Condition of Outer Coastal Estuaries of Washington State, 1999

A Statistical Summary

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Cover photo: Mouth of the Ozette River (Department of Ecology photo)

Condition of Outer Coastal Estuaries of Washington State, 1999

A Statistical Summary

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Table of Contents

Page

List of Figures

List of Tables

Abstract

The Coastal Environmental Monitoring and Assessment Program (EMAP) was developed by the U.S. Environmental Protection Agency to measure the condition of the nation's coastal waters. The purpose of EMAP is to assess how well pollution-control programs and policies are working to protect the environment. Numerous water, sediment, and biological measurements provide information on the physical environment, resident invertebrates and fish, and exposure of those animals to pollutants.

In 1999, estuaries along the outer coast of Washington were sampled as part of Coastal EMAP. The areas sampled included estuaries of the Strait of Juan de Fuca, Pacific Coast, and Columbia River, but not Puget Sound. This report provides a statistical summary of the results.

Fifty sample sites were selected randomly from four sizes of estuaries. Of those, 44 stations were sampled successfully, with all EMAP indicators measured at 37 stations and a partial set measured at 7 additional stations.

Overall, the estuaries had mostly well-mixed, clear waters with healthy levels of dissolved oxygen. Sediments were generally sandy, with relatively low organic content.

Sediments and whole-fish tissues were tested for pollutants. Of the metals examined, most were found in both sediments and fish. The sediment metals were all below Washington State sediment quality standards. Sediment polycyclic aromatic hydrocarbon (PAH) levels were generally below Washington State sediment quality standards, with a few unusually high exceptions. PCBs and DDTs were detected in all fish tissues analyzed, but rarely in sediment. Toxicity tests indicated that 5-16% of the area had toxic sediments.

The number of invertebrates living in the sediment ranged from 3 to over 3000 per sample, representing from 1 to 147 species. Of 431 invertebrate species found, 33 were non-native. Thirty-four bottom-living fish species were found. The trawl fish catches ranged from 1 to 336 fish, representing approximately 500-175,000 fish per square kilometer.

Preface

This document is a statistical summary of the data from the first annual Washington State estuaries component of the nationwide Environmental Monitoring and Assessment Program (EMAP). EMAP-West began as a partnership of: the States of California, Oregon, Washington, Alaska and Hawaii; the National Oceanic and Atmospheric Administration (NOAA); and the U.S. Environmental Protection Agency (EPA). The program is administered through the EPA and implemented through partnerships with a combination of federal and state agencies, universities, and the private sector.

Acknowledgements

The success of the Washington Coastal EMAP program is due to the dedication, hard work, and resources of many people and agencies. The EPA-Office of Research and Development (ORD) provided funds, direction, sample design, statistical-analysis programs, training, and other assistance. EPA Region 10 provided field and logistical support, from coordinating with native tribes, to obtaining access permits for various protected state and federal lands, to supplying personnel and vessel (*R/V Monitor*) for sampling operations. The NOAA National Marine Fisheries Service (NMFS) performed the fishing effort, providing equipment, supplies, and personnel, as well as performing the histopathological analyses. The Southern California Water Resources Research Program and the EPA-ORD designed, developed, and maintain the west coast database. All of the EMAP partners have provided technical assistance and support to each other.

Within the Washington State Department of Ecology, Dustin Bilhimer, Casey Clishe (project lead), and Christina Ricci planned and prepared for the sampling effort, wrote the field protocols, performed the field work, processed samples, and entered and QA'd data. Sandra Aasen and Ken Dzinbal assisted in the field on occasion. Kathy Welch coordinated the taxonomic work and standardized the taxonomy across all three west coast states. Managers were Ken Dzinbal and Maggie Dutch. Gary Koshi handled the fiscal aspects of the contract. Bernie Strong manufactured equipment, transported staff, and provided other support. Chemists at the Manchester Environmental Laboratory performed the chemistry lab analyses. Database management and quality assurance were done by Sandra Aasen, Karin Feddersen, and Christina Ricci.

The authors wish to thank Julia Bos, Margaret Dutch, Brian Grantham, Ed Long, Jan Newton, Dale Norton, and Kathy Welch, all of the Washington State Department of Ecology, as well as Mark Myers, of NOAA NMFS, for their review and suggestions for improvement of this report.

Executive Summary

The Environmental Monitoring and Assessment Program (EMAP) is a nationwide program developed by the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD) to provide information about the degree to which existing pollution-control programs and policies protect the nation's ecological resources. Data from this program are the basis for individual reports of condition for each state, as well as the National Coastal Assessment (NCA). In particular, the data can be used to meet reporting requirements of the federal Clean Water Act.

The NCA is a five-year effort by EPA-ORD to evaluate the assessment methods it developed to advance the science of ecosystem-condition monitoring. This program's goal is to create an integrated, comprehensive coastal monitoring program among the coastal states to assess the condition of the nation's coastal resources (estuaries and offshore waters). The NCA is made possible by strategic partnerships with all 24 U.S. coastal states. Using a compatible, probabilistic design and a common set of survey indicators, each state conducts the survey and assesses the condition of its coastal resources independently. Because of the compatible design, these estimates can be aggregated to assess conditions at the EPA regional, biogeographical, and national levels.

The Coastal Component of EMAP-West is a partnership of EPA with the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the states of California, Oregon, and Washington, to measure the condition of the estuaries of these three states. Sampling began during the summer of 1999, with small estuaries, and was completed in the summer of 2000, with large estuaries (such as Puget Sound). In subsequent years, sampling was designed to fulfill the objectives of the Coastal EMAP Western Pilot project, with sampling in intertidal zones (2002) and the continental shelf (2003).

This report provides a statistical summary of the data from the first year of Coastal EMAP sampling (1999) for Washington. The 1999 sampling efforts were focused on the estuaries along the outer coast. The sample area included the northern coast of the Olympic Peninsula/Strait of Juan de Fuca, the Pacific Coast and its estuaries (including Grays Harbor and Willapa Bay), and the tributary estuaries along the lower Columbia River.

Fifty sample sites were selected using a stratified, probability-based design with four strata representing differing sizes (area) of estuaries. To ensure that sampling would occur across the entire range of estuarine sizes, the samples were drawn to yield 10 stations in the smallest estuaries, 25 stations in the medium-size estuaries, and 15 stations in the largest estuaries. No alternate sites were included in the design as replacements for unsamplable target sites.

Field crews sampled 44 of the 50 planned sites during 29 sampling days between August 1 and October 14, 1999. Two stations were abandoned prior to sampling, based on geographical factors, and four stations were abandoned in the field, three due to inadequate water depths and one due to unsafe field conditions. Of the 44 sites sampled, all EMAP parameters were measured at 37; the other 7 sites were partially sampled. Sediment samples for chemical, physical, and toxicological analyses were taken at 41 sites; and sediment samples for sediment-dwelling (infaunal) invertebrate analyses were collected at 37 sites. Trawling was successful at 37 stations. Sufficient target-species fish were caught to enable chemical analyses of fish tissue from 24 stations. Water-column measurements were made on site at 40 sites, and water samples for laboratory analyses were collected at 44 sites.

The field and laboratory measurements acquired for each station represent three categories of ecological indicators, used to assess the physical environment, resident invertebrates and fish, and exposure of those animals to pollutants:

- *General Habitat Condition Indicators*: dissolved oxygen concentration, depth, salinity, temperature, pH, sediment lithology characteristics, water-quality indicators (chlorophyll-a, nutrients, total suspended solids)
- *Abiotic/Pollutant Exposure Condition Indicators*: sediment and fish-tissue contaminants, sediment toxicity, marine debris
- *Biotic Condition Indicators*: diversity and abundance of benthic infaunal and demersal fish species, fish pathological anomalies, epibenthic infauna

General Habitat Condition Indicators

Water Characteristics

The depths of the 44 stations sampled ranged from intertidal to 21.3 meters (m). Salinities ranged from < 0.1 practical salinity units (psu) in Grays Bay and other estuaries further upstream along the Columbia River, to 32-33 psu in Makah Bay, which is open to the Pacific Ocean. Water temperatures ranged from 8.5°C to 21.6°C and were higher in Columbia River estuaries than in most of the other estuaries. Surface and bottom salinities were similar almost everywhere; and surface and bottom temperatures were generally similar, except in areas with direct influence by the Pacific Ocean, in which case bottom temperatures were lower than surface temperatures. The similarity of surface and bottom salinities and temperatures indicates well-mixed waters.

The degree of water-column stratification, as measured by the difference in density between the surface and bottom, indicated that approximately 59% of the study area had well-mixed waters, and about 18% of the study area had strongly stratified waters. Washington’s estuaries are, overall, well-mixed, a fact consistent with the large tidal range across the area, which generally leads to a high level of water-column mixing.

The overwhelming majority of Washington's estuarine waters are well-oxygenated: with the exception of a few bottom dissolved oxygen (DO) concentrations between 4 and 5 mg/L, all DO concentrations were above 5 mg/L.

Makah Bay was the most alkaline location, with pH above 8; elsewhere pH averaged 7.2-7.5. Surface waters were often slightly more alkaline than bottom waters.

The majority of the study area had high water clarity, with low light attenuation and high transmissivity. Less than 2% of the study area had low water clarity, and the remainder had moderate clarity.

Surface chlorophyll-a concentrations ranged from 1 to 35 μg/L. Mean chlorophyll-a concentrations were similar everywhere, except at one station in Discovery Bay, where concentrations were very high.

Total dissolved nutrient concentrations were generally higher in the northern Olympic Peninsula than elsewhere. The ratio of nitrogen to phosphorus in nutrients (N:P ratio) was considerably higher in the Columbia River estuaries than in the estuaries of the outer coast, increasing upstream along the Columbia, and tended to be lower in Willapa Bay than in other coastal embayments. Approximately 93% of the study area was estimated to have N:P ratios of less than 16, suggesting nitrogen limitation. The remaining 7% had N:P ratios suggesting phosphorus limitation.

Sediment Characteristics

The silt-clay content of sediments ranged from 0% to 86%, with an average of about 15%. Approximately 76% of the study area had sediments composed of sands (< 20% silt-clay), approximately 23% had intermediate muddy sands (20-80% silt-clay), and < 1% was composed entirely of muds (> 80% silt-clay).

The organic content of the sediment ranged from zero to 3.2%, averaging approximately 0.6%. Approximately 68% of the area studied was estimated to have total organic carbon (TOC) content less than 0.5% by weight; approximately 50% of the area had TOC < 0.2%.

Abiotic/Pollutant Exposure Condition Indicators

Sediment and Fish-Tissue Contaminants

Chemical analyses were performed on sediments and ground *whole* fish to gauge ecological exposure only. *The results cannot be used to draw conclusions about fish for human consumption.*

Metals

Aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, silver, tin, and zinc were detected in sediments at all 41 stations for which sediments were analyzed for contaminants. Mercury was detected at 40 stations, and selenium was detected at only four stations.

Sediment metals concentrations varied widely in Columbia River estuaries and, to a lesser extent, Strait of Juan de Fuca estuaries and Grays Harbor. The highest concentrations occurred in Grays Bay, Discovery Bay, Baker Bay, Martin Slough, and parts of Grays Harbor. Metals concentrations were generally lower in Willapa Bay, Makah Bay, and the very small, shallow estuaries on the central Pacific Coast than elsewhere.

The concentrations of all of the metals tested were considerably lower than the respective NOAA Effects Range-Median (ERM) sediment quality guidelines, the Washington State Sediment Quality Standards (SQS), and the Washington State Cleanup Screening Levels (CSL). However, concentrations of arsenic, cadmium, chromium, and copper were higher than (exceeded) the NOAA Effects Range-Low (ERL) sediment guidelines at a few stations.

Aluminum, chromium, iron, mercury, and zinc were detected in fish tissues at all stations for which the analyses were performed (24); and lead was detected in fish tissue at all but one of those stations. Copper and selenium were detected in tissues at most of the stations. The other metals were detected at only a few stations.

Polynuclear Aromatic Hydrocarbons (PAHs) – Sediments Only

PAHs were detected in the sediments at 40 of the 41 stations sampled. Statistical analysis of the results was complicated by an *outlier*, an unusually high value, in the 4th laboratory replicate performed at one station. The anomaly is believed to have been caused by the presence of a tar ball, oil globule, or piece of creosoted wood. Although this represents inhomogeneity within the sample, it might still be considered representative of generalized conditions at that station. (The station is situated in Martin Slough, upstream from the mouth of the Columbia River and close to Interstate 5.)

With the exception of the Martin Slough station and one station in each Grays Harbor and Baker Bay, Total HPAH concentrations were generally similar everywhere. Total LPAH concentrations, however, were higher in Makah Bay than anywhere except the three previously-mentioned stations and Raft River (a small, shallow estuary on the Pacific Coast).

With the outlier included in the analysis, only the Martin Slough station, corresponding to about 0.15% of the study area, exceeded the Washington SQS and CSL sediment quality criteria, as well as the ERL and ERM, for Total LPAH. In addition, the Total HPAH level at that station exceeded the SQS, CSL, and ERL. The Total PAH (Total HPAH + LPAH) exceeded both the ERL and ERM. Even with the outlier excluded, the Martin Slough station exceeded the ERL for Total LPAH. All other stations, representing the other 99.85% of the study area, were below the state standards and the NOAA guidelines.

Polychlorinated Biphenyls (PCBs)

Fifteen PCB congeners were detected in sediments at only five stations. Of those, only two congeners were measurable at all five of the stations where PCBs were detected.

PCBs were detected in fish tissues at all stations sampled. The tissue Total PCB burden was one to two orders of magnitude higher in samples from the Columbia River estuaries than in all other samples.

DDTs

Only two DDT isomers were detected in sediments. Nine stations had measurable concentrations of 4,4'-DDE — all but one in the Columbia River — while only one (Martin Slough) had a detectable level of 4,4'-DDD.

One or more DDT isomers were detected in fish tissues at all stations. As with Total PCBs, the tissue Total DDT burden was one to two orders of magnitude higher in the samples from Columbia River than in samples from all of the other estuaries in Washington.

Other Chlorinated Pesticides

The only pesticide detected in sediments was hexachlorobenzene, which occurred at two stations.

Alpha-chlordane, trans-nonachlor, and hexachlorobenzene were the only pesticides detected in fish tissues; they were detected at only a subset of the stations.

Sediment Toxicity Tests

The toxicity tests indicated that the percent of the study area with toxic sediments was approximately 5% (sea urchin fertilization), 15% (sea urchin embryo development), and 16% (amphipod mortality).

Biotic Condition Indicators

Benthic Infauna

In all, 431 infauna species, 33 of which were introduced, were found in the 37 samples acquired. The number of species per sample (species richness) ranged from 1 to 157, with an average of 27. Species richness was greatest in the Strait of Juan de Fuca estuaries. The estuaries of the Columbia River had less community diversity than elsewhere, according to one commonly-used measure. The density of infaunal organisms ranged from 3 to 3106 individuals per sample, with an average of 483. Ten numerically-dominant species made up approximately 64% of all benthic infauna collected. Introduced species accounted for 5.6% of the total benthic infauna collected at all sites.

Demersal Fish

Thirty-four bottom-dwelling (demersal) species of fish were found. At any given station, 1 to 10 fish species were caught per trawl, with an average of 3 species per trawl. The number of fish caught in each trawl ranged from 1 to 336, equivalent to a catch per area swept of approximately 500 to 175,000 fish per square kilometer. Average catch per area swept was approximately 20,000 fish per square kilometer, though the median was less than 5,000 fish per square kilometer. Fish with tumors and parasites were found at only a few stations.

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Introduction

Program Background

The National Coastal Assessment (NCA) is a multi-year, comprehensive survey of the condition of the nation's coastal resources (estuaries and offshore waters) led by the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD). The NCA is accomplished in partnership with the coastal states in an integrated, comprehensive monitoring program based on the ORD's Environmental Monitoring and Assessment Program (EMAP). Each state conducts the survey and assesses the condition of its coastal resources independently using a compatible, probabilistic design and a common set of survey indicators (Nelson *et al.*, 2004). Because of the compatible design, these estimates can be aggregated to assess conditions at the EPA regional, biogeographical, and national levels (Nelson *et al.*, 2004); these aggregated results are used in the National Coastal Condition Reports (U.S. EPA, 2001c, 2005).

EMAP is a nationwide program to assess how well pollution-control programs and policies protect ecological resources, and to assist EPA's regional offices and the states in meeting reporting requirements of the federal Clean Water Act (Nelson *et al.*, 2004). Results of EMAP surveys along the eastern, southeastern, and Gulf of Mexico U.S. coasts are published in Macauley *et al.* (1994, 1995), Strobel *et al.* (1994, 1995), and Hyland *et al.* (1996, 1998).

West Coast Pilot EMAP Project

The Coastal Component of EMAP-West began as a partnership of EPA with the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the states of California, Oregon, and Washington, to measure the condition of these three states' estuaries (Nelson *et al.*, 2004). The Washington State EMAP partner is the Department of Ecology (Ecology). Estuaries were sampled during the summers of 1999 and 2000. Nelson *et al.* (2004) and Hayslip *et al.* (2006) are reports on the 1999 surveys of the three states combined and on the 1999-2000 results for EPA Region 10 (Washington and Oregon), respectively.

Objectives

The Washington EMAP program is a component of the larger EMAP Western Coastal Program, which has the following objectives (Nelson *et al.*, 2004):

- Assess the condition of estuarine resources of Washington, Oregon, and California, based on a range of indicators of environmental quality, using an integrated survey design.
- Implement pilot studies of the conditions of estuarine resources of Alaska and Hawaii, based on a range of appropriate indicators of environmental quality for these systems.
- Establish a baseline for evaluating how the conditions of the estuarine resources of these states change with time.

- Develop and validate improved methods for use in future coastal monitoring and assessment efforts in the western coastal states.
- Transfer the technical approaches and methods for designing, conducting, and analyzing data from probability-based environmental assessments to the states and tribes.

The specific objectives of the Washington component of the EMAP Western Coastal Program are to achieve the above program objectives for Washington estuarine waters. This report presents a statistical summary of data from the first year of sampling (1999) for the estuarine systems of Washington State; future reports will be interpretive.

The Washington Context

Western Washington falls within the Columbian Biogeographical Province, which extends along the northern Pacific Coast from Cape Mendocino, CA, to Vancouver Island, BC (Figure 1). Mountainous shorelands with rocky foreshores are prevalent. The province is influenced by both the Aleutian and California Currents, and estuaries are strongly influenced by freshwater runoff. The biota are primarily temperate with some boreal components, and there are extensive algal communities. The tidal range is moderate to large.

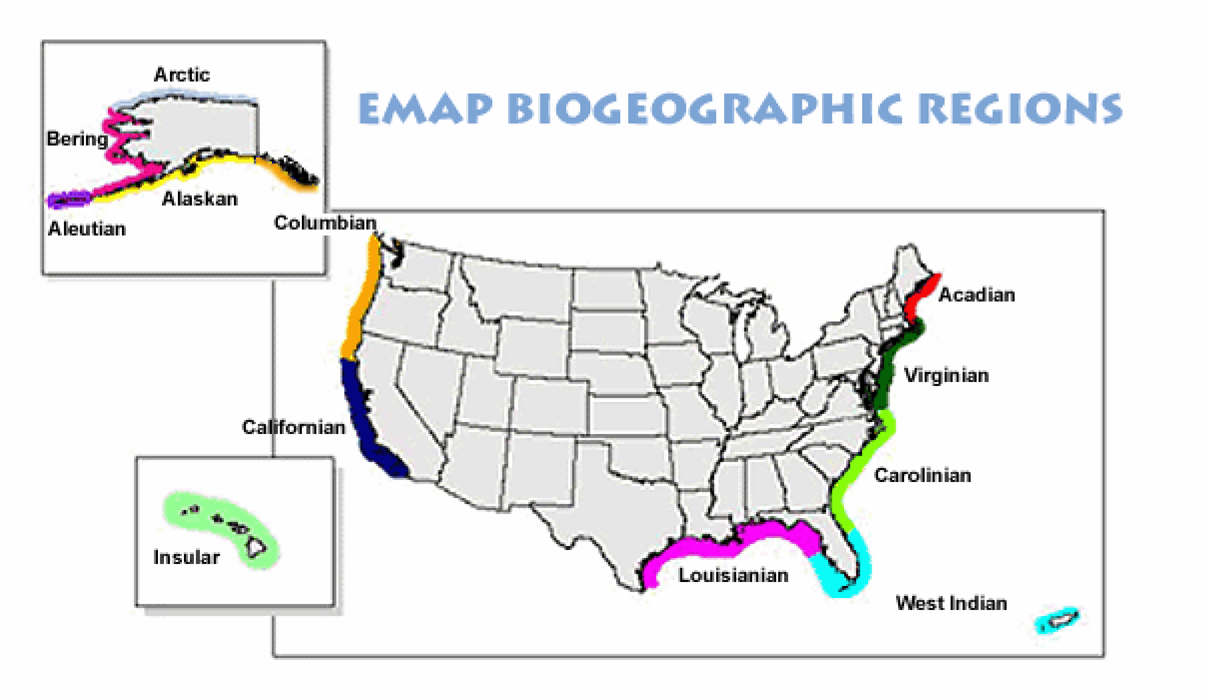

Figure 1. North American coastal biogeographic provinces

Washington State has more than 4000 kilometers (2500 miles) of marine coastline, including the outer coast, with its small estuaries bordering the Pacific Ocean, the Strait of Juan de Fuca, Puget Sound, the lower Columbia River, Grays Harbor, and Willapa Bay.

1999-2000 Overall West Coast Design

The Western Coastal EMAP program for 1999-2000 was designed as a two-year comprehensive assessment of all estuaries in the states of Washington, Oregon, and California, with smaller estuarine systems sampled in 1999 and larger estuarine systems sampled in 2000. Data from both years will be combined for analysis. Sample results in the combined analyses will be weighted by the proportion of the total estuarine area within a given design stratum (= estuarine size class) and the number of samples desired for that stratum (Nelson *et al.*, 2004).

The West Coast sampling frame comprised all of the estuaries from the Mexican border to the Canadian border, including San Francisco Bay, Puget Sound, and the lower Columbia River. Sampling areas were bounded inland by the shoreline, upstream by the head of salt water influence, and seaward by confluence with the Pacific Ocean. Emergent salt marsh areas were not included. Sample locations could fall in any water depth within the estuaries (Nelson *et al.*, 2004).

Washington Design

For Washington, the 1999 sample design included only estuaries along the coastline outside of the Puget Sound system. Tributary estuaries of the Columbia River located within Washington were included in the 1999 sampling effort, while the main channel of the Columbia River was sampled in 2000 as part of the Oregon design. Puget Sound was the focus of the sample design for Washington in 2000. Nelson *et al.* (2004) describes the 1999 sample designs for Oregon and California and the 2000 sample designs for all three states.

Indicators

The NCA uses a standard set of environmental parameters as indicators of environmental condition. There are three groups of indicators: General Habitat Condition Indicators, to represent general habitat condition; Abiotic/Pollutant Exposure Condition Indicators, to represent exposure to pollutants; and Biotic Condition Indicators, to represent the condition of benthic faunal and demersal fish resources (Table 1).

- *General Habitat Condition Indicators* describe physical and chemical conditions at the study site and provide information used to interpret the results of biotic condition indicators. Indicators include depth, salinity, temperature, dissolved oxygen concentration, chlorophyll-*a* concentration, dissolved nutrients concentrations, total suspended solids, and pH in the water, as well as grain size and total organic carbon in the sediment.
- *Abiotic/Pollutant Exposure Condition Indicators* characterize the amounts and types of pollutants present that may be harmful to the biota. Indicators include sediment and fish-tissue contaminants, sediment toxicity, and marine debris.
- *Biotic Condition Indicators* measure the status (health, abundance) of the biota at each site. Indicators include diversity and abundance of benthic infaunal and demersal fish species, and fish pathological anomalies.

Table 1. Core environmental indicators for Coastal EMAP West

Habitat Indicators	Exposure Indicators
Water depth	Sediment contaminants
Salinity	Fish-tissue contaminants
Water temperature	Sediment toxicity
Dissolved oxygen concentration	(amphipod *Ampelisca abdita* survival)
pH	**Biotic Indicators**
Light transmittance	Infaunal species composition
Secchi depth	Infaunal abundance
Total suspended solids	Infaunal species richness and diversity
Chlorophyll-*a* concentration	Fish species composition
Dissolved nutrient concentrations	Fish abundance
Percent silt-clay of sediments	Fish species richness and diversity
Percent total organic carbon in sediments	External pathological anomalies in fish

In Washington in 1999-2000, several supplemental indicators were measured by either Western Coastal EMAP participants or external collaborators, including additional chemical parameters, two sediment porewater toxicity tests, and a fish-tissue bioassay (Table 2).

Table 2. Supplemental environmental indicators measured or under development for the 1999 Washington State component of the EMAP Western Coastal survey

Benthic Indicators	EMAP Partner(s)
West Coast benthic infaunal index (under development)	Coastal EMAP-West
Exposure Indicators	
Additional sediment chemistry analytes (Appendix Tables A-1, A-2)	Washington State Department of Ecology
Sediment porewater toxicity (sea urchin *Arbacia punctulata* fertilization)	USGS/BEST (USGS, 2000)
Sediment porewater toxicity (sea urchin *Arbacia punctulata* embryo development)	USGS/BEST (USGS, 2000)
H4IIE Test for exposure of fish to planar halogenated hydrocarbons	USGS/BEST (USGS, 2001)

Descriptions of the EMAP indicators, their applicability, and their importance are given in Appendix A.

