1).

All sites from both states and for both years were combined for analysis in this report to represent the entire 8670 square kilometers of estuaries in Oregon and Washington. Of these, 710 square kilometers are in Oregon and 7960 square kilometers are in Washington.

B. Indicators - What to Assess at Each Selected Site

The objective of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. Therefore, in order to assess the nation's waters, it is important to measure chemical (including sediment chemistry and fish tissue contaminants), physical (such as water clarity, and silt-clay content) and biological condition (fish and invertebrate communities, and toxicity testing). Coastal EMAP uses ecological indicators to quantify these conditions. Indicators are measurable characteristics of the environment, both abiotic and biotic, that can provide information on ecological resources.

There is a great deal of information collected as part of Coastal EMAP. **Table 1** shows the selected core EMAP coastal indicators. For a list of the chemical analytes for sediment and tissue samples, see Appendix 2. In the following section, we will give an overview of the methods for those indicators that we describe in the results and discussion sections of this report. Additional detailed information on field and laboratory methods is available in U.S. EPA, 2001.

Indicator	**Rationale**
Water Column Indicators	
Water Clarity	Clear waters are valued by society and contribute to the maintenance of healthy and productive ecosystems. Light penetration into estuarine waters is important for submerged aquatic vegetation which serves as food and habitat for the resident biota.
Dissolved oxygen	Dissolved oxygen (DO) in the water column is necessary for all estuarine life. Low levels of oxygen (hypoxia) or lack of oxygen (anoxia) often accompany the onset of severe bacterial degradation, sometimes resulting in the presence of algal scums and noxious odors. In severe cases, low DO can lead to the death of large numbers of organisms.
Dissolved nutrients (Nitrogen and Phosphorus)	Dissolved inorganic nitrogen and dissolved inorganic phosphorous are necessary and natural nutrients required for the growth of phytoplankton. However, excessive dissolved nutrients can result in large, undesirable phytoplankton blooms.
Total Suspended Solids	Total suspended solids (TSS) refers to the matter that is suspended in water. TSS can be a useful indicator of the effects of runoff from construction, agricultural practices, logging activity, discharges, and other sources.
Sediment Indicators	
Silt-Clay Content	The percentage of particles present in bottom sediments that are silt and clay is an important factor determining the composition of the biological community. It is an important factor in the adsorption of contaminants to sediment particles and therefore for the exposure of organisms to contaminants.
Sediment contaminants	A wide variety of metals and organic substances are discharged into estuaries from urban, agricultural, and industrial sources in the watershed. The contaminants adsorb onto suspended particles that settle to the bottom, disrupt the benthic community and can concentrate in the tissue of fish and other organisms.
Sediment toxicity testing	A standard direct test of toxicity is to measure the survival of amphipods (commonly found, shrimp-like benthic crustaceans) exposed to sediments for 10 days under laboratory conditions.
Biological Indicators	
Benthic organisms	The organisms that inhabit the bottom substrates of estuaries are collectively called benthic macroinvertebrates or benthos. These organisms are an important food source for bottom-feeding fish, shrimp, ducks, and marsh birds. Benthic organisms are sensitive indicators of human-caused disturbance and serve as reliable indicators of estuarine environmental quality. We also examine which species are Non-Indigenous species (NIS).
Fish-tissue contaminants	Chemical contaminants may enter an organism in several ways: uptake from water, sediment, or previously contaminated organisms. Once these contaminants enter an organism, they tend to build up. When fish consume contaminated organisms, they may “inherit” the levels of contaminants in the organisms they consume. This same “inheritance” of contaminants occurs when other biota (such as birds) consume fish with contaminated tissues. The technical term for this is bioaccumulation.

Table 1. Selected Coastal EMAP Indicators

1. Field Methods

Detailed descriptions of the field methods are available in the "Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan 2001-2004" (U.S. EPA, 2001). The discussion below is a very brief summary of the methods used for the indicators that will be evaluated in this report.

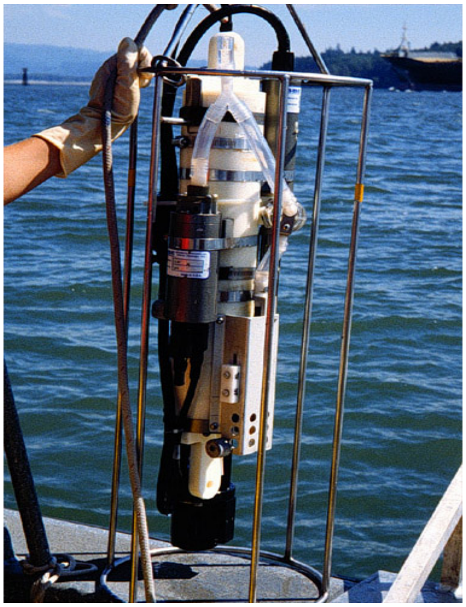


Photo: Example of water sampler

Water Column

Water depth, salinity, conductivity, temperature, pH and DO data were collected using an electronic instrument called a Conductivity Temperature Depth recorder (CTD), that takes measurements from the surface to the bottom of the water column. Photosythetically available radiation (PAR) was measured with LiCor® PAR sensors. The CTD and underwater PAR sensor were mounted for water column profiling. Water quality indicators were recorded with the CTD at discrete depth intervals, depending on the total station depth (**Table 2**).

Total Depth (m)	Sample Depth Increment
< 1.5	Mid-depth
≤ 2	Every 0.5m
> 2 and < 10	0.5m, Every 1m, 0.5 off bottom
> 10	0.5m, Every 1m up to 10m, Every 5m to 0.5m off bottom

Table 2. Station Total Depth and CTD Sampling Depths

Near-bottom measurements were taken after a three minute delay in the event that the sediment surface had been disturbed. Data were recorded for descending and ascending profiles. Secchi depth was recorded as the water depth at which a standard 20cm diameter black-and-white Secchi disc could be seen during ascent.

Discrete water samples were collected with bottles at one to three depths, which corresponded with the CTD and PAR measurement depths (**Table 3**). Water grab samples were analyzed for dissolved nutrients [forms of Nitrogen (Nitrate, Nitrite, Ammonium), and Phosphorus], Total Suspended Solids and Chlorophyll *a*.

Total Depth (m)	Discrete Sample depth
< 1.5	Mid-depth
≥ 1.5 to < 2	0.5m 0.5m off bottom
≥ 2	0.5m Mid-depth 0.5m off bottom

Table 3. Station Depth and Discrete Water Sampling Depths

Sediment

Sediment samples were collected with a 0.1-m^2 Van Veen grab sampler. All sediment sampling gear was decontaminated and rinsed with site water prior to sample collection. Acceptable grabs were ≥ 7 cm penetration, not canted, not overflowing, not washed out, and had an undisturbed sediment surface. Water overlying the sediment grab, if present, was siphoned off without disturbing the surface. The top 2-3 cm of sediment were removed with a stainless steel spoon and transferred to a decontaminated container. Sediments from a minimum of three grabs were composited to collect approximately

6 liters of sediment. Most sites required from 6 to 9 grabs. Once adequate sediment was collected, it was homogenized and transferred to clean jars, stored on wet ice and later refrigerated or frozen until analysis.

Benthic Invertebrates

Sediment samples to enumerate the benthic infauna were collected using a 0.1-m^2 Van Veen grab sampler. After collection, infauna were sieved through nested 1.0-mm and 0.5-mm mesh sieves using site water supplied by an adjustable flow hose. Material caught on the screens was fixed with 10% phosphate-buffered formalin. Samples were re-screened and preserved with 70% ethanol within two weeks of field collection. The 0.5 mm fraction was archived, and the 1.0 mm fraction was shipped for sorting and taxonomic identification.

Fish Trawls

Bottom trawls were conducted using a 16-foot otter trawl with a 1.25-inch mesh net. Trawls were intended to retrieve demersal fishes (fish living on or near the bottom) and benthic invertebrates. Trawling was performed after water quality and sediment sampling were completed. Fish were obtained by hook and line techniques at sites where trawling was not feasible due to safety and/or logistical concerns. The catch was brought on board, put alive into wells containing fresh site water and immediately sorted and identified. Information was recorded on species, fish length and number of organisms. All fish not retained for tissue chemistry or to study their diseased tissue (histopathology) or were returned to the estuary.

Photo: Ratfish, a commonly found fish in Puget Sound

Fish Tissue

From the fish caught, several species of flatfish (demersal soles, flounders, and dabs) were designated as target species for the analyses of chemical contaminants in whole-body fish tissue. These flatfish are common along the entire U.S. Pacific Coast and are intimately associated with the sediments. Where the target flatfish species were not collected in sufficient numbers, perchiform (see list below) species were collected. These species live in the water column but feed primarily or opportunistically on the benthos. In cases where neither flatfish species nor perches were collected, other species that feed primarily or opportunistically on the benthos were collected for tissue analysis. The target species analyzed for tissue contaminants were:

<u>Pleuronectiformes (flatfish)</u>
Citharichthys sordidus - Pacific sanddab
Citharichthys stigmaeus - speckled sanddab
Platichthys stellatus - starry flounder
Pleuronectes isolepis - butter sole
Pleuronectes vetulus - English sole
Psettichthys melanostictus - sand sole

<u>Perciformes (perchiform fish)</u>
Cymatogaster aggregata - shiner perch
Embiotoca lateralis - striped sea perch

<u>Other</u>
Leptocottus armatus - Pacific staghorn sculpin

Target species were used for whole-body tissue contaminant analyses. Individuals of a single species (ideally 5-10 fish) were combined for a single composite sample. Approximately 200-300 grams of tissue (wet weight) is needed to complete all analysis, but a minimum of 50 grams of tissue is required for mercury analysis.

2. Laboratory Methods

The detailed quality assurance/quality control (QA/QC) program and laboratory methods for the Western Coastal EMAP program are outlined in "Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan 2001-2004" (U.S. EPA, 2001). The methods are described briefly below.

Water

Discrete water samples were analyzed by the state environmental labs (Oregon DEQ and Ecology/University of Washington).

Sediment Chemistry

Sediment samples for chemical analysis were taken from the same sediment composite used for the sediment toxicity tests. Approximately 250-300 ml of sediment was collected from each station for analysis of the organic pollutants and another 250-300 ml for analysis of the total organic carbon (TOC) and metals (Appendix 2). The analytical methods are those used in the NOAA NS&T Program (Lauenstein, 1993) or documented in the EMAP-E Laboratory Methods Manual (U.S. EPA, 1994a).

Fish Tissue

Organic and metal contaminants were measured in the whole-body tissues of the species of fish listed above (Section II.B.1). Chemical residues in fish tissue (Appendix 5) were determined for each of the composited tissue samples. Quality control procedures for the tissue analysis were similar to those described above for sediments and followed the procedures detailed in U.S. EPA (1994a and 2001), including the use of certified reference materials, spikes, duplicates, and blanks.

Sediment Physical Parameters

Sediment silt-clay and TOC were analyzed by the State labs (Oregon and Washington). Grain size analysis was by dry and wet sieving. Sediment digestion for TOC analysis was by acidification and combustion.

Amphipod Sediment Toxicity Tests

The 10-day, solid-phase toxicity test with the marine amphipod *Ampelisca abdita* was used to evaluate potential toxicity of sediments from all sites. Mortality, and emergence from the sediment during exposure were the exposure criteria used. All bioassay tests were performed within 28 days of field collection using the benthic amphipod *Ampelisca abdita*. Amphipod toxicity tests were performed with the species *Hyalella azteca*, for the 30 freshwater sites in the Columbia in 2000. Procedures followed the general guidelines provided in ASTM Protocol E-1367-92 (ASTM 1993) and the EMAP-E Laboratory Methods Manual (U.S. EPA, 1994a).

Benthic Invertebrates

Benthic infauna data were processed according to protocols described in the EMAP lab method manual (U.S. EPA, 1994a). Both indigenous and exotic organisms were identified to the lowest practical taxonomic level (species where possible).

3. Data Analysis Methods

In this report, the primary method for evaluating indicators for sites selected using the EMAP probability design is the cumulative distribution function (CDF). A CDF is a graph that shows the distribution of indicator or parameter data accumulated over the entire "population" of concern. The "population" in this report is generally the total area of the estuaries of Oregon and Washington.

The EMAP statistical designs allows for extrapolation from data collected at specific sites to the entire "population", in this case the estuaries of Oregon and Washington. For example, if an indicator value above 3 is considered "impaired," then Figure 1 (CDF) shows that approximately 60 percent of the area of the estuaries of Oregon and Washington exceed that threshold (and the other 40% of the estuary area is below 3).

The EMAP design also allows for the calculation of confidence intervals for CDFs. For example, we could say that 60% of the area of the estuaries of Oregon and Washington exceed some threshold, plus or minus 8%. However, for ease of reading the CDFs, we did not include the confidence intervals for the graphs in this document. The CDF below is just an introductory example. The 50% line marked on all of the CDFs in this report, including the one below, is just a marker and not an ecologically important criterion.

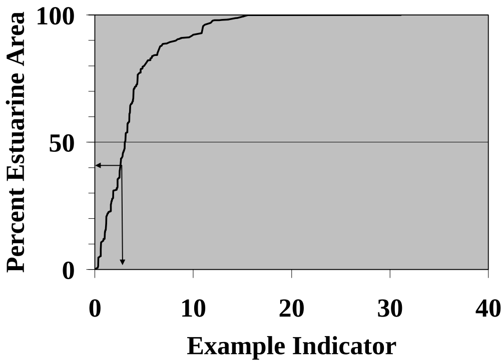


Figure 1. Example Cumulative Distribution Function (CDF).

III. RESULTS

In this section of the report we will describe the overall condition of the estuaries of Oregon and Washington based on analysis of data collected from over 200 randomly selected sites (**Map 1**) using the EMAP protocols (described in Section II). We are able to present only a portion of the indicators that were generated from the field data due to the large volume of information that was collected. Additional indicators are summarized in the Appendices.

A. Water Physical/Chemical Parameters

1. Water Clarity

Light transmissivity

The extent of light transmittance or attenuation at a given water depth is a function of the amount of ambient light and water clarity, with the latter affected by the amount of dissolved and particulate constituents in the water. Light transmissivity, the percent of light transmitted at 1m, in the estuaries of Oregon and Washington ranged from 0 to 87.6 percent (mean 17.7 percent) across the 224 stations where light transmissivity was measured (**Figure** 2).

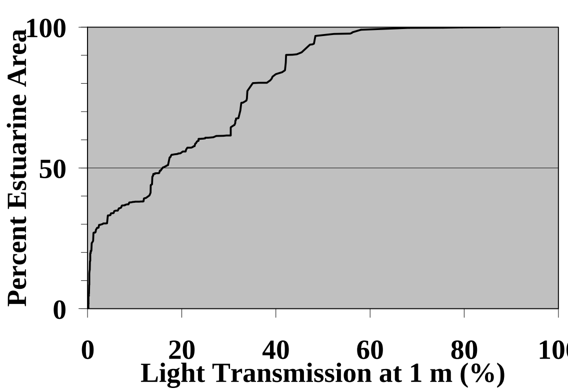


Figure 2. CDF of Water Clarity.

Secchi Depth

Secchi depth in the estuaries of Oregon and Washington ranged from 0.1 meters to 12.5 meters (mean 2.9 meters) across the 238 stations where Secchi depth was measured (**Figure 3**).

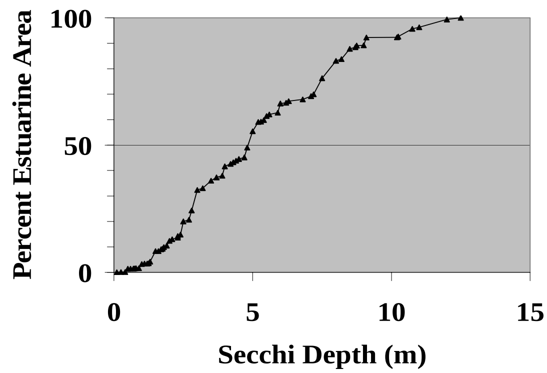


Figure 3. CDF of Secchi Depth.

2. Dissolved Oxygen

Dissolved oxygen is necessary for all estuarine life. Dissolved oxygen (DO) concentrations in the bottom water for the estuaries of Washington and Oregon ranged from 0.12 mg/L to 11.5 mg/L (mean 7.355), across the 242 stations of the total estuarine where bottom dissolved oxygen concentrations were measured (**Figure 4**).

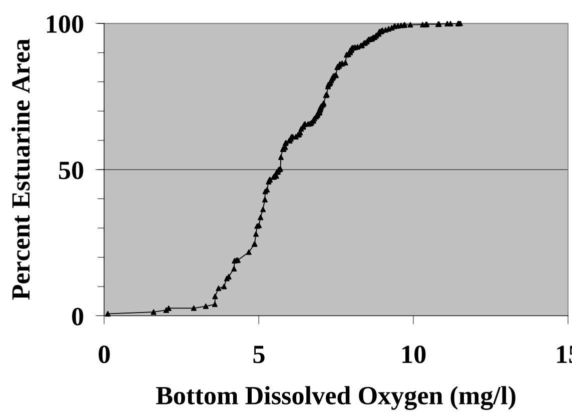


Figure 4. CDF of Bottom Dissolved Oxygen.

Surface dissolved oxygen (DO) concentrations in the estuaries of Oregon and Washington ranged from 3.4 mg/L to 11.5 mg/L (mean 8.2 mg/l) across the 242 stations where surface dissolved oxygen concentrations were measured (**Figure 5**).

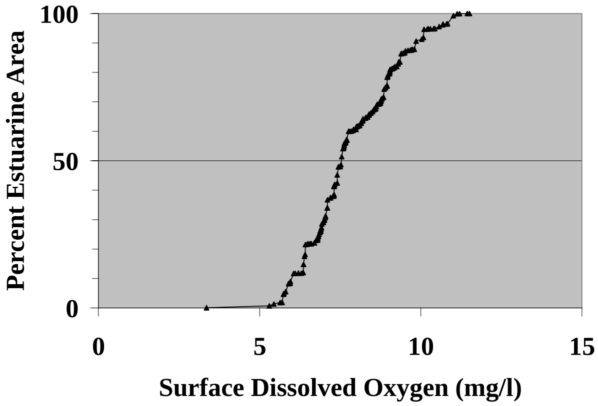


Figure 5. CDF of Surface Dissolved Oxygen.

3. Nutrients

Nutrients are chemical substances used by organisms for maintenance and growth, that are critical for survival. Plants require a number of nutrients. Of these, nitrogen and phosphorus are of particular concern in estuaries for two reasons: they are two of the most important nutrients essential for the growth of aquatic plants, and the amount of these nutrients being delivered to estuaries is increased by many human activities.

Eutrophication is a condition in which high nutrient concentrations stimulate excessive algal blooms, which then deplete oxygen as they decompose. Estuaries with insufficient mixing may become hypoxic (low in oxygen) and under the worst conditions, the bottom waters of an estuary turn anoxic (without oxygen).

Nutrient concentrations were measured at the surface, middle and bottom of the water column at 243 stations. The following graphs represent the mean of the three depths at each station.

The relationship between nitrogen and phosphorus (N:P ratio) can provide insights into which of these nutrients is limiting. Total dissolved inorganic nitrogen concentrations ranged from 0 to 2045 ug/L for the sites sampled. The three depths showed a similar distribution, but bottom and midwater samples generally had higher total nitrogen concentrations than did the surface samples.

About half of the estuary area had less than 238 ug/L total dissolved inorganic nitrogen (**Figure 6**) for the mean of the three depths at each station.

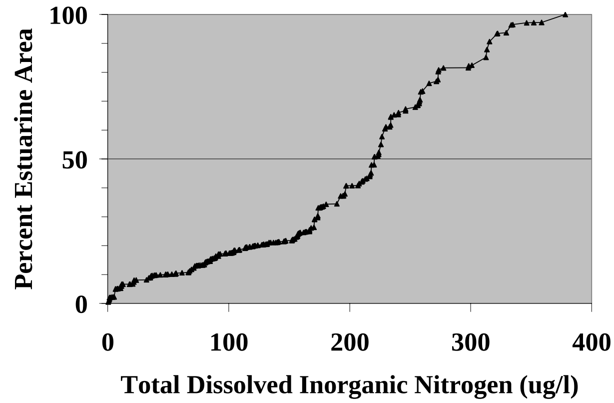


Figure 6. CDF of Total Dissolved Inorganic Nitrogen.

Soluble phosphorus concentrations ranged from 0 to 106.5 ug/L (**Figure 7**). About half of the estuarine area had soluble phosphorus concentrations less than 51.3 ug/L for the mean of the three depths at each station.

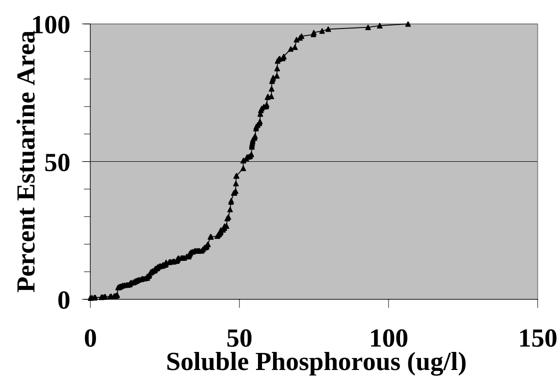


Figure 7. CDF of Soluble Phosphorus.

Phytoplankton are microscopic plants common to estuarine waters. Phytoplankton are primary producers of organic carbon and form the base of the estuary food chain. One procedure for determining the abundance of phytoplankton is to measure the amount of the photosynthetic pigment chlorophyll *a* that is present in water samples. Chlorophyll is a pigment common to all photosynthetic algae, and its amount in the water is in relation to the algal concentration. Chlorophyll *a* concentrations ranged from 0 to 31.1 ug/L (**Figure 8**). About one-half of the estuary area had less than 3.1 ug/L for the mean of the three depths at each station.