Methods

Sample Design

Background

The EMAP sampling approach is described in reports such as Nelson *et al.* (2004) and is presented in summaries at: www.epa.gov/wed/pages/EMAPDesign/

The EMAP sample design for 1999-2000 was a random tessellation stratified survey design. A random tessellation stratified design involves placing a regular grid, beginning in a random location, over the resource area to be sampled, selecting a cell at random, and then selecting a point at random within the cell (Stevens and Olsen, 1999, 2003). Separate subpopulations of interest may be sampled at different intensities, and thus sample units may be chosen according to different grid densities and inclusion probabilities. The final estimates of resource condition are weighted based on the areas of the subpopulations (estuarine classes, in this case).

According to Nelson *et al.* (2004), the sampling frame for the EMAP Western Coastal Program was developed from U.S. Geological Survey (USGS) 1:100,000-scale digital line graphs of all estuaries of the West Coast and stored as a GIS data layer in ARC/INFO. Sites were selected by ArcView programs and scripts written by Bourgeois *et al.* (1998) using a random tessellation stratified design. First, a sampling grid of hexagons was overlaid on the spatial resource. The size (area) of the hexagons within each stratum (estuarine class) was determined by the number of sample stations to be generated for each sampling region. Then hexagons were randomly selected, and within each hexagon a sampling point was randomly located. Only one sampling site was selected from any hexagon selected. The random-sample generator program determined whether a sampling point fell in water or on land; sites on land were not included. The program iterated until a hexagon size was determined which generated the desired number of sampling sites (Nelson *et al.*, 2004).

1999 Washington Sampling Design

The 1999 sample design for Washington consisted of 50 sites selected from estuaries along the Pacific Ocean, Strait of Juan de Fuca, and lower Columbia River coastlines. No alternate sites were included in the design as replacements for unsamplable target sites.

Estuaries were classified into four strata based on estuary size. To ensure adequate representation of each of the estuary size classes, 10 sites were selected from each Stratum 1 and Stratum 2, and 15 sites were selected from each Stratum 3 and Stratum 4.

Stratum 1: small estuaries (< 1 km^2 area), total frame area 8.363 km^2

Stratum 2: small-medium estuaries (1-10 km^2 area), total frame area 77.288 km^2

Stratum 3: medium-large estuaries (10-100 km^2 area), total frame area 111.478 km^2

Stratum 4: large estuaries (> 100 km^2 area), total frame area 562.230 km^2

The hexagonal grid sizes from which sample sites were drawn varied by stratum: 0.86 km^2 in Stratum 1, 7.79 km^2 in Strata 2 and 3, and 36.58 km^2 in Stratum 4.

The target and actual sampling locations are shown in Figure 2. Details of the selected targets are given in Appendix Table B-1. The stations in the smallest estuaries along the Pacific Coast were all intertidal, and those in estuaries along the Columbia River were less than 10 m deep. Station depths in the embayments along the Strait of Juan de Fuca ranged from intertidal to over 20 m.

Figure 2. Washington Coastal EMAP 1999 target (open square) and actual (solid square) survey sites. Location details are given in Appendix Table B-1.

Quality Assurance and Quality Control

The Western Coastal EMAP program quality assurance/quality control (QA/QC) program is described in the "Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan 2001-2004" (U.S. EPA, 2001a), which was in draft for the 1999 sampling program. That document lays out the data quality objectives and measurement quality objectives for all NCA field and laboratory parameters in terms of representativeness, completeness, comparability, accuracy, and precision. The NCA Quality Assurance Project Plan (QAPP) addresses all aspects of an EMAP program, including not only field and laboratory procedures, but also training, documentation, data-handling and assessment, management reports, and quality audits.

Analytical laboratories are required to demonstrate their technical capabilities and are expected to perform in general accord with the QAPP for NCA analytes (U.S. EPA, 2001a). Prescribed laboratory quality control measures include the use of standard NCA protocols, routine instrument calibrations, measures of analytical accuracy and precision (*e.g.*, analysis of standard reference materials, spiked samples, and laboratory replicates), and achievement of target method detection limits; see the QAPP (U.S. EPA, 2001a) for details. [In a general assessment of data collection and analyses, Ecology's Environmental Monitoring and Trends Section and the Manchester Environmental Laboratory were found to have "met or exceeded the requirements of the QAPP" (Macauley, 2003).]

Measures of data validation include evaluation of content, completeness, and consistency; range checks for reasonableness; and cross-checks between original data sheets (field or lab) and electronic data for transcription errors (U.S. EPA, 2001a).

Quality control for identification of infauna for the Western Coastal EMAP program was provided by a network of secondary QA/QC taxonomic specialists to confirm identifications made by the primary taxonomists and to provide standardization among the state participants.

Field Sampling and Laboratory Analyses

Water quality, fish, and sediment sampling were conducted by personnel from Ecology, EPA, and NOAA National Marine Fisheries Service (NMFS) from August 5 through October 14, 1999. Work was conducted aboard EPA's *R/V Monitor*, operated by EPA Region 10 personnel, and Ecology's 22-foot Boston Whaler, operated by Ecology and NMFS personnel, with the two vessels working in tandem. The *Monitor* operator and the field coordinator navigated and established sampling locations, using a Furuno DGPS navigation system, keeping the Whaler and crew within visual and radio contact at all times.

Although most of the selected sites were subtidal, a few were intertidal. Several stations were sampled a short distance from the target coordinates, mostly due to inadequate water depth (Figure 2; Appendix Table B-1). Four intertidal stations were visited on foot, rather than by boat, and are hereafter referred-to as the "walk-in" stations.

Field procedures are specified in the NCA Field Operations Manual (U.S. EPA, 2001b, in draft for the 1999 sampling effort) and detailed in Ecology protocols for Coastal EMAP West 1999, which are stored as metadata in the NCA database. The standard sampling protocols were modified for the walk-in stations and are documented in an Ecology protocol in the database. The laboratory analytical methods are specified in the NCA QAPP (U.S. EPA, 2001a) and in the individual laboratories' Standard Operating Procedures, which are stored as metadata in the NCA database. Brief descriptions of field and laboratory procedures, including QA/QC, are given below.

General Habitat Condition Indicators

Hydrographic Profile

Continuous water column profiles of conductivity, temperature, transmissivity, dissolved oxygen (DO), and pH were acquired at each site with a Sea-Bird Electronics SBE19 Seacat conductivity-temperature-depth (CTD) profiler and attached sensors (Table 3). The CTD was lowered into the water until it was completely submerged and held just below the surface for 3 minutes, allowing the water pump to purge any air in the system. The unit was then returned to the sea surface to begin the profile, and lowered slowly to the bottom at approximately 0.3 meters per second (m/s). The CTD was held 0.5-1.0 m above the seabed for 1 minute, then recovered at approximately 0.5 m/s. Data were stored in the unit and downloaded after sampling. In the lab, data were averaged for every 0.5 m.

Table 3. Hydrographic profile measurements

Parameter	Measurement	Source
Water depth	single measurement	Depth sounder; corrected for tidal height
Salinity	S,B*	Derived from conductivity (CTD)
Temperature	S,B*	CTD
Density	S,B	Derived from temperature and salinity
Density stratification	single measurement	Derived from surface and bottom densities
Dissolved oxygen	S,B*	Beckman sensor
pH	S,B*	Beckman sensor
Submerged PAR	S,M,B	Li-Cor PAR LI-93SA sensor
Terrestrial PAR	S,M,B	Li-Cor PAR LI-190SA sensor
Percent of Terrestrial PAR	S	Derived
Mean light-extinction coefficient	single measurement	Derived from PAR measurements
Secchi depth	single measurement	Secchi disk
Transmissivity	S,1,B*	Sea Tech transmissometer

* = Continuous depth profiles, 0.5-m bins; only surface, 1.0 m depth (transmissivity only), and bottom presented
S = Surface (0.5 m depth)
M = Mid-Water (mid-depth of water column)
B = Bottom (0.5 m above seabed)
1 = 1 m depth

As a check on the accuracy of the Beckman dissolved oxygen sensor deployed on the CTD, Winkler titrations were performed on water samples taken each day at randomly-chosen depths at randomly-chosen stations.

Although continuous profiles were captured, in this report only results for surface (0.5 m depth), 1 m depth (transmissivity only), and bottom (0.5 m above seabed) are presented and discussed.

Light Attenuation - PAR

Two sensors connected to a Li-Cor LI-1400 datalogger were deployed simultaneously to measure Photosynthetically Active Radiation (PAR) in the 400-700 nanometer (nm) waveband: a Li-Cor® LI-190SA Quantum Sensor to measure terrestrial PAR and a Li-Cor LI-193SA Spherical Quantum Sensor to measure PAR underwater. The terrestrial PAR sensor was secured to the cabin roof of the vessel, providing a 360° clear view of the sky. The marine sensor was attached to a weighted frame and deployed on the sunniest side of the vessel. The unit was lowered to and held at depths corresponding to depths at which surface, mid-water, and bottom discrete water samples were taken. Instantaneous Terrestrial PAR (TerPAR) and concurrent Submerged PAR (SubPAR) readings for surface, mid-water, and bottom depths were transcribed by hand from the datalogger's display to the field logs. (The continuous recordings were not kept.)

Simultaneous measurements of SubPAR and TerPAR at the surface were obtained at 38 stations; at the bottom at 32 stations; and at mid-water at 22 stations (Appendix Table B-3).

Secchi Depth

Secchi depth was measured with a standard 20-cm diameter black-and-white disc. The disc was lowered to the depth at which it could no longer be discerned, then slowly retrieved. The depth of its reappearance (rounded to the nearest 0.5 m) was recorded as Secchi depth.

Secchi depths were set to a default value of 0.7 m, rather than measured, for three of the four walk-in stations; no Secchi depth was recorded for the fourth.

Water Samples for Laboratory Analyses

Samples for analyses of dissolved nutrients (ammonium, nitrite, nitrate, ortho-phosphate, and silicic acid), chlorophyll-*a* concentration, and total suspended solids were taken at each site using a hand-deployed General Oceanics 1.7-liter Niskin bottle. Samples were taken near the surface (0.5 m depth), mid-way through the water column, and near the bottom (0.5 m above seabed). At sites 1-2 m in depth, only near-surface and near-bottom samples were taken; and at sites < 1 m in depth, only near-surface measurements were taken (Appendix Table B-2).

Total Suspended Solids (TSS)

One sample for TSS analysis was taken from the Niskin bottle for each tested depth. TSS samples were collected in pre-cleaned, 1-liter polyethylene bottles, then chilled at 4°C until delivery to the laboratory (within 7 days of acquisition).

The Manchester Environmental Laboratory analyzed the TSS samples using the *EPA 160.2 Total Suspended Solids* analysis method, which consists of filtering well-mixed samples through standard 1.5-µm glass fiber filters, then evaporating the filtrates and drying them at 180°C to constant weight. One set of laboratory duplicate samples was analyzed for each batch of 20 samples to evaluate precision (acceptable relative percent difference ≤ 20%), and accuracy was checked with a laboratory-prepared standard (acceptable recovery within 20% of the true value). The recovery was within 5% of the true value for all batches.

Chlorophyll-a

Two samples were collected from each Niskin bottle into pre-cleaned 66-ml sample bottles. Each sample was filtered through a 0.7-µm GFF filter by hand pump into a receiving flask. The GFF filter was then folded in half and placed in a glass centrifuge tube containing 10 ml of 90% acetone, and placed on ice until the tubes could be frozen at the end of the day. The frozen samples were stored in the dark until delivery to the laboratory (as soon as possible after acquisition).

In the lab, Ecology EMAP personnel analyzed the chlorophyll-*a* samples by the fluorometric analysis method for chlorophyll-*a* and phaeopigment (Lorenzen, 1966). Test tubes containing the GFF filters in 10 ml of 90% acetone were sonicated to rupture the chloroplasts and release the photosynthetic pigments into the acetone solution. The pigments were then centrifuged to obtain a pure extract of pigments in 90% acetone. A fluorometer was used to measure the level of fluorescence (F_0) of the suspended pigments. Next, 2 drops of HCl were added to the extract. Finally, the post-acidification fluorescence (F_a) was measured. The concentrations of chlorophyll and phaeopigments were calculated from the F_0 and F_a values.

The lab fluorometer is calibrated every 6-8 months against a chlorophyll-*a* dilution series of known concentrations, as determined by spectrophotometric analysis. Before analyzing samples, the fluorometer was checked for calibration by analyzing a 90% acetone blank (acceptable value ≤ 0.5 FU). Batches consisted of one initial calibration check and < 20 field samples.

Dissolved Nutrients

For each sample, approximately 40 ml of water from each Niskin bottle was filtered using a 60-ml plastic syringe with a 0.45-µm filter. Filtered samples were collected in pre-cleaned, 60-ml polyethylene sample bottles, placed on ice, then frozen until delivery to the laboratory (within three months of acquisition).

Laboratory analysis of dissolved nutrients was performed by the University of Washington Marine Chemistry Laboratory using a Technicon AutoAnalyzer II to quantify the concentrations of the dissolved reactive forms of ammonium (Slawyk and MacIsaac, 1972) and nitrite, nitrate, phosphate, and silicic acid in the water samples (UNESCO, 1994). Total dissolved nitrogen and total dissolved phosphorus concentrations were then calculated.

Each batch was preceded by a standard curve consisting of a matrix blank and two concentrations at lower and mid-high points in the analytical range, each in duplicate, followed by a laboratory control treatment sample. Two check standards, of concentrations different from those used in the standard curve (also at lower and mid-high points in the analytical range), were prepared using the same matrix water as that of the standards and run with each batch.

Sediment Lithology

Sediment for lithological characterization, chemical analyses, and toxicity testing was collected with a 0.1-m^2 stainless steel van Veen sampler. Sediment from multiple grabs was composited to collect around 6 liters of sediment. The number of grabs required depended on the sediment lithology and seabed density. Field replicates were taken at approximately 10% of the sample stations.

Upon recovery of each grab, overlying seawater was siphoned off, with great care taken to avoid the siphon tube touching – and contaminating – the sediment surface. The surface 2-3 cm of sediment was then scooped into a high-density polyethylene bucket, using a stainless steel spoon. At the four walk-in stations, a bottomless 25-cm-diameter bucket was pushed into the sediment where the water was quite shallow, then overlying water was siphoned off, and the sediment was scooped as described above.

Once adequate sediment was collected, it was homogenized in the bucket by thorough stirring. Certified pre-cleaned sample containers for chemical and toxicity analyses were filled, then held at 4°C until delivery to the labs.

All equipment used for sampling sediment was decontaminated prior to sampling each station. The decontamination procedure was to clean the equipment with Liquinox® detergent and rinse with *in-situ* water.

Total Organic Content (TOC)

Sediment TOC analyses were performed by the Manchester Environmental Laboratory. TOC was analyzed at both 70ºC (PSEP, 1986) and 104ºC (a modification of PSEP (1986) for EMAP, referred-to as PSEP-TOCM); the 104ºC results are presented in this report.

Samples for TOC analyses were frozen upon receipt by the lab, and all analyses were performed within the holding times specified by the QAPP (U.S. EPA, 2001a).

The Manchester Laboratory performed QA checks as specified by the QAPP (U.S. EPA, 2001a), including initial and continuing calibration checks and, for every batch of 20 or fewer test samples, analyses of certified reference material and/or laboratory control material samples, laboratory spiked sample matrices, laboratory reagent blanks, and laboratory replicates.

Grain Size

The Rosa Environmental and Geotechnical Laboratory determined the sediment particle size (grain size) distribution for each sample using the sieve-pipette method specified in PSEP (1986). Sediment samples were stored at 4°C until processed, then warmed to room temperature and homogenized prior to analysis.

PSEP (1986) is a combined sieve-pipette procedure, with the coarser fractions (retained on a 62.5-µm sieve wet) dried and then sieved through a stack of progressively finer sieves, and the silt-clay fraction separated according to the Wentworth scale by pipette withdrawals from a settling column (PSEP, 1986).

As specified by the QAPP (U.S. EPA, 2001a), 10% of samples were analyzed in triplicate, with a limit of no more than 10% deviation amongst the replicates. In addition, Rosa Laboratory internal QA checks required a limit of no more than 5% deviation from 100% in summed grain size percentages.

Exposure Condition Indicators

The procedures for sediment collection for chemical analyses and toxicity testing are described above for sediment lithological analyses.

Sediment Chemistry Analyses

Sediment chemistry analyses were performed by the Manchester Environmental Laboratory. Table 4 lists the target analytes and the analytical methods used. The analytical methods are those specified in the QAPP (U.S. EPA, 2001a) or, for the additional analytes not required by EMAP, used in the NOAA National Status and Trends Program (Lauenstein *et al.*, 1993). Only the results for the EMAP-required analytes are presented in this report.

Samples for organics analyses were frozen upon receipt by the lab, and all analyses were performed within the holding times specified by the QAPP (U.S. EPA, 2001a). All mercury analyses were performed on non-frozen sediment within the 28-day holding time specified by PSEP (1996) (*vs.* 1 year frozen, as in the NCA QAPP); then the remaining sediment in the samples was frozen prior to analyses of other metals. All metals analyses were performed within the holding times specified by the QAPP.

The Manchester Laboratory performed QA checks as specified by the QAPP (U.S. EPA, 2001a), including initial and continuing calibration checks and, for every batch of 20 or fewer test samples, analyses of certified reference material and/or laboratory control material samples, laboratory spiked sample matrices, laboratory reagent blanks, and laboratory replicates. The case narratives for the laboratory analyses are included as metadata in the EMAP database.

Total PCB concentration is calculated as the sum of the concentrations of the 21 congeners on the target list in Appendix Table A-1. Total DDT concentration is calculated as the summed concentrations of six DDT isomers: 2,4'-DDT; 4,4'-DDT; 2,4'-DDE; 4,4'-DDE; 2,4'-DDD; and 4,4'-DDD. Total PAH concentration is the sum of the concentrations of individual PAH compounds; the constituent compounds of the LPAH, HPAH, and PAH totals for EMAP are listed in Appendix Table A-1.

Table 4. Target analytes and analytical methods for sediment and fish-tissue chemistry analyses. Complete lists of chlorinated pesticides, PCBs, PAHs, and other classes of compounds are given in Appendix Tables A-1 and A-2. The methods are the same for all compounds within a class.

Parameter	Analytical Method	
	Sediment	Fish Tissue
EMAP Analytes		
Percent Fines – sediment only	PSEP (1986) (sieve-pipette)	
Total Organic Carbon – sediment only	PSEP-TOCM (104ºC)	
Metals*		
Aluminum**	SW6010 (ICPAES)	EPA200.7 (ICPAES)
Antimony - sediment only	EPA200.8 (ICPMS)	
Arsenic	EPA206.2 (GFAA)	SW7060 (GFAA)
Cadmium	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)
Chromium	SW6010 (ICPAES)	EPA200.8 (ICPMS)
Copper	SW6010 (ICPAES)	EPA200.8 (ICPMS)
Iron	SW6010 (ICPAES)	EPA200.7 (ICPAES)
Lead	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)
Manganese - sediment only	SW6010 (ICPAES)	
Mercury	EPA245.5 (CVAA)	EPA245.5 (CVAA)
Nickel	SW6010 (ICPAES)	EPA200.8 (ICPMS)
Selenium	EPA270.2 (GFAA)	SW7740 (GFAA)
Silver	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)
Tin	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)
Zinc	SW6010 (ICPAES)	EPA200.8 (ICPMS)
Chlorinated Pesticides, including DDTs (20)	SW8081 (GCECD)	SW8081/8082 (GCECD)
PCB Congeners (21)	SW8081 (GCECD)	SW8081/8082 (GCECD)
PAHs (22) – sediment only	SW8270 (GCMS)	
Additional Non-EMAP Analytes* **		
Percent Grain Size by phi – sediment only	PSEP (1986) (sieve-pipette)	
Total Organic Carbon – sediment only	PSEP (1986) (70ºC)	
Lipids – tissue only		MEL SOP #730009
Additional PAHs (12) – sediment only	SW8270 (GCMS)	
Carbaryl – sediment only	EPA8318 (GCMS)	
Organotins (3) - sediment only	NOAA-TBT (GCAED)	
Semi-volatile Organics (20) - sediment only	SW8270 (GCMS)	

*Total digestion (hydrofluoric acid) method used for extraction of metals from sediment.

**Aluminum values are qualified as estimated, because fish were wrapped and frozen in aluminum foil prior to processing.

***Results of non-EMAP analyses not included in this report

<u>Analytical Methods</u>:
CVAA = Cold Vapor Atomic Absorption spectroscopy
GCAED = Gas Chromatography with Atomic Emission Detection
GCECD = Gas Chromatography with Electron Capture Detection
GCMS = Gas Chromatography-Mass Spectroscopy
GFAA = Graphite Furnace Atomic Absorption spectroscopy
HPLC = High Precision Liquid Chromatography (fluorometric quantification)
ICPAES = Inductively Coupled Plasma-Atomic Emission Spectrophotometry
ICPMS = Inductively Coupled Plasma-Mass Spectroscopy
MEL SOP #730009 = Manchester Environmental Laboratory standard operating procedure #730009
NOAA-TBT = NOAA tributyltin procedure (Lauenstein et al., 1993)
PSEP (1986) = Puget Sound Estuary Program protocols 1986
PSEP-TOCM = modification of PSEP (1986) for EMAP

Sediment Toxicity

Amphipod Survival Test

Amphipod survival tests using *Ampelisca abdita* were conducted by the Marine Pollution Studies Laboratory of the University of California - Davis, following procedures detailed in U.S. EPA (1994) and U.S. EPA (1995). Samples were shipped on ice within 7 days to the laboratory. Upon arrival, samples were either refrigerated at 4°C or processed immediately. Each sample was inspected to ensure it was within acceptable temperature limits upon arrival and stored at 4°C until testing was initiated within 14 days of the collection date.

Amphipods were collected by John Brezina and Associates from San Francisco Bay. Animals were held in the laboratory in pre-sieved uncontaminated native habitat ("home") sediment under static conditions. Because static conditions result in elevated ammonia concentrations, toxic to the animals, 50% of the water in the holding containers was replaced every second day when the amphipods were fed, per U.S. EPA (1994). During holding, *A. abdita* were fed laboratory-cultured diatoms (*Phaeodactylum tricornutum*).

Five laboratory replicates of the home sediment were used as negative controls. Sub-samples of the negative control sediments were tested along with each series of samples from northern Puget Sound.

Sea Urchin Fertilization and Embryo-Development Tests

Sea urchin fertilization and embryo-development tests were performed by the USGS Corpus Christi laboratory. The tests were conducted with sediment porewater using gametes of the sea urchin *Arbacia punctulata*, following the methods of Carr and Chapman (1995), Carr *et al.* (1996a,b), Carr (1998), and USGS SOP F10.6. The methods and results of the urchin fertilization and embryo-development tests are described in a separate report (USGS, 2000).

Sediment from each sampling location was collected in pre-cleaned, 4-liter polyethylene jars, stored at 4°C, and shipped within 7 days to the laboratory by overnight courier in insulated coolers with blue ice. Upon arrival, samples were either refrigerated at 4°C or processed immediately. Porewater was extracted within 24 hours, using a pressurized squeeze extraction device (Carr and Chapman, 1995).

Sea urchins (*Arbacia punctulata*) were obtained from the Gulf Specimen Company in Panacea, Florida, and kept at 16±1°C in tanks at salinity 30±3 ppt. Tanks were segregated by sex. Temperature was gradually increased to 19±1°C at least one week prior to gamete collection. Spawning was induced by touching the tests of *Arbacia punctulata* adults with electrodes from a 12V transformer. Gametes were checked for a high degree of viability before being used.

Samples were tested in a dilution series of 100%, 50%, and 25% of the salinity-adjusted sample, with 5 replicates per treatment. Dilutions were made with clean, filtered (0.45 μm) seawater.

The endpoint in the fertilization test is percent fertilization of the urchin eggs, determined by counting fertilization membranes under a compound microscope; fertilization percentages were calculated for each replicate test. The endpoint in the embryo-development test is proportion of embryos which have developed to a normal pluteus larva, determined by observing embryos under a compound microscope; percentages of normal morphological development were calculated for each replicate test.

Porewater from sediments collected in Redfish Bay, Texas, an area located near the testing facility, was used as a negative control. Sediment porewaters from this location have been determined repeatedly to be non-toxic in this test in many trials (Long *et al.*, 1996). As a positive control, a dilution series test with sodium dodecyl sulfate (SDS) was included.

Fish-Tissue Contaminants

Fish sampling was attempted at 39 sample sites, and sampling was at least partially successful at all but one station. At five stations, trawling was hindered by rocks, kelp, or other obstructions; of those, partial success was achieved at 4 stations (Appendix Table B-1).

Fish trawls were conducted by NOAA NMFS personnel. A 16-foot otter trawl was used at all stations sampled by boat (termed 'Standard Trawls' in the results). The otter trawl had a 16-foot footrope, with 1.50-inch mesh in the body of the net and 1.25-inch mesh in the cod end. Trawling was conducted at 1.0-1.5 knots along a straight line centered on the site location. Trawl duration was usually 10 minutes per tow, but ranged from 2 to 15 minutes, depending on seabed conditions.

Up to four trawls were conducted at each station in order to acquire adequate specimens for fish-tissue contaminant analyses. Multiple trawls were conducted consecutively on the same day, except at one station where one trawl was taken in the late afternoon and two more trawls were taken early the next morning.