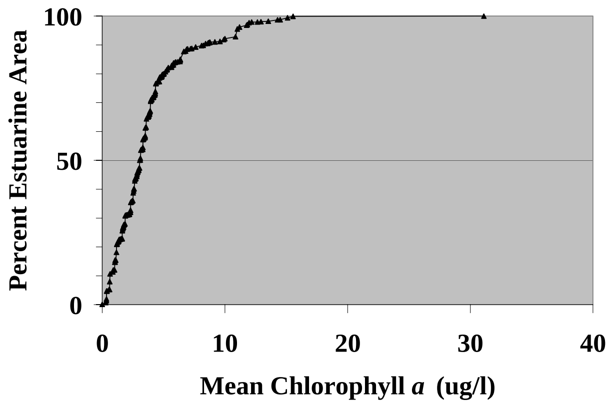


Figure 8. CDF of Mean Chlorophyll *a*.

Molar nitrogen to phosphorus ratios (N:P) ranged from 0.16 to 179 (**Figure 9**) for the mean of the three depths at each station. Essentially all of the estuary area had N:P < 16, which may indicate that production of phytoplankton at these sites is nitrogen limited.

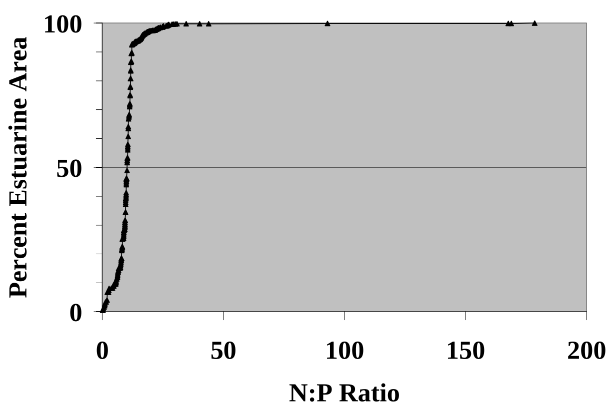


Figure 9. CDF of N:P Ratio.

4. TSS

Suspended materials include soil particles (clay and silt), algae, plankton, and other substances. Total suspended solids (TSS) refer to the matter that is suspended in water. The solids in water have different attributes and sizes.

Total suspended solids often increase sharply during and immediately following rainfall, especially in developed watersheds, which typically have relatively high proportions of impervious surfaces such as rooftops, parking lots, and roads. The flow of stormwater runoff from impervious surfaces rapidly increases stream velocity, which increases the erosion rates of streambanks and channels (U.S. EPA, 1993b).

Some of the physical effects of above normal suspended materials include:

- clogged fish gills, inhibiting the exchange of oxygen and carbon dioxide,
- reduced resistance to disease in fish,
- reduced growth rates,
- altered egg and larval development,
- fouled animal filter-feeding systems, and,
- hindered ability of aquatic predators from spotting and tracking down their prey.

Higher concentrations of suspended solids can also serve as carriers of toxins, which readily cling to suspended particles. Total Suspended Solids in the estuaries of Oregon and Washington ranged from 0 mg/L to 230 mg/L (mean 10.3 mg/L) across the 244 stations where TSS was measured (**Figure 10**).

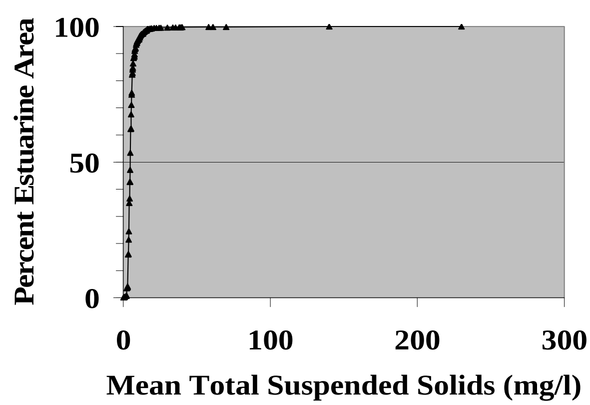


Figure 10. CDF of Total Suspended Solids.

Photo: Sediment sampling by Oregon DEQ.

B. Sediment Characteristics

Sampling of sediment was conducted at 225 stations, representing 81% of the estuarine area of Washington and Oregon. Silt-clay content and total organic carbon (TOC) are descriptors of the characteristics of the sediments. For contaminants in the sediments, the section below compares the concentrations of metals and organic chemicals in those sediment samples to state sediment standards, where available, and to sediment quality guidelines. See Appendix 4 for additional details.

The sediment quality guidelines used here are concentrations that have shown adverse effects on organisms in laboratory experiments. They are divided into ERLs (Effects Range-Low) and ERMs (Effects Range-Median) and are described more completely in Long, 1995. ERM guidelines were calculated as the 50th percentile concentrations associated with toxicity or other adverse biological effects in a database compiled from saltwater studies conducted throughout North America. The ERL guidelines were calculated as the 10th percentile of that dataset.

In this section of the report we will be using the ERLs and ERMs as descriptors, since a single exceedance may or may not indicate poor estuarine condition. In Section IV, we will examine sites with multiple exceedances, which may indicate poor estuarine condition.

Oregon does not have sediment quality standards, but Washington has both sediment quality standards, set at concentrations below which adverse biological effects are not expected to occur, and a higher concentration used as a cleanup and screening limit, above which at least moderate adverse biological effects are expected to occur (Washington State Department of Ecology, 1995). Both the Washington standards and cleanup limits are based on Puget Sound data. We will use these sediment quality standards, along with the ERLs and ERMs, as descriptors as a single exceedance may or may not indicate poor estuarine condition. In the next section (Section IV) we will examine sites with multiple exceedances, which may indicate poor estuarine condition.

1. Silt-Clay Content

The proportion of fine grained materials (silt and clay) in the estuarine sediments ranged from 0 to 94%, with a mean of 63% fines, across the 226 stations where silt-clay content was measured (**Figure 11**). If sediment samples with less than 20% fines are considered predominantly sand, then sandy sediments make up 40% of the estuarine area. If samples with more than 80% fines are considered muddy, then muddy sediments cover 15% of the estuarine area.

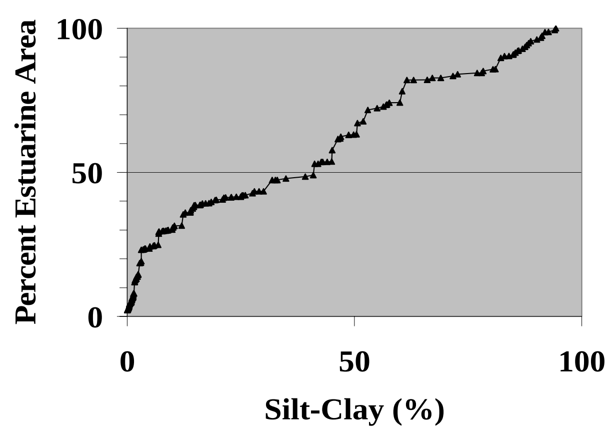


Figure 11. CDF of Percent Silt-Clay.

2. Total Organic Carbon

Total Organic Carbon (TOC) is the amount of organic matter within the sediment. TOC can be an important food source for deposit feeding benthos. Fine-grained, organic-rich sediments may be likely to become resuspended and transported to distant locations. Silty sediments high in total organic carbon (TOC) are more likely than sandy sediments, or sediments low in TOC, to have contaminants adsorbed to them. TOC concentrations in the estuaries of Oregon and Washington ranged from 0% to 4.48% (**Figure 12**) across the 225 stations where TOC was measured.

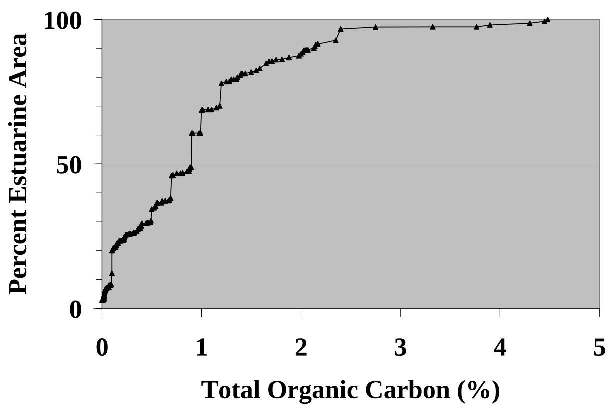


Figure 12. CDF of Total Organic Carbon.

3. Metals

Sediment samples were collected from 225 sites, representing 81% of the estuarine area, and were analyzed for metals. **Table 4** describes the mean, maximum and the percent of estuarine area exceeding the ERMs, ERLs, and Washington state sediment criteria.

Chromium, copper and nickel exceedances of the ERL will not be included in any aggregate sediment contaminant indicator. This is because the ERL for chromium is less than the average concentration found in the Earth's crust and in marine shales (100 and 90 ppm, respectively, Krauskopf and Bird, 1995.) The ERL for copper is also less than the average concentration in the Earth's crust and in shale (55 and 45 ppm, respectively). Also, the ERL and ERM values for nickel are not based on a strong correlation between concentration and effect, according to Long, 1995. Furthermore, both the ERL and ERM concentrations for nickel are well within the range of concentrations found in common rock types that make up the earth's crust. Even the highest concentration reported, from a sample from the Rogue River in Oregon, is from an area with naturally occurring "black sand" deposits of heavy minerals, which may be elevated in nickel. Therefore, we did not include chromium, copper or nickel exceedences of the ERL in the aggregate sediment contaminant indicator.

Metal	Mean (ppm)	Maximum (ppm)	ERL (ppm)	% of area that exceeds ERL	% of area that exceeds ERM	% of area that exceeds Washington sediment quality standards
Arsenic	6.6	20.8	8.2	18%	0	0
Cadmium	0.2	2.3	1.2	3%	0	0
Chromium	70.6	328	81	33%	0	<1%
Copper	24.5	219	34	19%	0	0
Lead	12.9	51	46.7	<1%	0	0
Mercury	0.1	0.3	0.15	8%	0	0
Nickel	29.6	275	20.9	65%	6% (ERM = 51.6)	Not applicable
Silver	0.2	2.1	1	<1%	0	0
Zinc	73.6	225	150	<1%	0	0

Table 4. Selected Metals in Sediments of the Estuaries of Oregon and Washington.

4. Polynuclear aromatic hydrocarbons (PAH)

Polynuclear aromatic hydrocarbons (PAHs) are petroleum- or coal combustion by-products often associated with elevated levels of tumors in fish. The PAHs of low molecular weight are relatively easy to degrade, whereas those with higher molecular weights are resistant to decomposition. The low molecular weight PAHs are acutely toxic to aquatic organisms, whereas the high molecular weight PAHs are not. However, several high molecular weight PAHs are known to be carcinogenic.

Total PAH

Total PAHs ranged in concentration from below detection to 59,878 ppb (ng/g dry weight), and were detected in 86% of the estuarine area (**Figure 13**). The ERL of 4022 ppb was exceeded in 3% of the area, and the ERM of 44792 ppb was not exceeded. There are no State of Washington sediment standards for total PAH.

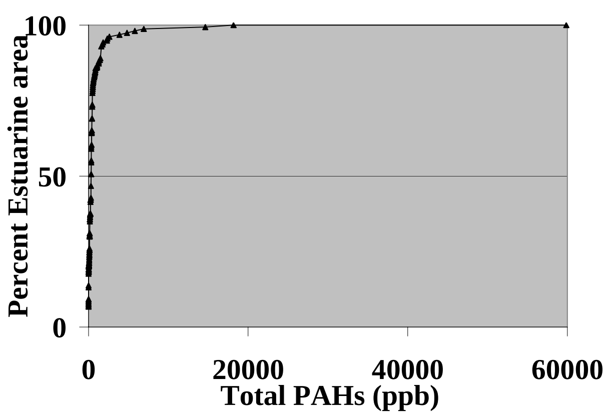


Figure 13. CDF of Total PAHs.

Low molecular weight PAH

Low molecular weight PAHs were detected in 83% of estuarine area at concentrations ranging from <1 ppb to 8636 ppb. The ERL of 5520 ppb was exceeded in 5% of the area, and the ERM of 3160 ppb was exceeded in <1% of the area. The State of Washington sediment standards are 370 and 780 ppm, normalized to the total organic carbon content. As a rule of thumb, samples with less than 0.5% TOC are not used in this comparison. One sample, representing well under 1% of the estuarine area, exceeded the sediment quality standard, and none exceeded the cleanup/ screening concentration.

High molecular weight PAH

Concentrations of high molecular weight PAHs were detected in 84% of the estuarine area at concentrations ranging from <1 ppb to 8613 ppb. The ERL of 1700 ppb was exceeded in 3% of the area, and the ERM of 9600 ppb was not exceeded. The State of Washington sediment standards are 960 and 5300 ppm, normalized to the total organic carbon content. No samples exceeded either the Washington sediment quality standard or the cleanup/screening concentration.

5. PCBs (Polychlorinated Biphenyls)

Polychlorinated biphenyls (PCBs) are a group of toxic, persistent chemicals formerly used in electrical transformers and capacitors. They often accumulate in sediments, fish, and wildlife, and are detrimental to the health of these organisms.

The sediment quality guidelines and standards for PCBs are based on a different analytical method than that used to analyze the EMAP sediments* so the "total PCB" concentrations using the two methods will not yield the same result. This is also true of PAHs, because the LPAH and HPAH totals for the Washington state standards, for EMAP, and for ERL/ERM benchmarks are based on slightly different lists of compounds. The EMAP totals are of the 21 PCB congeners measured, so the concentrations are biased low. The comparison is useful to highlight areas that are impacted by PCBs, but it is important to keep in mind that if identical methodology was used, additional sites might show exceedances of the Washington sediment quality guidelines and standards.

EMAP total* PCB concentrations ranged from below detection to 934 ppb. PCBs were detected in 14% of the estuarine area. The ERL of 22.7 ppb was exceeded in 3% of the area, according to the EMAP total PCBs. The ERM of 180 ppb was exceeded in one sample, representing <1%

of the area, according to the EMAP total PCBs. The station with the highest concentration is located in the Duwamish River in an area of known PCB contamination that is undergoing investigation as a Superfund site.

*The EMAP PCB analyte list includes the most common congeners, which are not necessarily the most toxic. Because the EMAP total PCB concentration is a sum of only the 21 congeners that were measured, it is important to remember that it is biased low. There are approximately 114 PCB congeners that are found in commercial mixtures (Frame et al, 1996) although some are found only rarely. In addition, quality assurance review following EMAP PCB analysis indicated low precision for the results at the individual congener level due to interferences. However, the review also concluded that it was acceptable to use the EMAP total PCBs as general indicators of sediment contamination.

Washington has a sediment quality standard, which normalizes total PCBs to the total organic carbon content in the sample. The sediment quality standard or "no effects level" is set at 12 mg total PCB/kg organic carbon. An additional standard of 65 mg total PCB/kg organic carbon is considered the "minor adverse effects level" and is used as "an upper regulatory level for source control and cleanup decision making."

When all Washington and Oregon data were normalized to the organic carbon content, none of the stations exceeded the higher adverse effects level standard, but 1% of the area (12 stations) exceeded Washington's sediment quality standard for total PCBs. Aside from the Duwamish station, all the other stations that exceeded this standard were in Oregon. The Oregon stations had low to very low total organic carbon, which can result in a high normalized concentration, even with a low total PCB concentration.

Normalization to total organic carbon content is done because toxicity often depends on the porewater concentration and samples with higher concentrations of contaminants in the organic fraction may be more bioavailable to organisms. It is important to note, however, that the relationship this conclusion is based on is not strong at low concentrations of TOC, and at TOC content of less than 0.5%, the relationship may not be reliable.

The highest TOC content in the Oregon stations exceeding the ERL was 0.67%, and all the rest were below 0.5%. The low-TOC Oregon stations represent very small areas, however, so whether or not stations with less than 0.5% carbon are excluded, less than 1% of the estuarine area in both states combined exceeds the Washington sediment quality standard.

6. Pesticides

None of the pesticides analyzed (Appendix 2) have state sediment quality standards, and only DDT and DDE have sediment quality guidelines. Approximately 83% of the area had no detected pesticides, 17% of the area had 1-3 detected, and 2% of the area had 3-5 pesticides detected (**Figure 14**).

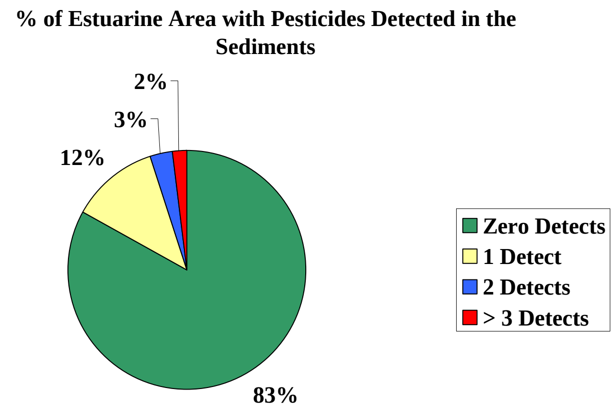


Figure 14. % of Estuarine Area with Pesticides Detected in the Sediments.

DDT

Total DDT was detected in 10% of the estuarine area, with concentrations ranging from below detection to 12 ppb (**Figure 15**). The ERL of 1.58 ppb was exceeded in 4% of the area, but the ERM was not exceeded.

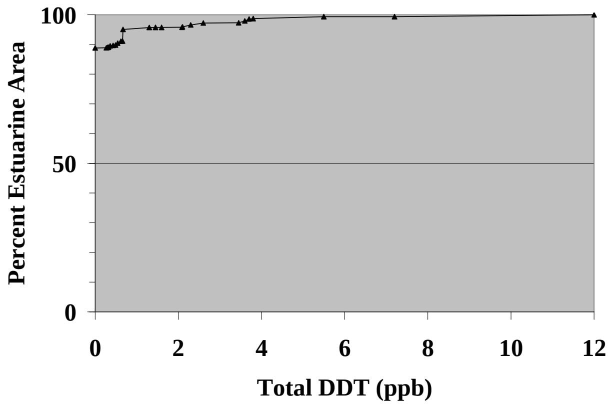


Figure 15. CDF of Total DDT.

The DDT breakdown product 4,4'-DDE was detected in 10% of the estuarine area with concentrations ranging from below detection to 6.7 ppb. The ERL of 2.2 ppb was exceeded in 2% of the area, but the ERM was not exceeded.

C. Toxicity

1. Acute sediment toxicity tests

Toxicity testing uses biological organisms, in this case either the marine amphipod *Ampelisca abdita* or the freshwater amphipod *Hyallela azteca*, to determine toxicity. Toxicity is a measure of the degree to which a chemical or mixture of chemicals in the sediments will harm living things. Fifty percent of the estuarine area had over 90% survival rate of the test organisms (*Ampelisca abdita* or *Hyallela azteca*) when they were exposed to sediments in the laboratory (i.e., 50% of the area had less than 10% mortality of test organisms in the lab) (**Figure 16**).

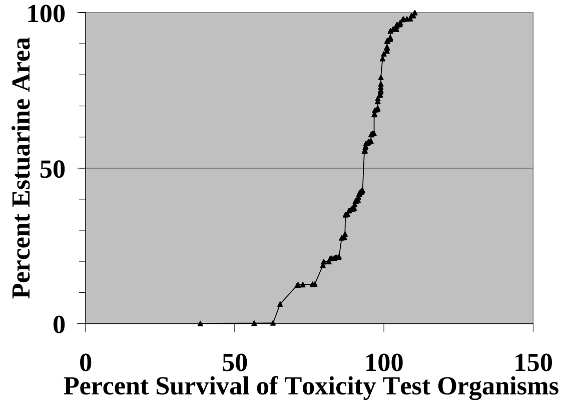


Figure 16. CDF of Toxicity Testing.

D. Chemicals in Fish Tissue

Tissue Parameter	Toxic Tissue Screening Concentration (TSC) in ppb (from Dyer et al, 2000 unless noted)	Mean (ppb)	Minimum (ppb)	Maximum (ppb)	% of area exceeding TSC
METALS					
Inorganic Arsenic	1600	56	0	595	0%
Cadmium	83 [1]	6	0	200	4%
Lead	59 [1]	132	0	967	78%
Mercury	60	29	0	256	2%
Selenium	560	234	0	2,390	12%
Silver	37	5	0	280	2.3%
Zinc	20,000	13,569	0	39,060	6.5%
PESTICIDES					
DDT	54 [2]	14	0	494	4.8%

Table 5. Selected Contaminants in Fish Tissue in the Estuaries of Oregon and Washington (n/a = no toxicity threshold exists).
[1] TSC is from Shephard, 2006. in press.
[2] EMAP data are reported as total DDT; DDE is reported separately. TSCs are for 4,4'-DDD, 4,4'-DDE, 4,4'-DDT. Because all the TSCs are the same concentration, the comparison was made with that number.

Chemicals were measured in fish tissues in the estuaries of Oregon and Washington. The values in **Table 5** were used to indicate if the levels found in tissue indicate levels that may be harmful to the fish. The Toxic Tissue Screening Concentration (TSC) is a product of U.S. EPA's water quality criterion (WQC) and bioconcentration factor (BCF) per respective chemical (TSC=WQC*BCF). The BCF are from the U.S. EPA (1986). For chemicals not listed in the EPA document, BCFs were calculated based on Dyer, 2000, unless otherwise noted.

1. Metals

<u>Inorganic Arsenic</u>

Fish tissue was analyzed for total arsenic (inorganic and organic). Since TSC is available only for inorganic arsenic, an estimate of the percentage of the total arsenic that is inorganic arsenic in fish tissue (2%) was made based on other studies of marine fish species.

Inorganic arsenic was detected in fish tissue in 85% of the estuarine area, with concentrations ranging from below detection to 595 ppb (**Figure 17**). The TSC of 1600 ppb not exceeded.

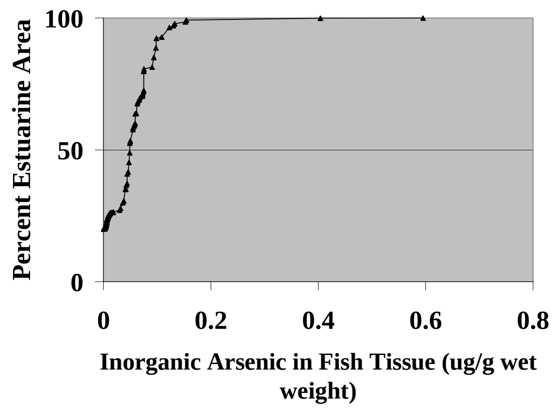


Figure 17. CDF of Inorganic Arsenic in Fish Tissue.

<u>Cadmium</u>

Cadmium was detected in fish tissue in 9% of the estuarine area, with concentrations ranging from below detection to 200 ppb. The TSC of 83 ppb was exceeded in 4% of the area.

<u>Lead</u>

Lead was detected in fish tissue in 81% of the estuarine area, with concentrations ranging from below detection to 967 ppb. The TSC of 59 ppb was exceeded in 78% of the area.

Mercury

In most (94%) of the estuarine area, mercury was detected in fish tissue. The concentrations ranged from below detection to 256 ppb (**Figure 18**).

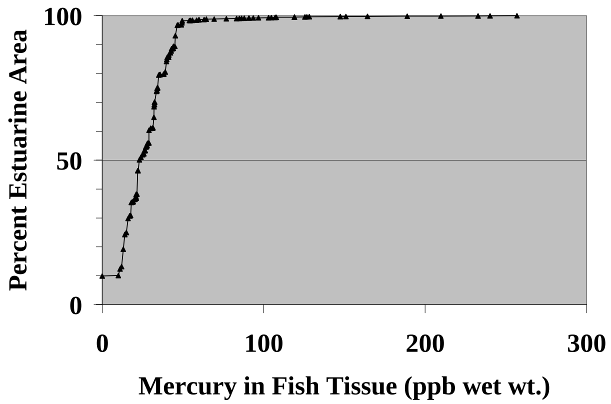
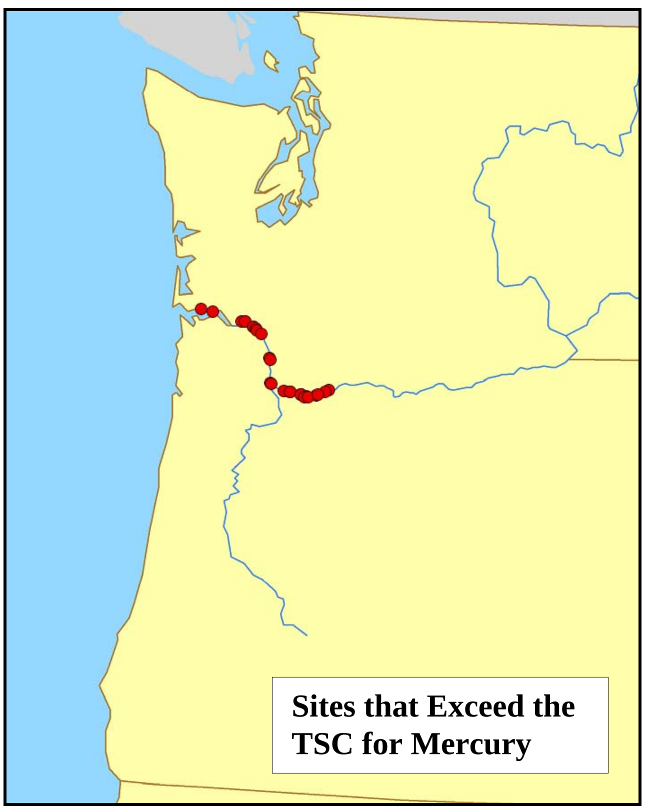


Figure 18. CDF of Mercury in Fish Tissue.

The TSC of 60 ppb was exceeded in 2% of the area. Sites with fish tissue levels exceeding the TSC for mercury were all in the Columbia River estuary (**Map 2**).



Map 2. Sites that Exceed the Toxic Screening Criteria (TSC) for Mercury.

Selenium

Selenium was detected in fish tissue in 22% of the estuarine area, with concentrations ranging from below detection to 2390 ppb. The TSC of 560 ppb was exceeded in 12% of the area.

Silver

Silver was detected in fish tissue in 17% of the estuarine area, with concentrations ranging from below detection to 280 ppb. The TSC of 37 ppb was exceeded in 2.3% of the area.

Zinc

In most (>99%) of the estuarine area, zinc was detected in fish tissue. The concentrations ranged from below detection to 39,060 ppb (**Figure 19**).

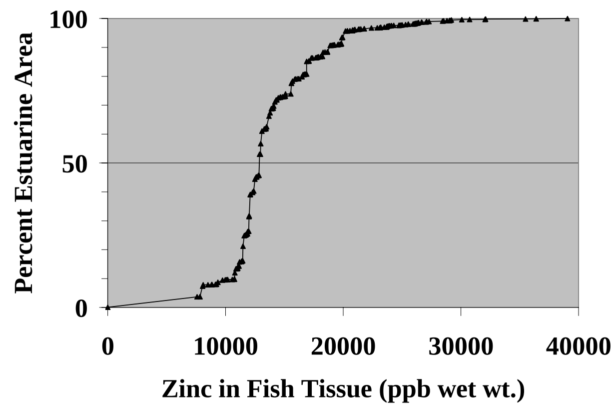
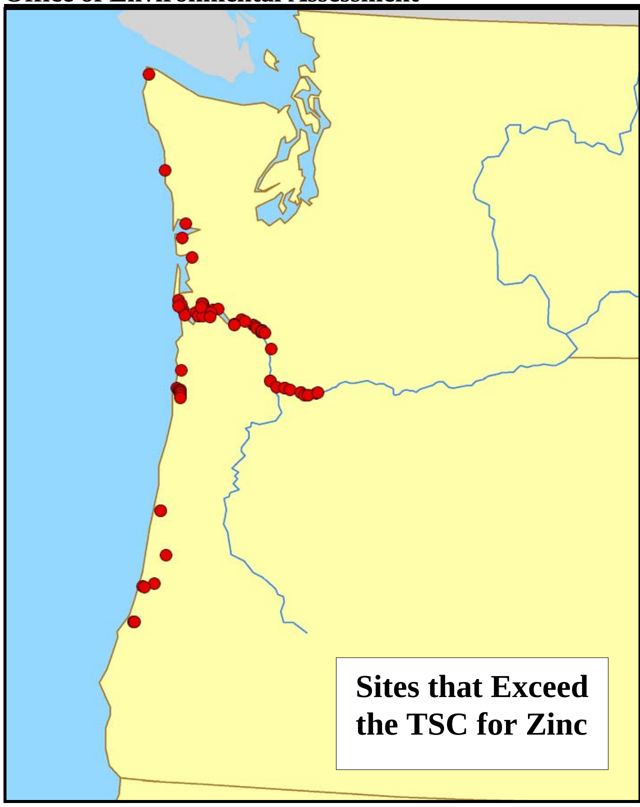


Figure 19. CDF of Zinc in Fish Tissue.

The TSC of 20,000 ppb was exceeded in 6.5% of the area. Sites with fish tissue levels exceeding the toxicity threshold were found scattered along the outer coast and Columbia River estuary, but were missing from Puget Sound (**Map 3**).



Map 3. Sites that Exceed the Toxic Screening Criteria (TSC) for Zinc.

2. Pesticides

DDT

In most (97%) of the estuarine area, DDT was found in the fish tissue analyzed. The concentrations ranged from below detection to 493 ppb (**Figure 20**).

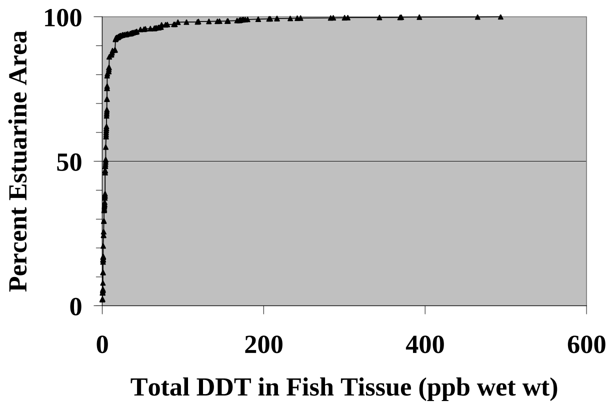
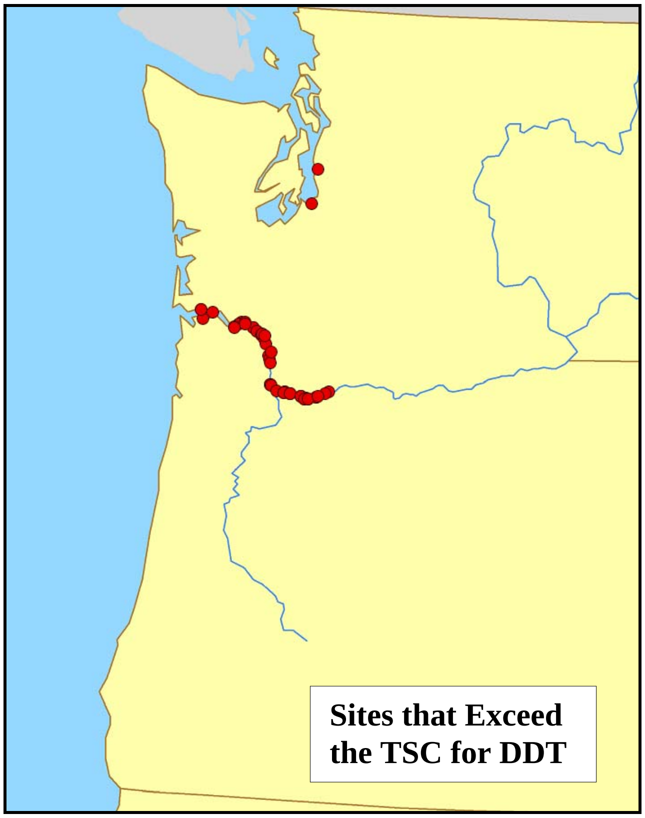


Figure 20. CDF of DDT in Fish Tissue.

The TSC of 54 ppb was exceeded in 4.8% of the area. Sites with fish tissue levels exceeding the TSC for DDT were mostly in the Columbia River estuary (**Map 4**). These results confirm the findings of the Bi-State report (Tetra Tech, 1993) which concluded that DDT was distributed in fish tissue samples collected throughout the lower Columbia River.



Map 4. Sites that Exceed the Toxic Screening Criteria (TSC) for DDT.

E. Benthic Invertebrates

Benthic invertebrates were sampled at 223 sites, representing 6988 square kilometers or 81% of the estuarine area of Oregon and Washington. Benthic invertebrate abundance and diversity are good indicators of environmental health. See Appendix 6 for additional information on the benthic invertebrate community.

1. Benthic abundance

Benthic invertebrate abundance is the number of organisms per unit area. It ranged from 0 to over 8000 organisms per $0.1m^2$ (**Figure 21**).

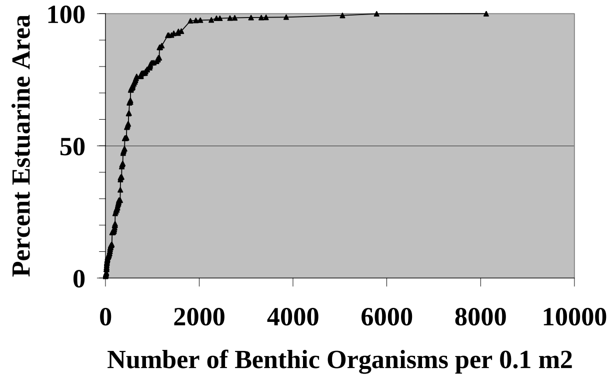


Figure 21. CDF of Number of Benthic Organisms per 0.1 m^2 (Abundance).

2. Benthic species richness/diversity

There were 982 species found overall in 1999-2000 (**Figure 22**). Of these, 338 were found at only 1 site, while an additional 172 were found at two sites. Seventy-two species were found at 20 or more sites.

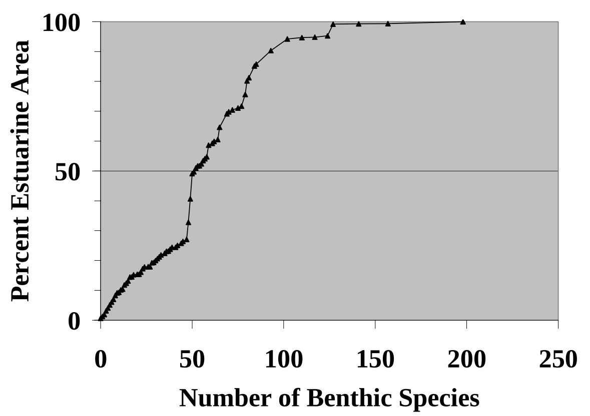


Figure 22. CDF of Number of Benthic Species.

The salinity of the waters sampled was quite varied. Since benthic invertebrates have varying tolerances to salinity, we divided the sites into three groups using the bottom salinity measurements:

- Marine, with > 25 psu (practical salinity units),
- Freshwater, with < 5psu, and
- Intermediate, with ≥ 5 and ≤ 25 psu.

Ninety-one percent of the estuarine area with benthos sampled fell into the marine category (121 sites). Six percent of the area was freshwater, and 3% was of intermediate salinity. The Columbia River estuary sites were all either freshwater or intermediate. Additional freshwater and intermediate sites were found along the outer coast of Oregon and Washington in smaller estuaries. All sites in Puget Sound fell into the marine category. It should be noted that while some of the some of species may have been found at very few sites, they can be extremely abundant locally.

At the marine sites, 912 species were found. Of these, 313 were found at only 1 site, and an additional 164 were found at two sites. Thirty eight species were found at 20 or more sites out of the total 121 marine sites. Of the 912 species, 842 species (92%) were found only at marine sites.

At the freshwater sites, 83 species were found. Of these, 42 were found at only 1 site, and an additional 11 were found at two sites. Four species were found at 20 or more sites of the 64 freshwater sites. Of the 83 species, 44 species (53%) were found only at freshwater sites.

At the intermediate sites, 93 species were found. Of these, 42 were found at only 1 site, and an additional 18 were found at two sites. Only one species was found at 20 or more sites of the 35 intermediate sites. Of the 93 species, 10 species (9%) were found only at intermediate sites.

There were an additional 12 species found at both the freshwater and intermediate sites that were not found at the marine sites at all. **Figure 23** shows the most common species for each of the three salinity categories: marine, freshwater and intermediate. Even the most common freshwater species (*Corbicula fluminea*) or intermediate species (*Americorophium salmonis*) are rare compared to many marine species. This is because the freshwater/intermediate sites represent only a small portion of the total estuarine area sampled.

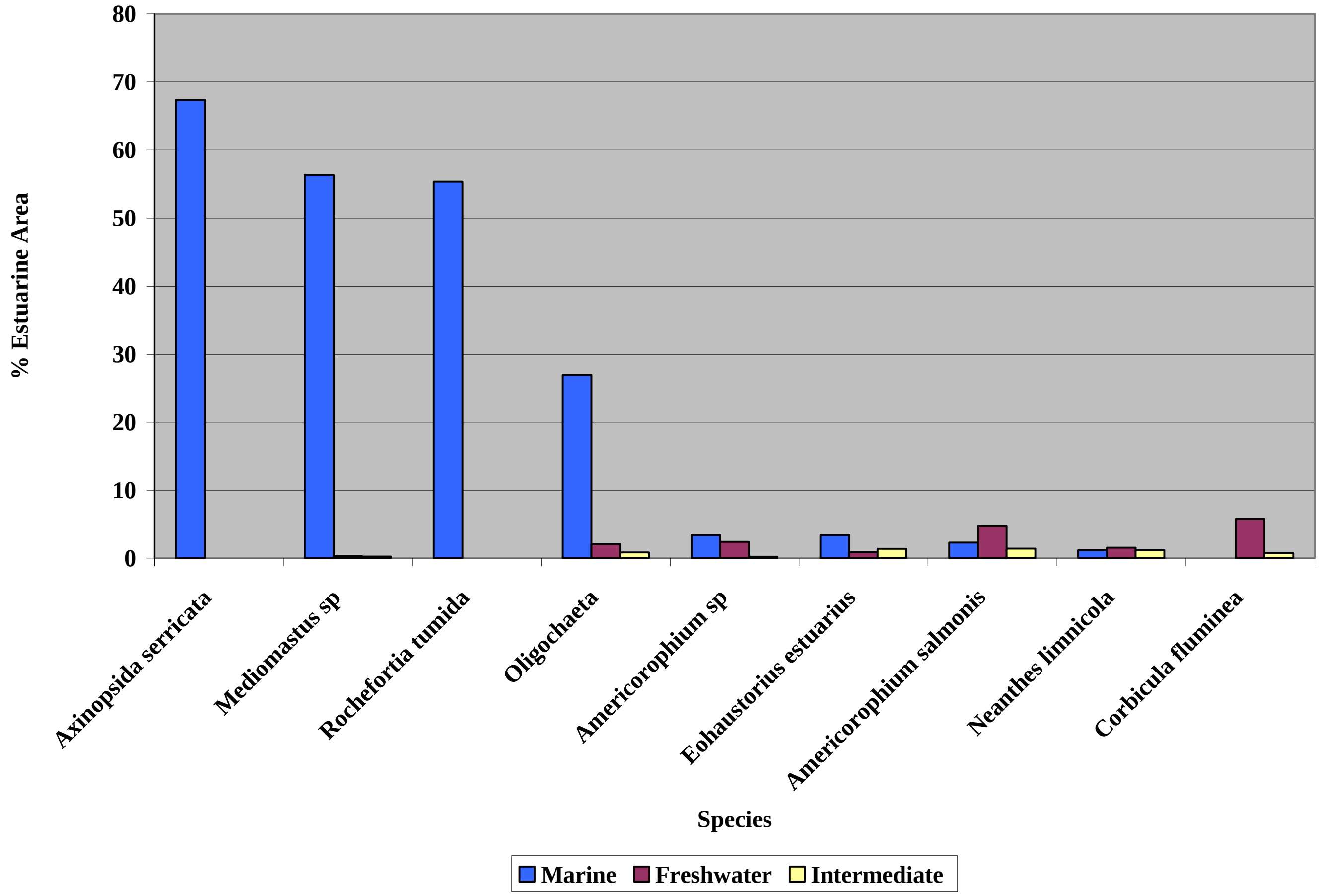


Figure 23. Most Common Benthic Invertebrates (for each of the three salinity categories: marine, freshwater and intermediate).

F. Fish

Fish sampling was conducted at 226 sites, representing 7666 square kilometers (88% of the estuarine area of Oregon and Washington). At 27 sites, there were no fish captured. English sole (*Pleuronectes vetulus*) was the most commonly occurring species; it was found in nearly 70% of the estuarine area. **Figure 24** shows the fish species most commonly occurring. Twenty seven fish species were found at only one site. It should be noted that while some of the species may have been found at very few sites, they can be extremely abundant locally.

An additional 34 species were found at 5 or fewer sites. Only 10 species were found at 25 or more sites. Appendix 7 lists all of the fish species found.

Due to the varying tolerances of fish to salinity, we divided the sites into three groups (the same as for the benthic invertebrates) using the bottom salinity measurements:

- Marine, with > 25 psu,
- Freshwater, with < 5psu, and
- Intermediate, with ≥ 5 and ≤ 25 psu.

Ninety percent of the estuarine area sampled for fish sites was in the marine category, 3% of the area was intermediate, and 7% was freshwater. The Columbia River estuary sites were all either freshwater or intermediate. Additional freshwater and intermediate sites were found along the outer coast of Oregon and Washington in smaller estuaries. All sites in Puget Sound fell into the marine category.

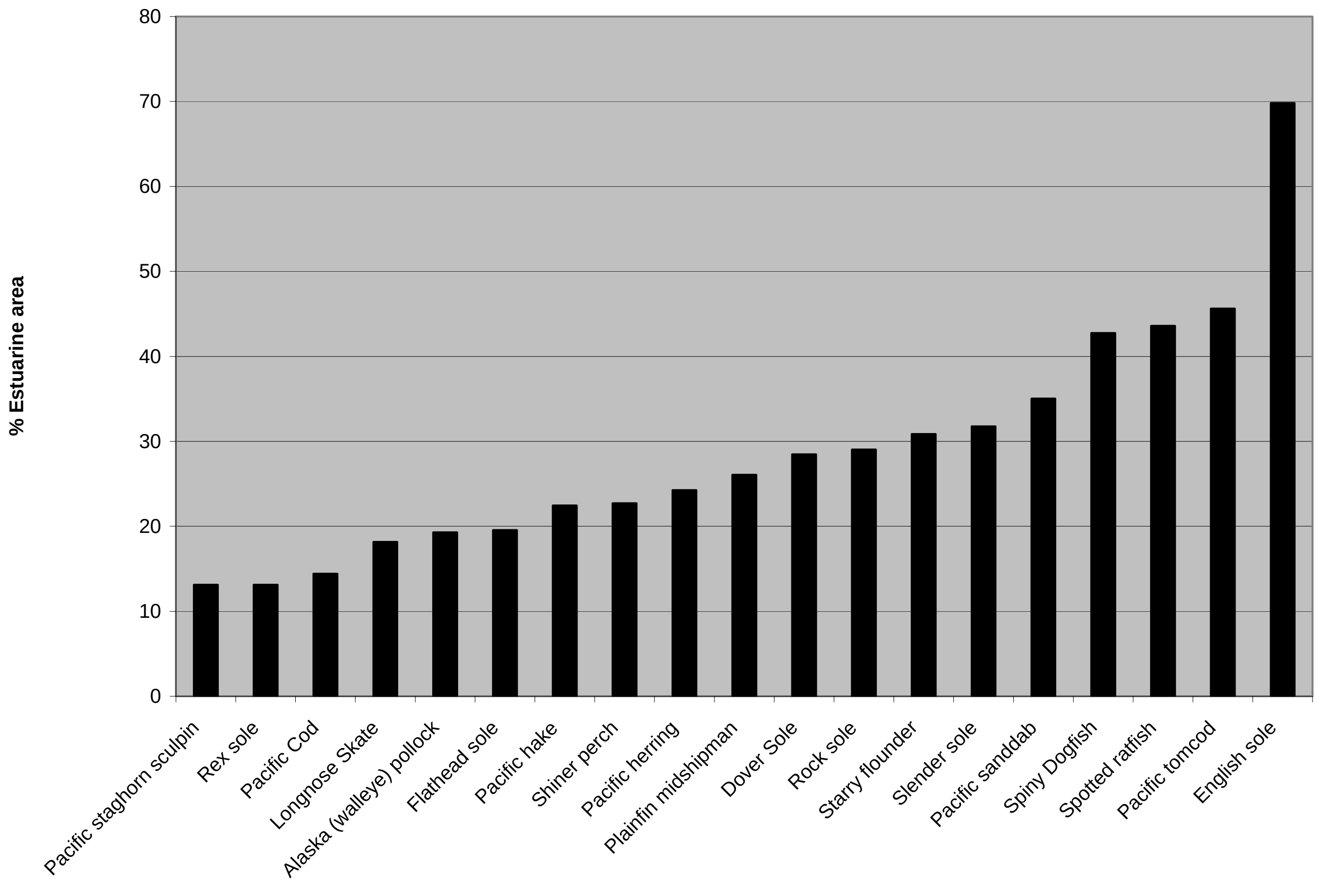


Figure 24. Fish Species Found at all Sites (showing the most commonly occurring species).