Of necessity, due to water depths < 0.25 m, three of the four walk-in stations were sampled using a 30-foot beach seine ('Non-standard Trawls'). The fourth walk-in station was not sampled for fish. The beach seine had 1-inch mesh in the wings and 0.375-inch mesh in the bag.

Four species of demersal fish which are ubiquitous along the U.S. Pacific Coast were targeted samples for analysis of chemical contaminants in whole-body tissue: English sole (*Pleuronectes vetulus*), sand sole (*Psettichthys melanostictus*), speckled sanddab (*Citharichthys stigmaeus*), and starry flounder (*Platichthys stellatus*). The number of individuals of a target species needed was determined by the size of the fish, the amount of tissue required by the lab for analysis, and the goal of having at least 5 fish for statistical variability; in this study, 3 to 50 fish were combined into a composite sample. The fish were measured (fork length or total length, as above), rinsed with site water, individually wrapped with heavy-duty aluminum foil, and placed together in a plastic zipper-type bag. The fish for chemistry samples were held on wet ice in the field until they were transferred to shore and frozen to await laboratory analysis.

Frozen or slightly thawed fish were ground whole three times in a decontaminated food grinder, composited, and stirred to homogeneity each time. Aliquots of the composited ground whole-body tissues of target fish species were placed into certified pre-cleaned jars and frozen. The decontamination procedure consisted of scrubbing all implements with detergent, and then rinsing them with tap water, 10% nitric acid, and deionized water, in succession. After that, they were rinsed with pesticide-grade acetone, dried in a fume hood, rinsed with hexane, and dried again.

Tissue samples from 24 stations were sent to the Manchester Environmental Laboratory for analysis of organic and metal contaminant concentrations. Additional samples from 19 of those 24 stations were sent to the USGS Columbia Environmental Research Center for H4IIE analysis.

Tissue Chemistry

Wet/dry weight ratio (% moisture), lipid content, and contaminant concentrations were determined for each of the composited samples by the Manchester Laboratory. The target analytes and analytical methods are listed in Table 4, above. Aluminum values were qualified as estimated because fish were wrapped and frozen in aluminum foil prior to processing. PAHs were not measured in fish tissues due to their rapid metabolism in vertebrates.

The lipid analysis procedure (Manchester Environmental Laboratory, 1997) is to pipette sample extract into a 30-mL pre-weighed beaker, allow the solvent of the sample extract to evaporate overnight, and then dry the sample extracts in a drying oven for four hours. The residue is weighed, and the percent lipids is calculated.

Quality control procedures for the tissue chemical analyses were similar to those described above for sediments and followed the procedures detailed in U.S. EPA (2001a), including the use of certified reference materials, spikes, duplicates, and blanks. The case narratives for the laboratory analyses are included as metadata in the EMAP database.

H4IIE bioassay

H4IIE bioassays were conducted on ground whole-body tissues of the four composited target fish species (sand sole, English sole, speckled sanddab, and starry flounder) from 19 sample stations by the USGS Columbia Environmental Research Center. The H4IIE test is a semi-quantitative procedure which examines the overall toxic potency of planar halogenated hydrocarbons (PHHs) in fish tissue extracts. PHHs consist largely of polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). When present in fish tissue, these chemicals are able to increase 7-ethoxyresorufin-O-deethylase (EROD) activity in the H4IIE rat hepatoma cell line. The results of the induction of EROD are evaluated relative to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). TCDD equivalents (TCDD-EQs) are a measure of the exposure that fish have received to this class of compounds (USGS, 2001).

Samples were shipped overnight on ice to the laboratory, at which time they were refrozen at -80°C until processed for extraction. The methods and results of the H4IIE test are described in a separate report (USGS, 2001). Quoting from that report on QA/QC performed:

> "QC samples (matrix and procedural blanks and positive control materials) were prepared concurrently with the test samples. Positive control was provided by common carp tissue collected from Saginaw Bay, Michigan, in 1988. Matrix blank material was derived from clean bluegill raised in CERC's holding pond. … A TCDD dose-response curve was generated from the average of four independent determinations for each sample. Ten percent of samples were assayed in triplicate, as were all positive controls and blanks. Eight-point resorufin and seven-point BSA standard curves were prepared at six replicates for each concentration, and analyzed concurrently with the samples and TCDD standards. Positive controls were analyzed on each assay date along with the samples to assure that both the EROD enzyme assay and the reagents were behaving according to specifications. The concentrations of the resorufin, ethoxyresorufin, and NADPH reagents were checked on each assay date with a spectrophotometer and compared to known concentrations; measured concentrations were to be within 10% of the known concentrations for the reagents to be acceptable for use." (USGS, 2001)

Marine Debris

Marine debris, whether of natural or anthropogenic (human-caused) origin, encountered in sediment or fish collection was recorded as to type and relative amount.

Biotic Condition Indicators

Benthic Infauna

Single sediment samples for analysis of benthic infauna were collected using a 0.1-m^2 van Veen grab sampler. At the four walk-in stations, a bottomless, 25-cm-diameter bucket was pushed into the sediment where the water was quite shallow, and used as a sampler. The contents of the grab or sampler were sieved through nested 1.0-mm and 0.5-mm sieves using *in-situ* seawater. The material retained on each sieve was placed into Ziploc® freezer bags and preserved with a 10% aqueous solution of borax-buffered formalin.

Preserved samples were rescreened in the lab and transferred to 70% ethanol within 2 weeks of field collection. The 1.0-mm-sieve samples were shipped for sorting and taxonomic identification. The 0.5-mm-sieve samples were archived for future reference; results are not reported for those samples.

All macroinfaunal invertebrates and fragments were removed from the formalin-preserved samples and sorted into the following taxonomic groups: Annelida, Arthropoda, Mollusca, Echinodermata, and miscellaneous taxa. Meiofaunal organisms such as nematodes and foraminiferans were not removed from samples, though their presence and relative abundance were recorded. Representative samples of colonial organisms such as hydrozoans, sponges, and bryozoans were collected, and their relative abundance noted.

Sorting QA/QC procedures consisted of resorting 20% of each sample by a second sorter to determine whether a sorting efficiency of 95% removal was met. If not, the entire sample was resorted.

The majority of the post-sorting taxonomic work was contracted to recognized, regional specialists (Table 5) who identified the organisms to the lowest practical taxonomic level (usually species) and counted them. The primary taxonomists also generated a collection of voucher specimens and voucher sheets for each provisional species identified. The voucher sheet listed the major taxon (*e.g.*, Annelida), family, provisional identification, sample from which the specimen was taken, references used in the identification, and a detailed description of the specimen, including characteristics that distinguished it from similar species.

Table 5. Primary and QA/QC taxonomists by taxonomic group and region for the 1999 Western Coastal EMAP study

Organisms	QA/QC Taxonomist	Primary Taxonomists	Region
Annelida	Gene Ruff	John Oliver	Northern California
		Larry Lovell	Southern California
		Gene Ruff	Washington & Oregon
		Kathy Welch	Washington & Oregon
Arthropoda	Don Cadien	Peter Slattery	Northern California
		Tony Phillips	Southern California
		Jeff Cordell	Washington & Oregon
Mollusca	Don Cadien	Peter Slattery	Northern California
		Kelvin Barwick	Northern California
		John Ljubenkov	Southern California
		Susan Weeks	Washington & Oregon
Echinodermata	Gordon Hendler	Peter Slattery	Northern California
		Nancy Carder	Southern California
		Scott McEuen	Washington & Oregon
Miscellaneous taxa	John Ljubenkov	Peter Slattery	Northern California
		John Ljubenkov	Southern California
		Scott McEuen	Washington & Oregon
Freshwater fauna	Rob Plotnikoff / Chad Wiseman	Not Applicable	Northern California
		Not Applicable	Southern California
		Jeff Cordell	Washington & Oregon

Quality control for taxonomy included re-identification of 10% of all samples and verification of voucher specimens by another qualified taxonomist (Table 5). To assure uniform taxonomy and nomenclature across the entire Coastal EMAP West region among the primary taxonomists for each group, and to avoid problems with data standardization at the end of the project, progressive QA/QC and standardization were implemented. At frequent, regular intervals (usually monthly), as primary taxonomy was completed, vouchers, voucher sheets, and a portion of the QA samples were sent to the secondary, QA taxonomists. Immediate feedback from the QA taxonomists to the primary taxonomists was used to correct work and standardize identifications between regional taxonomists. As voucher specimens and bulk samples were processed by the QA taxonomist, any differences in identifications or counts were discussed and resolved with the primary taxonomist. The original data set remained with the primary taxonomist, and changes agreed upon between the primary and QA taxonomists were made by the primary taxonomist on a copy of the original data set. Changes to the data based on QA/QC analysis were tracked in writing by both the primary and QA taxonomists.

The data from benthic infauna acquired with the van Veen grab, only, were used to compute total numbers of individuals (abundance) and total number of species (species richness) per grab; the samples acquired with a 25-cm bucket at the walk-in stations were excluded from the analyses. Several indices of community were calculated: Shannon-Weaver information diversity index H' (log base 2), Pielou's evenness index J', Swartz' dominance index (number of taxa comprising the most abundant 75% of individuals), and Swartz' dominance standardized by taxa richness. Colonial species were included with a count of 1 in the estimates of abundance, taxa richness, and other bioindices.

Fish

Methods for fish collection are described above for fish-tissue contaminants.

Fish Species and Abundance

All fish from a tow were identified, separated by species, and counted. Up to 30 fish per species were measured to the nearest centimeter (fork length when tail is forked, otherwise total length - snout to tip of caudal fin). If more than 30 specimens of a given species were caught, the remaining fish were enumerated but not measured. Fish not required for histopathology or chemistry were returned to the estuary.

Only the first successful trawl (standard trawls only) was used for fish community characterization, *i.e.*, for the fish species and abundances presented in this report. Catch per area swept was calculated as (total abundance)/[(distance trawled) x (width of net)].

Fish Gross Pathology

Any externally visible pathologies (*e.g.*, tumors) observed on fish were photographed, then excised and placed into labeled pathology containers with Dietrich's solution. Excised tissue included the entire gross lesion and some adjacent healthy tissue. Upon completion of sampling, all samples were sent to Dr. Mark Myers (NOAA Fisheries, Seattle) for analysis. A separate fish pathology report is to be prepared by NOAA.

Epibenthic Invertebrates

Any invertebrates collected in the trawls were sorted by taxonomic group, counted, and then returned to the water.

Fish

Methods for fish collection are described above for fish-tissue contaminants.

Statistical Data Analysis

Data Preparation

Where samples were analyzed in replicate in the laboratory, the results of the lab replicates were averaged before statistical analyses were performed. Measured sediment and fish-tissue analyte concentrations which were below the method detection limit or the reporting limit (*i.e.*, non-detects) were set to zero and included in calculations. The values used in the statistical analyses and graphical summaries of the data are given in Appendices C, D, and E.

Cumulative Distribution Function Analyses

Cumulative distribution functions (CDFs) with 95% confidence limits are presented for each indicator. Fiftieth and 90th percentiles are used to describe the spatial extent of each indicator's results across the study area. Analysis of indicator data by CDFs is an approach that has been used extensively in other EMAP coastal studies (Summers and Macauley, 1993; Strobel *et al.*, 1994; Hyland *et al.*, 1996). The statistical theory is described in Diaz-Ramos *et al.* (1996); formulae used for calculation of the CDFs and their variance estimations are contained in Nelson *et al.* (2004).

A CDF shows the distribution of values of an indicator in relation to the areal extent across the sampling region of interest. To calculate the CDF, the measured values are arranged in increasing order and weighted according to the proportion of the total area, *i.e.*, according to their inclusion probabilities. (Samples have different inclusion probabilities because they represent differing areas.) The sums of the inclusion probabilities for successive indicator values are the estimated cumulative probabilities. Variance estimates are used to compute a 95% confidence interval around the probability estimate at each value.

A CDF, with 95% confidence band, is depicted in Figure 3. The measured values of the indicator are on the horizontal axis, and the cumulative probabilities (or estimates of percent area) are on the vertical axis. Because the sample values are weighted according to the amount of area that they represent, the estimated percent area for a given value of the indicator represents the percent of the sampling region of interest for which the indicator has that value or smaller. The confidence limits depict the range of cumulative percent area which is expected to have a 95% chance of containing the true, but unknown, underlying population cumulative percent area.

The 50th and 90th percentiles are found by locating the 50% and 90% cumulative probabilities on the CDF curve from the vertical axis and projecting down to the horizontal axis. *These percentiles are used solely as benchmarks and do not represent ecologically important values.* However, the CDF can also be used to find the cumulative percent area for which the indicator is less than a specified ecologically relevant value, by locating the value of interest on the horizontal axis and projecting across to the vertical axis.

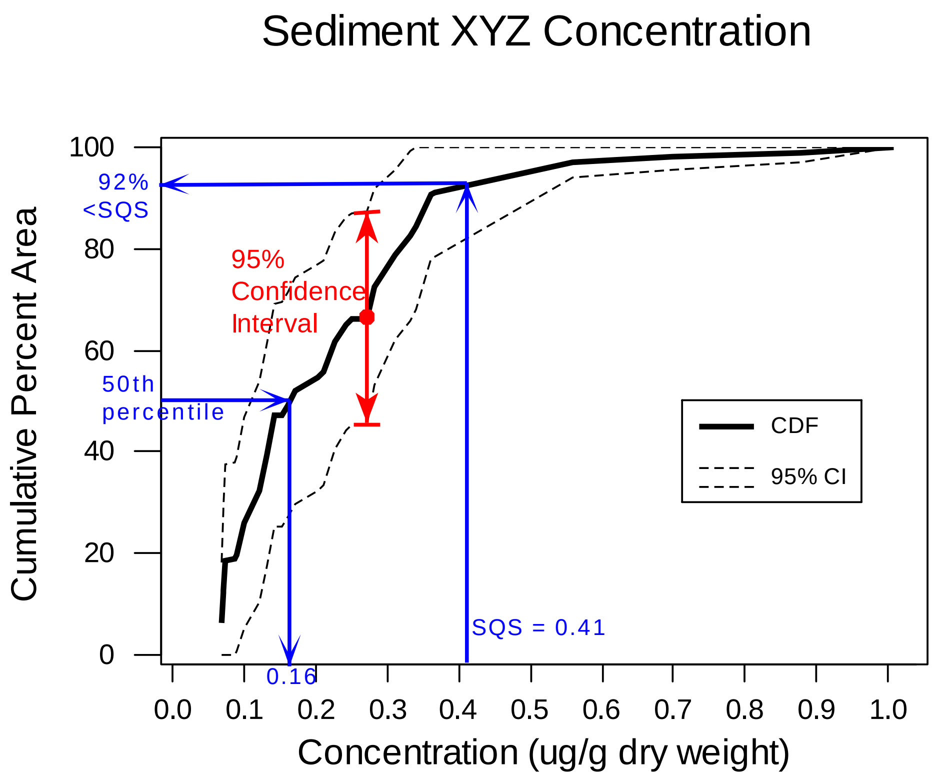

Figure 3. Sample cumulative distribution function (CDF) graph. The CDF indicates the percent area with a given indicator value or less. Dashed lines indicate the 95% confidence band (confidence interval, or CI) for the cumulative distribution function. For this example, it is estimated that 67% ± 21% of the sample area has sediment XYZ contaminant concentrations of 0.27 µg/g or less. The 50th percentile in this example would be described by stating that it is estimated that 50% of the study area has sediment XYZ contaminant concentrations of 0.16 µg/g or less. Any percentile of interest may be estimated in this way. The CDF can also be used to compare survey results to an ecologically important value. In this example, it is estimated that 92% of the study area has sediment XYZ contaminant concentrations less than the Washington State Sediment Quality Standard (SQS) of 0.41 µg/g, and 8% of the study area exceeds the standard.

Comparisons to Sediment Quality Standards and Guidelines for Contaminants

Sediment metals and PAH contaminant levels were compared to Washington State regulatory sediment quality standards (Washington State Department of Ecology, 1995) and to NOAA sediment quality guidelines (Long *et al*., 1995). Non-detects were excluded, except as noted for PAH totals. The LPAH and HPAH compounds composing the PAH totals for the sediment quality standards and guidelines, given in Appendix Table A-3, differ from those composing the EMAP Total LPAH and Total HPAH.

The NOAA Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines represent the 10^{th} and 50^{th} percentiles, respectively, of chemical concentrations associated with toxicity or other adverse biological effects in North American saltwater studies (Long *et al*., 1995). The ERM for nickel was not employed due to the relative unreliability of this value in accurately predicting toxicity (Long *et al.*, 1995; Long and MacDonald, 1998).

Washington State sediment quality standards were enacted into law in 1991 as part of sediment management rules for the purpose of reducing or eliminating harmful effects of sediment contamination on biota, including humans (Washington State Department of Ecology, 1995). The Sediment Quality Standards (SQS) are sediment chemical concentration levels below which adverse biological effects are not expected, while the Cleanup Screening Limits (CSL) are concentration levels above which at least moderate adverse biological effects are expected to occur (Washington State Department of Ecology, 1995). The SQS and CSL are based on data from Puget Sound.

The degree to which organic pollutants are bioavailable is in part determined by the degree to which they are bound by organic matter in the sediments (DiToro *et al.*, 1991). For that reason, concentrations of organic pollutants are normalized by the TOC content of the sediments before comparison to the SQS and CSL (Washington State Department of Ecology, 1995). Total LPAH and HPAH values for comparison with the SQS and CSL were calculated for each station by summing detected values of the TOC-normalized constituent compounds (Appendix Table A-3). If all results were qualified as undetected, the largest reporting limit was used as the total, and the total was qualified as undetected (Washington State Department of Ecology, 1995).

Data Management

Responsibility for the EMAP Western Coastal Information Management Program was initially given to the Southern California Water Resources Research Program (SCCWRP), but now resides within the U.S. EPA Office of Research and Development in Newport, Oregon. Data from the individual states are submitted to EMAP Information Management in a multi-stage process:

1. Field crew leaders and laboratory supervisors compile data generated by their organizations and enter data into Microsoft Excel® spreadsheets. The State Information Management (IM) Coordinator compiles all data generated within a state into a unified state database. An independent person performs a quality assurance check on the data at each step, 100% for all hand-typed transcribed data and 10% or more, up to 100%, for electronic data.

2. The State IM Coordinators submit data to the centralized West Coast EMAP database, created and managed by the Western EMAP IM Coordinator for the centralized West Coast EMAP database. The Western EMAP IM Coordinator works with State IM Coordinators to develop standardized data transfer protocols for data submission.

3. Integrated multi-state data tables in the regional database are certified by the Western EMAP IM Coordinator and provided to the Western EMAP Quality Assurance Coordinator for scientific-content QA review. Discrepancies revealed by this review are communicated to the Western EMAP IM Coordinator, who works with the State IM Coordinators to make necessary changes. Ozretich (2004) contains the QA review of the chemistry data for all three states.

4. Following certification of all data by the Western EMAP Quality Assurance Coordinator, the Western EMAP IM Coordinator submits the integrated multi-state data set to the national EMAP IM Coordinator, located at the Atlantic Ecology Division of EPA at Narragansett, Rhode Island for storage in the national EMAP database and for data-transfers to other EPA databases, such as STORET. The national EMAP IM Coordinator is the point of contact for data requests.

Results

The results reported herein were analyzed in 2003 with data taken from Version 6.2 of the 1999 West Coast EMAP database, with corrections approved by the Washington EMAP Information Management Coordinator. The corrections were incorporated into subsequent versions of the West Coast EMAP database. Fish catch data were re-analyzed in 2005 with data from Version 6.05.03 of the database.

Site Visits

Sampling was attempted at 48 of the 50 proposed 1999 Washington stations (Appendix Table B-1). The other two stations (WA99-0018 and WA99-0032) were determined prior to sampling to be inaccessible. Of the 48 stations visited, five were abandoned in the field due to insufficient water depth or unsafe marine conditions, four prior to sampling. The fifth abandoned station and six others were partially sampled. Details are given in Appendix Table B-1.

A full set of EMAP parameters was measured at 37 of 44 stations; the remainder of the stations were partially sampled (Appendix Table B-1, Figure B-1). CTD-cast data and discrete water samples were acquired at Station WA99-0030 prior to station abandonment. Due to hard seabed (rock, boulders, and gravel), inadequate sediment for chemistry analyses was obtained at Stations WA99-0006 and WA99-0008. Kelp obstructed trawling at WA99-0008. Station WA99-0001 was too deep, and Station WA99-0017 too close to a river mouth, to trawl safely. Rough water and fog prevented trawling at Stations WA99-0033 and WA99-0035, respectively.

Four intertidal stations (WA99-0015, -0016, -0017, and -0019) were visited on foot, rather than by boat. Several stations were sampled short distances away from the target coordinates, mostly due to inadequate water depth (Appendix Table B-1).

General Habitat Condition Indicators

Hydrographic Profile

Surface (0.5 m depth) and bottom results (0.5 m above seafloor) are summarized here for continuously-measured parameters (salinity, temperature, dissolved oxygen, pH, and transmissivity) for the stations sampled by boat. The walk-in stations were too shallow for the water column to be profiled with the CTD. Surface, mid-water, and bottom results are presented for discrete water parameters (PAR, TSS, photosynthetic pigments, and dissolved nutrients) for all stations sampled. Appendix Tables B-2 and B-3 indicate which parameters were measured at each water level for each station; the measured values and graphical summaries are given in Appendix C. Tables 6 and 7 present summary statistics for the physical and chemical parameters, respectively.

Table 6. Summary statistics for water vertical-profile physical parameters

Parameter (units)	Water Level	Number of Stations	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Depth (m)		44	21.3	intertidal	2.7	0.27
Salinity (psu)*	Surface	40	0.04	32.85	28.3	32.2
	Bottom	40	0.04	33.23	29.3	33
Water Temperature (°C)*	Surface	40	9.79	21.59	16.23	18.68
	Bottom	40	8.53	21.59	15.23	18.31
Density Stratification ($\Delta\sigma_t$)* [$Density_{Bottom}$ - $Density_{Surface}$]		40	-0.003	8.02	0.6	3.56
Dissolved Oxygen (mg/L)*	Surface	40	6.48	11.44	7.46	9.47
	Bottom	40	4.28	11.47	7.16	8.98
pH*	Surface	40	6.65	8.43	7.51	7.63
	Bottom	40	6.58	8.17	7.46	7.61
Transmissivity* (% of Light Transmitted)	Surface	40	8.4	81.9	50.32	68.13
	1 m Depth	40	5.1	82.8	51.36	67.64
	Bottom	40	< 1	87.6	49.59	67.12
Submerged PAR Percent of Terrestrial PAR (%)	Surface	36	4.9	93.6	41.6	70.8
Light-Extinction	Surface	36	0.13	6.03	1.47	3.72
Coefficient K_d (m^{-1})	Mean**	38	0.19	3.4	1	1.83
Secchi Depth (m)*		39	0.75	10.2	1.95	4.06

*Excluding walk-in stations

**Water-column mean light-extinction coefficient may be skewed because not all stations had bottom or mid-water PAR measurements.

Table 7. Summary statistics for water vertical-profile chemical parameters. The proportions of area stated for the water levels are based on different sort orders of the stations. Only the water-column mean represents simultaneous conditions at surface, mid-water, and bottom.

Parameter (units)	Water Level	Number of Stations	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
TSS (mg/L)	Surface	44	2	40	5.8	8.7
	Mid-water	28	2	14	7.17	11.51
	Bottom	38	2	40	6.75	17.17
	Mean	***44***	***2***	***40***	***7.08***	***12.98***
Chlorophyll-*a* (µg/L)	Surface	44	0	34.73	4.49	11.61
	Mid-water	28	0	14.38	4.58	11.58
	Bottom	38	0.84	27.49	4.47	12.4
	Mean	***44***	***0.55***	***31.11***	***4.28***	***13.5***
Phaeopigment (µg/L)	Surface	44	0	10.61	1.79	4.03
	Mid-water	28	0	8.89	2.35	4.79
	Bottom	38	0.54	14.14	2.93	6.19
	Mean	***44***	***0.48***	***10.61***	***2.46***	***4.36***
Dissolved Ammonium (µg/L)	Surface	44	0	55.06	11.75	48.94
	Mid-water	28	1.45	59.96	12.38	36.34
	Bottom	38	0	84.19	13.59	51.4
	Mean	***44***	***0.65***	***57.35***	***13.68***	***44.36***
Dissolved Nitrite (µg/L)	Surface	44	0	5.54	1.91	4.43
	Mid-water	28	0	5.53	2.84	4.68
	Bottom	38	0	5.65	2.96	4.37
	Mean	***44***	***0***	***5.45***	***2.44***	***4.25***
Dissolved Nitrate (µg/L)	Surface	44	0	349.35	37.79	101.37
	Mid-water	28	0	371.74	80.52	201.62
	Bottom	38	0	427.25	83.47	241.13
	Mean	***44***	***0***	***355.06***	***67.25***	***155.98***
Total Inorganic Nitrogen (µM)	Surface	44	0.07	26.11	3.9	11.29
	Mid-water	28	0.24	26.95	8.26	16.73
	Bottom	38	0.19	30.73	9.06	18.95
	Mean	***44***	***0.23***	***25.95***	***8.04***	***12.68***
Dissolved Inorganic Phosphate (µg/L)	Surface	44	0.14	63.11	27.53	43.81
	Mid-water	28	0.73	67.09	34.45	53.71
	Bottom	38	0.43	76.6	36.27	55.34
	Mean	***44***	***0.53***	***64.87***	***33.27***	***47.04***
Total Inorganic Phosphorus (µM)	Surface	44	0.0045	2.04	0.89	1.41
	Mid-water	28	0.02	2.16	1.11	1.73
	Bottom	38	0.01	2.47	1.17	1.79
	Mean	***44***	***0.02***	***2.09***	***1.07***	***1.52***
N:P Ratio	Surface	44	0.17	652.27	4.88	14.79
	Mid-water	28	0.17	132.16	7.19	12.44
	Bottom	38	0.15	133.63	7.82	13.83
	Mean	***44***	***0.16***	***178.62***	***7.63***	***14.85***
Dissolved Silicic Acid (µg/L)	Surface	44	372.04	5193.64	1329.4	1922.05
	Mid-water	28	912.36	6358.45	1320.87	1934.92
	Bottom	38	860.43	6424.74	1319.61	1987.44
	Mean	***44***	***372.04***	***5992.28***	***1351.13***	***1897.4***

Depth

The tidally-corrected depths of the 44 stations sampled ranged from intertidal to 21.3 m below MLLW. About half of the study area was less than 3 m deep. Ten stations, accounting for only about 2% of the study area, were intertidal according to the predicted tide heights for the specific dates and times sampled; of those, all were less than 2 m above MLLW, and all but three were less than 1 m above MLLW. Three additional sites were not sampled due to inadequate water depth.

The stations in the smallest estuaries along the Pacific Coast were all intertidal, and those in estuaries along the Columbia River were less than 10 m deep. Station depths in the embayments along the Strait of Juan de Fuca ranged from intertidal to over 20 m.

Salinity

Salinities ranged from 32-33 psu in Makah Bay, which is open to the Pacific Ocean, to < 0.1 psu in Grays Bay and other estuaries further upstream along the Columbia River. Estuaries off the Strait of Juan de Fuca had salinities of 27-33 psu. The salinities in Grays Harbor and Willapa Bay ranged from 26 to 33 psu, though stations up the Elk River and at the mouth of the Chehalis River had salinities of about 13 and 20, respectively. Salinities in Baker Bay, near the mouth of the Columbia River, varied considerably, from 3 to 13 psu. Surface and bottom salinities were similar, except at two stations in Grays Harbor and one station in Baker Bay, at the mouth of the Columbia River. Approximately 9% of the study area was oligohaline (salinity < 5 psu), 11% mesohaline (5-18 psu), and 80% polyhaline (> 18 psu).

Temperature

Water temperatures ranged from 8.5°C to 16.5°C in the estuaries of the northern Olympic Peninsula, 10.3-18.8°C in Grays Harbor and Willapa Bay, and 15.1-21.6°C along the Columbia River. Surface and bottom temperatures were similar for the majority of stations. Bottom temperatures were several degrees cooler than surface temperatures at a few stations at the mouths of estuaries opening onto the Pacific Ocean and at three stations in Discovery Bay.

Density and Water Column Stratification

Water density is a function of salinity and temperature, and the difference between surface and bottom densities indicates the degree of water-column stratification. The *Stratification Index* is calculated as the bottom density minus the surface density. A stratification index less than 1 σ_t indicates well-mixed waters, whereas strongly stratified waters are indicated by a stratification index greater than 2 σ_t. Between 1 σ_t and 2 σ_t is intermediate stratification.

A few stations had stratification indices of zero (*i.e.*, surface and bottom densities equal) or slightly negative (*i.e.*, density higher at surface than bottom): one in Willapa Bay and two in Grays Bay. The greatest stratification occurred at one station in Baker Bay, where density was considerably lower at the surface (0.55 σ_t) than at the bottom (8.57 σ_t). Aside from that one station, stratification index values were generally less than 1.5 σ_t, except in Grays Harbor, where stratification indices ranged from 0.04 to 5.2 σ_t.

Fifty-nine percent of the study area had stratification index values less than 1 σ_t , indicating well-mixed waters (Figure 4). About 18% of the area had stratification indices greater than 2 σ_t , indicating strongly stratified waters. The remaining 13% had intermediate stratification.

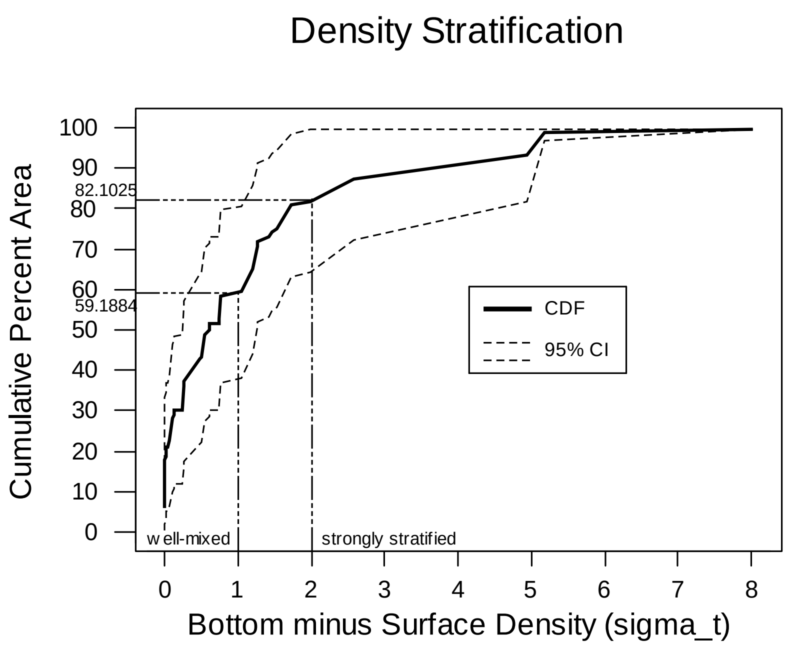

Figure 4. Cumulative percent of study area by water column density stratification index, indicating well-mixed and strongly stratified water.

Dissolved Oxygen (DO)

With the exception of a few bottom DO concentrations between 4 and 5 mg/L in Discovery, Freshwater, and Makah Bays, all DO concentrations were above 5 mg/L. All surface DO concentrations were above 6.4 mg/L. Bottom DO concentrations were generally above 7.3 mg/L in Willapa Bay and the Columbia River estuaries, and below 7.3 mg/L in Grays Harbor and Makah Bay. DO concentrations in Grays Harbor occupied a narrower range than in the other estuaries — ± 0.5 mg/L or less — compared to ± 1 mg/L to about ± 3 mg/L elsewhere. Surface and bottom DO concentrations were quite similar, except in Makah Bay and the estuaries off the Strait of Juan de Fuca, where the bottom DO was often much lower than the surface DO.

None of the study area was severely hypoxic (DO < 2 mg/L), and none of the area had moderately hypoxic (DO < 5 mg/L) surface waters. Three stations, one in each Discovery Bay, Freshwater Bay, and Makah Bay, together accounting for 3.78% of the study area, had moderately hypoxic (DO < 5 mg/L) bottom waters.

pH

Makah Bay was the most alkaline location, with pH above 8. The pH ranged from 7.0 to 7.9 in the estuaries off the Strait of Juan de Fuca, 6.7-7.6 in Grays Harbor, 7.3-7.6 in Willapa Bay, and 6.6-8.0 in Columbia River estuaries. Surface and bottom pH were quite similar at most stations. Bottom waters were more acidic than surface waters at Martin Slough, the mouth of Makah Bay, and at three stations in Discovery Bay.

Light Transmissivity and Water Clarity

Transmissivities, both surface and bottom, were largely in the range of 35-70% light transmission. Only a single station, Grass Creek in Grays Harbor, had transmissivity less than 10%. Transmissivity was generally above 50%, and frequently 70-85%, in the northern Olympic Peninsula estuaries. Transmissivity was far lower at the bottom than at the surface along the northern shore of Grays Harbor, at the mouths of Makah and Willapa Bays, and at one very muddy station in Discovery Bay. Elsewhere, surface and bottom transmissivities tended to be similar.

More than 97% of the study area had high water clarity, as indicated by transmissivities > 25% at 1 meter depth (Figure 5). Only about 0.4% of the study area (Grass Creek) had low water clarity, as indicated by transmissivities < 10%. The remaining 2% had moderate water clarity, with transmissivities at 1 m in the 10-25% range.

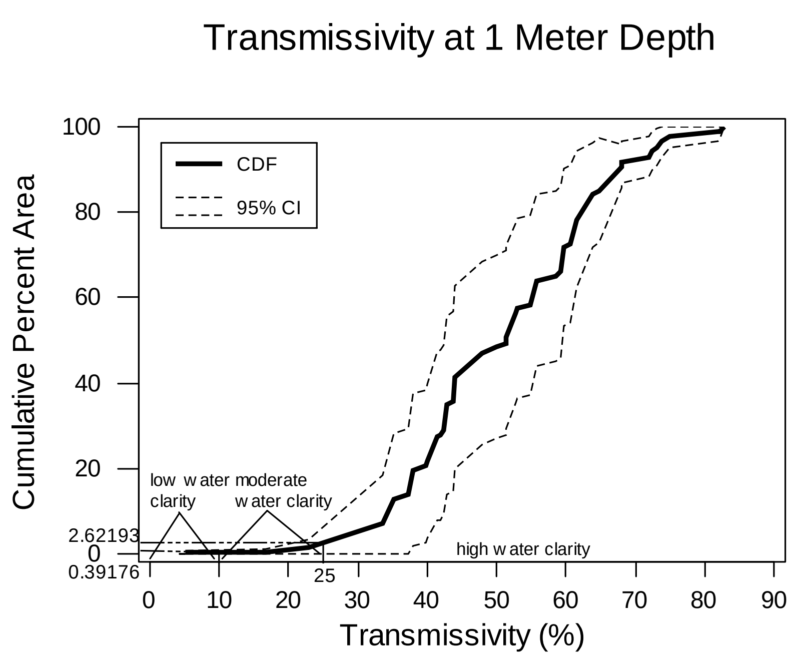

Figure 5. Cumulative percent of study area by transmissivity at 1 m depth, indicating ranges of high, moderate, and low water clarity.

Photosynthetically Active Radiation (PAR) and Water Clarity

Percent of TerPAR — The surface SubPAR/TerPAR ratio was generally above 40% in Columbia River estuaries, Grays Harbor, and Willapa Bay, and generally below 40% in the estuaries of the northern Olympic Peninsula. Surface SubPAR/TerPAR ratios were < 10% at six stations (two in each Makah, Freshwater, and Discovery Bays). At two stations (one in each Baker Bay and Grays Bay) the ratio was over 100%, *i.e.*, the terrestrial PAR reading was lower than the submerged PAR measurement.

Surface Light-Extinction Coefficient — The surface light-extinction coefficients were generally below 2.0 m^{-1} along the Columbia River, in Grays Harbor, and in Willapa Bay, and above 2.0 m^{-1} in the estuaries of the northern Olympic Peninsula.

Mean Light-Extinction Coefficient — Approximately 64% of the study area had mean light-extinction coefficients less than 1.387 m^{-1}, indicative of high water clarity (Figure 6). About 1.5% of the area (the walk-in stations) had mean light-extinction coefficients greater than 2.303 m^{-1}, indicative of low water clarity. The remaining 34.5% had moderate water clarity, with mean light-extinction coefficients between 1.387 and 2.303 m^{-1}.

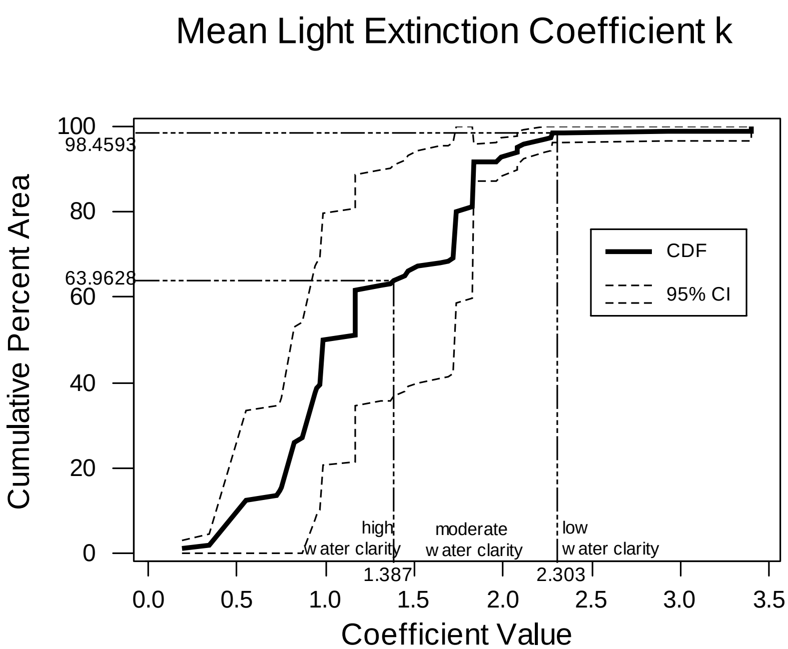

Figure 6. Cumulative percent of study area by water-column mean light-extinction coefficient k, indicating areas of high, moderate, and low water clarity. Water-column mean light-extinction coefficient may be skewed because not all stations had bottom or mid-water PAR measurements.

Note that the mean light-extinction coefficients (average of surface, mid-water, bottom) may be skewed because not all stations had bottom or mid-water PAR measurements due to insufficient depth. In particular, SubPAR could be measured only at the surface at the walk-in stations

(< 1 m deep). No mid-water PAR measurements were taken at the one station in Dungeness Bay, many of the stations in Grays Harbor, one station in Willapa Bay, and about half the stations in both Grays and Baker Bays. Furthermore, the middle and/or bottom of the water column may not be in the photic zone at some stations.

Secchi Depth

Secchi depths were generally 2.5 m or less in Grays Harbor, Willapa Bay, and the estuaries of the Columbia River. Secchi depths at stations situated around the northern Olympic Peninsula ranged from 2.3 to 10.2 m. At the Hoko River station, the Secchi disk was visible on the seabed, 5 m deep.

Water Laboratory Analyses

Summary statistics for the results of water laboratory analyses are given in Table 7. The measured values and graphical summaries of the data are given in Appendix C.

Total Suspended Solids (TSS)

TSS concentrations at both surface and bottom depths ranged from 2 to 40 mg/L, and were between 2 and 16 mg/L at all but four stations: one of the shallow walk-in stations and three stations in Grays Harbor. Mean TSS concentrations were generally above 6 mg/L (not an ecologically important value, merely an observation) in Willapa Bay and Grays Harbor, and below 6 mg/L in Makah Bay and the Strait of Juan de Fuca estuaries.

Photosynthetic Pigments

Chlorophyll-a

Surface chlorophyll-*a* concentrations varied considerably: for example, 0-28.9 µg/L in Makah Bay, 0.9-34.7 µg/L in Discovery Bay, 0-15.6 µg/L in Willapa Bay. All but a few surface and bottom chlorophyll-*a* concentrations were between 1 and 10 µg/L, the exceptions being Martin Slough (the station farthest upstream in the Columbia River), the deepest stations in Makah and Willapa Bays, and the shallowest station in Discovery Bay. Except at that one station in Discovery Bay (31.1 µg/L), mean chlorophyll-*a* concentrations were less than 16 µg/L (not an ecologically important value, merely an observation); most were < 10 µg/L.

Phaeopigment

Surface phaeopigment concentrations were less than 5 µg/L (not an ecologically important value, merely an observation), except at two of the walk-in stations. Bottom phaeopigment concentrations were less than 7 µg/L (also just an observation, not an ecologically important value), except at Makah Bay and the deepest Willapa Bay station. Bottom phaeopigment concentrations were higher than surface concentrations in Makah Bay. Mean phaeopigment concentrations were generally lower in the Strait of Juan de Fuca estuaries than elsewhere.

Dissolved Nutrients

Ammonium (NH_4)

Mean dissolved ammonium concentrations were considerably higher in Baker Bay than in the rest of the Columbia River estuaries, and were generally lower in Freshwater Bay and Willapa Bay than in most of the other estuaries. Mean dissolved ammonium concentrations were quite variable in Grays Harbor. About 80% of the study area had mean NH_4 concentrations in the lower half of the range (Appendix Figure C-2).

Nitrite (NO_2)

Mean dissolved nitrite concentrations were generally higher in Makah Bay and the Strait of Juan de Fuca estuaries than in the other estuaries. The mean dissolved nitrite concentration at the shallowest Discovery Bay station was considerably lower than in the rest of the bay. Over 90% of the study area had mean NO_2 concentrations in the lower half of the range (Appendix Figure C-2).

Nitrate (NO_3)

With the exception of the shallowest station in Discovery Bay, the mean dissolved nitrate concentrations in the estuaries of the northern Olympic Peninsula were generally 2 to 4 times higher than in the other estuaries. Several stations in Willapa Bay and one in Grays Harbor had zero or near-zero mean dissolved nitrate concentrations. The mean NO_3 concentrations were fairly evenly distributed through the study area (Appendix Figure C-2).

Total Nitrogen

The surface total dissolved inorganic nitrogen concentrations (Total N) were lower, overall, than those for the middle and bottom of the water column (Appendix Figure C-2). The mean Total N in Hoko River and Freshwater Bay was considerably higher than in all the other estuaries. Mean Total N was below 4 µM at the walk-in stations and several Willapa Bay and Grays Harbor stations, and the mean Total N was higher in Baker Bay than in the Columbia River estuaries further upstream.

Phosphate (PO_4) and Total Phosphorus

The only component of total dissolved inorganic phosphorus in this analysis was dissolved phosphate (expressed in units of µM instead of µg/L). Mean dissolved phosphate concentrations (Total P) were generally higher in the northern Olympic Peninsula estuaries, and lower in Grays Bay and estuaries further upstream in the Columbia River, than in the other estuaries. The mean Total P was one to two orders of magnitude lower at the Cowlitz River station in the Columbia River than at all other stations. Surface Total P was lower, overall, than that for the middle and bottom of the water column (Appendix Figure C-2).

Nitrogen-to-Phosphorus Ratio (N:P Ratio)

N:P ratios were higher in the Columbia River estuaries, increasing upstream along the Columbia, than in other estuaries. N:P ratios tended to be lower in Willapa Bay than in Makah Bay and embayments along the Strait of Juan de Fuca. The mean N:P ratio at the Cowlitz River station was one to three orders of magnitude higher than at all other stations, due to a very low total dissolved inorganic phosphorus concentration. Overall, the mid-water and bottom N:P ratios were about the same, while the surface N:P ratio was generally lower.

Approximately 93% of the study area had an N:P ratio less than 16, which in freshwater systems may indicate nitrogen-limitation; approximately 7% of the study area had an N:P ratio greater than 16, which in freshwater systems may indicate phosphorus-limitation.

Silicic Acid ($Si(OH)_4$)

Mean dissolved silicic acid concentrations had a wide range of variation in the Columbia River estuaries and among the walk-in stations. Mean dissolved silicic acid concentrations in the Columbia River estuaries were generally higher those than in Grays Harbor, which were in turn higher than those in Grays Harbor, Makah Bay, and the estuaries of the Strait of Juan de Fuca.

Sediment Characteristics

Where samples were analyzed in replicate in the laboratory, the results of the lab replicates were averaged before statistical analyses were performed. The averaged measurements and graphical summaries of the data are given in Appendix C. Summary statistics are given in Table 8.

Table 8. Summary statistics for sediment lithology

	Percent Fines (% silt-clay)	TOC (%)
Number	41	41
Minimum	0	0
Maximum	86.1	3.24
CDF 50th Percentile	5.8	0.21
CDF 90th Percentile	41.7	0.98

Silt-Clay Content (Grain Size Analysis)

Approximately 76% of the area has sandy sediment (< 20% silt-clay), less than one percent of the area is composed of muds (> 80% silt-clay), and the remainder is intermediate (Figure 7). Half of the area has < 6% silt-clay (not an ecologically important value, merely an observation; Table 8).

Silt-clay content in Makah Bay sediments was less than 7%. Silt-clay content in Willapa Bay and at the walk-in stations was in the range 0-35%, and in Grays Harbor, 0-60%. Sediments in the other Strait of Juan de Fuca estuaries ranged from ~10% to 86% silt-clay. At all but one of the Columbia River stations, silt-clay content ranged from 0% to 35%; the one exception had 50% silt-clay. There were seven stations with no measurable silt or clay, being composed entirely of sand and gravel fractions, in Pacific Coast estuaries (including Grays Harbor and Willapa Bay) and near the mouth of the Columbia River.

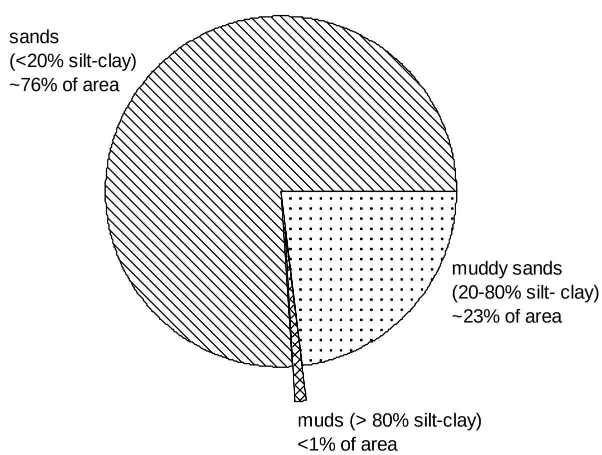

Figure 7. Distribution of sediment types in Washington's coastal estuaries

Total Organic Carbon (TOC) Content

Organic carbon was detected at 40 of the 41 stations analyzed (Table 8); TOC was not detected at one station in Grays Harbor. Approximately 68% of the area had TOC content less than 0.5% (Figure 8). TOC was < 0.5% except in Discovery Bay, much of Grays Harbor, and a few other locations. TOC was < 0.2% at the remaining stations in Grays Harbor, three stations in Willapa Bay, and several other locations.

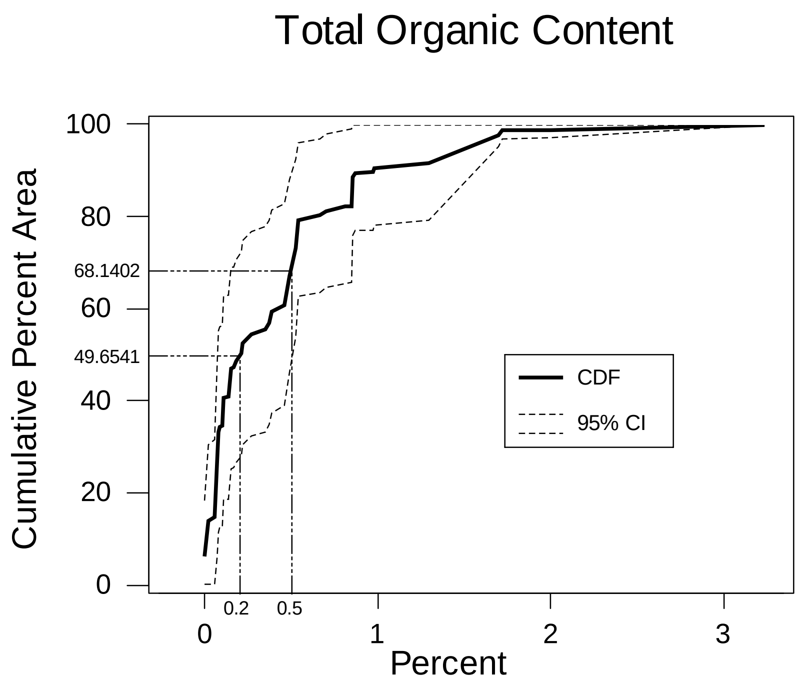

Figure 8. Cumulative percent of study area by sediment TOC

Exposure Condition Indicators

Sediment Contaminants

Where samples were analyzed in replicate in the laboratory, the results of the lab replicates were averaged before statistical analyses were performed. The averaged measurements and graphical summaries of the data are given in Appendix D.

Metals

The following 13 metal contaminants were detected in sediment from all 41 stations analyzed: aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, silver, tin, and zinc. Mercury was detected at 40 of the 41 stations; selenium was detected at 4 of the 41 stations (Table 9). Across the study area, Discovery Bay, Grays Harbor, and the Columbia River estuaries had the highest concentrations of metal contaminants. Metals concentrations were generally higher in estuaries along the Columbia River and the Strait of Juan de Fuca than in Makah Bay, Willapa Bay, and the walk-in stations.

Table 9. Summary statistics for sediment metal concentrations (µg/g dry weight). Non-detects were set to zero and included in the statistical analyses.

Analyte	Number of Detects (N=41 stations)	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Aluminum	41	8750	47900	21832	34866
Antimony	41	0.14	0.98	0.3	0.42
Arsenic	41	0.69	18.6	5.1	6.8
Cadmium	41	0.075	2.31	0.13	0.39
Chromium	41	21.3	94.3	42.95	82.09
Copper	41	6.6	59	14.53	54.07
Iron	41	16300	75200	27374.2	44573.6
Lead	41	3.89	25.9	7.57	11.28
Manganese	41	239	1390	405.49	687.02
Mercury	40	0	0.101	0.016	0.0358
Nickel	41	7.9	49.2	16.42	33.68
Selenium	4	0	0.22	0	0
Silver	41	0.12	0.98	0.248	0.557
Tin	41	0.7	2.67	0.987	2.07
Zinc	41	29.2	147	48.01	80.65

Comparisons to Sediment Quality Standards and Guidelines for Metal Contaminants

The ERL was exceeded for only four metals (arsenic, cadmium, chromium, and copper) at only a few stations. In no samples analyzed were the ERM, SQS, or CRL exceeded for any metal (Table 10, Appendix Table D-1).