Of the 93 fish species found overall in 1999-2000, 81 were found in the marine sites, 18 in freshwater sites and 17 in the intermediate sites (**Figure 25**). See Appendix 7 for additional details.

Marine sites had bottom salinities of greater than 25 psu and surface salinities between 13.0 psu and 33.0 psu. Of the 81 species found at these marine sites, 66 species were found only at marine sites.

Freshwater sites had bottom salinities of less than 5 psu and surface salinities between 0.01 psu and 3.4 psu. Of the 18 species found at freshwater sites, 10 of these species were found only at freshwater sites. Unique freshwater species included Cutthroat trout, Crappies, Northern Pikeminnow, Peamouth, Three-spine stickleback, and Sand roller. The overall most commonly found species in 1999-2000 study, English sole, was not found at any of the freshwater sites.

Intermediate sites had bottom salinities between 5 psu and 25 psu and surface salinities from 2.7 psu to 24.9 psu. No species found at the intermediate sites were unique to those sites. **Figure 25** shows the most common species for each of the three salinity categories: marine, freshwater and intermediate. Even the most common species found at freshwater locations (Starry flounder) or at intermediate salinity locations (Pacific staghorn sculpin) are rare, based on percent area of occurrence compared to those species that were dominant at marine locations. This is because the freshwater/intermediate sites represent only a small portion of the total estuarine area sampled.

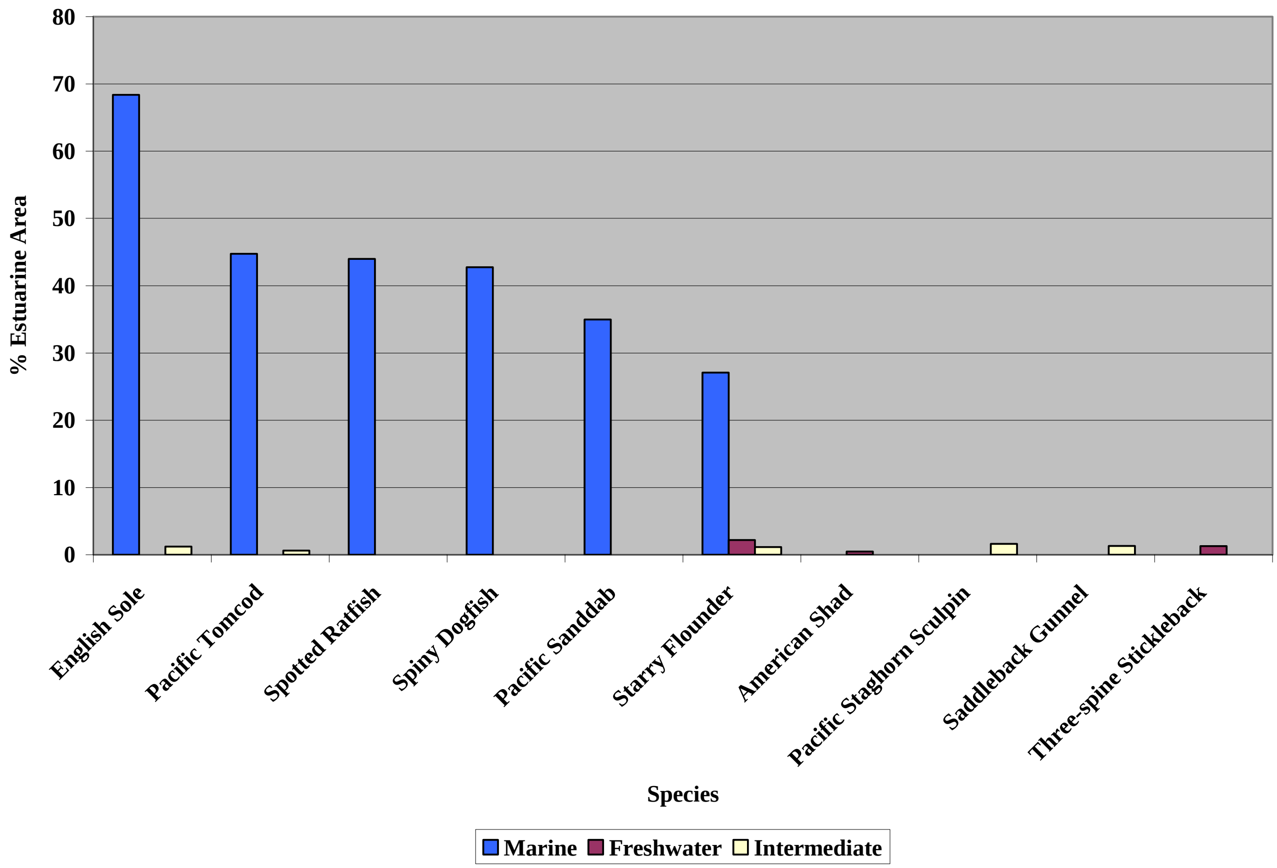


Figure 25. Most Commonly Found Fish at Marine, Freshwater and Intermediate Sites.

G. Non-indigenous species

Invasive species are considered one of the most important environmental stressors to coastal ecosystems and represent a threat to both local and regional economies and the fundamental ecological integrity of aquatic ecosystems throughout the U.S. (Lee and Thompson, 2003). While some of these non-indigenous species (NIS) have been purposefully introduced, such as the Japanese oyster for aquaculture, others have quietly hitch-hiked in to become invasive species, such as the Zebra mussel and European green crab. Coastal waters are particularly vulnerable to foreign-species invasions because human activities and practices associated with shipping and transportation, such as ship ballast water exchange and the aquaculture of non-indigenous species, are major and effective transport mechanisms. The United Nations recently stated that invasive species are second only to habitat loss as the greatest threat to decreasing global biodiversity.

Species were classified based on the "*Pacific Coast Ecosystem Information System*" (*PCEIS*), a joint project between EPA and the USGS to develop a spatial database of the marine/estuarine native and nonindigenous species (NIS) in Oregon, Washington, and California. The primary classifications and groupings for invertebrates (not fish) used are:

Native: Indigenous to the Northeast Pacific.

Nonindigenous species (NIS): Species not native to the Northeast Pacific.

Cryptogenic: Species of unknown origin so they can not be classified as native or NIS. These species should not be considered "de facto" NIS.

The relative abundance of nonindigenous species (NIS) were calculated for all sites with salinity $\geq$5 psu using the following metric:

Abundance Invasion Metric (AIM) = (Abundance of NIS)/(Abundance of NIS & Abundance of Natives) * 100

The cut-points of 0-10%, 10-50% and >50% were suggested as "background," "moderately invaded," and "highly invaded" for AIM. The current analysis does not include the cryptogenic species, which are both widespread and abundant in many sites.

Oregon and Washington show low levels of invasion, with approximately 37% of the area containing no NIS and approximately 90% of the area showing "background" levels (0-10%) of invasion. Less than 4% of the area was classified as highly invaded (**Figure 26**).

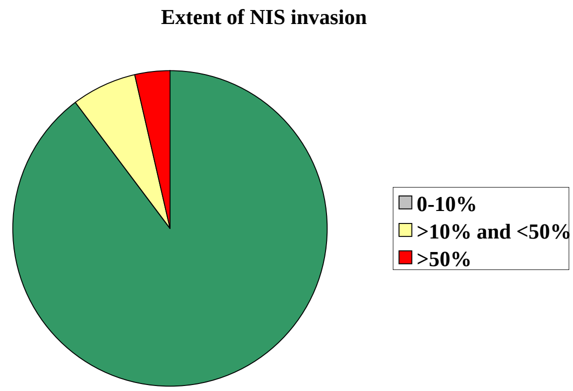


Figure 26. Extent of NIS Invasion in the Estuaries of Oregon and Washington

Puget Sound is much less invaded than the coastal estuaries or the Columbia River. In particular, the deeper ($\geq$30 m) samples from Puget Sound were less invaded. Of the 26 deeper samples in Puget Sound, 10 contained no NIS, with an average AIM of 4.9%. The coastal estuaries and the Columbia River were much more invaded than Puget Sound, with about 75% – 80% of the area invaded to some extent (i.e., NIS >0) and 12% - 25% highly invaded.

IV. CONCLUSIONS

Photo: English Sole, a target fish species.

Most historic assessments of estuary quality have focused on describing the chemical quality of estuaries and, occasionally, impacts to sport fisheries. However, the goal of the Clean Water Act is to maintain and restore the physical, chemical and biological integrity of the nation's waters. In this assessment we try to address this issue by incorporating direct measurements of physical, chemical and biological condition of estuaries.

To assess whether or not a specific metric indicates good or poor condition, a benchmark, standard or target is needed for comparison. Not all parameters or indicators have benchmarks developed. Therefore, we will only interpret those indicators that have benchmarks or targets developed that are relevant to the estuaries of Oregon and Washington.

A. Water Physical/Chemical Indicators

Dissolved Oxygen

Dissolved Oxygen (DO) concentrations below approximately 2 mg/L are thought to be stressful to many estuarine organisms (Diaz and Rosenberg, 1995; U.S. EPA, 2000a). These low levels most often occur in bottom waters and affect the organisms that live in the sediments. Low levels of oxygen (hypoxia) or lack of oxygen (anoxia) often accompany the onset of severe bacterial degradation, sometimes resulting in the presence of algal scums and noxious odors. However, in some estuaries, low levels of oxygen occur periodically or may be a part of the natural ecology. Therefore, although it is easy to show a snapshot of the conditions of the nation's estuaries concerning oxygen concentrations, it is difficult to interpret whether this snapshot is representative of all summertime periods or the result of natural physical processes.

Dissolved oxygen was rated good, fair, or poor using the following criteria:

Good: > 5 mg/L
Fair: 2–5 mg/L
Poor: < 2 mg/L

Less than two percent of estuarine area was in poor condition, having a bottom DO concentration below 2 mg/L. The sites with low bottom DO were in Hood Canal, an area in Washington state with well known low DO issues. Approximately 70% of the area of the estuaries was in good condition, having bottom DO concentrations above 5mg/L (**Figure 29**).

Nutrients

Some nutrient inputs (such as nitrogen and phosphorus) to estuaries are necessary for healthy, functioning estuarine ecosystems. When nutrients from various sources, such as sewage and fertilizers, are introduced into an estuary, the concentration of nutrients will increase beyond natural background levels. Excess nutrients can lead to excess plant production, and thus, to increased phytoplankton, which can decrease water clarity and lower concentrations of dissolved oxygen. To assess whether a site was in good, fair or poor condition (**Table 6**), we used the criteria developed for the National Coastal Assessment (U.S. EPA, 2004).

	Good	Fair	Poor
Nitrogen	<0.5mg/L	0.5 - 1.0 mg/L	>1 mg/L
Chlorophyll *a*	< 5 ug/L	5 - 20 ug/L	>20 ug/L

Table 6. Criteria for Assessing Nutrients

For nitrogen, none of the estuarine area was considered in poor condition, and very little was in fair condition. For Chlorophyll *a*, almost none (0.1%) of the area was in poor condition, some (19.9%) was in fair condition and the majority of the area (80%) was in good condition.

B. Sediment Characteristics

Approximately 3 percent of the estuarine area has total organic carbon (TOC) content greater than 3.5%. The 3.5% level was found by Hyland, 2005, to be associated with decreased benthic abundance and biomass. The National Coastal Assessment Program (U.S. EPA, 2004) uses concentrations above 2% and above 5% TOC to indicate fair and poor habitat, respectively. Using these values, 14.1% of the area is in fair condition (above 2%) and none is in poor condition (above 5%).

To assess the degree of sediment contamination, the sediment concentrations of contaminants were compared with both the ERM and ERL guidelines (Long, 1995) and the Washington State sediment quality standards. A station with a concentration exceeding an ERM or a Washington state sediment quality standard is classified as being in poor condition.

For this comparison, nickel, copper, and chromium exceedances that were within background ranges were excluded. Samples with less than 0.5% total organic carbon were excluded when comparing results with Washington standards that are based on normalization to TOC content.
Using these criteria, less than 1% of the estuarine area exceeded an ERM or a Washington sediment quality standard, indicating a poor sediment condition (**Figure 27**). In 5% of the area, no ERMs were exceeded, but more than 3 ERLs were exceeded, indicating a fair rating for sediment contamination (Figure 27).

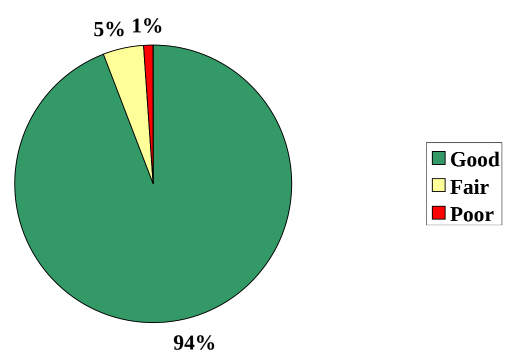


Figure 27. Summary of Sediment Contamination.

C. Chemicals in Fish Tissue

The Toxic tissue Screening Criteria (TSC) are tissue residue levels that, when exceeded, may be harmful to fish. We evaluated the TSC for arsenic, cadmium, DDT, lead, mercury, selenium and zinc. In the estuaries of Oregon and Washington, 3.3% of the estuarine area had 4 of these chemicals in tissues exceeding the TSC (at the same site, which indicates a likely poor condition), 11.1% had 3 chemicals above the TSC, 38.9% had 2 and 46.7% have one or zero above the TSC, indicating good conditions (**Figure 28**).

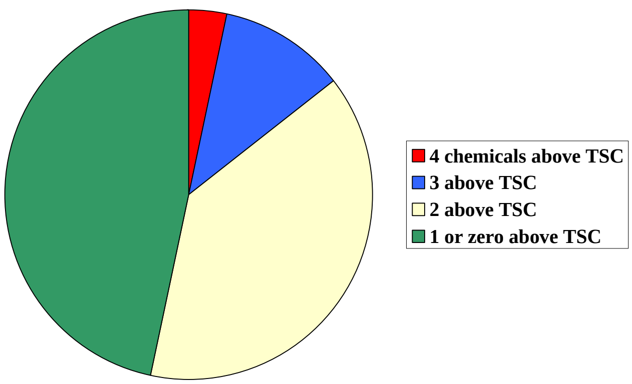


Figure 28. Summary of Chemicals in Fish Tissue.

D. Non-Indigenous Species (NIS)

When looking at NIS species, we will be assessing only those species whose origin is known with reasonable certainty. The estuaries of Oregon and Washington show low levels of invasion, with less than 4% of the area classified as highly invaded ($\geq$ 50% AIM) or poor condition.

The coastal estuaries and the Columbia River were much more invaded than Puget Sound, with about 75% – 80% of the area invaded to some extent (i.e., NIS >0) and 12% - 25% highly invaded. However, due to the large size of Puget Sound, the overall estimates for Oregon and Washington essentially reflect this low extent of invasion in Puget Sound (the average AIM is 4.9%).

Photo: Corbicula fluminea, an NIS species.
Photo credit: Noel M. Burkhead, U.S. Geological Survey

E. Summary

This project was designed to evaluate the overall condition of estuaries in Washington and Oregon. In this assessment we used direct measurements of the biota themselves as indicators of ecological condition. Information on the biota is supplemented by indicators of stress, which are measurements of other estuarine characteristics or factors that might influence or affect ecological condition, especially water chemistry and sediment characteristics.

Very little (0-2%) of the estuarine area of Oregon and Washington (**Figure 29**) is in “poor” condition using bottom dissolved oxygen, chlorophyll a and nitrogen as water chemistry indicators. Sediment indicators (total organic carbon and sediment contaminants) also showed very little ($\leq$1% - 3%) of the estuarine area of Oregon and Washington (**Figure 29**) in “poor” condition. A slightly higher percentage (3.4% - 4%) of the estuarine area of Oregon and Washington were in “poor” condition for biological indicators (NIS and chemicals in fish tissue). In conclusion, overall, very little of the estuarine area of Oregon and Washington (0-4%) is in "poor" condition for any indicator that we examined (**Figure 29**).

However, there were some geographic areas where the results that indicate concerns. All of the sites with low bottom DO were in Hood Canal, an area in Washington state with well known low DO issues. In contrast, sites with fish tissue levels exceeding the TSC for mercury were all in the Columbia River estuary. Also, sites with fish tissue levels exceeding the TSC for DDT were mostly in the Columbia River estuary. Finally, the coastal estuaries and the Columbia River were much more invaded by NIS species than Puget Sound, with 12% - 25% of the area in the highly invaded category.

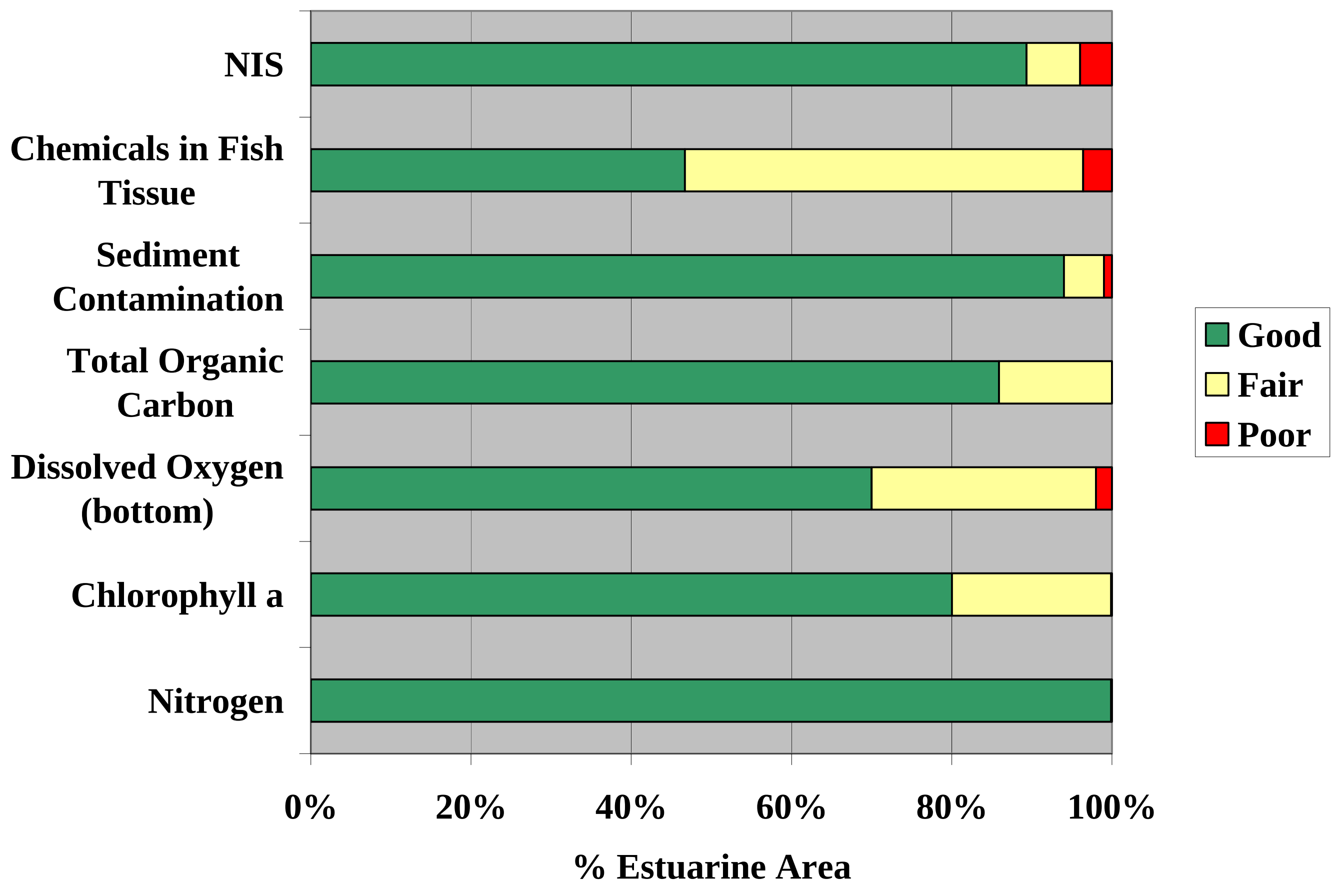


Figure 29. Overall Condition of Estuarine Area in Oregon and Washington for Selected Indicators.

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VI. APPENDICES

Appendix 1. Site location information (Note that some sites sampled by Washington Department of Ecology were in Canadian Waters).