Table 10. Comparisons of sediment metals concentrations to Washington State sediment quality standards and NOAA sediment quality guidelines

Analyte	ERL (µg/g)	% of area > ERL	ERM (µg/g)	% of area > ERM	SQS (µg/g)	% of area > SQS	CSL (µg/g)	% of area > CSL
Arsenic	8.2	2.90%	70	0	57	0	93	0
Cadmium	1.2	1%	9.6	0	5.1	0	6.7	0
Chromium	81	12.80%	370	0	260	0	270	0
Copper	34	15.70%	270	0	390	0	390	0
Lead	46.7	0	218	0	450	0	530	0
Mercury	0.15	0	0.71	0	0.41	0	0.59	0
Silver	1	0	3.7	0	6.1	0	6.1	0
Zinc	150	0	410	0	410	0	960	0

Aluminum

Aluminum was detected at all 41 stations. Concentrations varied widely in Columbia River estuaries, Willapa Bay, and Grays Harbor. Aluminum concentrations occupied narrow ranges in the other estuaries, greater in Strait of Juan de Fuca estuaries than in Makah Bay, and greater in Makah Bay than at the walk-in stations.

Antimony

Antimony was detected at all 41 stations. Concentrations varied widely in the estuaries of the Columbia River and Strait of Juan de Fuca. Antimony concentrations tended to be lower in all of the embayments on the Pacific Coast than along the Columbia River or the Strait of Juan de Fuca.

Arsenic

Arsenic was detected at all 41 stations. Within each estuary except Grays Bay, arsenic concentrations tended to be fairly consistent; those in Grays Bay were quite variable. Arsenic concentrations in Grays Bay were generally higher than in other Columbia River estuaries, and concentrations in Makah Bay were generally higher than in other estuaries outside the Columbia River. The ERL for arsenic (8.2 µg/g) was exceeded at one station in Discovery Bay and two stations in Grays Bay, together representing 2.9% of the study area.

Cadmium

Cadmium was detected at all 41 stations. Concentrations varied widely in the estuaries of the Columbia River and the Strait of Juan de Fuca, and were generally higher than in the other estuaries. The largest concentration occurred in Discovery Bay and was approximately an order of magnitude higher than in almost all of the estuaries outside the Columbia River. The ERL for cadmium (1.2 µg/g) was exceeded at only that one station in Discovery Bay, representing approximately 1% of the study area.

Chromium

Chromium was detected at all 41 stations. Concentrations in Grays Harbor, Columbia River estuaries, and Strait of Juan de Fuca estuaries tended to be higher than in Willapa Bay and the other Pacific Coast estuaries. The ERL for chromium (81 µg/g) was exceeded at two stations in Grays Harbor and three stations in Grays Bay, together representing 12.8% of the study area.

Copper

Copper was detected at all 41 stations. Concentrations varied widely in Grays Harbor, Discovery Bay, and along the Columbia River. Copper concentrations in Willapa Bay and the northern Olympic Peninsula estuaries outside Discovery Bay varied little and were generally lower than in Discovery Bay or the Columbia River estuaries. The ERL for copper (34 µg/g) was exceeded at eight stations (one in each Discovery Bay and Baker Bay, two in Grays Harbor, and four in Grays Bay), together representing 15.7% of the study area.

Iron

Iron was detected at all 41 stations. Concentrations in Grays Bay were generally about twice as high as elsewhere. Iron concentrations in Grays Harbor and the rest of the Columbia River estuaries were similar and generally higher than in the rest of the Pacific Coast estuaries.

Lead

Lead was detected at all 41 stations. Concentrations varied widely along the Columbia River and, to a lesser extent, in Discovery Bay. Lead concentrations were generally higher in Willapa Bay and the Columbia River estuaries than in the other Pacific Coast estuaries.

Manganese

Manganese was detected at all 41 stations analyzed. Concentrations varied widely in Grays Bay, and were generally higher along the Columbia River than elsewhere.

Mercury

Mercury was detected at 40 of the 41 stations; mercury was not detected at the station in the Cowlitz River. Concentrations varied widely in Discovery Bay and along the Columbia River. Martin Slough, Baker Bay, and Discovery Bay had particularly high values.

Nickel

Nickel was detected at all 41 stations. Concentrations varied widely in Grays Harbor and along the Columbia River and the Strait of Juan de Fuca, and were higher in those estuaries, especially in Grays Bay, than elsewhere.

Selenium

Selenium was detected at only 4 of the 41 stations; more than 90% of the study area had non-detected selenium concentrations. The largest concentration occurred at one station in Discovery Bay. The smallest measurable selenium concentration occurred at one station in Grays Bay. The other two stations at which selenium was detected were in Discovery Bay and Raft River.

Silver

Silver was detected at all 41 stations. Concentrations varied more widely, and were generally higher, along the Columbia River than elsewhere.

Tin

Tin was detected at all 41 stations. Concentrations along the Columbia River were higher than at the walk-in stations and in the northern Olympic Peninsula estuaries outside Discovery Bay. Tin concentrations varied more widely in Grays Harbor than elsewhere.

Zinc

Zinc was detected at all 41 stations. Concentrations varied widely along the Columbia River and were generally higher there than elsewhere.

Polynuclear Aromatic Hydrocarbons (PAHs)

Station WA99-0050 Laboratory Replicate #4 Outlier

An outlier exists within the PAH data: Laboratory replicate #4 at Station WA99-0050 (Martin Slough) yielded unusually high concentrations of most PAH compounds. The reason for more than two lab replicates for that particular sample was multiple dilutions (Manchester Environmental Laboratory, 2000).

Within the LPAH group, lab replicate #4 results were, on average, 40 times higher than the largest values without the outlier (in lab replicates #1-3 at that station), the multiplicative factor ranging from less than 2 to almost 175, depending on the particular LPAH compound. Within the HPAH group, lab replicate #4 results were, on average, more than 3 times higher than the largest values without the outlier, the multiplicative factor ranging from less than 2 to 5.5, depending on the particular HPAH compound.

The replicate #4 anomaly is believed to have been caused by the presence of a tar ball, oil globule, or piece of creosoted wood (Manchester Environmental Laboratory, 2000). Although this represents inhomogeneity within the sample, it might still be considered representative of generalized conditions in Martin Slough.

PAH results are presented with and without the outlier.

Individual PAHs

PAHs were detected at 40 of the 41 stations analyzed, though not all PAH compounds were measured at all stations. One station in Grays Harbor had non-detects for all PAHs.

<u>Including the outlier (Station WA99-0050 lab replicate #4) in the analysis</u> — The concentrations of individual LPAHs were highest at Station WA99-0050 for all except acenaphthylene, acenaphthene, 1-methylnaphthalene, and 2,3,5-trimethylnaphthalene (Table 11). Acenaphthene and acenaphthylene were highest at one station in Grays Harbor, and the other two were highest at one of the Makah Bay stations. The concentration of retene was higher in lab replicate #3 than in lab replicate #4 at Station WA99-0050. The concentrations of individual HPAHs were highest at Station WA99-0050 for all except perylene (Table 10), where the highest concentration occurred at one station in Grays Harbor.

<u>Excluding the outlier (Station WA99-0050 lab replicate #4) from the analysis</u> — The concentrations of individual LPAHs were highest at Station WA99-0050 for only anthracene, fluorene, phenanthrene, and retene; whereas HPAH concentrations were highest at Station WA99-0050 for all but benz(a)anthracene, benzo(g,h,i)perylene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene, and perylene (Table 11). Concentrations of individual LPAHs without outlier were highest at Makah Bay, Raft River, or Grays Harbor, depending on the compound (Appendix Table D-2). Concentrations of individual HPAHs without outlier were highest in Discovery Bay, Grays Harbor, or Baker Bay, depending on the compound (Appendix Table D-3).

Table 11. Summary of sediment individual PAH Concentrations (ng/g dry weight), with and without outlier at Station WA99-0050 Lab Replicate #4

PAH Compound	Number of Detects (N=41 stations)	Minimum	Maximum with Outlier	Maximum without Outlier
LPAHs				
1-Methylnaphthalene	6	0.13	158*	158*
1-Methylphenanthrene	39	0.21	810.25	65*
2,3,5-Trimethylnaphthalene	34	0.34	75*	75*
2,6-Dimethylnaphthalene	37	0.1	165.1	98*
2-Methylnaphthalene	34	1	1177.7	191*
Acenaphthene	28	0.29	43*	43*
Acenaphthylene	22	0.32	19*	19*
Anthracene	33	0.4	25110.8	214.3
Biphenyl	18	0.98	136.13	46*
Dibenzothiophene	30	0.05	606.3	14*
Fluorene	36	0.36	7633	44
Naphthalene	30	3.3	407	74*
Phenanthrene	40	0.97	65200	669
Retene	39	1.3	3130	3130
HPAHs				
Benz(a)anthracene	12	0.72	401.5	112*
Benzo(a)pyrene	15	1	199.75	76.7
Benzo(b)fluoranthene	24	0.55	142.25	84
Benzo(e)pyrene	19	0.74	356	67
Benzo(g,h,i)perylene	12	1.6	72.75	47*
Benzo(k)fluoranthene	17	0.61	207.5	80.7
Chrysene	36	1.2	2465.25	450.3
Dibenz(a,h)anthracene	7	0.24	20.98	11*
Fluoranthene	39	0.41	2163.35	407.7
Indeno(1,2,3-c,d)pyrene	11	1.5	99.25	50*
Perylene	37	6.8	756*	756*
Pyrene	40	0.32	1291.5	338.7

* Station WA99-0050 did not have the highest concentration of this compound.

Total PAHs

Because none of the individual PAHs composing the EMAP PAH totals was detected at Station WA99-0029 in Grays Harbor, the PAH totals for that station were zero.

Including the outlier (Station WA99-0050 lab replicate #4) in the analysis — The largest Total LPAH, Total HPAH, and Total PAH concentrations were from the outlier (Table 12).

Table 12. Summary of sediment EMAP Total PAH concentrations (ng/g dry weight), with and without outlier at Station WA99-0050 Lab Replicate #4

	Total LPAH	Total HPAH	Total PAH
Number of Detects (N=41 stations)	40	40	40
Minimum	0	0	0
Maximum with Outlier	36184.5	7064	43248.4
Maximum without Outlier	746.7	1602	1987.3
CDF 50th Percentile	14.88	23.47	41.53
CDF 90th Percentile	312.34	140.98	608.16

Excluding the outlier (Station WA99-0050 lab replicate #4) from the analysis — The largest Total HPAH and Total PAH concentrations still occurred at Station WA99-0050 (Martin Slough), but the largest Total LPAH concentration occurred at one station in Makah Bay. The smallest detected concentrations occurred at two stations in Willapa Bay, one in Grays Bay, and the station at Cowlitz River.

Total LPAH concentrations were quite variable in the northern Olympic Peninsula, though Total HPAH concentrations were not. Total LPAH concentrations were higher in Makah Bay than anywhere else except Raft River, and were generally higher in Strait of Juan de Fuca estuaries than in Willapa Bay and most of the stations in Grays Harbor and along the Columbia River. That pattern did not hold for Total HPAH or Total PAH.

PAH totals (LPAH, HPAH, and/or Total) at a few stations were exceptionally high, about 5 to 10 times those in nearby areas.

Comparisons with sediment quality standards and guidelines

Only the outlier (Station WA99-0050 lab replicate #4) exceeded any sediment quality standards or guidelines for PAH totals (Table 13, Appendix Table D-6). Station 50 (Martin Slough) represents 0.11% of the total study area.

Table 13. Comparisons of sediment Total PAH concentrations (including outlier at Station WA99-0050 Lab Replicate #4) to Washington State sediment quality standards and NOAA sediment quality guidelines

	ERL (ng/g)	% of area > ERL	ERM (ng/g)	% of area > ERM	SQS (ppm org. carbon)	% of area > SQS	CSL (ppm org. carbon)	% of area > CSL
Total LPAH	552	0.11%	3160	0.11%	370	0.11%	780	0.11%
Total HPAH	1700	0.11%	9600	0	960	0	5300	0
Total PAH	4022	0.11%	44792	0	NA	NA	NA	NA

Polychlorinated Biphenyls (PCBs)

Of the 21 PCB congeners on the target list, 15 were detected: PCB Congeners 8, 18, 28, 44, 52, 66, 101, 105, 110, 118, 138, 153, 170, 180 and 187. PCBs were detected at only five of the 41 stations analyzed: one station in each Makah Bay, Discovery Bay, Raft River, Grays Harbor, and Martin Slough.

Only two PCB congeners (Congeners 138 and 153) were measured at all five of the stations which had measurable concentrations of PCBs (Table 14, Appendix Table D-7). Two other congeners were measured at three of the five stations, six congeners were detected at two of the five stations, and five congeners were measured at one of the five stations. PCB Congeners 77, 126, 128, 195, 206, and 209 were not detected at any station.

Table 14. Summary of sediment individual PCB congener concentrations (ng/g; detects only). PCB congeners were detected at only five stations.

Measured at all 5 Stations		Measured at 3 of 5 Stations		Measured at 2 of 5 Stations		Measured at 1 of 5 Stations	
Congener	Range	Congener	Range	Congener	Range	Congener	Value
138	0.23-0.49	101	0.17-0.47	52	0.33-0.61	8	0.22
153	0.14-1.10	118	0.18-0.41	105	0.16-0.22	18	0.33
				110	0.27-0.40	28	0.66
				170	0.30-0.32	44	0.43
				180	0.77-1.00	66	0.59
				187	0.32-1.50		

Twelve of the 15 PCB congeners detected, and the highest Total PCB concentration, were measured in Martin Slough. The other four stations had measurable concentrations of five or six congeners each. The lowest detected Total PCB concentration occurred at the walk-in station at Raft River. Ninety percent (and therefore also 50%) of the study area had immeasurable concentrations of Total PCB (Table 15).

Table 15. Summary statistics for sediment Total PCB and Total DDT concentrations (ng/g dry weight)

	Total PCB	Total DDT
Number of Detects (41 Stations)	5	9
Minimum	0	0
Maximum	4.9	2.09
CDF 50th Percentile	0	0
CDF 90th Percentile	0	0

Total DDT

Only 4,4'-DDE and 4,4'-DDD were measurable in the sediment at any station sampled; the other isomers were all non-detect at all stations (Table 16). Nine stations had measurable concentrations of 4,4'-DDE (three in each Baker Bay and Grays Bay, two in Discovery Bay, and the one in Martin Slough), while only one had a detectable level of 4,4'-DDD (Martin Slough). The concentration of 4,4'-DDE (1.5 ng/g), and thus Total DDT (2.09 ng/g), was considerably higher at Station WA99-0050 (Martin Slough) than the other eight stations (range: 0.21 – 0.66 ng/g).

Table 16. Summary of sediment individual DDT concentrations (ng/g: detects only). DDT isomers were detected at only nine stations.

Measured at all 9 Stations		Measured at 1 of 9 Stations	
Isomer	Range	Isomer	Result
4,4'-DDE	0.21 – 1.5	4,4'-DDD	0.59

Ninety percent (and therefore also 50%) of the study area had immeasurable concentrations of Total DDT (Table 15).

Other Chlorinated Pesticides

With the exception of Hexachlorobenzene, all non-DDT chlorinated pesticides were not quantifiable (*i.e.*, non-detect) at all stations.

Hexachlorobenzene

Hexachlorobenzene was analyzed by two methods, SW8081 (GC-ECD) and SW8270 (GC-MS). The former method detected hexachlorobenzene in sediment samples from two of 41 stations: one station in Discovery Bay (0.34 ng/g) and the walk-in station at Quinault River (23.1 ng/g). The latter method detected hexachlorobenzene in only one of 40 sediment samples analyzed, that from the Quinault River station (43 ng/g). The detected results are not adequate to allow calculation and presentation of CDFs.

Sediment Toxicity

There was no overlap between the toxicity indications of the amphipod and urchin tests, and consistent results between the two urchin tests at only two stations (Appendix Table D-10). All of the Discovery Bay samples and one sample each from almost all other northern Olympic Peninsula estuaries had less than 80% normal morphological development rate in sea urchin embryos (Appendix Table D-13). Of those, sediment samples from Raft River and one Discovery Bay station also had less than 80% success in fertilization of sea urchin eggs (Appendix Table D-12). Only one Willapa Bay station and three Columbia River stations had less than 80% survival in the amphipod test (Appendix Table D-11).

Amphipod Survival Test

Control conditions for a successful toxicity test with this species require a mean of 90% survival in the five replicates in control sediments, with no replicate less than 80%. These requirements were not met in 7 of the 41 samples; accordingly, those results were excluded from the CDF analysis, leaving 34 samples included in the analysis (Table 17, Appendix Table D-11). The 7 stations excluded were four in Grays Harbor, two in Willapa Bay, and the one in Martin Slough.

Table 17. Summary of control-corrected sediment toxicity test results

Number of Samples	Amphipod Survival	Sea Urchin Fertilization	Sea Urchin Normal Morphological Development
Meeting Control Conditions (N=41 Stations)	34	41	41
< 80% of Control	4 (15.9% of area)	2 (4.7% of area)	9 (15.0% of area)
< 100% of Control	31 (87.4% of area)	9 (12.8% of area)	31 (71.9% of area)

Test Results	% Amphipod Survival	% Sea Urchin Fertilization	% Sea Urchin Normal Morphological Development
Minimum	56.5	1.3	0
Maximum	102.2	104.3	103.2
CDF 50th Percentile	89.8	102.4	99.1
CDF 90th Percentile	101.3	103.9	101.3

Approximately 16% of the study area had control-corrected percent survival of *Ampelisca abdita* < 80% (Figure 9). Approximately 87% of the study area had < 100% survival; the remaining 13% of area had > 100% survival, indicating better survival of amphipods in test sediments than in controls.

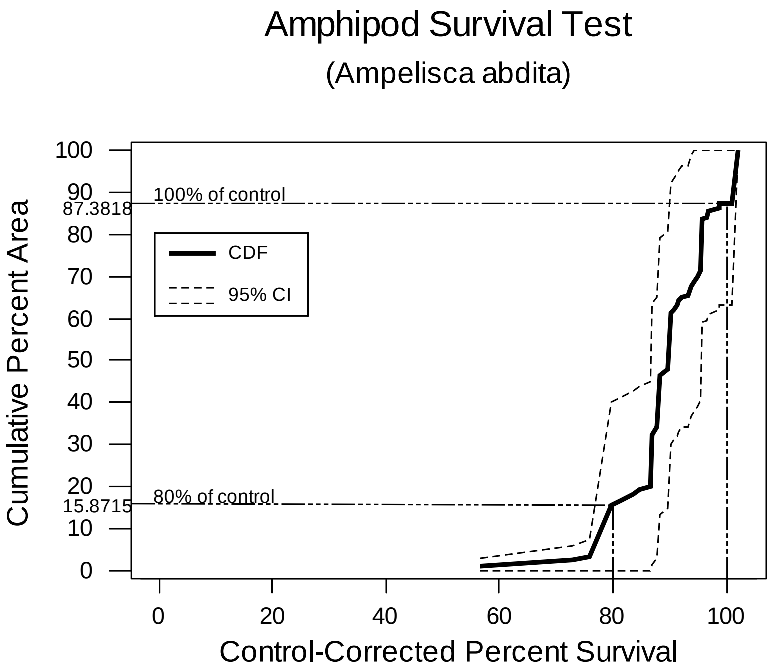

Figure 9. Cumulative percent of study area by control-corrected survival of *Ampelisca abdita*, indicating comparison to control

Sea Urchin Fertilization and Embryo Development Tests

Sea Urchin Fertilization Test

Percent control-corrected fertilization of *Arbacia punctulata* eggs in porewater toxicity tests ranged from 1% to 104% at 100% salinity-adjusted porewater (Table 17).

At 100% salinity-adjusted porewater, 32 of the 41 stations had control-corrected fertilization > 100%. The station with the lowest fertilization rate (1.3%) was in Discovery Bay; the next-lowest was 61.4% at Raft River. The fertilization rates for all other stations sampled were > 90%.

Approximately 4.7% of the study area had sediments in which control-corrected fertilization was < 80% (Figure 10). Approximately 12.8% of area had < 100% fertilization, and the remaining 87% of area had > 100% fertilization, indicating better fertilization of sea urchin eggs in test sediments than in controls.

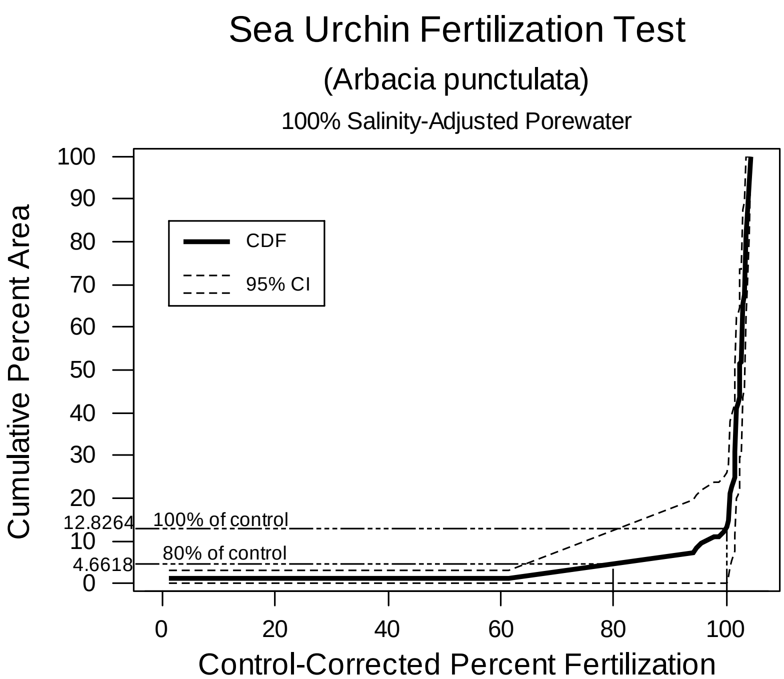

Figure 10. Cumulative percent of study area by control-corrected fertilization success of *Arbacia punctulata* at 100% salinity-adjusted porewater, indicating comparison to control

Sea Urchin Embryo Development Test

Percent control-corrected normal morphological development of *Arbacia punctulata* embryos in porewater toxicity tests ranged from 0% to 103% at 100% salinity-adjusted porewater (Table 17).

At 100% salinity-adjusted porewater, 10 of the 41 stations had control-corrected normal morphological development > 100%; all but 10 stations had > 80% normal development. Five stations had 0% normal development: one in Makah Bay, three in Discovery Bay, and the walk-in station at Raft River.

Approximately 15% of the study area had sediments in which control-corrected percent normal morphological development was < 80% (Figure 11). Approximately 72% of area had < 100% normal development; the remaining 18% of area had > 100% normal development, indicating more normal development of sea urchin embryos in test sediments than in controls.

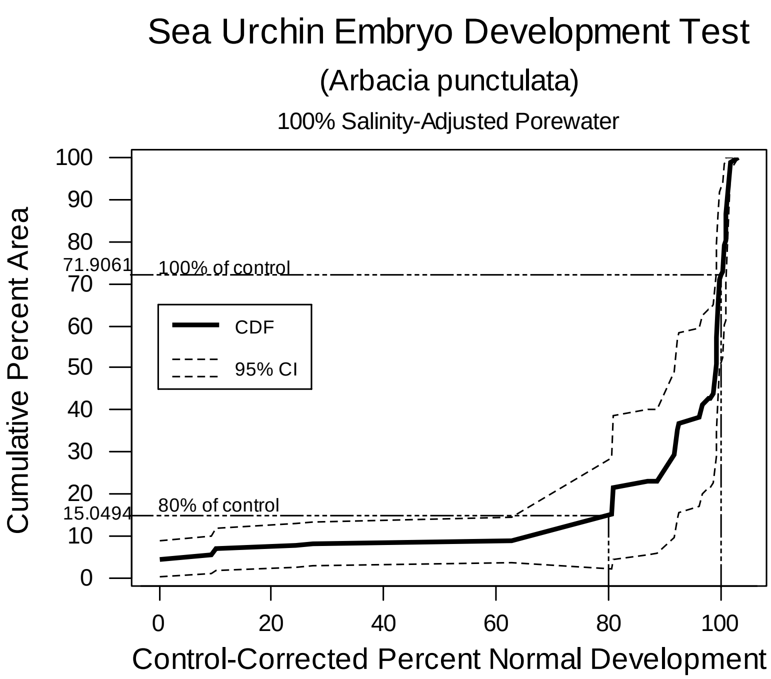

Figure 11. Cumulative percent of study area by control-corrected normal morphological development of *Arbacia punctulata* at 100% salinity-adjusted porewater, indicating comparison to control

Fish-Tissue Contaminants

Chemical analyses were performed on ground *whole* fish to gauge ecological exposure only. *The results cannot be extrapolated to fish for human consumption.*

Since only 24 stations had fish-tissue analyses, no CDFs were generated for fish-tissue contaminants. (A minimum of 30 samples is required for CDFs and associated confidence intervals.) Where samples were analyzed in replicate in the laboratory, the results of the lab replicates were averaged before statistical analyses were performed. The averaged measurements and graphical summaries of the data are given in Appendix D.

Metal Residues

Aluminum, iron, mercury, and zinc were found in all 24 composited fish-tissue samples; lead was found in all but one sample; and nickel was measurable in only one sample (Table 18).