STATE	YEAR	ESTUARY NAME	EMAP Station ID	LATITUDE	LONGITUDE
OREGON	2000	COLUMBIA RIVER, RIVER MILE 51.4	OR00-0001	46.18642	-123.181
OREGON	2000	COLUMBIA RIVERRIVER MILE 49.2	OR00-0002	46.16893	-123.216
OREGON	2000	COLUMBIA RIVERRIVER MILE 53.2	OR00-0003	46.18787	-123.141
OREGON	2000	COLUMBIA RIVER, RIVER MILE 45.9	OR00-0004	46.14234	-123.275
OREGON	2000	COLUMBIA RIVER, RIVER MILE 59.2	OR00-0005	46.14628	-123.036
OREGON	2000	COLUMBIA RIVER, RIVER MILE 61.5	OR00-0006	46.12905	-122.999
OREGON	2000	COLUMBIA RIVER, RIVER MILE 62.9	OR00-0007	46.1142	-122.978
OREGON	2000	COLUMBIA RIVER	OR00-0008	46.10204	-122.915
OREGON	2000	COLUMBIA RIVER, RIVER MILE 66.2	OR00-0009	46.0889	-122.923
OREGON	2000	COLUMBIA RIVER, RIVER MILE 69	OR00-0010	46.05742	-122.887
OREGON	2000	COLUMBIA RIVER, RIVER MILE 72.5	OR00-0011	46.01564	-122.858
OREGON	2000	COLUMBIA RIVER, RIVER MILE 80.2	OR00-0012	45.91205	-122.81
OREGON	2000	COLUMBIA RIVER, RIVER MILE 82.8	OR00-0013	45.87721	-122.793
OREGON	2000	COLUMBIA RIVER, RIVER MILE 83.6	OR00-0014	45.86531	-122.788
OREGON	2000	COLUMBIA RIVER, RIVER MILE 85.1	OR00-0015	45.84555	-122.786
OREGON	2000	COLUMBIA RIVER, RIVER MILE 99	OR00-0016	45.6517	-122.763
OREGON	2000	COLUMBIA RIVER, RIVER MILE 99.7	OR00-0017	45.64532	-122.751
OREGON	2000	COLUMBIA RIVER	OR00-0018	45.60626	-122.675
OREGON	2000	COLUMBIA RIVER, RIVER MILE 109.4	OR00-0019	45.59698	-122.569
OREGON	2000	COLUMBIA RIVER	OR00-0020	45.59403	-122.582
OREGON	2000	COLUMBIA RIVER, RIVER MILE 112.6	OR00-0021	45.5839	-122.502
OREGON	2000	COLUMBIA RIVER, RIVER MILE 119.9	OR00-0022	45.56827	-122.366
OREGON	2000	COLUMBIA RIVER, RIVER MILE 119.9	OR00-0023	45.56863	-122.363
OREGON	2000	COLUMBIA RIVER, RIVER MILE 138.8	OR00-0024	45.62269	-122.018
OREGON	2000	COLUMBIA RIVER, RIVER MILE 136.6	OR00-0025	45.605	-122.053
OREGON	2000	COLUMBIA RIVER	OR00-0026	45.55558	-122.3
OREGON	2000	COLUMBIA RIVER, RIVER MILE130.8	OR00-0027	45.5745	-122.165
OREGON	2000	COLUMBIA RIVER, RIVER MILE 123.1	OR00-0028	45.54575	-122.315
OREGON	2000	COLUMBIA RIVER, RIVER MILE 125.3	OR00-0029	45.55037	-122.271
OREGON	2000	COLUMBIA RIVER, RIVER MILE 131.6	OR00-0030	45.58123	-122.149
OREGON	2000	COLUMBIA RIVER	OR00-0031	46.27134	-124.045
OREGON	2000	COLUMBIA RIVER	OR00-0032	46.2592	-124.021
OREGON	2000	COLUMBIA RIVER, RIVER MILE 3.8	OR00-0033	46.22675	-123.978
OREGON	2000	COLUMBIA RIVER	OR00-0034	46.24636	-123.865
OREGON	2000	COLUMBIA RIVER	OR00-0035	46.28297	-123.793
OREGON	2000	COLUMBIA RIVER	OR00-0036	46.23201	-123.939
OREGON	2000	COLUMBIA RIVER	OR00-0037	46.242	-123.859
OREGON	2000	COLUMBIA RIVER	OR00-0038	46.23394	-123.88
OREGON	2000	COLUMBIA RIVER	OR00-0039	46.23854	-123.79
OREGON	2000	COLUMBIA RIVER	OR00-0040	46.26919	-123.713
OREGON	2000	COLUMBIA RIVER	OR00-0041	46.20529	-123.882

STATE	YEAR	ESTUARY NAME	EMAP Station ID	LATITUDE	LONGITUDE
OREGON	2000	COLUMBIA RIVER	OR00-0042	46.22234	-123.797
OREGON	2000	COLUMBIA RIVER	OR00-0043	46.24003	-123.732
OREGON	2000	COLUMBIA RIVER, RIVER MILE 21.4	OR00-0044	46.26385	-123.658
OREGON	2000	COLUMBIA RIVER, RIVER MILE 25.7	OR00-0045	46.25365	-123.562
OREGON	2000	COLUMBIA RIVER, RIVER MILE 14.5	OR00-0046	46.21268	-123.781
OREGON	2000	COLUMBIA RIVER	OR00-0047	46.22227	-123.665
OREGON	2000	COLUMBIA RIVER, RIVER MILE 28.8	OR00-0048	46.2683	-123.502
OREGON	2000	COLUMBIA RIVER, RIVER MILE 32.5	OR00-0049	46.24906	-123.44
OREGON	2000	COLUMBIA RIVER, RIVER MILE 33.5	OR00-0050	46.23561	-123.427
OREGON	1999	YOUNGS BAY, RIVER MILE 8.3	OR99-0001	46.113	-123.547
OREGON	1999	CATHLAMET BAY	OR99-0002	46.12633	-123.434
OREGON	1999	YOUNGS BAY	OR99-0003	46.10801	-123.519
OREGON	1999	CATHLAMET BAY	OR99-0004	46.13026	-123.403
OREGON	1999	YOUNGS BAY	OR99-0005	46.10038	-123.536
OREGON	1999	CATHLAMET BAY	OR99-0006	46.12473	-123.413
OREGON	1999	YOUNGS BAY	OR99-0007	46.1014	-123.523
OREGON	1999	MARSH ISLAND CREEK	OR99-0008	46.13569	-123.353
OREGON	1999	CATHLAMET BAY	OR99-0009	46.11381	-123.447
OREGON	1999	CATHLAMET BAY	OR99-0010	46.11322	-123.448
OREGON	1999	CATHLAMET BAY	OR99-0011	46.11171	-123.409
OREGON	1999	YOUNGS RIVER	OR99-0012	46.08924	-123.49
OREGON	1999	KNAPPA SLOUGH	OR99-0013	46.11229	-123.355
OREGON	1999	BRADBURY SLOUGH	OR99-0014	46.10196	-123.086
OREGON	1999	WALLACE SLOUGH	OR99-0015	46.0805	-123.163
OREGON	1999	CLATSKANIE RIVER	OR99-0016	46.07717	-123.136
OREGON	1999	RINEARSON SLOUGH	OR99-0017	46.07408	-123.021
OREGON	1999	NEHALEM RIVER	OR99-0018	45.41459	-123.54
OREGON	1999	NETARTS BAY	OR99-0019	45.23627	-123.572
OREGON	1999	NESTUCCA RIVER	OR99-0020	45.118	-123.577
OREGON	1999	LITTLE NESTUCCA RIVER	OR99-0021	45.09967	-123.566
OREGON	1999	SALMON RIVER	OR99-0022	45.024	-123.597
OREGON	1999	SILETZ BAY	OR99-0023	44.55499	-124.011
OREGON	1999	YAQUINA BAY	OR99-0024	44.37293	-124.021
OREGON	1999	YAQUINA RIVER	OR99-0025	44.35913	-124.009
OREGON	1999	YAQUINA RIVER	OR99-0026	44.34432	-123.578
OREGON	1999	ALSEA RIVER	OR99-0027	44.2485	-123.599
OREGON	1999	YACHATS RIVER	OR99-0028	44.1829	-124.069
OREGON	1999	ROCK CREEK	OR99-0029	44.1125	-124.022
OREGON	1999	SIUSLAW RIVER	OR99-0030	44.00688	-124.076
OREGON	1999	SIUSLAW RIVER	OR99-0031	44.01321	-123.529
OREGON	1999	UMPQUA RIVER	OR99-0032	44.44395	-124.082
OREGON	1999	SMITH RIVER	OR99-0033	43.4574	-124.003
OREGON	1999	UMPQUA RIVER	OR99-0034	43.43516	-124.087
OREGON	1999	SMITH RIVER	OR99-0035	44.46317	-123.542
OREGON	1999	UMPQUA RIVER	OR99-0036	43.43332	-124.074

STATE	YEAR	ESTUARY NAME	EMAP Station ID	LATITUDE	LONGITUDE
OREGON	1999	SCHOLFIELD CREEK	OR99-0037	43.41587	-124.06
OREGON	1999	UMPQUA RIVER	OR99-0038	43.41531	-124.039
OREGON	1999	COOS BAY	OR99-0039	43.25364	-124.147
OREGON	1999	COOS BAY	OR99-0040	43.24828	-124.124
OREGON	1999	COOS BAY	OR99-0041	43.24386	-124.131
OREGON	1999	COOS BAY	OR99-0042	43.23183	-124.175
OREGON	1999	COOS BAY	OR99-0043	43.24243	-124.119
OREGON	1999	COOS BAY	OR99-0044	43.22076	-124.182
OREGON	1999	SOUTH SLOUGH	OR99-0045	43.20486	-124.192
OREGON	1999	COOS RIVER	OR99-0046	43.22203	-124.089
OREGON	1999	COOS RIVER	OR99-0047	43.22624	-124.065
OREGON	1999	CATCHING SLOUGH	OR99-0048	43.20993	-124.101
OREGON	1999	CATCHING SLOUGH	OR99-0049	43.19278	-124.092
OREGON	1999	ROGUE RIVER	OR99-0050	42.25353	-124.251
OREGON	1999	TILLAMOOK BAY	OR99-0051	45.33106	-123.557
OREGON	1999	TILLAMOOK BAY	OR99-0052	45.32825	-123.561
OREGON	1999	TILLAMOOK BAY	OR99-0053	45.33083	-123.547
OREGON	1999	TILLAMOOK BAY	OR99-0054	45.32038	-123.561
OREGON	1999	TILLAMOOK BAY	OR99-0055	45.32322	-123.554
OREGON	1999	TILLAMOOK BAY	OR99-0056	45.32166	-123.559
OREGON	1999	TILLAMOOK BAY	OR99-0057	45.32279	-123.543
OREGON	1999	TILLAMOOK BAY	OR99-0058	45.31667	-123.558
OREGON	1999	TILLAMOOK BAY	OR99-0059	45.31864	-123.547
OREGON	1999	TILLAMOOK BAY	OR99-0060	45.31424	-123.557
OREGON	1999	TILLAMOOK BAY	OR99-0061	45.31049	-123.561
OREGON	1999	TILLAMOOK BAY	OR99-0062	45.31424	-123.547
OREGON	1999	TILLAMOOK BAY	OR99-0063	45.30644	-123.553
OREGON	1999	TILLAMOOK BAY	OR99-0064	45.31033	-123.535
OREGON	1999	TILLAMOOK BAY	OR99-0065	45.30551	-123.56
OREGON	1999	TILLAMOOK BAY	OR99-0066	45.30887	-123.541
OREGON	1999	TILLAMOOK BAY	OR99-0067	45.30181	-123.56
OREGON	1999	TILLAMOOK BAY	OR99-0068	45.30534	-123.547
OREGON	1999	TILLAMOOK BAY	OR99-0069	45.30684	-123.535
OREGON	1999	TILLAMOOK BAY	OR99-0070	45.29868	-123.532
OREGON	1999	TILLAMOOK BAY	OR99-0071	45.30365	-123.537
OREGON	1999	TILLAMOOK BAY	OR99-0072	45.29853	-123.545
OREGON	1999	TILLAMOOK BAY	OR99-0073	45.29827	-123.535
OREGON	1999	TILLAMOOK BAY	OR99-0074	45.29454	-123.537
OREGON	1999	TILLAMOOK BAY	OR99-0075	45.3003	-123.521
OREGON	1999	TILLAMOOK BAY	OR99-0076	45.29727	-123.536
OREGON	1999	TILLAMOOK BAY	OR99-0077	45.29464	-123.54
OREGON	1999	TILLAMOOK BAY	OR99-0078	45.28834	-123.54
OREGON	1999	TILLAMOOK BAY	OR99-0079	45.281	-123.531
OREGON	1999	TILLAMOOK RIVER	OR99-0080	45.26483	-123.526

STATE	YEAR	ESTUARY NAME	EMAP Station ID	LATITUDE	LONGITUDE
WASHINGTON	2000	BOUNDARY BAY, WEST	WA00-0001	48.98417	-122.993
WASHINGTON	2000	BOUNDARY BAY, SOUTH	WA00-0002	48.95498	-122.951
WASHINGTON	2000	CHERRY POINT	WA00-0003	48.81575	-122.719
WASHINGTON	2000	BELLINGHAM BAY	WA00-0004	48.73828	-122.515
WASHINGTON	2000	SAMISH BAY/ BELLINGHAM	WA00-0005	48.62525	-122.526
WASHINGTON	2000	PADILLA BAY, INNER	WA00-0006	48.53133	-122.551
WASHINGTON	2000	FIDALGO BAY, INNER	WA00-0007	48.49933	-122.6
WASHINGTON	2000	FIDALGO BAY, INNER	WA00-0008	48.48667	-122.586
WASHINGTON	2000	SARATOGA PASSAGE, NORTH	WA00-0009	48.24275	-122.622
WASHINGTON	2000	OAK HARBOR	WA00-0010	48.27445	-122.652
WASHINGTON	2000	PENN COVE	WA00-0011	48.2247	-122.711
WASHINGTON	2000	SARATOGA PASSAGE, MIDDLE	WA00-0012	48.15833	-122.539
WASHINGTON	2000	POSSESSION SOUND	WA00-0013	48.03952	-122.318
WASHINGTON	2000	EVERETT HARBOR, MIDDLE	WA00-0014	47.98223	-122.223
WASHINGTON	2000	PORT TOWNSEND BAY, INNER	WA00-0015	47.98157	-122.503
WASHINGTON	2000	USELESS/OAK BAY	WA00-0016	48.04018	-122.743
WASHINGTON	2000	USELESS/OAK BAY	WA00-0017	48.1204	-122.622
WASHINGTON	2000	POSSESSION SOUND	WA00-0018	47.9075	-122.338
WASHINGTON	2000	PORT MADISON	WA00-0019	47.72597	-122.531
WASHINGTON	2000	LIBERTY BAY, OUTER	WA00-0020	47.71493	-122.63
WASHINGTON	2000	ELLIOT BAY, NORTHEAST	WA00-0021	47.6239	-122.374
WASHINGTON	2000	DUAMISH RIVER - EAST WATERWAY	WA00-0022	47.58417	-122.344
WASHINGTON	2000	PORT LUDLOW	WA00-0023	47.99372	-122.678
WASHINGTON	2000	HOOD CANAL (NORTH)	WA00-0024	47.8363	-122.579
WASHINGTON	2000	PORT GAMBLE BAY	WA00-0025	47.92443	-122.68
WASHINGTON	2000	DABOB BAY	WA00-0026	47.82138	-122.819
WASHINGTON	2000	DABOB BAY	WA00-0027	47.73425	-122.844
WASHINGTON	2000	HOOD CANAL (CENTRAL)	WA00-0028	47.42163	-123.11
WASHINGTON	2000	HOOD CANAL (SOUTH)	WA00-0029	47.8415	-122.646
WASHINGTON	2000	HOOD CANAL (SOUTH)	WA00-0030	47.39667	-122.956
WASHINGTON	2000	PORT OF SHELTON	WA00-0031	47.20893	-123.081
WASHINGTON	2000	BUDD INLET	WA00-0032	47.12948	-122.914
WASHINGTON	2000	PORT OF OLYMPIA	WA00-0033	47.05633	-123.896
WASHINGTON	2000	CASE INLET	WA00-0034	47.27117	-122.852
WASHINGTON	2000	EAST ANDERSON ISLAND	WA00-0035	47.14957	-122.659
WASHINGTON	2000	HALE PASSAGE	WA00-0036	47.25463	-122.598
WASHINGTON	2000	GIG HARBOR	WA00-0037	47.33752	-122.584
WASHINGTON	2000	COLVOS PASSAGE	WA00-0038	47.51067	-122.486
WASHINGTON	2000	COLVOS PASSAGE	WA00-0039	47.47235	-122.507
WASHINGTON	2000	S.E. COMMENCEMENT BAY	WA00-0040	47.2846	-122.472
WASHINGTON	2000	HYLEBOS WATERWAY	WA00-0041	47.27855	-122.398
CANADA	2000	ROSARIO STRAIT	WA00-0042	48.93723	-123.735
CANADA	2000	STRAIT OF GEORGIA	WA00-0043	48.9524	-123.363
CANADA	2000	STUART CHANNEL (MIDDLE)	WA00-0044	48.86519	-123.599
WASHINGTON	2000	STRAIT OF GEORGIA	WA00-0045	48.93708	-123.201
WASHINGTON	2000	STRAIT OF GEORGIA	WA00-0046	48.95555	-123.004
WASHINGTON	2000	STRAIT OF GEORGIA	WA00-0047	48.90143	-122.925

STATE	YEAR	ESTUARY NAME	EMAP Station ID	LATITUDE	LONGITUDE
CANADA	2000	SWANSON CHANNEL	WA00-0048	48.80498	-123.395
CANADA	2000	STUART CHANNEL (SOUTH)	WA00-0049	48.71188	-123.528
WASHINGTON	2000	CHERRY POINT	WA00-0050	48.82385	-122.73
CANADA	2000	BOUNDARY PASS	WA00-0051	48.74782	-123.092
WASHINGTON	2000	PRESIDENT CHANNEL	WA00-0052	48.71291	-123
WASHINGTON	2000	PRESIDENT CHANNEL	WA00-0053	48.70131	-122.995
CANADA	2000	CORDOVA CHANNEL	WA00-0054	48.57157	-123.335
WASHINGTON	2000	WEST SOUND	WA00-0055	48.62548	-122.961
WASHINGTON	2000	DEER HARBOR	WA00-0056	48.61167	-123
WASHINGTON	2000	SAN JUAN CHANNEL	WA00-0057	48.58917	-123.019
WASHINGTON	2000	EAST SOUND	WA00-0058	48.61069	-122.838
WASHINGTON	2000	SAN JUAN CHANNEL	WA00-0059	48.54453	-122.98
WASHINGTON	2000	LOPEZ SOUND	WA00-0060	48.52361	-122.847
WASHINGTON	2000	SAN JUAN CHANNEL	WA00-0061	48.50041	-122.957
WASHINGTON	2000	GRIFFIN BAY	WA00-0062	48.48797	-122.997
CANADA	2000	BAYNES CHANNEL	WA00-0063	48.4262	-123.288
WASHINGTON	2000	MIDDLE CHANNEL	WA00-0064	48.38886	-122.92
WASHINGTON	2000	STRAIT OF JUAN DE FUCA (EAST)	WA00-0065	48.32328	-123.055
WASHINGTON	2000	STRAIT OF JUAN DE FUCA (EAST)	WA00-0066	48.3159	-122.8
WASHINGTON	2000	STRAIT OF JUAN DE FUCA (EAST)	WA00-0067	48.19263	-123.024
WASHINGTON	2000	ADMIRALTY BAY	WA00-0068	48.11994	-122.623
WASHINGTON	2000	MUTINY BAY	WA00-0069	47.96587	-122.554
WASHINGTON	2000	ADMIRALTY INLET (SOUTH)	WA00-0070	47.86602	-122.419
WASHINGTON	2000	PUGET SOUND	WA00-0071	47.59016	-122.428
WASHINGTON	1999	MAKAH BAY	WA99-0001	48.19197	-124.408
WASHINGTON	1999	MAKAH BAY	WA99-0002	48.18824	-124.402
WASHINGTON	1999	MAKAH BAY	WA99-0003	48.183	-124.402
WASHINGTON	1999	HOKO RIVER	WA99-0004	48.17287	-124.219
WASHINGTON	1999	OZETTE RIVER	WA99-0005	48.10873	-124.425
WASHINGTON	1999	FRESHWATER BAY	WA99-0006	48.08958	-123.38
WASHINGTON	1999	FRESHWATER BAY	WA99-0007	48.08878	-123.361
WASHINGTON	1999	FRESHWATER BAY	WA99-0008	48.08586	-123.37
WASHINGTON	1999	DUNGENESS BAY	WA99-0009	48.09579	-123.089
WASHINGTON	1999	DISCOVERY BAY	WA99-0010	48.04758	-122.54
WASHINGTON	1999	DISCOVERY BAY	WA99-0011	48.03478	-122.543
WASHINGTON	1999	DISCOVERY BAY	WA99-0012	48.01248	-122.516
WASHINGTON	1999	DISCOVERY BAY	WA99-0013	48.00182	-122.506
WASHINGTON	1999	DISCOVERY BAY	WA99-0014	47.59839	-122.524
WASHINGTON	1999	KALALOCH CREEK	WA99-0015	47.36379	-124.224
WASHINGTON	1999	RAFT RIVER	WA99-0016	47.27751	-124.203
WASHINGTON	1999	QUINAULT RIVER	WA99-0017	47.20816	-124.179
WASHINGTON	1999	QUINAULT RIVER	WA99-0018	-99.99	99.99
WASHINGTON	1999	CONNER CREEK	WA99-0019	47.05356	-124.106
WASHINGTON	1999	GRAYS HARBOR	WA99-0020	47.00251	-124.024
WASHINGTON	1999	GRASS CREEK	WA99-0021	47.00318	-123.6
WASHINGTON	1999	GRAYS HARBOR	WA99-0022	46.57931	-123.571
WASHINGTON	1999	GRAYS HARBOR	WA99-0023	46.56396	-124.062

STATE	YEAR	ESTUARY NAME	EMAP Station ID	LATITUDE	LONGITUDE
WASHINGTON	1999	GRAYS HARBOR	WA99-0024	46.56105	-124.017
WASHINGTON	1999	GRAYS HARBOR	WA99-0025	46.57992	-123.515
WASHINGTON	1999	GRAYS HARBOR	WA99-0026	46.55256	-124.04
WASHINGTON	1999	BEARDSLEE SLOUGH	WA99-0027	46.52354	-124.02
WASHINGTON	1999	BEARDSLEE SLOUGH	WA99-0028	46.52216	-124.013
WASHINGTON	1999	GRAYS HARBOR	WA99-0029	46.50898	-124.019
WASHINGTON	1999	WILLAPA BAY	WA99-0030	46.42902	-124.027
WASHINGTON	1999	WILLAPA BAY	WA99-0031	46.42244	-123.532
WASHINGTON	1999	WILLAPA BAY	WA99-0032	-99.99	99.99
WASHINGTON	1999	WILLAPA BAY	WA99-0033	46.38973	-124.007
WASHINGTON	1999	WILLAPA BAY	WA99-0034	46.34047	-123.565
WASHINGTON	1999	WILLAPA BAY	WA99-0035	46.32311	-123.554
WASHINGTON	1999	WILLAPA BAY	WA99-0036	46.25063	-123.251
WASHINGTON	1999	WILLAPA BAY	WA99-0037	-99.99	99.99
WASHINGTON	1999	BAKER BAY	WA99-0038	46.18577	-124.006
WASHINGTON	1999	BAKER BAY	WA99-0039	46.18082	-124.016
WASHINGTON	1999	BAKER BAY	WA99-0040	46.16402	-123.584
WASHINGTON	1999	GRAYS RIVER	WA99-0041	-99.99	99.99
WASHINGTON	1999	BAKER BAY	WA99-0042	46.15784	-123.599
WASHINGTON	1999	GRAYS BAY	WA99-0043	46.181	-123.426
WASHINGTON	1999	GRAYS BAY	WA99-0044	46.17998	-123.419
WASHINGTON	1999	GRAYS BAY	WA99-0045	46.17716	-123.422
WASHINGTON	1999	GRAYS BAY	WA99-0046	46.17232	-123.436
WASHINGTON	1999	GRAYS BAY	WA99-0047	46.16495	-123.43
WASHINGTON	1999	COWLITZ RIVER	WA99-0048	46.05688	-122.553
WASHINGTON	1999	CARROLLS CHANNEL	WA99-0049	46.05073	-122.528
WASHINGTON	1999	MARTIN SLOUGH	WA99-0050	45.56797	-122.472

Appendix 2. Chemicals measured in sediments and fish tissues.

CHEMICAL CATECORY	CHEMICALS	
Polynuclear Aromatic Hydrocarbons (PAHs)		
	Acenaphthene	2-methylnaphthalene
	Anthracene	1-methylnaphthalene
	Benz(a)anthracene	1-methylphenanthrene
	Benzo(a)pyrene	2,6-dimethylnaphtalene
	Biphenyl	Naphthalene
	Chrysene	Naphtalene(C1-C4)
	Chrysene(C1-C4)	Phenanthene
	Dibenz(a,h)anthracene	Pyrene
	Dibenzothiophene	Benzo(b)fluoranthene
	Dibenzothiophene(C1-C3)	Acenaphthylene
	2,6-dimethylnaphthalene	Benzo(k)fluoranthene
	Fluoranthene	Benzo(g,h,i)perylene
	Fluorene	Ideno(1,2,3-c,d)pyrene
	Fluorene(C1-C3)	2,3,5-trimethylnaphthalene
PCB Congeners		
	PCB No. Compound Name	PCB No. Compound Name
	8 2,4'-dichlorobiphenyl	126 3,3,4,4',5-pentachlorobiphenyl
	18 2,2',5-trichlorobiphenyl	128 2,2',3,3',4,4'-hexachlorobiphenyl
	28 2,4,4'-trichlorobiphenyl	138 2,2',3,4,4',5'-hexachlorobiphenyl
	44 2,2',3,5'-tetrachlorobiphenyl	153 2,2',4,4',5,5'-hexachlorobiphenyl
	52 2,2',5,5'-tetrachlorobiphenyl	170 2,2',3,3',4,4',5-heptachlorobiphenyl
	66 2,3',4,4'-tetrachlorobiphenyl	180 2,2',3,4,4',5,5'-heptachlorobiphenyl
	101 2,2',4,5,5'-pentachlorobiphenyl	187 2,2',3,4',5,5',6-heptachlorobiphenyl
	105 2,3,3',4,4'-pentachlorobiphenyl	195 2,2',3,3',4,4',5,6-octachlorobiphenyl
	110/77 2,3,3',4',6-pentachlorobiphenyl	206 2,2',3,3',4,4',5,5',6-nonachlorobiphenyl
	3,3',4,4'-tetrachlorobiphenyl	209 2,2'3,3',4,4',5,5',6,6'-decachlorobiphenyl
	118 2,3,4,4',5-pentachlorobiphenyl	
DDT and its metabolites		
	2,4'-DDD	4,4'-DDE
	4,4'-DDD	2,4'-DDT
	2,4'-DDE	4,4'-DDT
Chlorinated pesticides other than DDT		
	Aldrin	Heptachlor
	Alpha-Chlordane	Heptachlor epoxide
	Dieldrin	Hexachlorobenzene
	Endosulfan I	Lindane (gamma-BHC)
	Endosulfan II	Mirex
	Endosulfan sulfate	Toxaphene
	Endrin	Trans-Nonachlor
Trace Elements		
	Aluminum	Manganese (sediment only)
	Antimony (sediment only)	Mercury
	Arsenic	Nickel
	Cadmium	Selenium
	Chromium	Silver
	Copper	Tin
	Iron	Zinc
	Lead	
Other Measurements		
	Total organic carbon (sediments)	

Appendix 3. Summary statistics for water chemistry and habitat indicators. Total estuarine area is 8670 square kilometers.

Indicator	Units	N	Mean	95% Confidence	Median	Minimum	Range of Detected Results	Variance	Standard Deviation	Standard Error
Water Clarity – Light transmissivity at 1m	%	224	21.674	22.182	16.800	ND*	0.1 - 87.600	438.126	20.931	0.259
Secchi Depth	m	238	3.093	3.153	2.000	0.100	0.1- 12.500	6.898	2.626	0.030
Dissolved Oxygen - Bottom	mg/l	242	7.747	7.787	8.000	0.100	0.1- 11.500	3.315	1.821	0.021
Dissolved Oxygen - Surface	mg/l	242	8.260	8.291	8.100	3.400	3.400- 11.500	1.864	1.365	0.016
Chlorophyll a	ug/l	244	4.667	4.760	3.600	ND*	0.2933 - 31.110	17.441	4.176	0.047
Mean Orthophosphate Phosphorus	ug/l	244	30.510	30.957	24.625	ND*	0.53 - 106.537	403.694	20.092	0.228
Mean Total Dissolved Nitrogen	ug/l	244	135.515	137.696	118.510	3.230	3.230 - 640.770	9615.794	98.060	1.113
Mean Nitrogen to Phosphorus Ratio	ratio	238	17.672	18.351	11.507	0.164	0.164 - 178.455	929.692	30.491	0.347
Total Suspended Solids	mg/l	244	7.437	7.631	6.000	ND*	0.5 - 230.000	76.322	8.736	0.099

*ND = not detected
Summary statistics were calculated with non-detects set to zero.

Appendix 4. Summary statistics for sediment characteristics. Total estuarine area is 8670 square kilometers.

Indicator	Units	N	Mean	95% Confidence	Median	Minimum	Detection Frequency**	Range of Dectected Results	Variance	Standard Deviation	Standard Error
Antimony	ug/g dry wt	225	0.356	0.371	0.24	ND*	32%	0.14-5.66	0.431	0.657	0.008
Aldrin	ng/g dry wt	225	0.0104	0.013	ND*	ND*	3.5%	0.45-2.9	0.0155	0.125	0.002
Aluminum	ug/g dry wt	225	68771.64	69258.92	75100	8750	100%	8750 - 95900	4.31E+08	20758.28	248.571
Arsenic	ug/g dry wt	225	6.601	6.675	6.340	ND*	>99%	0.69 - 20.800	10.016	3.165	0.038
Cadmium	ug/g dry wt	225	0.191	0.200	0.068	ND*	44%	0.012 - 2.310	0.145	0.380	0.005
Chlordane	ng/g dry wt	225	0.019	0.0225	ND*	ND*	<1%	1.0 - 1.4	0.023	0.152	0.002
Chromium	ug/g dry wt	225	70.570	71.285	72.4	12.3	100 %	12.3 - 328.0	927.668	30.458	0.365
Copper	ug/g dry wt	225	24.431	25.029	17.6	2.060	100 %	2.06 - 219.0	650.970	25.514	0.306
DDE	ng/g dry wt	225	0.159	0.176	ND*	ND*	9.7%	0.27 - 6.7	0.487	0.698	0.008
DDT - Total	ng/g dry wt	225	0.296	0.328	ND*	ND*	11%	0.27 - 12	1.684	1.298	0.016
Dieldrin	ng/g dry wt	225	0.005	0.007	ND*	ND*	<1%	1.5 - 1.8	0.007	0.085	0.001
Endosulfan Sulfate	ng/g dry wt	225	0.0594	0.074	ND*	ND*	6%	1.05 - 11.8	0.367	0.606	0.007
Endosulfan I	ng/g dry wt	225	0.004	0.007	ND*	ND*	<1%	3.8 - 3.8	0.0145	0.120	0.001
Endosulfan II	ng/g dry wt	225	0.002	0.003	ND*	ND*	<1%	1.75 - 1.75	0.003	0.051	0.001
Endrin	ng/g dry wt	225	0.002	0.004	ND*	ND*	<1%	2.7 - 2.7	0.006	0.079	0.001
Heptachlor	ng/g dry wt	223	0.050	0.058	ND*	ND*	10%	0.6 - 3.7	0.114	0.337	0.004
Heptachlor Epoxide	ng/g dry wt	225	0.008	0.013	ND*	ND*	1.3%	1.3 - 6.7	0.048	0.219	0.003
Hexachlorobenzene	ng/g dry wt	225	0.234	0.284	ND*	ND*	5.7%	0.65 - 33.05	4.473	2.115	0.025
Iron	ug/g dry wt	225	33701.05	33998.64	35700	6000	100%	6000 - 126000	1.61E+08	12677.48	151.807
Lead	ug/g dry wt	225	12.858	13.034	11.6	1.470	100 %	1.47 - 51.3	56.212	7.497	0.090

Indicator	Units	N	Mean	95% Confidence	Median	Minimum	Detection Frequency**	Range of Dectected Results	Variance	Standard Deviation	Standard Error
Lindane	ng/g dry wt	225	0.029	0.035	ND*	ND*	1.7%	1.0 - 2.7	0.064	0.252	0.003
Manganese	ug/g dry wt	225	566.294	575.352	446	84.8	100%	84.8 – 3330	148918.4	385.900	4.621
Mercury	ug/g dry wt	225	0.057	0.058	0.040	< 0.001 MDL*	>99%	0.0049 - 0.316	0.003	0.059	0.001
Mirex	ng/g dry wt	225	ND*		ND*	ND*	0%	All ND	0	0	0
Nickel	ug/g dry wt	225	29.529	29.956	25.2	7.5	100 %	7.5 – 275.5	330.778	18.187	0.218
PAH - Total	ng/g dry wt	225	852.150	907.079	332.9	ND*	59%	1.0 - 59878.2	5475564	2339.992	28.020
PAH – High Molecular Weight	ng/g dry wt	225	471.043	499.435	125.7	ND*	59%	0.75 - 8613	1462949	1209.524	14.484
PAH – Low Molecular Weight	ng/g dry wt	225	275.594	295.968	137.05	ND*	45%	0.58 - 8636	753305.8	867.932	10.393
Selenium	ug/g dry wt	225	0.160	0.168	ND*	ND*	19%	0.13 - 1.75	0.105	0.324	0.004
Silt & clay -Percent	%	225	18.089	18.630	9.886	ND*	94.6%	0.05 - 94.31	545.190	23.349	0.276
Silver	ug/g dry wt	225	0.155	0.163	0.044	ND*	55 %	0.013 - 2.1	0.116	0.340	0.004
Tin	ug/g dry wt	225	1.546	1.571	1.4	ND*	72%	0.45 - 8.32	1.138	1.067	0.013
Total Organic Carbon	%	225	0.985	1.006257	0.9	ND*	97%	0.01 - 4.48	0.830	0.911	0.011
Toxaphene	ng/g dry wt	225	ND*		ND*	ND*	0%	All ND	0	0	0
Trans Nonachlor	ng/g dry wt	225	0.008	0.010	ND*	ND*	<1%	0.74 - 1.1	0.007	0.082	0.001
Zinc	ug/g dry wt	225	73.540	74.240	73.4	12.5	100 %	12.5 - 225	889.167	29.819	0.357

*ND = not detected
**Detection frequency refers to the percent of individual samples analyzed, not to the percentage of the area.
Summary statistics were calculated with non-detects set to zero.

Appendix 5. Summary statistics for contaminants in fish tissue. Total estuarine area is 8670 square kilometers.

Tissue Parameter	Units	N	Mean	95% Confidence	Median	Detection Frequency**	Range of Detected Results	Variance	Standard Deviation	Standard Errror
Aldrin	ng/g wet wt	188	0.003	0.005	ND*	3	1.6 - 2.398	0.005	0.074	0.001
Aluminum	ug/g wet wt	179	108.894	110.848	91.7	98	0.5313 - 568.170	6502.980	80.641	0.996
Inorganic Arsenic	ug/g wet wt	179	.0564	.0577	.0492	84	0.0905 - .595	.003	.0517	0.001
Cadmium	ug/g wet wt	179	0.006	0.006	ND*	66	0.01001 - 0.2	0.001	0.023	0.000
Chlordane	ng/g wet wt	188	0.073	0.081	ND*	9	0.125 - 4.855	0.100	0.317	0.004
Chromium	ug/g wet wt	179	0.300	0.317	ND*	72	0.0671 - 5.313	0.461	0.679	0.008
Copper	ug/g wet wt	179	0.308	0.331	ND*	97	0.2140 - 7.771	0.853	0.923	0.011
Dieldrin	ng/g wet wt	188	0.066	0.080	ND*	53	0.48 - 14.787	0.369	0.607	0.007
Endosulfan I	ng/g wet wt	188	0.024	0.029	ND*	3	2.025 - 5.168	0.059	0.242	0.003
Endosulfan II	ng/g wet wt	188	0.126	0.160	ND*	8	0.9 - 40.223	1.988	1.410	0.017
Endosulfan Sulfate	ng/g wet wt	188	0.056	0.073	ND*	19	2.633 - 21.4	0.497	0.705	0.009
Endrin	ng/g wet wt	188	0.120	0.147	ND*	10	0.788 - 27.063	1.286	1.134	0.014
Heptachlor	ng/g wet wt	188	0.018	0.025	ND*	9	0.985 - 9.8	0.079	0.282	0.003
Heptachlor epoxide	ng/g wet wt	188	0.009	0.013	ND*	2	1.044 - 4.464	0.027	0.165	0.002
Hexachlorobenzene	ng/g wet wt	188	0.290	0.361	ND*	33	0.43 - 32	8.554	2.925	0.036
Iron	ug/g wet wt	179	100.112	102.754	81	100	5.2 - 1090	11903.146	109.102	1.348
Lead	ug/g wet wt	179	0.132	0.135	0.099	49	0.09 - 0.967	0.018	0.136	0.002

Tissue Parameter	Units	N	Mean	95% Confidence	Median	Detection Frequency**	Range of Detected Results	Variance	Standard Deviation	Standard Errror
Lindane	ng/g wet wt	188	0.000	0.001	ND*	0	0.25 - 1.62	0.000	0.020	0.000
Mercury	ug/g wet wt	179	0.029	0.029	0.027	87	0.016 - 0.257	0.000	0.021	0.000
Mirex	ng/g wet wt	188	0.000		ND*	0	All ND	0.000	0.000	0.000
Nickel	ug/g wet wt	179	0.068	0.080	ND*	30	0.3 - 13.169	0.239	0.488	0.006
PPDDE	ng/g wet wt	188	9.509	10.224	3.6	78	0.34-405.444	872.737	29.542	0.365
Selenium	ug/g wet wt	179	0.234	0.248	ND*	96	1 - 2.39	0.340	0.583	0.007
Silver	ug/g wet wt	179	0.005	0.006	ND*	25	0.01 - 0.28	0.001	0.024	0.000
Tin	ug/g wet wt	156	5.918	6.065	5.37	45	0.13-56.5	35.869	5.989	0.075
Total DDT	ng/g wet wt	188	13.751	14.792	4.5	81	0.34 - 493.644	1843.961	42.941	0.531
Total EMAP PCBs	ng/g wet wt	188	31.763	33.966	8.06	82	0.34-769.7	8286.177	91.028	1.124
Toxaphene	ng/g wet wt	188	0.000		ND*	0	All ND	0.000	0.000	0.000
Trans nonachlor	ng/g wet wt	188	0.320	0.360	ND*	26	0.19 - 46.066	2.745	1.657	0.020
Zinc	ug/g wet wt	179	13.661	13.554	12.9	100	7.59 - 39.060	14.63	3.824	0.047

* ND = Not Detected
**Detection frequency refers to the percent of individual samples analyzed, not to the percentage of the area.
Summary statistics were calculated with non-detects set to zero.

Appendix 6. Benthic invertebrate species from 1999-2000. Species are identified as Native (N) or Non-Indigenous (NIS) species, or blank where it unknown. Freshwater sites have <5 psu bottom salinity, Intermediate sites have ≥5 psu and ≤ 25 psu bottom salinity, and Marine sites have >25psu bottom salinity.

Species	**Native (N)/Non-Indigenous (NIS)**	**# of total sites**	**Found at Freshwater sites**	**Found at Intermediate sites**	**Found at Marine Sites**
Abarenicola pacifica	N	1			Yes
Abietinaria sp		7			Yes
Acanthoptilum gracile		1			Yes
Acarina		5	Yes	Yes	Yes
Achelia alaskensis	N	2			Yes
Achelia echinata	NIS	3			Yes
Acila castrensis		26			Yes
Acteocina culcitella		9			Yes
Acteocina eximia		1			Yes
Acteocina harpa		2			Yes
Actiniaria		1			Yes
Actiniidae		3		Yes	Yes
Adontorhina cyclia		11			Yes
Aglaja ocelligera		2			Yes
Aglaophenia sp		1			Yes
Agraylea sp		2	Yes		
Alcyonidium sp		3			Yes
Alia carinata	N	3			Yes
Alienacanthomysis macropsis		1			Yes
Alvania compacta	N	33			Yes
Amaeana occidentalis	N	1			Yes
Amage anops		2			Yes
Americhelidium millsi		3			Yes
Americhelidium rectipalmum		1			Yes
Americhelidium shoemakeri	N	6			Yes
Americhelidium variabilum		2			Yes
Americorophium salmonis	N	75	Yes	Yes	Yes
Americorophium sp		20	Yes	Yes	Yes
Americorophium spinicorne	N	26	Yes	Yes	Yes
Ampelisca agassizi		3			Yes
Ampelisca brachycladus		1			Yes
Ampelisca brevisimulata		4			Yes
Ampelisca careyi	N	16			Yes
Ampelisca hancocki Cmplx		3			Yes
Ampelisca lobata		3			Yes
Ampelisca pugetica		9			Yes
Ampelisca sp		11			Yes
Ampharete acutifrons		10			Yes
Ampharete cf crassiseta		8			Yes
Ampharete finmarchica		13			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Ampharete labrops	N	7			Yes
Ampharete sp		5			Yes
Ampharetidae		6			Yes
Amphicteis glabra		1			Yes
Amphicteis mucronata		1			Yes
Amphicteis scaphobranchiata		1			Yes
Amphilochus neapolitanus Cmplx		1			Yes
Amphiodia occidentalis		1			Yes
Amphiodia periercta		4			Yes
Amphiodia sp		28			Yes
Amphiodia urtica		12			Yes
Amphipholis pugetana		3			Yes
Amphipholis sp		4			Yes
Amphipholis squamata		6			Yes
Amphipoda		1			Yes
Amphiporus sp		5			Yes
Amphissa columbiana		5			Yes
Amphitrite edwardsi		2			Yes
Amphitrite robusta		2			Yes
Amphiura sp		1			Yes
Amphiuridae		18			Yes
Ampithoe lacertosa		1			Yes
Ampithoe sp		4		Yes	Yes
Ampithoe valida	NIS	4			Yes
Anchicolurus occidentalis	N	1			Yes
Anisogammarus pugettensis	N	1			Yes
Anobothrus gracilis		7			Yes
Anonyx cf lilljeborgi		4			Yes
Anonyx sp		1			Yes
Anopla		2			Yes
Anoplodactylus viridintestinalis		1			Yes
Antropora tincta		1			Yes
Aoroides columbiae		1			Yes
Aoroides exilis		1			Yes
Aoroides intermedius		3			Yes
Aoroides sp		8			Yes
Aoroides spinosa		4			Yes
Aphelochaeta glandaria	N	29			Yes
Aphelochaeta monilaris	N	19			Yes
Aphelochaeta sp		15		Yes	Yes
Aphelochaeta tigrina		3			Yes
Aphrodita japonica		1			Yes
Aphrodita negligens		1			Yes
Aphrodita sp		2			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Apistobranchus ornatus		5			Yes
Araphura breviaria		2			Yes
Araphura cuspirostris		1			Yes
Archaeomysis grebnitzkii	N	18	Yes	Yes	Yes
Archidistoma sp		1			Yes
Arcteobia cf anticostiensis		2			Yes
Argissa hamatipes		1			Yes
Aricidea (Acmira) catherinae		2			Yes
Aricidea (Acmira) lopezi		23			Yes
Aricidea (Allia) ramosa		8			Yes
Aricidea sp		3			Yes
Armandia brevis	N	26		Yes	Yes
Artacama coniferi		4			Yes
Asabellides lineata		5			Yes
Asabellides sibirica		3			Yes
Ascidia sp		1			Yes
Ascidiacea		1			Yes
Asclerocheilus beringianus		1			Yes
Astarte esquimalti		2			Yes
Asteroidea		1			Yes
Astyris gausapata	N	25			Yes
Atylus levidensus		1			Yes
Autolytus sp		2			Yes
Axinopsida serricata	N	55			Yes
Axiothella rubrocincta		5			Yes
Balanomorpha		1			Yes
Balanophyllia elegans		1			Yes
Balanus crenatus	N	3			Yes
Balanus glandula		1			Yes
Balanus sp		1			Yes
Balcis sp		1			Yes
Bankia setacea		1			Yes
Barantolla nr americana	N	17		Yes	Yes
Barentsia benedeni		2			Yes
Barentsia parva		3			Yes
Bathyleberis sp		6			Yes
Bathymedon pumilus		2			Yes
Bispira elegans		1			Yes
Bittium sp		4			Yes
Bivalvia		6		Yes	Yes
Bivalvia sp 1		3	Yes		
Boccardia pugettensis		5			Yes
Boccardiella hamata		2			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Boccardiella ligerica	NIS	2		Yes	
Boltenia villosa		2			Yes
Bonelliidae		1			Yes
Bougainvilliidae		2			Yes
Bowerbankia gracilis		8			Yes
Brada sachalina		4			Yes
Brada villosa		1			Yes
Brisaster latifrons		2			Yes
Bugula pacifica		1			Yes
Bugula sp		1			Yes
Byblis millsi		7			Yes
Bylgides macrolepidus		2			Yes
Caberea ellisi		2			Yes
Caecidotea racovitzai	NIS	3	Yes		
Caecum occidentale	N	2			Yes
Caecum sp		1			Yes
Calanoida		11			Yes
Caligidae		1			Yes
Calliostoma ligatum		1			Yes
Callipallene pacifica		1			Yes
Calocarides sp		2			Yes
Calocarides spinulicauda		1			Yes
Calycella syringa		1			Yes
Calyptraea fastigiata		4			Yes
Campanulariidae		3			Yes
Campylaspis hartae		1			Yes
Cancer gracilis		4			Yes
Cancer magister	N	4			Yes
Cancer oregonensis	N	5			Yes
Cancer productus		1			Yes
Cancer sp		1			Yes
Capitella capitata Cmplx		54		Yes	Yes
Capitellidae		2			Yes
Caprella californica	N	2			Yes
Caprella drepanochir		2			Yes
Caprella laeviuscula		9			Yes
Caprella mendax		3			Yes
Caprella pilidigitata		1			Yes
Caprella sp		3			Yes
Cardiomya pectinata		5			Yes
Carinoma mutabilis	N	10			Yes
Carinomella lactea		1			Yes
Caulibugula californica		1			Yes
Caulibugula ciliata		2			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Caulleriella pacifica		11			Yes
Cellaria mandibulata		1			Yes
Cellaria sp		1			Yes
Celleporella hyalina		2			Yes
Cephalothricidae		1			Yes
Ceradocus spinicaudus		1			Yes
Ceratopogonidae		3	Yes	Yes	
Cerebratulus californiensis		1			Yes
Cerebratulus montgomeryi		9			Yes
Cerebratulus sp		7			Yes
Chaetoderma sp		9			Yes
Chaetognatha		1			Yes
Chaetozone acuta		9			Yes
Chaetozone bansei		1			Yes
Chaetozone commonalis		2			Yes
Chaetozone nr setosa		17			Yes
Chaetozone sp		11			Yes
Chaetozone sp N1		2			Yes
Chaetozone sp N2		3			Yes
Chapperiopsis patula		2			Yes
Cheilopora praelonga		1			Yes
Cheirimedeia sp		2			Yes
Cheirimedeia zotea		1			Yes
Chirimia nr biceps		2			Yes
Chirimia similis		1			Yes
Chironomidae		26	Yes	Yes	Yes
Chironomus sp		3	Yes		
Chlamys hastata		3			Yes
Chlamys rubida		1			Yes
Chone duneri		3			Yes
Chone ecaudata		1			Yes
Chone magna		1			Yes
Chone minuta		1			Yes
Circeis armoricana		2			Yes
Circeis spirillum		1			Yes
Cirratulidae		18			Yes
Cirratulus multioculatus		1			Yes
Cirratulus sp		1			Yes
Cirratulus spectabilis	N	4			Yes
Cirrophorus branchiatus		2			Yes
Cladopelma sp		1	Yes		
Cladotanytarsus sp		1	Yes		
Clausidium vancouverense	N	1			Yes
Clavidae		2	Yes	Yes	