Table 18. Summary of fish-tissue metal concentrations (µg/g wet weight).
Non-detects were set to zero and included in the statistical analyses.

Analyte	Number of Detects (N=24 Samples)	Minimum	Maximum
Aluminum	24	8.9	186
Arsenic	15	0	3.77
Cadmium	4	0	0.2
Chromium	24	0.38	2.2
Copper	19	0	3.99
Iron	24	13	233
Lead	23	0	0.84
Mercury	24	0.0042	0.0314
Nickel	1	0	1.2
Selenium	20	0	0.63
Silver	6	0	0.27
Tin	10	0	0.16
Zinc	24	14.7	32.1

Organics Residues — PCBs, DDT, and other Pesticides

PCB Congeners 138 and 153 were measured in all 24 fish-tissue samples, while Congeners 8, 170, and 209 were not measured in any. The Total PCB burden was an order of magnitude higher in the tissue samples from the stations in the Cowlitz River and Carrolls Channel than in samples from the other Columbia River stations, and two orders of magnitude higher than in samples from all of the other estuaries.

All DDT isomers were detected in fish-tissue samples from the Columbia River stations. 4,4'-DDE was detected in fish-tissue samples at all stations, and 4,4'-DDD was detected in samples from a handful of locations outside the Columbia River system. The 4,4'-DDE and Total DDT burdens were one to two orders of magnitude higher in samples from the Columbia River stations than from all of the other estuaries.

Only three other pesticides (alpha-Chlordane, Hexachlorobenzene, and trans-Nonachlor) were detected, at only a subset of the stations (Table 19). Those pesticides were detected in all of the fish-tissue samples from Columbia River stations and the majority of samples from Strait of Juan de Fuca stations, plus the walk-in station at Raft River. No pesticides were detected in fish-tissue samples from Makah Bay, Grays Harbor, or Willapa Bay.

Table 19. Summary of fish-tissue PCB, DDT, and other pesticide residues (ng/g wet weight). Non-detects were set to zero and included in the statistical analyses, except when the compound was not detected in any sample. Target PCBs and pesticides not included in this table were not detected in fish tissues from any station for which tissue samples were taken.

	Number of Detects (N=24 Samples)	Minimum	Maximum
Total PCB	24	0.202	116.88
Total DDT	24	0.34	168.3
Alpha-Chlordane	8	0	1.4
Hexachlorobenzene	16	0	1.9
Trans-Nonachlor	14	0	4.1

Marine Debris

The only debris of anthropogenic source in the trawls was a steel cable in Carrolls Channel. Other items brought up in trawls at other stations included rocks, algae, eelgrass, and terrestrial vegetation. Shell hash and wood debris were in the sediment grabs at several stations, and ash from Mount St. Helens was found in the sediment at one station (Appendix Table D-18).

Biotic Condition Indicators

The infaunal, fish, and epifaunal data and graphical summaries are given in Appendix E.

Infaunal Species Richness and Diversity

Benthic invertebrate samples were collected at 37 stations, excluding the four walk-in stations. In all, 431 benthic taxa were found. The taxa included 23 colonial species growing on hard substrates (*e.g.*, bryozoans on shell hash) and 33 exotic species, two of which are colonial (Appendix Table E-1).

Taxa richness ranged from 1 to 157 taxa per sample (Table 20), averaging 27 taxa. One sample from the Cowlitz River contained only a single species, an amphipod. There were generally more infaunal taxa in the Strait of Juan de Fuca estuaries than in Makah Bay or the Columbia River estuaries. Up to 157 taxa were found in Discovery Bay, up to 40 in Grays Harbor, up to 35 in Willapa Bay, up to 18 in Baker Bay in the Columbia River estuary system, and up to 13 in Makah Bay. Three stations – one in Freshwater Bay and two in Discovery Bay – had > 100 taxa per sample (Appendix Table E-2). These three stations, in bays on the Strait of Juan de Fuca, represented 4% of the entire study area. All of the other stations (representing 96% of the area) had 65 or fewer taxa per sample.

Table 20. Summary statistics for benthic macrofauna bioindices of community richness and diversity

	Taxa Richness (Number of Taxa)	Shannon-Wiener Diversity H'	Pielou's Evenness J'	Swartz' Dominance (Number of Taxa)	Dominance Standardized by Taxa Richness (%)
Minimum	1	0	0	1	4.6
Maximum	157	5.99	0.37	34	100
CDF 50th Percentile	13.4	3	0.17	4.1	32.9
CDF 90th Percentile	33.5	3.7	0.27	7.5	51.5

The *Shannon-Wiener Diversity Index (H')* ranged from 0, at the one station with only a single species, to 5.99, in the Discovery Bay sample which contained 147 non-colonial and 10 colonial taxa. Shannon-Wiener diversity was generally lower in the Columbia River estuaries than elsewhere.

Pielou's Evenness Index (J') ranged from 0 to 0.37, averaging 0.16. The largest value of J' occurred in one Makah Bay sample which contained 7 taxa.

Swartz' Dominance Index (SDI), the number of taxa accounting for at least 75% of the total abundance, ranged from 1 to 34, averaging 5.87. At eight stations – in Grays Bay, Cowlitz River, and, Carrolls Channel – a single taxon accounted for at least 75% of the abundance. (The Cowlitz River station had only one species.) Eight or fewer taxa accounted for at least 75% of the abundance (*i.e.*, SDI $\leq$ 8) for 96% of the area.

When standardized by taxa richness (the total number of taxa in the sample), the *standardized Swartz' Dominance Index (SDISTD)* ranged from less than 5% to 100%, averaging about 29%.

Infaunal Abundance and Taxonomic Composition

Infaunal abundance ranged from 3 individuals per 0.1 m^2 at the Cowlitz River station to 3106 individuals per 0.1 m^2 in Discovery Bay, averaging 483.3 individuals per 0.1 m^2 (Table 21, Figure 12). Colonial species were included with an abundance of 1.

Table 21. Summary statistics for total benthic macrofauna abundance (# individuals/0.1 m^2)

	All Taxa	Annelida	Arthropoda	Echinodermata	Mollusca	Misc. Taxa
Minimum	3	0	0	0	0	0
Maximum	3106	2589	976	115	414	47
CDF 50th Percentile	67.7	28.7	8.9	0	8.6	0.9
CDF 90th Percentile	896.7	533.4	116.9	1.8	57.8	13.6

The Strait of Juan de Fuca estuaries had the most abundant and diverse infaunal communities, dominated by annelids, while Makah Bay had sparse infaunal communities (Figure 13, Appendix Table E-2). Annelids dominated the infauna at Willapa Bay and Grays Harbor. Arthropods and, to a lesser extent, annelids dominated the infauna in the Columbia River estuaries.

The abundance and proportion of all of the taxa found, including the 10 most abundant, are given in Appendix Tables E-1 and E-2. Exotic and colonial species are indicated. The ten numerically-dominant taxa made up 63.7% of the total benthic macrofauna (Appendix Table E-1). Exotic species accounted for 5.6% of the total benthic infauna collected.

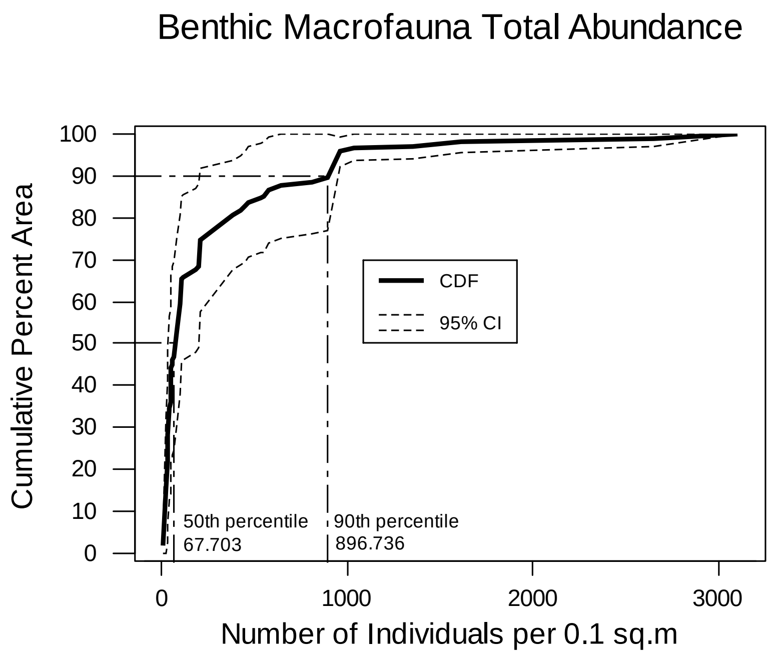

Figure 12. Cumulative percent of study area by benthic macrofauna total abundance (number of individuals per sampled 0.1-m^2 area). Colonial species were included with an abundance of 1.

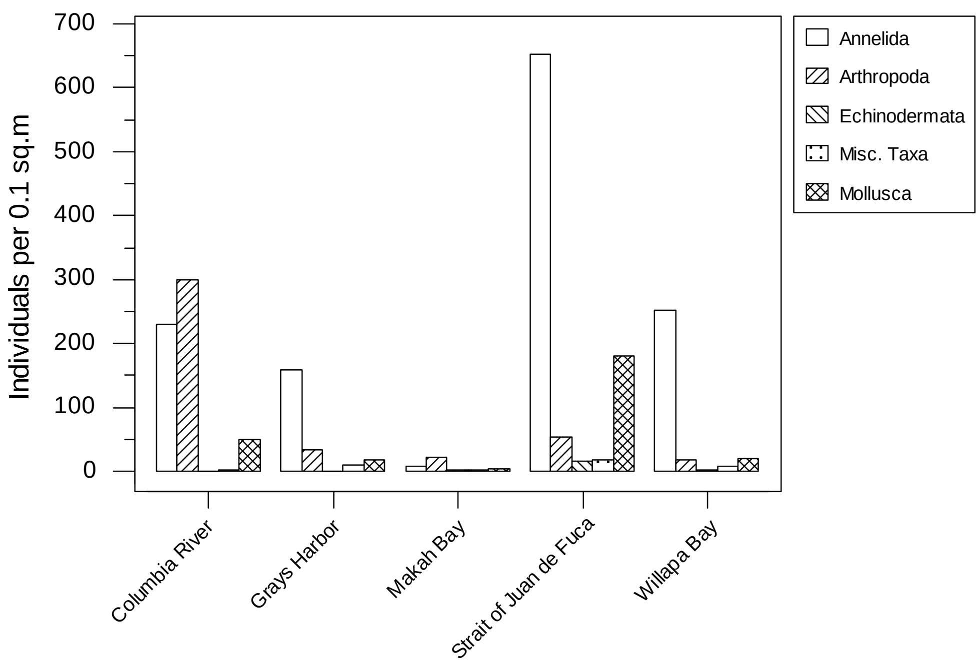

Figure 13. Mean abundance of major taxonomic groups by geographic area

The infaunal communities within the various geographic areas tended to be similar to each other and different between geographic areas, with the exception of Grays Harbor and Willapa Bay, which were similar to each other, as indicated in the multidimensional scaling (MDS) diagram in Figure 14. The three infaunal communities sampled in Makah Bay were fairly divergent from each other. The infauna sampled in the Hoko River estuary (Station WA99-0004) bore more resemblance to those in Makah Bay than to those in the other estuaries opening off the Strait of Juan de Fuca. Station WA99-0013, in Discovery Bay, was quite different in infauna than elsewhere in Discovery Bay or nearby embayments, possibly due to its very different sediment grain size distribution.

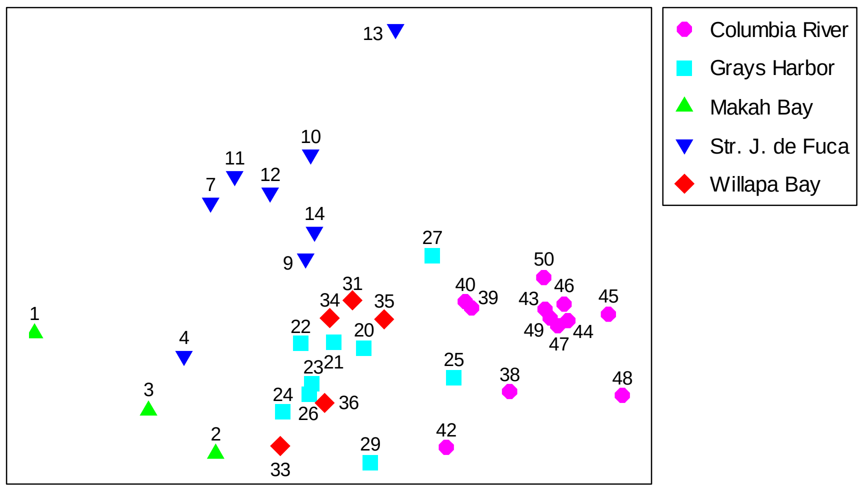

Figure 14. Multidimensional scaling (MDS) map of benthic macrofaunal community similarity (taxa and abundance), based on Bray-Curtis similarity of 4th-root-transformed abundance data (stress = 0.13). The numbers in the figure are the station IDs. The closer the stations are in this map, the more similar their infaunal communities are to each other; the farther the stations are from each other, the more dissimilar their infaunal communities are.

Demersal Fish Species Richness and Abundance

Thirty-two fish species were found over the 31 stations at which fish were acquired from complete standard trawls. Three of those stations had only a single individual of a single species each, and two more stations had <10 individuals of a single species (Appendix Table E-6).

English sole were caught in all areas except those opening directly onto the Pacific Ocean, whereas sand sole were found only in Makah Bay (Figure 15). Starry flounder were caught in the Columbia River estuaries and at the walk-in stations. Speckled sanddab were caught only in estuaries off the Strait of Juan de Fuca.

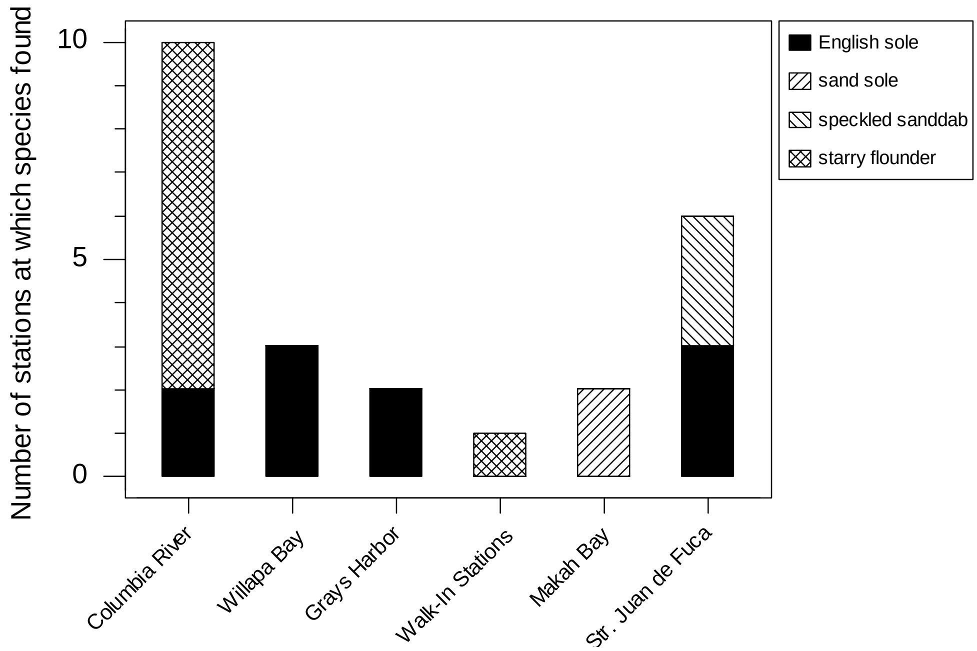

Figure 15. Number of stations at which target species of fish were caught

Catch per Area Swept

The number of fish caught in each trawl ranged from 1 in Carrolls Channel to 336 in Discovery Bay, equivalent to a catch per area swept of just over 500 fish per km^2 to almost 175,000 fish per km^2 (Table 22). The catch per area swept in Discovery Bay spanned almost the entire range observed for the study area, from the second-lowest to the highest. The second-highest catch per area swept, almost 115,000 fish per km^2, occurred in the Hoko River estuary; all others were less than half that (Appendix Table E-7, Figure E-5). Average catch per area swept was approximately 20,000 fish per km^2, though the median was less than 5,000 fish per km^2.

Table 22. Summary statistics for fish taxa richness, abundance, and catch per area swept, complete standard trawls (1st trawl only)

	Taxa Richness (# of taxa/trawl)	Abundance (# individuals/trawl)	Catch per Area Swept (# fish / km^2)
Minimum	1	1	508
Maximum	10	336	174,374
CDF 50th Percentile	1.7	6.2	3,649
CDF 90th Percentile	3.7	54.5	36,173

Demersal Fish Species Gross Pathology

Fish with pathological anomalies (X-cell pseudotumors, trematode metacercariae, or the nematode *Philometra*) were caught at four stations (Table 23). No grossly visible anomalies were observed on fish caught at the other 33 stations fished, though either sea lice or copepods were present on some fish at two stations. Except for one fish with an X-cell pseudotumor caught in Grays Harbor, all of the fish with anomalies or parasites were caught in estuaries off the Strait of Juan de Fuca.

Table 23. Gross pathological anomalies observed in fish specimens

EMAP Station ID	Occurrence in Species; in Total Fish Caught	Species	Fish Size Class (cm)	Anomaly	Severity Index	Distribution Index	Location
WA99-0006 (Freshwater Bay)	2 of 2 in species; 2 of 9 total fish	*Pleuronectes bilineatus*	32	No Anomalies. Sea lice present.	N/A	N/A	N/A
			38	No Anomalies. Sea lice present.	N/A	N/A	N/A
WA99-0009 (Dungeness Bay)	1 of 7 in species; 1 of 11 total fish	*Pleuronectes vetulus*	12	X-cell pseudotumor	6	3	skin
WA99-0012 (Discovery Bay)	1 of 5 in species; 1 of 17 total fish	*Pleuronectes vetulus*	16	Philometra, no histo taken	N/A	N/A	skin/fins
WA99-0013 (Discovery Bay)	4 of 65 in species; 4 of 110 total fish	*Pleuronectes vetulus*	13	X-cell pseudotumor	6	3	fin
			12	Trematode metacercariae	5	3	fin
			11	Trematode metacercariae	5	1	skin
			11	Trematode metacercariae	5	1	muscle
WA99-0014 (Discovery Bay)	1 of 2 in species; 1 of 308 total fish	*Microgadus proximus*	7	No Anomalies. Copepod on gills, no histo taken	N/A	N/A	gills
WA99-0021 (Grass Creek)	1 of 10 in species; 1 of 26 total fish	*Pleuronectes vetulus*	14	X-cell pseudotumor	5	1	skin

Epibenthic Invertebrate Occurrence

The occurrence of epibenthic invertebrates in the trawls is summarized in Appendix Table E-8 by station and by species. No epibenthic invertebrates were recorded from the seines at the walk-in stations.

Dungeness crabs (*Cancer magister*) were caught in all geographic regions, and were the only species caught in Makah Bay and one of only two species caught in Willapa Bay. Shrimp (*Natantia* sp.) were caught in all areas except Makah Bay. The Strait of Juan de Fuca estuaries had more taxa and greater abundance than the other areas.

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List of Acronyms, Abbreviations, and Units of Measure

°C	degrees Celsius
BSA	bovine serum albumin
CDF	cumulative distribution function
CERC	USGS Columbia Analytical Research Center
CI	confidence interval
cm	centimeter
CSL	Washington State sediment Cleanup Screening Level
CTD	Conductivity-Temperature-Depth
DO	Dissolved Oxygen
Ecology	Washington State Department of Ecology
EMAP	Environmental Monitoring and Assessment Program
EPA-ORD	Environmental Protection Agency – Office of Research and Development
ERL	Effects Range-Low
ERM	Effects Range-Median
EROD	7-ethoxyresorufin-O-deethylase
F_0	level of fluorescence of the suspended pigments
F_a	post-acidification fluorescence measured
g	gram
GFF	glass fiber filter
H'	Shannon-Wiener Diversity Index
H4IIE	rat hepatoma cells (one particular cultured line of cells)
HPAH	High molecular weight PAH
IM	Information Management
J'	Pielou’s Evenness Index
kg	kilogram
km	kilometer
L	liter
LPAH	Low molecular weight PAH
m	meter
mg	milligram
mm	millimeter
N:P ratio	Nitrogen-to-phosphorus ratio
NADPH	Nicotinamide adenine dinucleotide phosphate, reduced form
NCA	National Coastal Assessment
ng	nanogram
NH_4	Ammonium (dissolved inorganic ammonium)
nm	nanometer
nmi	nautical mile
NMFS	NOAA National Marine Fisheries Service
NO_2	Nitrite (dissolved inorganic nitrite)
NO_3	Nitrate (dissolved inorganic nitrate)

NOAA	National Oceanic and Atmospheric Administration
PAH	Polycyclic aromatic hydrocarbon
PAR	Photosynthetically Active Radiation
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzofuran
pH	measure of acidity or alkalinity
PHH	Planar halogenated hydrocarbons
PO_4	Phosphate (dissolved inorganic phosphate)
ppt	parts per thousand
PSEP	Puget Sound Estuary Program
psu	practical salinity unit
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
SAV	submerged aquatic vegetation
SCCWRP	Southern California Water Resources Research Program
SDI	Swartz' Dominance Index
$Si(OH)_4$	Silicic Acid (dissolved inorganic silicic acid)
SOP	standard operating procedure
SQS	Washington State Sediment Quality Standard
STORET	EPA's STOrage and RETrieval database
SubPAR	Submerged PAR (PAR measured underwater)
TBT	Tributyltin
TCDD	8-tetrachlorodibenzo-p-dioxin
TCDD-EQ	TCDD equivalent
TerPAR	Terrestrial PAR (PAR measured in air)
TOC	Total Organic Carbon
Total N	Total Nitrogen (total dissolved inorganic nitrogen)
Total P	Total Phosphorus (total dissolved inorganic phosphorus)
TSS	Total Suspended Solids
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
$\Delta\sigma_t$ or delta sigma-t	difference between two seawater densities each expressed as σ_t
µg or ug	microgram
µm or um	micrometer
µM or uM	micromolar
σ_t or sigma-t	shorthand for the remainder of subtracting 1000 kg/m^3 from the density of seawater at atmospheric pressure, measured in kg/m3 units

Appendices

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Appendix A

Descriptions of Indicators

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General Habitat Condition Indicators

Hydrographic Profile

Water Depth

Water-column depth influences physical, chemical, and biological aspects of the estuarine environment. The landward boundary of the EMAP sample frame is defined by the head of salt, *i.e.*, measurable salinity, and thus includes intertidal areas, which are susceptible to terrestrial as well as marine influences.

Salinity

Salinity is a measure of the salt content of water, measured in parts per thousand (or more precisely, Practical Salinity Units, PSU). Salinity is a conservative tracer — it is not created or consumed by chemical or biological processes. Salinity in the estuary represents a balance between the influx of high-salinity ocean water and freshwater inputs from rivers and streams, and is increased by a short oceanic exchange time and a long fresh water replacement time. Salinity is a major determinant of density, which influences stratification and circulation, which in turn affect dissolved oxygen concentrations, phytoplankton productivity, and the residence time of dissolved nutrients and contaminants.

Water Temperature

Water temperature also affects density, as well as the biota and other attributes of estuarine habitat (water quality, sediment characteristics, sediment contamination).

Density Stratification

Differences in water-column density are a function of salinity, water temperature, and mixing. Strong, persistent stratification can lead to anoxic bottom conditions. Stratification can develop in summer months due to strong surface warming and reduced mixing. During winter months, mixing is greater, due to cooler air temperatures and more intense wind-wave regime, and stratification is reduced. Proximity to rivers and tidal mixing also influence stratification.

Stratification is measured by the difference in density ($\Delta\sigma_t$) between the surface and bottom densities:

$$\text{Stratification Index} = D_{bottom} - D_{surface}$$

Density is derived from temperature and salinity.

Dissolved Oxygen (DO)

The concentration of dissolved oxygen in the water column is determined by a series of complex interactions between the biological processes of photosynthesis and respiration and physical factors such as inputs of fresh and oceanic waters, stratification, circulation, mixing, and the exchange of oxygen across the air-water interface. A common cause of low DO is decomposition of organic material, such as dead phytoplankton, in waters that are not well mixed with the atmosphere or more oxygenated waters. The greatest potential for severe oxygen depletion occurs when high phytoplankton growth rates are fueled by abundant nutrients and strong, persistent water-column stratification inhibits mixing.

Low oxygen concentrations (anoxia, or lack of oxygen, and hypoxia, or low oxygen) can have significant impacts on aquatic life. Even relatively short-duration hypoxic or anoxic events can change water chemistry (*e.g.*, release of dissolved inorganic phosphorus) and cause mass mortality of fish and invertebrates. Coastal EMAP defines a system as *moderately hypoxic* if dissolved oxygen is < 5 mg/L, and as *severely hypoxic* if DO < 2 mg/L.

pH

The pH of the water plays an important role in determining the solubility (how much can be dissolved in water) of many chemicals. The pH of water can also determine the bioavailability (how much can be used by organisms) of many chemicals. The chemicals can be nutrients necessary for life or pollutants that can poison living organisms. For example, many metals are more toxic at a lower pH because they are more soluble.