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Clinocardium blandum		1			Yes
Clinocardium nuttallii	N	38		Yes	Yes
Clinocardium sp		12		Yes	Yes
Clunio sp		1			Yes
Clymenura gracilis		1			Yes
Clytia sp		2			Yes
Coenagrionidae		1	Yes		
Compsomyax subdiaphana		21			Yes
Copidozoum adamantum		1			Yes
Copidozoum protectum		1			Yes
Corbicula fluminea	NIS	64	Yes	Yes	
Corixidae		1	Yes		
Corophiidae		13	Yes		
Corymorpha sp A	NIS	1			Yes
Corynidae		1		Yes	
Cossura bansei		6			Yes
Cossura pygodactylata	N	26		Yes	Yes
Cossura sp		5			Yes
Coullana canadensis	NIS	1			Yes
Crangon alaskensis	N	16			Yes
Crangon franciscorum	N	17	Yes	Yes	Yes
Crangon sp		12		Yes	Yes
Crangonyx floridanus subgroup		1	Yes		
Cranopsis sp		1			Yes
Crepidula nummaria		1			Yes
Crepipatella dorsata		6			Yes
Cricotopus sp		2	Yes	Yes	
Crisia serrulata		1			Yes
Crisia sp		2			Yes
Crossaster papposus		2			Yes
Crucigera zygophora		1			Yes
Cryptochironomus sp		6	Yes		
Cryptomya californica	N	32		Yes	Yes
Cucumaria piperata		1			Yes
Cumacea		1			Yes
Cumella vulgaris	N	4			Yes
Cyclocardia ventricosa		8			Yes
Cyclopidae		1	Yes		
Cyclostomata		1			Yes
Cyclostremella cf concordia		3			Yes
Cylichna attonsa	N	10			Yes
Cylindroleberididae		1			Yes
Cyphocaris challengeri		3			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Cytherideidae		1	Yes		
Decamastus gracilis	N	8			Yes
Deflexilodes enigmaticus		2			Yes
Deflexilodes similis		2			Yes
Delectopecten vancouverensis		1			Yes
Demicryptochironomus sp		1	Yes		
Demonax rugosus		3			Yes
Demonax sp		2			Yes
Demospongiae		4			Yes
Dendraster excentricus	N	7			Yes
Dendrobeania lichenoides		3			Yes
Dendrochirotida		3			Yes
Desdimelita desdichada		7			Yes
Deutella californica		1			Yes
Diaperoecia sp		2			Yes
Diaphana californica		6			Yes
Diastylis alaskensis		3			Yes
Diastylis bidentata		3			Yes
Diastylis pellucida		6			Yes
Diastylis santamariensis	N	10			Yes
Diastylis sentosa		3			Yes
Diastylis sp		1			Yes
Diastylopsis dawsoni	N	3			Yes
Diastylopsis tenuis	N	1			Yes
Dichonemertes hartmanae		1			Yes
Dicrotendipes sp		3	Yes		
Diopatra ornata		7			Yes
Diopatra sp		3			Yes
Dipolydora bidentata		3			Yes
Dipolydora cardalia		9			Yes
Dipolydora caulleryi	NIS	8			Yes
Dipolydora quadrilobata		1			Yes
Dipolydora socialis		30			Yes
Diptera		2	Yes		Yes
Discorsopagurus schmitti		1			Yes
Disporella fimbriata		1			Yes
Distaplia occidentalis		2			Yes
Dolichopodidae		1		Yes	Yes
Doridacea		1			Yes
Dorvillea (Schistomeringos) annulata	N	5			Yes
Drilonereis longa	N	9			Yes
Drilonereis sp		1			Yes
Dubiraphia sp		1	Yes		

Species	**Native (N)/Non-Indigenous (NIS)**	**# of total sites**	**Found at Freshwater sites**	**Found at Intermediate sites**	**Found at Marine Sites**
Dulichia sp		2			Yes
Dyopedos arcticus		2			Yes
Dyopedos sp		2			Yes
Echiurus echiurus alaskanus		2			Yes
Ectinosoma sp		1			Yes
Ectopleura sp		1			Yes
Edwardsia sipunculoides	N	4			Yes
Edwardsia sp G		4			Yes
Electra crustulenta arctica		1			Yes
Ennucula tenuis		24			Yes
Enopla		1			Yes
Enteropneusta		2			Yes
Eobrolgus chumashi	N	7			Yes
Eobrolgus sp		1			Yes
Eochelidium sp		1			Yes
Eogammarus confervicolus CMPLX	N	14	Yes	Yes	Yes
Eogammarus sp		3	Yes	Yes	
Eohaustorius estuarius	N	39	Yes	Yes	Yes
Eohaustorius washingtonianus	N	1		Yes	
Ephydridae		1	Yes		
Epoicocladius sp		1	Yes		
Eranno bicirrata		6			Yes
Ericthonius brasiliensis		1			Yes
Eteone columbiensis	N	14	Yes	Yes	Yes
Eteone fauchaldi	N	3		Yes	Yes
Eteone lighti	N	9		Yes	Yes
Eteone pacifica		1			Yes
Eteone sp		22		Yes	Yes
Eteone spilotus		1			Yes
Eualus subtilis		2			Yes
Euchone incolor		7			Yes
Euchone limnicola		1			Yes
Euclymene sp		3			Yes
Euclymeninae		25			Yes
Euclymeninae sp A		9			Yes
Eudistylia catharinae		3			Yes
Eudistylia polymorpha		1			Yes
Eudistylia sp		4			Yes
Eudorella pacifica	N	35			Yes
Eudorellopsis integra		3			Yes
Eudorellopsis longirostris		2			Yes
Eugyra arenosa		1			Yes
Eulalia californiensis		3			Yes
Eulalia quadrioculata	N	3			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Eulalia sp N1		1			Yes
Eumida longicornuta		9			Yes
Eumida sp		2			Yes
Eunoe sp		1			Yes
Euphausia pacifica		1			Yes
Euphausia sp		1			Yes
Euphilomedes carcharodonta		25			Yes
Euphilomedes producta		23			Yes
Euphilomedes sp		1			Yes
Euphysa ruthae	N	4			Yes
Euphysa sp A		1			Yes
Eupolymnia heterobranchia		1			Yes
Eurystomella bilabiata		1			Yes
Eusarsiella zostericola	NIS	2			Yes
Eusirus columbianus		1			Yes
Euspira pallida		1			Yes
Eusyllis blomstrandi		2			Yes
Eusyllis habei		6			Yes
Eusyllis magnifica		1			Yes
Euzonus mucronata	N	2			Yes
Exogone dwisula	N	8			Yes
Exogone lourei		17			Yes
Exogone molesta		3			Yes
Exogone sp		1			Yes
Eyakia robusta		2			Yes
Filicrisia sp		1			Yes
Flabelligera affinis		1			Yes
Flabellina sp		2			Yes
Fluminicola virens	N	2	Yes		
Foxiphalus similis		5			Yes
Foxiphalus xiximeus		1			Yes
Galatheidae		1			Yes
Galathowenia oculata		25			Yes
Gammaridea		2			Yes
Gammaropsis ellisi		1			Yes
Gammaropsis thompsoni		3			Yes
Gastropoda		5	Yes		Yes
Gastropoda sp 3		1	Yes		
Gastropoda sp 4		3	Yes		
Gastropteron pacificum		5			Yes
Gattyana cirrosa		5			Yes
Gattyana treadwelli		4			Yes
Geminosyllis ohma		2			Yes
Glycera americana	N	16			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Glycera macrobranchia	N	10			Yes
Glycera nana		32			Yes
Glycera sp		2			Yes
Glycera tenuis	N	1			Yes
Glycinde armigera	N	24			Yes
Glycinde polygnatha	N	59		Yes	Yes
Glycinde sp		11			Yes
Gnathopleustes sp		1			Yes
Gnorimosphaeroma oregonense	N	7		Yes	Yes
Golfingia vulgaris		2			Yes
Gomphidae		4	Yes		
Goniada brunnea		1			Yes
Goniada maculata		3			Yes
Grandidierella japonica	NIS	25		Yes	Yes
Grandifoxus grandis		13	Yes	Yes	Yes
Grantiidae		1			Yes
Guernea reduncans		1			Yes
Gyptis sp		1			Yes
Halcampa decemtentaculata	N	3			Yes
Halcampa sp		1			Yes
Halecium sp		1			Yes
Haliophasma geminatum		5			Yes
Halocynthia igaboja		1			Yes
Haminaea vesicula		1			Yes
Haplosyllis spongiphila		1			Yes
Harmothoe extenuata		5			Yes
Harmothoe imbricata		7			Yes
Harmothoe multisetosa		3			Yes
Harmothoinae		6			Yes
Harpacticoida		2			Yes
Harpacticus sp		1		Yes	
Harpiniopsis fulgens		4			Yes
Hebella pocillum		1			Yes
Helisoma sp		1	Yes		
Hemicyclops subadhaerens		1		Yes	
Hemilamprops californicus		1			Yes
Hemipodia borealis	N	2			Yes
Heptacarpus kincaidi		1			Yes
Hermissenda crassicornis	N	1			Yes
Hesperonoe complanata	N	5			Yes
Hesperonoe sp		1			Yes
Heteromastus filiformis	NIS	6			Yes
Heteromastus filobranchus	N	18			Yes
Heteromastus sp		9		Yes	Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Heteronemertea		1		Yes	
Heterophoxus affinis		19			Yes
Heterophoxus conlanae		12			Yes
Heterophoxus ellisi		5			Yes
Heterophoxus oculatus group		1			Yes
Heterophoxus sp		4			Yes
Heteropodarke heteromorpha	N	5			Yes
Heteropora pacifica		1			Yes
Hexagenia sp		5	Yes		
Hiatella arctica	N	6			Yes
Hippolytidae		4			Yes
Hirudinea		6	Yes		
Hobsonia florida	NIS	17	Yes	Yes	Yes
Homalopoma luridum		1			Yes
Hoplonemertea		9		Yes	Yes
Humilaria kennerlyi		2			Yes
Huntemannia jadensis		2		Yes	
Hyalella azteca		1	Yes		
Hyas lyratus		1			Yes
Hydrobiidae		10	Yes		
Hyperiidae		3			Yes
Idanthyrsus saxicavus		2			Yes
Idotea fewkesi	N	2			Yes
Idotea sp		1			Yes
Imogine exiguus		2			Yes
Inusitatomysis insolita		1			Yes
Iphimedia rickettsi		1			Yes
Ischnochiton trifidus		2			Yes
Ischyrocerus sp		7			Yes
Jaeropsis dubia		1			Yes
Juga plicifera	N	1	Yes		
Juga sp		2	Yes	Yes	
Kellia suborbicularis		1			Yes
Kurtzia arteaga		2			Yes
Kurtziella crebricostata		3			Yes
Kurtziella plumbea		1			Yes
Lacuna sp		4			Yes
Lacuna vincta		4			Yes
Lafoea sp		2			Yes
Lafoeidae		1			Yes
Lagenicella neosocialis		1			Yes
Lagenipora socialis		1			Yes
Lamprops carinatus		1			Yes
Lamprops quadriplicatus		15			Yes

Species	**Native (N)/Non-Indigenous (NIS)**	**# of total sites**	**Found at Freshwater sites**	**Found at Intermediate sites**	**Found at Marine Sites**
Lanassa nordenskioeldi		1			Yes
Lanassa venusta		13			Yes
Laonice cirrata		17			Yes
Laonice pugettensis		2			Yes
Laonome kroeyeri		3			Yes
Lasaeidae		1			Yes
Laticorophium baconi		1			Yes
Leitoscoloplos pugettensis	N	40			Yes
Lepidasthenia berkeleyae		4			Yes
Lepidasthenia longicirrata		1			Yes
Lepidepecreum garthi		1			Yes
Lepidochitona dentiens		2			Yes
Lepidochitona flectens		1			Yes
Lepidonotus sp		1			Yes
Lepidonotus spiculus		1			Yes
Lepidonotus squamatus		3			Yes
Leptasterias hexactis		1			Yes
Leptochelia dubia		28		Yes	Yes
Leptochiton rugatus		2			Yes
Leptoplanidae		1			Yes
Leptosynapta sp		6			Yes
Leucon sp		1			Yes
Leucon subnasica		6			Yes
Levinsenia gracilis		35			Yes
Levinsenia oculata		6			Yes
Limnoria lignorum		2			Yes
Lineidae		32		Yes	Yes
Lineus sp		3			Yes
Lirobittium sp		5			Yes
Lirularia lirulata		6			Yes
Littorina sp		1			Yes
Longipedia sp		1			Yes
Lophopanopeus bellus		5			Yes
Lucinoma annulatum		12			Yes
Lumbrineridae		15			Yes
Lumbrineris californiensis		19			Yes
Lumbrineris cruzensis	N	13			Yes
Lumbrineris latreilli		1			Yes
Lumbrineris limicola		2			Yes
Lumbrineris sp		9			Yes
Lyonsia californica	N	17			Yes
Lysippe labiata		2			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Macoma balthica	N	29	Yes	Yes	Yes
Macoma calcarea		5			Yes
Macoma carlottensis		31			Yes
Macoma elimata		20			Yes
Macoma golikovi		16			Yes
Macoma inquinata	N	9			Yes
Macoma moesta		1			Yes
Macoma nasuta	N	22			Yes
Macoma secta	N	1			Yes
Macoma sp		48		Yes	Yes
Macoma yoldiformis		16			Yes
Mactridae		1			Yes
Mactromeris polynyma		2			Yes
Magelona longicornis		21			Yes
Magelona pitelkai	N	5		Yes	Yes
Magelona sacculata	N	10			Yes
Magelona sp		3			Yes
Majidae		2			Yes
Majoxiphalus major	N	2			Yes
Maldane sarsi		11			Yes
Maldanidae		5			Yes
Malmgreniella bansei		5			Yes
Malmgreniella liei		2			Yes
Malmgreniella macginitiei	N	2			Yes
Malmgreniella nigralba	N	5			Yes
Malmgreniella sp		2			Yes
Manayunkia aestuarina	NIS	1			Yes
Manayunkia speciosa	NIS	4	Yes		
Mandibulophoxus gilesi	N	1			Yes
Mandibulophoxus mayi	N	2			Yes
Margarites pupillus		5			Yes
Margarites sp		1			Yes
Mayerella banksia		2			Yes
Mediomastus ambiseta		5			Yes
Mediomastus californiensis	N	41			Yes
Mediomastus sp		78	Yes	Yes	Yes
Megalomma splendida		3			Yes
Megamoera dentata		1			Yes
Megayoldia thraciaeformis		1			Yes
Melanochlamys diomedea	N	6			Yes
Melinna oculata	N	4			Yes
Melita nitida	NIS	2		Yes	
Membranipora membranacea		2			Yes
Membranipora sp		2			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Mesochaetopterus taylori		4			Yes
Metacaprella anomala		2			Yes
Metacaprella kennerlyi		2			Yes
Metaphoxus frequens		1			Yes
Metopa dawsoni		1			Yes
Metridium sp		1			Yes
Microclymene caudata		7			Yes
Microjassa sp		1			Yes
Microphthalmus sczelkowii		2			Yes
Micropodarke dubia		4			Yes
Micropora coriacea		2			Yes
Micrura alaskensis	N	18		Yes	Yes
Micrura sp		23			Yes
Modiolus rectus		1			Yes
Modiolus sp		6			Yes
Molgula pugetiensis		2			Yes
Molpadia intermedia		4			Yes
Monocorophium acherusicum	NIS	15		Yes	Yes
Monocorophium californianum		1			Yes
Monocorophium carlottensis		2			Yes
Monocorophium cf uenoi	NIS	1			Yes
Monocorophium insidiosum	NIS	1			Yes
Monoporeia affinis	N	6	Yes	Yes	
Monostylifera		2			Yes
Monticellina secunda		1			Yes
Monticellina serratiseta		5			Yes
Monticellina sp		3			Yes
Monticellina sp N1		2			Yes
Monticellina tesselata		1			Yes
Mopalia sinuata		3			Yes
Mopalia sp		1			Yes
Munna sp		2			Yes
Munnogonium tillerae	N	2			Yes
Musculus discors		2			Yes
Mya arenaria	NIS	29	Yes	Yes	Yes
Myidae		1			Yes
Myosoma spinosa		2			Yes
Myriochele heeri		4			Yes
Myriozoum tenue		2			Yes
Mysidacea		1			Yes
Mytilidae		17		Yes	Yes
Mytilus sp		1			Yes
Myxicola infundibulum		1			Yes
Myxilla incrustans		1			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Nacellina		2			Yes
Naineris quadricuspida		1			Yes
Naineris uncinata	N	7			Yes
Narpus sp		1	Yes		
Nassarius mendicus	N	9			Yes
Natica clausa		1			Yes
Neanthes limnicola	N	47	Yes	Yes	Yes
Neanthes sp		19	Yes	Yes	Yes
Neanthes virens	N	1			Yes
Nebalia pugettensis Cmplx		5			Yes
Nemertea		3	Yes		Yes
Nemocardium centifilosum		5			Yes
Neomysis kadiakensis		2			Yes
Neomysis mercedis	N	4	Yes	Yes	
Neosabellaria cementarium		4			Yes
Neotrypaea californiensis	N	12		Yes	Yes
Neotrypaea gigas		1			Yes
Neotrypaea sp		2			Yes
Nephasoma diaphanes		2			Yes
Nephasoma sp		2			Yes
Nephtys caeca		7			Yes
Nephtys caecoides	N	22		Yes	Yes
Nephtys californiensis	N	5		Yes	Yes
Nephtys cornuta	N	33		Yes	Yes
Nephtys ferruginea	N	34			Yes
Nephtys punctata		4			Yes
Nephtys sp		5		Yes	Yes
Nereididae		3			Yes
Nereis procera	N	22			Yes
Nereis sp		1			Yes
Nereis zonata		1			Yes
Nicomache lumbricalis		2			Yes
Nicomache personata		3			Yes
Ninoe gemmea		2			Yes
Nippoleucon hinumensis	NIS	14	Yes	Yes	Yes
Nolella sp		1			Yes
Nolella stipata		1			Yes
Notomastus hemipodus		22			Yes
Notomastus latericeus		6			Yes
Notomastus sp		1			Yes
Notoplana sp		2			Yes
Notoproctus pacificus		1			Yes
Nuculana minuta		16			Yes
Nudibranchia		1			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Nutricola lordi		32			Yes
Nutricola tantilla	N	4			Yes
Obelia dichotoma		2			Yes
Obelia longissima		1			Yes
Obelia sp		2			Yes
Odontosyllis phosphorea		5			Yes
Odostomia sp		32			Yes
Oenopota sp		3			Yes
Oligochaeta		91	Yes	Yes	Yes
Olivella baetica	N	6			Yes
Olivella biplicata		1			Yes
Olivella pycna	N	3			Yes
Onuphidae		6			Yes
Onuphis elegans		5			Yes
Onuphis iridescens		13			Yes
Onuphis sp		4			Yes
Ophelia assimilis	N	7			Yes
Opheliidae		1	Yes		
Ophelina acuminata		16			Yes
Ophiodermella incisa	N	1			Yes
Ophiodromus pugettensis		7			Yes
Ophiura leptoctenia		1			Yes
Ophiura luetkenii		2			Yes
Ophiurida		7			Yes
Ophiuridae		3			Yes
Ophiuroidea		1			Yes
Ophryotrocha sp		2			Yes
Oplorhiza gracilis		1			Yes
Orchomene obtusa		2			Yes
Orchomene pacificus		5			Yes
Orchomene pinguis		3			Yes
Oregonia gracilis		8			Yes
Ostracoda		2			Yes
Owenia fusiformis		26			Yes
Oweniidae		2			Yes
Pachycerianthus fimbriatus		2			Yes
Pachynus cf barnardi		2			Yes
Pacifoculodes zernovi		2			Yes
Paguridae		3			Yes
Pagurus armatus		1			Yes
Pagurus ochotensis		1			Yes
Pagurus setosus		1			Yes
Pagurus sp		7			Yes
Palaeonemertea		3			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Paleanotus bellis	N	10			Yes
Pandora bilirata		7			Yes
Pandora sp		2			Yes
Panomya ampla		1			Yes
Paralauterborniella sp		1	Yes		
Parandalia fauveli		1			Yes
Parandalia ocularis		1			Yes
Paranemertes californica	N	10		Yes	Yes
Paraonella platybranchia	N	3		Yes	Yes
Paraphoxus cf gracilis		1			Yes
Paraphoxus oculatus		3			Yes
Parapleustes americanus		2			Yes
Parapleustinae		3		Yes	Yes
Paraprionospio pinnata		37			Yes
Paratanytarsus sp		1		Yes	
Parathemisto pacifica		2			Yes
Parvaplustrum sp A		1			Yes
Parvilucina tenuisculpta		40			Yes
Pectinaria californiensis		11			Yes
Pectinaria granulata		15			Yes
Pectinatella magnifica		1	Yes		
Pentamera lissoplaca		5			Yes
Pentamera populifera		1			Yes
Pentamera pseudocalcigera		1			Yes
Pentamera sp		3			Yes
Pentidotea resecata	N	1			Yes
Perigonimus repens		1			Yes
Perigonimus sp		1			Yes
Petaloproctus borealis		5			Yes
Phaenopsectra sp		2	Yes	Yes	
Pherusa plumosa		2			Yes
Pherusa sp		1			Yes
Phlebobranchiata		1			Yes
Pholoe glabra	N	2			Yes
Pholoe minuta		1			Yes
Pholoe sp Cmplx		32			Yes
Pholoe sp N1		1			Yes
Pholoides asperus		12			Yes
Phoronida		1			Yes
Phoronidae		3			Yes
Phoronis sp		10			Yes
Phoronopsis harmeri		7			Yes
Phoronopsis sp		1			Yes

Species	**Native (N)/Non-Indigenous (NIS)**	**# of total sites**	**Found at Freshwater sites**	**Found at Intermediate sites**	**Found at Marine Sites**
Photis bifurcata		1			Yes
Photis brevipes	N	13			Yes
Photis parvidons		6			Yes
Photis sp		14			Yes
Phoxichilidium femoratum		2			Yes
Phoxocephalidae		1			Yes
Phyllaplysia taylori		1			Yes
Phyllochaetopterus pottsi		2			Yes
Phyllochaetopterus prolifica		11			Yes
Phyllodoce citrina		1			Yes
Phyllodoce cuspidata		3			Yes
Phyllodoce groenlandica		4			Yes
Phyllodoce hartmanae	N	7			Yes
Phyllodoce longipes	N	3			Yes
Phyllodoce mucosa		1			Yes
Phyllodoce sp		7			Yes
Phyllophoridae		1			Yes
Phylo felix		5			Yes
Physella sp		4	Yes		
Pilargis maculata		12			Yes
Pinnixa occidentalis		5			Yes
Pinnixa schmitti		30			Yes
Pinnixa sp		19			Yes
Pinnixa tubicola		1			Yes
Pinnotheridae		14			Yes
Pisaster sp		1			Yes
Pista brevibranchiata		7			Yes
Pista elongata		3			Yes
Pista moorei	N	2			Yes
Pista sp		1			Yes
Pista wui		8			Yes
Platynereis bicanaliculata	N	18			Yes
Pleurogonium rubicundum		1			Yes
Pleusymtes coquilla		2			Yes
Plumularia corrugata		1			Yes
Podarkeopsis glabrus	N	20			Yes
Podarkeopsis perkinsi		1			Yes
Podoceridae		1			Yes
Podocerus cristatus		1			Yes
Podocopida		3			Yes
Pododesmus macrochisma		2			Yes
Poecilosclerida		2			Yes
Polycirrus californicus	N	9			Yes
Polycirrus sp		15			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Polycirrus sp I		7			Yes
Polycirrus sp V		1			Yes
Polydora cornuta	NIS	16		Yes	Yes
Polydora limicola	N	6			Yes
Polydora sp		1			Yes
Polydora websteri		1			Yes
Polynoidae		2			Yes
Polypedilum sp		1	Yes		
Polyplacophora		1			Yes
Pontogeneia rostrata	NIS	4			Yes
Pontoporeia femorata		1			Yes
Potamopyrgus antipodarum	NIS	10	Yes	Yes	
Praxillella gracilis		7			Yes
Praxillella pacifica		13			Yes
Praxillella sp		4			Yes
Prionospio (Minuspio) lighti	N	51		Yes	Yes
Prionospio (Minuspio) multibranchiata	N	9			Yes
Prionospio (Prionospio) jubata		7			Yes
Prionospio (Prionospio) steenstrupi		44			Yes
Prionospio sp		3			Yes
Proceraea cornuta		15			Yes
Procladius sp		4	Yes	Yes	Yes
Proclea graffi		3			Yes
Protodorvillea gracilis	N	5			Yes
Protolaeospira eximia		1			Yes
Protomedeia grandimana		10			Yes
Protomedeia prudens	N	11			Yes
Protomedeia sp		11			Yes
Protothaca staminea	N	13			Yes
Psammonyx longimerus	N	1			Yes
Pseudochironomus sp		2	Yes	Yes	
Pseudochitinopoma occidentalis		2			Yes
Pseudodiaptomus forbesi	NIS	2	Yes		
Pseudomma truncatum		1			Yes
Pseudopolydora kempi	NIS	26		Yes	Yes
Pseudopolydora paucibranchiata	NIS	6			Yes
Pseudopolydora sp		2		Yes	
Pseudopotamilla occelata		2			Yes
Pseudopotamilla sp		1			Yes
Ptilosarcus gurneyi		4			Yes
Pulsellum salishorum		13			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Puncturella cucullata		1			Yes
Pygospio elegans		26	Yes	Yes	Yes
Ramellogammarus oregonensis	N	1	Yes		
Raricirrus maculatus		1			Yes
Rhabdocoela		3		Yes	Yes
Rhabdus rectius		2			Yes
Rhachotropis oculata		1			Yes
Rhepoxynius abronius	N	5			Yes
Rhepoxynius barnardi		4			Yes
Rhepoxynius boreovariatus		4			Yes
Rhepoxynius daboius		2			Yes
Rhepoxynius sp		1			Yes
Rhepoxynius stenodes		5		Yes	Yes
Rhizocaulus verticillatus		1			Yes
Rhodine bitorquata		8			Yes
Rhynchospio glutaea	N	11			Yes
Rictaxis punctocaelatus		1			Yes
Rochefortia compressa		1			Yes
Rochefortia tumida	N	53			Yes
Rocinela belliceps		1			Yes
Rocinela propodialis		2			Yes
Rutiderma lomae		6			Yes
Sabaco elongatus	NIS	2			Yes
Sabellidae		6			Yes
Sabelliphilidae		1			Yes
Saccocirridae		1			Yes
Saccoglossus sp		2			Yes
Saduria entomon		6	Yes	Yes	
Sagitta sp		2			Yes
Sagittidae		1			Yes
Saxidomus giganteus	N	8			Yes
Scalibregma californicum		4			Yes
Scalibregma inflatum		1			Yes
Scaphander sp		1			Yes
Scintillona bellerophon		2			Yes
Scionella japonica		2			Yes
Scleroplax granulata	N	3			Yes
Scolelepis nr yamaguchii		2			Yes
Scolelepis sp		1		Yes	
Scolelepis squamata		7			Yes
Scoletoma luti	N	36			Yes
Scoloplos acmeceps		4			Yes
Scoloplos armiger alaskensis		4			Yes
Scoloplos armiger armiger		16	Yes	Yes	Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Scoloplos sp		2			Yes
Scyphozoa		1			Yes
Selaginopsis triserialis		1			Yes
Semele rubropicta		1			Yes
Serpulidae		1			Yes
Sialis sp		4	Yes		
Sigalion spinosus	N	1			Yes
Sigambra bassi		16			Yes
Sige bifoliata		1			Yes
Siliqua sp		14	Yes	Yes	Yes
Sinelobus stanfordi	NIS	1			Yes
Sipuncula		1			Yes
Skenea sp		2			Yes
Smittina sp		1			Yes
Solamen columbianum		7			Yes
Solariella sp		3			Yes
Solen sicarius	N	5			Yes
Solidobalanus hesperius		1			Yes
Sphaeriidae		1	Yes		
Sphaerodoropsis sphaerulifer		10			Yes
Sphaerosyllis californiensis	N	10			Yes
Sphaerosyllis ranunculus	N	2			Yes
Sphaerosyllis sp N1		3			Yes
Spio butleri	N	8		Yes	Yes
Spio cirrifera		6			Yes
Spio filicornis		2			Yes
Spiochaetopterus costarum	N	25		Yes	Yes
Spionidae		3			Yes
Spiophanes berkeleyorum	N	29			Yes
Spiophanes bombyx		15			Yes
Spirontocaris arctuatus		1			Yes
Spirontocaris ochotensis		2			Yes
Spirontocaris prionota		1			Yes
Spirontocaris sica		1			Yes
Stenothoidae		1			Yes
Stenothoides sp		2			Yes
Sternaspis cf fossor		22			Yes
Sthenelais berkeleyi		1			Yes
Sthenelais tertiaglabra		1			Yes
Stictochironomus sp		3	Yes	Yes	
Stolidobranchiata		2			Yes
Streblosoma bairdi		2			Yes
Streblosoma sp B		1			Yes
Streblospio benedicti	NIS	12		Yes	Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Styela coriacea		1			Yes
Styela gibbsii		2			Yes
Styela sp		1			Yes
Stylatula sp A		3			Yes
Syllidae		2			Yes
Symplectoscyphus sp		1			Yes
Synidotea consolidata		1			Yes
Synidotea sp		1			Yes
Tabanidae		1	Yes		
Tanytarsus sp		2	Yes		
Tecticeps pugettensis	N	2			Yes
Tellina bodegensis	N	1			Yes
Tellina carpenteri		1			Yes
Tellina modesta	N	17			Yes
Tellina nuculoides	N	6			Yes
Tellina sp		4			Yes
Tenonia priops		10			Yes
Terebellidae		9			Yes
Terebellides californica		12			Yes
Terebellides horikoshii		3			Yes
Terebellides kobei		1			Yes
Terebellides reishi		3			Yes
Terebellides sp		12			Yes
Terebellides stroemi		6			Yes
Terebratalia transversa		3			Yes
Terebratulida		1			Yes
Tetrastemma candidum		17	Yes	Yes	Yes
Tetrastemma nigrifrons		3			Yes
Tetrastemma sp		23		Yes	Yes
Tetrastemmatidae		5			Yes
Tharyx parvus		12			Yes
Tharyx sp N1		3			Yes
Thelepus setosus		1			Yes
Themiste pyroides		2			Yes
Thracia challisiana		1			Yes
Thracia trapezoides		2			Yes
Thyasira flexuosa		11			Yes
Thysanocardia nigra		12			Yes
Travisia forbesii		2			Yes
Travisia pupa		1			Yes
Tresus sp		9			Yes
Trichobranchus glacialis		1			Yes
Trichoptera		2	Yes		
Trichotropis cancellata		2			Yes

Species	Native (N)/Non-Indigenous (NIS)	# of total sites	Found at Freshwater sites	Found at Intermediate sites	Found at Marine Sites
Tritella pilimana		8			Yes
Trochochaeta multisetosa		13			Yes
Tubulanus cingulatus		2			Yes
Tubulanus polymorphus		22			Yes
Tubulanus sp		14			Yes
Tubulariidae		1			Yes
Tubulipora sp		3			Yes
Turbonilla sp		20			Yes
Typhloplanoidea		1	Yes		
Typosyllis alternata	N	1			Yes
Typosyllis armillaris		1			Yes
Typosyllis caeca		8			Yes
Typosyllis cornuta		5			Yes
Typosyllis elongata		2			Yes
Typosyllis heterochaeta		7			Yes
Typosyllis sp		3			Yes
Upogebia pugettensis	N	1			Yes
Velutina plicatilis		1			Yes
Venerupis philippinarum	NIS	1			Yes
Virgularia agassizi		2			Yes
Westwoodilla caecula		12			Yes
Westwoodilla sp		4			Yes
Yoldia hyperborea		10			Yes
Yoldia seminuda		10			Yes
Yoldia sp		13			Yes
Zygonemertes virescens		7			Yes

Appendix 7. Fish species from 1999-2000.

SCIENTIFIC NAME	COMMON NAME	# of SITES	% ESTUARINE AREA	SALINTY FOUND
Class Actinopterygii				
Order Batrachoidiformes				
Family Batrachoididae				
Porichthys notatus	Plainfin midshipman	24	26	Marine
Order Clupeiformes				
Family Clupeidae				
Clupeidae sp	Herrings, shads, sardines, sardinellas, sprats, etc.	1	<1	Freshwater
Alosa sapidissima	American Shad	7	1	Freshwater
Clupea pallasii	Pacific herring	25	24	All
Family Engraulidae				
Engraulis mordax	Californian anchovy	2	1	Marine, Intermediate
Order Cypriniformes				
Family Cyprinidae				
Mylocheilus caurinus	Peamouth	2	<1	Freshwater
Ptychocheilus oregonensis	Northern pikeminnow	2	<1	Freshwater
Order Gadiformes				
Family Gadidae				
Gadus macrocephalus	Pacific Cod	9	14	Marine
Microgadus proximus	Pacific tomcod	44	46	Marine, Intermediate
Theragra chalcogramma	Alaska (walleye) pollock	12	19	Marine
Family Merlucciidae				
Merluccius productus	Pacific hake	17	22	Marine
Order Gasterosteiformes				
Family Syngnathidae				
Syngnathus leptorhynchus	Bay pipefish	2	1	Marine, Intermediate
Family Gasterosteidae				
Gasterosteus aculeatus	Three-spine	15	1	Freshwater

SCIENTIFIC NAME	COMMON NAME	# of SITES	% ESTUARINE AREA	SALINTY FOUND
	stickleback			
Order Osmeriformes				
Family Osmeridae				
Spirinchus thaleichthys	Longfin smelt	10	3	Marine
Order Perciformes				
Family Centrarchidae				
Pomoxis annularis	White Crappie	1	<1	Freshwater
Pomoxis sp	Crappie	1	<1	Freshwater
Family Gobiidae				
Gobiidae sp.	Gobies	1	<1	Marine
Family Pholidae				
Apodichthys flavidus	Penpoint gunnel	1	3	Marine
Pholis ornate	Saddleback gunnel	15	2	All
Family Embiotocidae				
Cymatogaster aggregata	Shiner perch	56	23	All
Embiotoca lateralis	Stripped sea perch	4	<1	Marine, Intermediate
Hyperprosopon anale	Spotfin surfperch	1	<1	Marine
Hyperprosopon argenteum	Walleye surfperch	1	<1	Marine
Family Embiotocidae (continued)				
Hypsurus caryi	Rainbow seaperch	1	1	Marine
Phanerodon furcatus	White seaperch	3	1	Marine, Intermediate
Rhacochilus vacca	Pile Surfperch	6	2	Marine
Family Stichaeidae				
Lumpenus sagitta	Snake prickleback	3	1	Marine
Family Trichodontidae				
Trichodon trichodon	Pacific sandfish	3	2	Marine
Family Zoarcidae				
Lycodes cortezianus	Bigfin eelpout	2	6	Marine
Lycodes diapterus	Black eelpout	4	5	Marine
Lycodes palearis	Wattled eelpout	10	12	Marine
Lycodopsis pacifica	Blackbelly Eelpout	4	3	Marine
Order Percopsiformes				

SCIENTIFIC NAME	COMMON NAME	# of SITES	% ESTUARINE AREA	SALINTY FOUND
Family Percopsidae				
Percopsis transmontana	Sand roller	1	<1	Freshwater
Order Pleuronectiformes				
Family Paralichthyidae				
Citharichthys sordidus	Pacific sanddab	27	35	Marine
Citharichthys stigmaeus	Speckled sanddab	34	6	Marine, Intermediate
Family Pleuronectidae				
Eopsetta exilis	Slender sole	23	32	Marine
Errex zachirus	Rex sole	9	13	Marine
Hippoglossoides elassodon	Flathead sole	14	20	Marine
Microstomus pacificus	Dover Sole	19	2	Marine
Platichthys stellatus	Starry flounder	83	31	All
Pleuronectes bilineatus	Rock sole	24	29	Marine
Pleuronectes isolepis	Butter sole	6	8	Marine
Pleuronectes vetulus	English sole	110	70	Marine, Intermediate
Pleuronichthys coenosus	C-O sole	2	1	Marine
Pleuronichthys decurrens	Curlfin sole	2	1	Marine
Psettichthys melanostictus	Sand sole	21	11	Marine
Reinhardtius stomias	Arrowtooth flounder	1	1	Marine
Order Salmoniformes				
Family Salmonidae				
Oncorhynchus tshawytscha	Chinook salmon	6	<1	All
Salmo clarkia	Cutthroat trout	1	<1	Freshwater
Order Scorpaeniformes				
Family Agonidae				
Agonopsis vulsa	Northern spearnose poacher	2	6	Marine
Bathyagonus alascanus	Gray starsnout	1	<1	Marine
Bathyagonus nigripinnis	Blackfin poacher	5	4	Marine
Bathyagonus pentacanthus	Bigeye poacher	1	1	Marine
Podothecus acipenserinus	Sturgeon poacher	5	8	Marine
Sarritor frenatus	Sawback poacher	1	<1	Marine

SCIENTIFIC NAME	COMMON NAME	# of SITES	% ESTUARINE AREA	SALINTY FOUND
Xeneretmus triacanthus	Bluespotted poacher	1	3	Marine
Family Cottidae				
Artedius fenestralis	Padded sculpin	2	<1	Freshwater
Chitonotus pugetensis	Roughback sculpin	5	7	Marine
Clinocottus embryum	Calico sculpin	1	1	Marine
Cottus asper	Prickly sculpin	4	<1	Freshwater, Intermediate
Enophrys bison	Buffalo Sculpin	6	1	Marine
Gymnocanthus galeatus	Armorhead sculpin	4	3	Marine
Hemilepidotus hemilepidotus	Red Irish lord	2	4	Marine
Hemilepidotus spinosus	Brown Irish Lord	1	<1	Marine
Icelus spiniger	Thorny sculpin	3	4	Marine
Leptocottus armatus	Pacific staghorn sculpin	49	13	All
Myoxocephalus polyacanthocephalus	Great sculpin	4	4	Marine
Oligocottus maculosus	Tidepool sculpin	2	<1	Freshwater
Radulinus asprellus	Slim sculpin	1	3	Marine
Triglops macellus	Roughspine sculpin	1	1	Marine
Triglops pingeli	Ribbed sculpin	1	1	Marine
Family Hemitripteridae				
Nautichthys oculofasciatus	Sailfin sculpin	3	5	Marine
Family Hexagrammidae				
Hexagrammos decagrammus	Kelp greenling	3	2	Marine
Hexagrammos stelleri	Whitespotted greenling	5	1	Marine, Intermediate
Ophiodon elongates	Lingcod	5	3	Marine
Family Liparidae				
Liparis callyodon	Spotted snailfish	1	<1	Marine
Liparis dennyi	Marbled snailfish	2	3	Marine
Liparis fucensis	Slipskin snailfish	1	<1	Marine
Liparis sp.	Snailfish	1	3	Marine
Family Psychrolutidae				
Malacocottus kincaidi	Blackfin sculpin	4	3	Marine

SCIENTIFIC NAME	COMMON NAME	# of SITES	% ESTUARINE AREA	SALINTY FOUND
Family Scorpaenidae				
Sebastes auriculatus	Brown Rockfish	4	5	Marine
Sebastes dallii	Calico Rockfish	1	<1	Marine
Sebastes diploproa	Splitnose rockfish	2	1	Marine
Sebastes caurinus	Copper Rockfish	3	7	Marine
Sebastes emphaeus	Puget Sound rockfish	1	3	Marine
Sebastes maliger	Quillback Rockfish	9	11	Marine
Sebastolobus alascanus	Shortspine thornyhead	1	3	Marine
Class Chondrichthyes				
Order Rajiformes				
Family Arhynchobatidae				
Bathyraja interrupta	Bering skate	1	3	Marine
Raja binoculata	Big Skate	6	8	Marine
Raja rhina	Longnose Skate	16	18	Marine
Order Carcharhiniformes				
Family Triakidae				
Mustelus henlei	Brown Smooth-hound Shark	4	5	Marine
Order Chimaeriformes				
Family Chimaeridae				
Hydrolagus colliei	Spotted ratfish	30	44	Marine
Order Squaliformes				
Family Squalidae				
Squalus acanthias	Spiny Dogfish	31	43	Marine