Low pH can result during hypoxic and anoxic conditions. In addition to the stress to organisms from low oxygen, low pH will also damage living organisms. Many species have trouble surviving if the pH drops below 5.0. Typical pH ranges for seawater are 8.1-8.3 at the surface, and 7.5 – 8.4 overall (Sverdrup *et al*., 1942). Estuarine pH can range from 7.5 to 9.0 (U.S. EPA, 2000), though may be 7.0 or less (Sverdrup *et al*., 1942).

Lower pH values present a problem for most organisms, with the exception of bacteria, which can survive pHs as low as 2.0. Low pH is especially harmful to immature fish. Acidic water also speeds the leaching of heavy metals harmful to fish.

Water Clarity

The *rate of light attenuation through the water column* can have a strong impact on benthic communities. The depth of the photic zone, defined with respect to the amount of *photosynthetically-active radiation* (PAR), affects the growth of phytoplankton and submerged aquatic vegetation (such as eelgrass), which in turn affect higher trophic levels.

The attenuation, or light-extinction, coefficient quantifies the rate at which light levels decline with depth due to absorption and backscatter by suspended solids, phytoplankton, and dissolved organic matter. To calculate the attenuation coefficient (K_d), we rely on the Beer-Lambert Law, which expresses the light level at a depth of z meters (I_z) as a function of the surface light level (I_0), depth, and extinction coefficient. I_z and I_0 can be measured directly by PAR sensors deployed in the water and above the surface, respectively. Rearranging the Beer-Lambert equation, we can calculate the extinction coefficient at each depth (*z*) from the PAR measurements by:

$$K_d = \ln(I_0/I_z) / z.$$

To estimate the mean light-extinction coefficient, the individual light-extinction coefficients are calculated for each depth at which simultaneous air and submerged PAR readings are taken, then averaged.

Secchi depth, the depth at which a plate-sized black-and-white disk disappears from view as it is lowered through the water column, is a simple measure of light attenuation. The light-attenuation coefficient and Secchi depth are inversely proportional to each other, and thus the extinction coefficient can also be estimated from the Secchi depth. However, Secchi-depth measurements are susceptible to weather and sea conditions and operator differences.

The Coastal EMAP program defines low water clarity as < 10% of the incident light reaching a depth of 1 m ($K_d \geq 2.303$), moderate clarity as 10-25% of incident sunlight reaching 1 m depth ($K_d \geq 1.387$ and < 2.303), and high clarity as > 25% of incident light reaching 1 m depth ($K_d <$ 1.387).

Light transmissivity is another indicator of water clarity. In contrast to the light-extinction coefficient, which characterizes light attenuation between the surface and a given depth, light transmissivity characterizes the amount of light transmitted through water between a light source and a detector located a short distance away, typically 10-25 cm. Transmissivity is measured throughout the water column using a transmissometer. High water clarity is defined as transmissivity > 25%, moderate water clarity as transmissivity in the 10-25% range, and low water clarity as transmissivity < 10%.

Water Laboratory Analyses

Total Suspended Solids

Total suspended solids (TSS) within the water column are often composed of small mineral particles. TSS concentration has several important ecological impacts. Particulate matter suspended in the water column attenuates light, decreasing the level of light reaching deeper waters. Suspended particles absorb heat in sunlight, and thus raise water temperature. High TSS concentrations effectively remove dissolved inorganic phosphorus, an important nutrient for plants and algae, from the water column by adsorption onto the particle surfaces. Because suspended solids can also adsorb toxic substances, they are often the primary carrier of pollutants to coastal zones. Fine particles are a food source for filter-feeders, so high TSS levels can lead to biomagnification of chemical pollutants within the food chain.

TSS concentrations are dependent on loading and settling rates, and on freshwater dilution and resuspension of surficial sediment. When clay minerals suspended in river water reach the estuarine environment, higher salinity leads to flocculation and deposition, potentially blanketing the estuary floor and affecting bottom habitats.

Photosynthetic Pigments

Chlorophyll-a is a plant pigment that can be used to estimate the biomass of planktonic plants or algae forming the base of the aquatic food chain. Chlorophyll concentration is a commonly-used measure of overall water quality: high levels of chlorophyll can indicate algal blooms that may result from high nutrient loading. Algal blooms can reduce water clarity and deplete oxygen levels in deeper water. Phytoplankton productivity is a function of available light, nutrients, and the stability of the water column (stratification, mixing processes).

Phaeopigments result from the degradation of chlorophyll-*a*, caused by the senescence of phytoplankton or by the digestion of phytoplankton by grazers. As chlorophyll-*a* concentration is a proxy for phytoplankton biomass, so phaeopigment concentration is a proxy for non-photosynthesizing cells.

Dissolved Nutrients

Nitrogen and phosphorus (in their different forms) are major plant nutrients. In estuaries nitrogen is typically the most important nutrient controlling plant growth. (In freshwater phosphorus is typically the most important nutrient). Nitrogen and phosphorus concentrations in the estuary represent a balance between inputs (diffuse catchment loads, point source loads, import from the ocean) and losses (export to the ocean and exchange with sediments). The nutrients are present in large and small phytoplankton and zooplankton, suspended microphytobenthos, dissolved organic and inorganic nitrogen compounds, and detritus. Large changes in nutrient levels, whether natural or anthropogenic, can adversely affect the ecosystem.

Total nitrogen and total phosphorus are the sums of the nitrogen or phosphorus present in all nitrogen- or phosphorus-containing components, respectively, in the water column. Measurements of phosphorus are complicated by the adsorption of phosphate onto particles, which renders the phosphorus temporarily unavailable for plant growth. For Coastal EMAP, only the *dissolved reactive forms of inorganic nitrogen-containing compounds, phosphate, and silicic acid* are quantified.

The ratio of nitrogen to phosphorus is used as an indicator of which nutrient might be controlling primary production in estuaries. A ratio above 16 generally indicates of phosphorus limitation, while a ratio below 16 indicates nitrogen limitation.

Sediment Characteristics

Silt-Clay Content

The percent fines (silt and clay, < 63 μm particle diameter) in bottom sediments is an important determinant of the composition of benthic community composition (Gray, 1974; Rhoads, 1974). Sediment particle size and mineralogy are also important factors in the adsorption of contaminants to sediment particles (Lefkovitz *et al.*, 1997) and therefore exposure of organisms to contaminants.

Total Organic Carbon

The percent total organic carbon (TOC) present in sediment influences the health and composition of benthic communities. Sediments with high TOC are usually a rich food source for benthic invertebrates. However, organic carbon can sequester water-column toxicants in the sediment and can also mediate their bioavailability (DiToro *et al.*, 1991). TOC content is often < 0.5% in sandy or gravelly areas, but in finer sediments may be > 3% in nearshore areas (Michelsen and Bragdon-Cook, 1993).

Abiotic/Pollutant Exposure Condition Indicators

Abiotic condition indicators provide insight into potential stresses acting upon a system and its resident organisms.

Sediment and Fish-Tissue Contaminants

Metals

Heavy metals can be toxic to organisms. The extent to which pollution affects concentrations, and bioavailability, of metals in sediments is complicated by natural geochemical variation.

Polycyclic Aromatic Hydrocarbons (PAHs) - Sediment Only

PAHs are formed by the incomplete/inefficient combustion of organic material, physical changes to sediments, and biological processes. PAHs are ubiquitous in the environment, with natural background levels resulting from forest fires, volcanoes, and possibly production by some plants. However, a significant fraction of PAHs in the environment is due to anthropogenic sources (*e.g.*, burning of fuel, internal-combustion engines, etc.). PAHs reach the marine environment via sewage discharges, surface run-off, industrial discharges, oil spillages and deposition from the atmosphere (CCME, 1992).

Low molecular weight PAHs (LPAHs) are more soluble and volatile and have less affinity for surfaces than high molecular weight PAHs, but high molecular weight PAHs (HPAHs) are thought to be more carcinogenic (Irwin *et al.*, 1997).

PAH compounds tend to co-occur, so analyses are concentrated on the summed concentrations of LPAHs, HPAHs, and total PAHs.

Because PAHs are broken down metabolically, tissue PAH concentrations are not measured for EMAP.

Polychlorinated Biphenyls (PCBs)

PCBs are man-made chemicals, many of which are used as coolants and lubricants in electrical equipment such as transformers and insulators (Bernhard and Petron, 2001). There are 209 different PCB compounds, differentiated by the number and placement of chlorine atoms. The number and placement of chlorine atoms also determines the persistence of PCBs in the environment, their toxicity, and their bioaccumulation properties (Bernhard and Petron, 2001). PCBs generally occur as mixtures.

DDTs and Other Chlorinated Pesticides

Despite the banning of the use of DDT some three decades ago, DDT and its metabolites, DDE and DDD, persist in the environment. DDTs and other chlorinated pesticides are bioaccumulative.

Toxicity

Sediment Toxicity

Toxicity tests are performed on sediment to characterize the aggregate effects of contaminants on biota. Amphipod survival tests are used to indicate acute toxicity, and urchin gamete-development and fertilization tests are used to indicate chronic toxicity. Sediments are classified as toxic if amphipod survival rates are less than 80% of a control group, or if urchin fertilization or embryo development rates are less than 80% of a control group.

Amphipod Survival Test

Amphipod survival tests are the most commonly performed sediment tests in North America, using test crustaceans exposed to relatively unaltered bulk sediment samples. In surveys performed by the NOAA National Status and Trends Program (Long *et al*., 1996), tests with *Ampelisca abdita* provided wide ranges in responses among samples, strong statistical associations with elevated toxicant levels, and small within-sample variability. *Ampelisca abdita* has shown relatively little sensitivity to factors such as grain size, ammonia, and organic carbon (Long *et al*., 1996).

Ampelisca abdita is a euryhaline benthic amphipod that ranges from Newfoundland to south-central Florida, and along the eastern Gulf of Mexico. It is also abundant in San Francisco Bay and along the Pacific coast. The amphipod test with *A. abdita* has been routinely used for sediment toxicity tests in support of numerous EPA programs, including the Environmental Monitoring and Assessment Program (EMAP) in the Virginian (Schimmel *et al*., 1994; Strobel *et al*., 1994, 1995), Louisianian (Summers and Macauley, 1993; Macauley *et al*., 1995), Californian (Bay, 1996), and Carolinian provinces (Hyland *et al*., 1996, 1998).

Sea Urchin Fertilization and Embryo-Development Tests

Toxicants exist in a dissolved state in sediment pore water, making them highly bioavailable. The sea urchin fertilization test assesses the effects of exposure to sediment pore water on early life stages of invertebrates. (Sperm cells are more sensitive than adult forms.)

Fish-Tissue Toxicity

The H4IIE test is a semi-quantitative method for examining the combined potential impacts of polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in fish tissue extracts (USGS, 2001). Results of the H4IIE bioassay can be ranked based on concerns due to dioxin-like effects. The amounts of individual chemicals present in the environmental samples are not measured with this assay.

Marine Debris

Marine debris may have multiple degrading effects on estuarine biota, mainly due to ingestion and entanglement, but potentially due to local poisoning events. Public perception of the overall environmental condition of an area is also linked very clearly to debris levels, and this can affect tourism. Some debris is anthropogenic, while some is naturally-occurring, such as wood.

Biotic Condition Indicators

Biotic condition indicators provide quantitative information on the status of ecological resources (Messer, 1990). Healthy estuarine ecosystems have near-undisturbed environments with balanced populations of benthic infauna and demersal fish species. Biotic condition is investigated by several means in EMAP – benthic infaunal diversity and abundance, demersal fish diversity and abundance, and fish gross pathology.

Benthic Community Structure

Organisms which inhabit the sediments are continually exposed to contaminants in both water and sediments, so the structure of benthic communities may directly reflect the overall impacts of pollution. Benthic infaunal taxonomic identification and abundance data are used to compute total numbers of individuals (total abundance) and total number of species (taxa richness) per grab. Several indices of community are calculated: Shannon-Weaver diversity index H' (log base 2), Pielou's evenness index J', Swartz' dominance index (number of taxa comprising the most abundant 75% of individuals), and Swartz' dominance standardized by taxa richness. The Shannon-Weaver diversity (H') is used as a measure of community heterogeneity, whereas Pielou's evenness (J') is a measure of equitability of distribution. Swartz' dominance (SDI) indicates the degree to which few taxa compose the bulk of the community, and the standardized dominance (SDISTD) translates SDI from number of taxa to percent of taxa.

Demersal Fish Species Richness and Abundance

Demersal fish, including flatfish and species such as sculpins and some types of perch, are in near-constant contact with the seabed and therefore, presumably, with any contaminants in the sediment. (Pelagic fish species are not investigated in Coastal EMAP.) In addition, because the fish are predators, they bioaccumulate toxins over time as they eat smaller organisms which have taken up toxins from the environment. Fish taxonomic identification and abundance data are used to compute total numbers of individuals (total abundance) and total number of species (taxa richness) per tow; total abundance, in turn, is used to calculate catch per unit effort. Many factors influence fish abundance, and a low catch per unit effort may reflect only the natural abundance of fish in that habitat.

Fish Gross Pathology

The occurrence of gross external pathologies (lumps, ulcers, growths, and fin erosion) and parasites may represent direct effects of environmental stressors, such as tumors or true neoplasms, or indirect effects, such as weakened immune systems.

Table A-1. PCBs, Pesticides, and PAHs for Coastal EMAP. Constituents of Total PCB, Total DDT, and PAH totals are indicated.

PCB Congeners	DDT Isomers	PAHs	Total LPAH	Total HPAH	Total PAH
8	2,4'-DDD	1-Methylnaphthalene	X		X
18	2,4'-DDE	2-Methylnaphthalene	X		X
28	2,4'-DDT	2,6-Dimethylnaphthalene	X		X
44	4,4'-DDD	2,3,5-Trimethylnaphthalene	X		X
52	4,4'-DDE	1-Methylphenanthrene	X		X
66	4,4'-DDT	Acenaphthene	X		X
77	**Chlorinated Pesticides**	Acenaphthylene	X		X
101		Anthracene	X		X
105	Aldrin	Benz(a)anthracene		X	X
110	Alpha-Chlordane	Benzo(a)pyrene		X	X
118	Dieldrin	Benzo(b)fluoranthene		X	X
126	Endosulfan I	Benzo(k)fluoranthene		X	X
128	Endosulfan II	Benzo(g,h,i)perylene		X	X
138	Endosulfan Sulfate	Biphenyl	X		X
153	Endrin	Chrysene		X	X
170	Heptachlor	Dibenz(a,h)anthracene		X	X
180	Heptachlor Epoxide	Dibenzothiophene	X**	**	X
187	Hexachlorobenzene*	Fluoranthene		X	X
195	Lindane (gamma-BHC)	Fluorene	X		X
206	Mirex	Indeno(1,2,3-c,d)pyrene		X	X
209	Toxaphene	Naphthalene	X		X
	Trans-Nonachlor	Pyrene		X	X
	*Hexachlorobenzene was analyzed both with the pesticides and with the semi-volatile organics.	** Dibenzothiophene can be considered a LPAH or a HPAH – its carcinogenicity suggests that it is a HPAH, while its molecular weight suggests it is a LPAH (Feddersen, *pers. comm.*). It is included as a LPAH in the statistical analyses.			

Table A-2. Non-EMAP PAHs and other organic compounds

PAHs	Semi-Volatiles
2-Methylfluoranthene	1,2,4-Trichlorobenzene
2-Methylphenanthrene	1,2-Dichlorobenzene
4,6-Dimethyldibenzothiophene	1,3-Dichlorobenzene
9-H-Fluorene, 1-methyl	1,4-Dichlorobenzene
Benzo[e]pyrene	2,4-Dimethylphenol
Carbazole	2-Methylphenol
Chrysene, 5-methyl-	4-Methylphenol
Dibenzofuran	Benzoic Acid
Perylene	Benzyl Alcohol
Phenanthrene	Bis(2-Ethylhexyl) Phthalate
Phenanthrene, 3,6-dimethyl-	Butylbenzylphthalate
Retene	Diethylphthalate
	Dimethylphthalate
Organotins	Di-N-Butylphthalate
Dibutyltin Dichloride	Di-N-Octyl Phthalate
Monobutyltin Trichloride	Hexachlorobutadiene
Tributyltin Chloride	N-Nitrosodiphenylamine
	Pentachlorophenol
	Phenol
	Phenol, 4-Nonyl-

Table A-3. Total PAH constituent compounds and treatment of non-detects for EMAP, ERL/ERM, and SQS/CSL

	EMAP			SQS & CSL			ERL & ERM		
	Total LPAH	Total HPAH	Total PAH	Total LPAH	Total Benzo-fluoranthenes	Total HPAH	Total LPAH	Total HPAH	Total PAH
Use and Handling of Non-Detects	Use all results, detects & non-detects, with non-detects set to = 0			Use detects only, non-detects set to = RL (See note below for details.*)			Use detects only, non-detects excluded		
Units	ppb dry wt (ng/g equivalent)			ppm organic carbon (TOC-normalized)			ppb dry wt (ng/g equivalent)		
1-Methylnaphthalene	X		X						
2-Methylnaphthalene	X		X				X		X
2,6-Dimethylnaphthalene	X		X						
2,3,5-Trimethylnaphthalene	X		X						
1-Methylphenanthrene	X		X						
Acenaphthene	X		X	X			X		X
Acenaphthylene	X		X	X			X		X
Anthracene	X		X	X			X		X
Benz(a)anthracene		X	X			X		X	X
Benzo(a)pyrene		X	X			X		X	X
Benzo(b)fluoranthene		X	X		X				
Benzo(j)fluoranthene					X				
Benzo(k)fluoranthene		X	X		X				
Total Benzofluoranthenes						X			
Benzo(g,h,i)perylene		X	X			X			
Biphenyl	X		X						
Chrysene		X	X			X		X	X
Dibenz(a,h)anthracene		X	X			X		X	X
Dibenzothiophene	X**	**	X						
Fluoranthene		X	X			X		X	X
Fluorene	X		X	X			X		X
Indeno(1,2,3-c,d)pyrene		X	X			X			
Naphthalene	X		X	X			X		X
Phenanthrene				X			X		X
Pyrene		X	X			X		X	X

*For the SQS/CSL PAH totals, sum detected values only unless all values are non-detects, in which case set the total to the largest reporting limit (RL). For individual PAHs, average detected replicates only, unless all values are non-detects, in which case use the largest RL (Washington State Department of Ecology, 1995).

**If based on molecular weight, dibenzothiophene is an LPAH. If based on carcinogenicity, dibenzothiophene is an HPAH. It has been included as an LPAH in the analysis

Appendix B

Sampling Success

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Table B-1. Locations sampled and sampling success

* - signifies station was abandoned prior to sampling

EMAP Station Number	Estuary	Sampled Latitude DD.ddd		Sampled Longitude DDD.ddd		Water	Sed.	Fish	Conditions Hindering Sampling
WA99-0001	Makah Bay	48.320	N	124.680	W	Y	Y	N	Too deep to trawl.
WA99-0002	Makah Bay	48.314	N	124.670	W	Y	Y	Y	Sediment grabs taken 0.27 nautical miles (nmi) from station where WQ samples acquired due to rocky bottom at other coordinates. Boulders obstructed trawling.
WA99-0003	Makah Bay	48.305	N	124.671	W	Y	Y	Y	
WA99-0004	Hoko River	48.288	N	124.365	W	Y	Y	Y	Target coordinates up river – station moved 0.23 nmi to nearest samplable water.
WA99-0005	Ozette River	48.181	N	124.708	W	N	N	N	River mouth – cannot sample safely.
WA99-0006	Freshwater Bay	48.149	N	123.633	W	Y	N	Y	No sediment due to rocky substrate.
WA99-0007	Freshwater Bay	48.148	N	123.601	W	Y	Y	Y	
WA99-0008	Freshwater Bay	48.143	N	123.616	W	Y	N	N	Target coordinates on land – station moved 0.13 nmi. No sediment due to gravel substrate. Kelp obstructed trawling.
WA99-0009	Dungeness Bay	48.160	N	123.148	W	Y	Y	Y	Too shallow at target coordinates – station moved 0.61 nmi to nearest samplable water.
WA99-0010	Discovery Bay	48.079	N	122.900	W	Y	Y	Y	Too deep at target coordinates – station moved to nearest samplable location.
WA99-0011	Discovery Bay	48.058	N	122.905	W	Y	Y	Y	
WA99-0012	Discovery Bay	48.021	N	122.859	W	Y	Y	Y	
WA99-0013	Discovery Bay	48.003	N	122.843	W	Y	Y	Y	Too deep at target coordinates – station moved 0.42 nmi to nearest samplable location.
WA99-0014	Discovery Bay	47.997	N	122.874	W	Y	Y	Y	
WA99-0015	Kalaloch Creek	47.606	N	124.373	W	Y	Y	Y	Too shallow to sample by boat – sampled on foot.
WA99-0016	Raft River	47.463	N	124.339	W	Y	Y	Y	Too shallow to sample by boat – sampled on foot.
WA99-0017	Quinault River	47.347	N	124.298	W	Y	Y	N	Too shallow to sample by boat – sampled on foot. River mouth – too dangerous to fish.
WA99-0018	Quinault River	*		*		N	N	N	Location inaccessible.

EMAP Station Number	Estuary	Sampled Latitude DD.ddd		Sampled Longitude DDD.ddd		Water	Sed.	Fish	Conditions Hindering Sampling
WA99-0019	Conner Creek	47.089	N	124.176	W	Y	Y	Y	Too shallow to sample by boat – sampled on foot. Target coordinates in creek mouth – moved station 0.75 nmi.
WA99-0020	Grays Harbor	47.004	N	124.040	W	Y	Y	Y	Target coordinates in creek channel – moved station 0.75 nmi.
WA99-0021	Grass Creek	47.005	N	124.000	W	Y	Y	Y	Too shallow at target coordinates – station moved 1 nmi to nearest samplable water.
WA99-0022	Grays Harbor	46.966	N	123.951	W	Y	Y	Y	
WA99-0023	Grays Harbor	46.940	N	124.104	W	Y	Y	Y	
WA99-0024	Grays Harbor	46.935	N	124.028	W	Y	Y	Y	
WA99-0025	Grays Harbor	46.967	N	123.858	W	Y	Y	Y	
WA99-0026	Grays Harbor	46.921	N	124.067	W	Y	Y	Y	
WA99-0027	Beardslee Slough	46.873	N	124.034	W	Y	Y	Y	
WA99-0028	Beardslee Slough	46.870	N	124.022	W	N	N	N	Too shallow to sample.
WA99-0029	Grays Harbor	46.848	N	124.032	W	Y	Y	Y	Too shallow at target coordinates – station moved to nearest samplable water.
WA99-0030	Willapa Bay	46.715	N	124.045	W	Y	N	N	Too rough to sample safely.
WA99-0031	Willapa Bay	46.704	N	123.887	W	Y	Y	Y	
WA99-0032	Willapa Bay	*		*	W	N	N	N	Location inaccessible.
WA99-0033	Willapa Bay	46.650	N	124.012	W	Y	Y	N	Too rough to sample safely.
WA99-0034	Willapa Bay	46.567	N	123.942	W	Y	Y	Y	
WA99-0035	Willapa Bay	46.539	N	123.924	W	Y	Y	N	Fog – cannot sample safely.
WA99-0036	Willapa Bay	46.418	N	123.418	W	Y	Y	Y	Too shallow at target coordinates – station moved 1 nmi to nearest samplable water.
WA99-0037	Willapa Bay	46.380	N	123.970	W	N	N	N	Too shallow to sample.
WA99-0038	Baker Bay	46.310	N	124.009	W	Y	Y	Y	Too shallow at target coordinates – station moved 0.2 nmi to nearest samplable water.
WA99-0039	Baker Bay	46.301	N	124.026	W	Y	Y	Y	Too shallow at target coordinates – station moved 0.13 nmi to nearest samplable water.
WA99-0040	Baker Bay	46.273	N	123.973	W	Y	Y	Y	Too shallow at target coordinates – station moved 0.15 nmi to nearest samplable water.

EMAP Station Number	Estuary	Sampled Latitude DD.ddd		Sampled Longitude DDD.ddd		Water	Sed.	Fish	Conditions Hindering Sampling
WA99-0041	Grays River	46.346	N	123.618	W	N	N	N	Too shallow to sample.
WA99-0042	Baker Bay	46.263	N	123.998	W	Y	Y	Y	
WA99-0043	Grays Bay	46.302	N	123.711	W	Y	Y	Y	
WA99-0044	Grays Bay	46.300	N	123.698	W	Y	Y	Y	Target coordinates located in marsh/grassland area – station established at nearest samplable water.
WA99-0045	Grays Bay	46.295	N	123.703	W	Y	Y	Y	
WA99-0046	Grays Bay	46.287	N	123.727	W	Y	Y	Y	
WA99-0047	Grays Bay	46.275	N	123.717	W	Y	Y	Y	
WA99-0048	Cowlitz River	46.095	N	122.922	W	Y	Y	Y	
WA99-0049	Carrolls Channel	46.085	N	122.880	W	Y	Y	Y	
WA99-0050	Martin Slough	45.947	N	122.786	W	Y	Y	Y	

Table B-2. Water parameter sample levels

S - Surface (0.5 m depth); M - Mid-Water (mid-depth of water column); B - Bottom (0.5 m above seabed); 1 - 1 m depth

EMAP Station ID	Salinity	Temperature	Dissolved Oxygen	pH	Transmissivity	Submerged PAR	Terrestrial PAR	TSS	Photo-synthetic Pigments	Dissolved Nutrients
WA99-0001	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0002	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0003	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0004	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0005	station not sampled									
WA99-0006	SB	SB	__B	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0007	SB	SB	___	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0008	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0009	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0010	SB	SB	S__	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0011	SB	SB	S__	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0012	SB	SB	__B	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0013	SB	SB	__B	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0014	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0015	___	___	___	___	____	S___	S___	S___	S___	S___
WA99-0016	___	___	___	___	____	S___	S___	S___	S___	S___
WA99-0017	___	___	___	___	____	S___	S___	S___	S___	S___
WA99-0018	station not sampled									
WA99-0019	___	___	___	___	____	S___	S___	S___	S___	S___
WA99-0020	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0021	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0022	SB	SB	SB	SB	S1B	____	____	SMB	SMB	SMB
WA99-0023	SB	SB	SB	SB	S1B	____	S__B	SMB	SMB	SMB
WA99-0024	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0025	SB	SB	SB	SB	S1B	____	SMB	SMB	SMB	SMB
WA99-0026	SB	SB	SB	SB	S1B	____	SMB	SMB	SMB	SMB
WA99-0027	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0028	station not sampled									
WA99-0029	SB	SB	SB	SB	S1B	S__B	S___	S__B	S__B	S__B
WA99-0030	SB	SB	S__	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0031	SB	SB	SB	SB	S1B	____	SMB	SMB	SMB	SMB

EMAP Station ID	Salinity	Temperature	Dissolved Oxygen	pH	Transmissivity	Submerged PAR	Terrestrial PAR	TSS	Photo-synthetic Pigments	Dissolved Nutrients
WA99-0032	station not sampled									
WA99-0033	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0034	SB	SB	SB	SB	S1B	____	SMB	SMB	SMB	SMB
WA99-0035	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0036	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0037	station not sampled									
WA99-0038	SB	SB	SB	SB	S1B	S__B	S___	S__B	S__B	S__B
WA99-0039	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0040	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0041	station not sampled									
WA99-0042	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0043	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0044	SB	SB	SB	SB	S1B	S__B	S__B	S__B	S__B	S__B
WA99-0045	SB	SB	S__	SB	S1B	S___	S___	S___	S___	S___
WA99-0046	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0047	SS*	SS*	SS*	SS*	S__S*	S___	S___	S___	S___	S___
WA99-0048	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0049	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB
WA99-0050	SB	SB	SB	SB	S1B	SMB	SMB	SMB	SMB	SMB

* In absence of bottom measurement, surface measurement was used for bottom.

Table B-3. Submerged PAR (S) and Terrestrial PAR (T) measurements at each level of the water column

EMAP Station ID	Surface	Mid-Water	Bottom
WA99-0001	S&T	S&T	S&T
WA99-0002	S&T	S&T	S&T
WA99-0003	S&T	S&T	S&T
WA99-0004	S&T	S&T	S&T
WA99-0005		station not sampled	
WA99-0006	S&T	S&T	S&T
WA99-0007	S&T	S&T	S&T
WA99-0008	S&T	S&T	S&T
WA99-0009	S&T		S&T
WA99-0010	S&T	S&T	S&T
WA99-0011	S&T	S&T	S&T
WA99-0012	S&T	S&T	S&T
WA99-0013	S&T	S&T	S&T
WA99-0014	S&T		S&T
WA99-0015	S&T		
WA99-0016	S&T		
WA99-0017	S&T		
WA99-0018		station not sampled	
WA99-0019	S&T		
WA99-0020	S&T	S&T	S&T
WA99-0021	S&T		S&T
WA99-0022			
WA99-0023	T		T
WA99-0024	S&T	S&T	S&T
WA99-0025	T	T	T
WA99-0026	T	T	T
WA99-0027	S&T		S&T
WA99-0028		station not sampled	
WA99-0029	S&T		S
WA99-0030	S&T	S&T	S&T
WA99-0031	T	T	T
WA99-0032		station not sampled	
WA99-0033	S&T	S&T	S&T
WA99-0034	T	T	T
WA99-0035	S&T		S&T
WA99-0036	S&T	S&T	S&T
WA99-0037		station not sampled	
WA99-0038	S&T		S
WA99-0039	S&T		S&T
WA99-0040	S&T		S&T
WA99-0041		station not sampled	
WA99-0042	S&T	S&T	S&T
WA99-0043	S&T	S&T	S&T
WA99-0044	S&T		S&T
WA99-0045	S&T		
WA99-0046	S&T	S&T	S&T
WA99-0047	S&T		
WA99-0048	S&T	S&T	S&T
WA99-0049	S&T	S&T	S&T
WA99-0050	S&T	S&T	S&T

Table B-4. Whole-fish composites for tissue analyses

EMAP Station ID	Species	Number of Fish	Size Range (cm)	Weight Range (g)	Chemistry Analyses	H4IIE Bioassay
WA99-0001	no fish sampled					
WA99-0002	sand sole	6	10 - 17	11 - 43	X	X
WA99-0003	sand sole	11	6 - 13	2 - 22	X	X
WA99-0004	speckled sanddab	21	7 - 13	4 - 33	X	X
WA99-0005	station not sampled					
WA99-0006	speckled sanddab	6	9 - 15	10 - 54	X	X
WA99-0007	speckled sanddab	7	11 - 12, 16*	16 - 23, 59*	X	X
WA99-0008	no fish sampled					
WA99-0009	insufficient target species fish obtained					
WA99-0010	insufficient target species fish obtained					
WA99-0011	no target species obtained					
WA99-0012	English sole	5	11 - 15	12 - 35	X	X
WA99-0013	English sole	10	9 - 16, 19*	7 - 42, 70*	X	X
WA99-0014	English sole	30	7 - 13	4 - 22	X	X
WA99-0015	insufficient target species fish obtained					
WA99-0016	starry flounder	8	7 - 12	5 - 23	X	
WA99-0017	no fish sampled					
WA99-0018	station not sampled					
WA99-0019	no target species obtained					
WA99-0020	insufficient target species fish obtained					
WA99-0021	English sole	34	4 - 10	1 - 9	X	
WA99-0022	insufficient target species fish obtained					
WA99-0023	insufficient target species fish obtained					
WA99-0024	insufficient target species fish obtained					
WA99-0025	insufficient target species fish obtained					
WA99-0026	insufficient target species fish obtained					
WA99-0027	English sole	23	4 - 12	1 - 16	X	X
WA99-0028	station not sampled					
WA99-0029	insufficient target species fish obtained					
WA99-0030	no fish sampled					
WA99-0031	English sole	40	4 - 8	1 - 5	X	
WA99-0032	station not sampled					
WA99-0033	no fish sampled					
WA99-0034	English sole	9	6 - 12	2 - 20	X	
WA99-0035	no fish sampled					
WA99-0036	English sole	47	5 - 10	1 - 11	X	X
WA99-0037	station not sampled					
WA99-0038	starry flounder	12	6 - 9, 22*	2 - 9, 154*	X	X
WA99-0039	insufficient target species fish obtained					
WA99-0040	English sole	47	5 - 9	1 - 8	X	X
WA99-0041	station not sampled					
WA99-0042	English sole	39	6 - 10	2 - 9	X	X
WA99-0043	starry flounder	22	4 - 10	1 - 11	X	
WA99-0044	starry flounder	45	5 - 8	2 - 6	X	X
WA99-0045	no fish kept for tissue analyses					
WA99-0046	starry flounder	50	5 - 10, 16*	1 - 13, 50*	X	X
WA99-0047	starry flounder	37	6 - 11, 16*	3 - 18, 51*	X	X
WA99-0048	starry flounder	3	13, 16, 18	29, 47, 73	X	X
WA99-0049	starry flounder	7	13 - 15, 17*	30 - 47, 77*	X	X
WA99-0050	starry flounder	9	15 - 20	49 - 99	X	X

* one unusually large fish, in relation to others in sample

Figure B-1. Sampling success

Figure B-2. Stations sampled, by geographical area

Geographical Area	Stations	Geographical Area	Stations
Makah Bay	WA99-0001 through WA99-0003	Grays Harbor	WA99-0020 through WA99-0029
Strait of Juan de Fuca	WA99-0004 through WA99-0014	Willapa Bay	WA99-0030 through WA99-0037
Walk-In Stations	WA99-0015 through WA99-0019	Columbia River	WA99-0038 through WA99-0050

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Appendix C

General Habitat Condition Indicators

The data tables in this appendix contain the values used in the statistical analyses. For sediment lithology, the values are the averaged results of lab and/or field replicates, if any. For CTD data, the values are the 0.5-m bin average values from near-surface (0.5 m), near-bottom (0.5 m above bottom), and mid-water depths. The raw data are available in the national EMAP database or upon request.

The boxplots in Figures C-1 through C-3 group the data for estuaries geographically as shown in Figure B-2 in Appendix B.

Box-and-whisker plots, or boxplots, display median (50th-percentile), 25th-percentile, 75th-percentile, and extreme values of the results, with a 95% confidence interval for the median. Outliers are unusually high or unusually low values. The width of the boxplot is proportional to the number of samples.

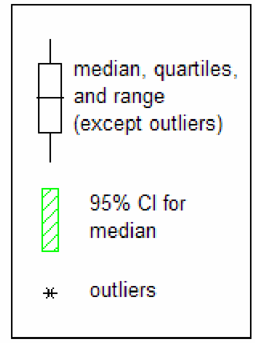


Table C-1. Depth, salinity, temperature, density, stratification, dissolved oxygen (DO), pH, transmissivity

EMAP Station ID	Station Location	Tidally-Corrected Depth (m below MLLW; if intertidal, m above MLLW)	Surface Salinity (psu)	Bottom Salinity (psu)	Surface Temperature (°C)	Bottom Temperature (°C)	Surface Density (σ)	Bottom Density (σ)	Density Stratification (Δσ)
WA99-0001	MAKAH BAY	17.5	32.3	33.1	13.6	9.0	24.19	25.65	1.46
WA99-0002	MAKAH BAY	7.2	32.8	32.9	11.3	10.3	24.99	25.25	0.27
WA99-0003	MAKAH BAY	8.1	32.8	32.9	10.8	10.6	25.13	25.19	0.06
WA99-0004	HOKO RIVER	2.8	31.5	32.1	9.8	9.5	24.27	24.77	0.50
WA99-0005	OZETTE RIVER	station not sampled							
WA99-0006	FRESHWATER BAY	17.9	31.5	32.8	10.8	8.5	24.06	25.47	1.41
WA99-0007	FRESHWATER BAY	21.3	31.6	32.2	10.1	9.3	24.27	24.89	0.61
WA99-0008	FRESHWATER BAY	11.7	31.6	32.1	10.3	9.3	24.23	24.83	0.60
WA99-0009	DUNGENESS BAY	1.4	27.1	29.7	13.5	13.3	20.22	22.20	1.98
WA99-0010	DISCOVERY BAY	4.5	30.7	30.7	12.4	11.9	23.15	23.27	0.12
WA99-0011	DISCOVERY BAY	20.4	30.7	31.5	13.6	10.0	22.94	24.20	1.26
WA99-0012	DISCOVERY BAY	15.1	30.6	30.8	15.4	12.2	22.54	23.28	0.74
WA99-0013	DISCOVERY BAY	18.9	30.1	28.6	16.5	10.3	21.87	21.89	0.02
WA99-0014	DISCOVERY BAY	intertidal, +0.48	30.4	30.5	16.4	16.4	22.08	22.21	0.13
WA99-0015	KALALOCH CREEK	intertidal, +1.64	not sampled with CTD						
WA99-0016	RAFT RIVER	intertidal, +0.78	not sampled with CTD						
WA99-0017	QUINAULT RIVER	intertidal, +0.08	not sampled with CTD						
WA99-0018	QUINAULT RIVER	station not sampled							
WA99-0019	CONNER CREEK	intertidal, +1.25	not sampled with CTD						
WA99-0020	GRAYS HARBOR	1.5	28.2	29.5	16.4	15.2	20.42	21.67	1.26
WA99-0021	GRASS CREEK	1.3	27.4	27.5	17.6	17.6	19.56	19.60	0.04
WA99-0022	GRAYS HARBOR	3.4	28.3	29.1	15.9	15.3	20.64	21.40	0.75
WA99-0023	GRAYS HARBOR	10.7	29.5	31.2	16.0	13.8	21.54	23.28	1.73
WA99-0024	GRAYS HARBOR	2.6	28.1	33.1	17.1	10.3	20.22	25.40	5.19
WA99-0025	GRAYS HARBOR	1.8	20.7	26.8	17.6	16.5	14.41	19.35	4.94
WA99-0026	GRAYS HARBOR	11.5	29.8	32.3	15.0	11.3	22.00	24.59	2.59
WA99-0027	BEARDSLEE SLOUGH	intertidal, +0.95	26.8	27.7	16.7	16.3	19.34	20.07	0.73
WA99-0028	BEARDSLEE SLOUGH	station not sampled							
WA99-0029	GRAYS HARBOR	1.3	13.0	13.6	16.1	16.1	8.88	9.37	0.48
WA99-0030	WILLAPA BAY	14.6	32.6	32.9	10.9	10.4	24.95	25.21	0.26

Depth, salinity, temperature, density, stratification, dissolved oxygen (DO), pH, transmissivity (continued)

EMAP Station ID	Station Location	Tidally-Corrected Depth (m below MLLW; if intertidal, m above MLLW)	Surface DO (mg/L)	Bottom DO (mg/L)	Surface pH	Bottom pH	Surface Transmissivity (%)	Transmissivity at 1m depth (%)	Bottom Transmissivity (%)
WA99-0001	MAKAH BAY	17.51	10.46	4.87	8.4	8.1	41.9	42.3	21.7
WA99-0002	MAKAH BAY	7.16	7.47	6.66	8.1	8.1	75.1	75.0	70.6
WA99-0003	MAKAH BAY	8.11	7.35	7.18	8.2	8.2	73.4	73.7	66.7
WA99-0004	HOKO RIVER	2.79	6.48	5.80	7.2	7.2	79.0	82.0	86.7
WA99-0005	OZETTE RIVER	station not sampled							
WA99-0006	FRESHWATER BAY	17.85	6.81	4.32	7.2	7.0	72.5	72.5	78.1
WA99-0007	FRESHWATER BAY	21.30	6.88	5.62	7.1	7.0	71.9	71.9	71.6
WA99-0008	FRESHWATER BAY	11.74	7.45	5.85	7.1	7.1	50.3	49.9	49.5
WA99-0009	DUNGENESS BAY	1.37	8.30	7.96	7.5	7.5	56.3	60.6	63.4
WA99-0010	DISCOVERY BAY	4.55	8.72	8.67	7.4	7.3	72.1	73.2	75.7
WA99-0011	DISCOVERY BAY	20.41	9.71	5.37	7.7	7.3	78.9	82.8	85.5
WA99-0012	DISCOVERY BAY	15.12	10.82	8.64	7.7	7.4	81.9	81.9	87.6
WA99-0013	DISCOVERY BAY	18.91	10.47	4.28	7.8	7.3	68.1	68.1	12.4
WA99-0014	DISCOVERY BAY	intertidal, +0.48	10.73	11.10	7.9	7.9	43.6	43.8	54.9
WA99-0015	KALALOCH CREEK	intertidal, +1.64	not sampled with CTD						
WA99-0016	RAFT RIVER	intertidal, +0.78	not sampled with CTD						
WA99-0017	QUINAULT RIVER	intertidal, +0.08	not sampled with CTD						
WA99-0018	QUINAULT RIVER	station not sampled							
WA99-0019	CONNER CREEK	intertidal, +1.25	not sampled with CTD						
WA99-0020	GRAYS HARBOR	1.48	7.20	6.97	7.6	7.6	34.3	35.3	11.3
WA99-0021	GRASS CREEK	1.26	6.88	6.97	7.5	7.5	8.4	5.1	1.5
WA99-0022	GRAYS HARBOR	3.37	6.92	7.07	7.5	7.5	38.7	33.5	1.0
WA99-0023	GRAYS HARBOR	10.67	7.70	6.90	7.6	7.5	62.3	61.5	49.8
WA99-0024	GRAYS HARBOR	2.58	6.78	7.09	7.6	7.4	48.1	48.0	56.4
WA99-0025	GRAYS HARBOR	1.76	7.34	6.91	7.2	7.3	38.4	37.9	5.9
WA99-0026	GRAYS HARBOR	11.50	7.42	6.99	7.5	7.5	63.9	63.9	67.6
WA99-0027	BEARDSLEE SLOUGH	intertidal, +0.95	7.06	7.01	7.4	7.4	42.4	41.8	41.3
WA99-0028	BEARDSLEE SLOUGH	station not sampled							
WA99-0029	GRAYS HARBOR	1.28	7.09	7.02	6.8	6.7	44.5	44.0	43.2
WA99-0030	WILLAPA BAY	14.58	8.84	8.88	7.3	7.3	59.6	59.8	40.8

EMAP Station ID	Station Location	Tidally-Corrected Depth (m below MLLW; if intertidal, m above MLLW)	Surface Salinity (psu)	Bottom Salinity (psu)	Surface Temperature (°C)	Bottom Temperature (°C)	Surface Density (σ)	Bottom Density (σ)	Density Stratification (Δσ)
WA99-0031	WILLAPA BAY	2.6	27.0	27.6	18.4	18.2	19.04	19.58	0.53
WA99-0032	WILLAPA BAY	station not sampled							
WA99-0033	WILLAPA BAY	13.8	32.3	33.2	11.9	9.4	24.48	25.67	1.19
WA99-0034	WILLAPA BAY	0.5	28.3	28.3	17.0	17.0	20.39	20.39	0.00
WA99-0035	WILLAPA BAY	0.1	29.7	29.7	16.6	16.6	21.55	21.55	0.00
WA99-0036	WILLAPA BAY	7.8	28.6	28.6	18.8	18.4	20.19	20.29	0.10
WA99-0037	WILLAPA BAY	station not sampled							
WA99-0038	BAKER BAY	intertidal, +1.22	8.4	9.7	18.0	18.0	4.98	6.04	1.06
WA99-0039	BAKER BAY	intertidal, +0.11	8.1	10.0	17.7	17.4	4.82	6.34	1.52
WA99-0040	BAKER BAY	intertidal, +0.07	5.8	5.8	18.8	18.8	2.88	2.88	0.00
WA99-0041	GRAYS RIVER	station not sampled							
WA99-0042	BAKER BAY	8.7	2.9	12.6	19.4	16.1	0.55	8.57	8.02
WA99-0043	GRAYS BAY	3.0	0.1	0.1	20.8	20.8	-1.92	-1.92	0.00
WA99-0044	GRAYS BAY	0.5	0.1	0.1	21.6	21.6	-2.09	-2.09	0.00
WA99-0045	GRAYS BAY	intertidal, +0.54	0.1	0.1	20.2	20.2	-1.78	-1.78	0.00
WA99-0046	GRAYS BAY	9.4	0.1	0.1	20.3	20.2	-1.80	-1.78	0.02
WA99-0047	GRAYS BAY	0.1	0.1	0.1	20.4	20.4	-1.82	-1.82	0.00
WA99-0048	COWLITZ RIVER	2.7	0.0	0.0	15.2	15.1	-0.90	-0.88	0.02
WA99-0049	CARROLLS CHANNEL	3.6	0.1	0.1	20.5	20.4	-1.84	-1.84	0.00
WA99-0050	MARTIN SLOUGH	7.0	0.1	0.1	21.5	20.3	-2.06	-1.81	0.25

EMAP Station ID	Station Location	Tidally-Corrected Depth (m below MLLW; if intertidal, m above MLLW)	Surface DO (mg/L)	Bottom DO (mg/L)	Surface pH	Bottom pH	Surface Transmissivity (%)	Transmissivity at 1m depth (%)	Bottom Transmissivity (%)
WA99-0031	WILLAPA BAY	2.57	7.46	7.42	7.4	7.5	41.9	41.5	39.9
WA99-0032	WILLAPA BAY	station not sampled							
WA99-0033	WILLAPA BAY	13.81	9.55	8.79	7.4	7.3	68.2	68.0	61.7
WA99-0034	WILLAPA BAY	0.47	9.19	9.38	7.6	7.6	56.0	55.9	53.5
WA99-0035	WILLAPA BAY	0.13	7.38	7.32	7.6	7.6	44.7	42.8	39.6
WA99-0036	WILLAPA BAY	7.76	8.08	8.02	7.6	7.6	50.4	52.7	51.6
WA99-0037	WILLAPA BAY	station not sampled							
WA99-0038	BAKER BAY	intertidal, +1.22	8.10	8.05	7.5	7.5	40.4	39.9	33.4
WA99-0039	BAKER BAY	intertidal, +0.11	7.77	7.68	7.5	7.4	22.6	23.0	36.4
WA99-0040	BAKER BAY	intertidal, +0.07	8.36	8.34	7.6	7.6	52.3	52.9	52.9
WA99-0041	GRAYS RIVER	station not sampled							
WA99-0042	BAKER BAY	8.70	8.58	7.98	7.6	7.4	38.2	37.3	35.7
WA99-0043	GRAYS BAY	2.96	8.44	8.44	6.7	6.6	51.9	51.4	50.5
WA99-0044	GRAYS BAY	0.50	11.44	11.47	8.0	8.0	57.7	58.4	57.3
WA99-0045	GRAYS BAY	intertidal, +0.54	9.06	8.96	7.4	7.5	59.4	59.3	59.3
WA99-0046	GRAYS BAY	9.35	8.16	8.12	6.8	6.7	54.8	54.8	58.4
WA99-0047	GRAYS BAY	0.12	8.97	8.97	7.4	7.4	64.9	64.9	64.9
WA99-0048	COWLITZ RIVER	2.68	10.88	10.83	7.0	6.9	42.2	51.4	51.3
WA99-0049	CARROLLS CHANNEL	3.64	9.81	9.72	7.0	6.9	40.7	40.0	39.4
WA99-0050	MARTIN SLOUGH	6.97	9.18	8.93	7.3	7.0	16.5	16.7	11.9

Table C-2. Mean light-extinction coefficient, Secchi depth

EMAP Station ID	Station Location	Mean Light-Extinct. Coeff. K (1/m)	Surface Depth (m)	Surface Light-Extinct. Coeff. k (1/m)	Mid-Water Depth (m)	Mid-Water Light-Extinct. Coeff. k (1/m)	Bottom Depth* (m)	Bottom Light-Extinct. Coeff. k (1/m)	Secchi Depth (m)
WA99-0001	MAKAH BAY	2.28	0.5	6.03	10.0	0.43	18.5	0.37	3.5
WA99-0002	MAKAH BAY	1.99	0.5	5.15	4.5	0.46	7.5	0.36	5.3
WA99-0003	MAKAH BAY	1.45	0.5	3.55	5.0	0.40	9.5	0.39	4.8
WA99-0004	HOKO RIVER	1.69	0.5	4.11	2.5	0.66	4.5	0.31	5.0 (on seabed)
WA99-0005	OZETTE RIVER	station not sampled							
WA99-0006	FRESHWATER BAY	1.52	0.5	4.03	10.0	0.28	19.5	0.24	8.5
WA99-0007	FRESHWATER BAY	1.83	0.5	5.04	11.0	0.25	22.0	0.20	8.0
WA99-0008	FRESHWATER BAY	2.08	0.5	5.70	7.0	0.26	12.5	0.27	10.2
WA99-0009	DUNGENESS BAY	0.96	0.5	1.24	no mid-water PAR		2.0	0.69	2.3
WA99-0010	DISCOVERY BAY	1.46	0.5	3.76	3.5	0.33	6.0	0.30	6.0
WA99-0011	DISCOVERY BAY	0.75	0.5	1.74	11.0	0.28	23.0	0.23	9.0
WA99-0012	DISCOVERY BAY	2.11	0.5	5.79	9.0	0.31	17.0	0.25	7.2
WA99-0013	DISCOVERY BAY	2.08	0.5	5.64	10.0	0.34	19.0	0.24	5.0
WA99-0014	DISCOVERY BAY	1.64	0.5	2.09	no mid-water PAR		1.5	1.20	2.0
WA99-0015	KALALOCH CREEK	2.34	0.5	2.34	no mid-water PAR		no bottom PAR		0.7 (default)
WA99-0016	RAFT RIVER	3.40	0.5	3.40	no mid-water PAR		no bottom PAR		0.7 (default)
WA99-0017	QUINAULT RIVER	3.40	0.5	3.40	no mid-water PAR		no bottom PAR		not measured
WA99-0018	QUINAULT RIVER	station not sampled							
WA99-0019	CONNER CREEK	2.93	0.5	2.93	no mid-water PAR		no bottom PAR		0.7 (default)
WA99-0020	GRAYS HARBOR	0.94	0.5	0.92	2.0	0.86	3.5	1.03	1.7
WA99-0021	GRASS CREEK	1.96	0.5	1.48	no mid-water PAR		1.0	2.44	0.75
WA99-0022	GRAYS HARBOR	no PAR measurements							1.9
WA99-0023	GRAYS HARBOR	no Submerged PAR							2.5
WA99-0024	GRAYS HARBOR	0.82	0.5	1.48	2.5	0.52	5.0	0.47	2.0
WA99-0025	GRAYS HARBOR	no Submerged PAR							1.3
WA99-0026	GRAYS HARBOR	no Submerged PAR							2.4
WA99-0027	BEARDSLEE SLOUGH	1.37	0.5	1.36	no mid-water PAR		1.0	1.37	1.6
WA99-0028	BEARDSLEE SLOUGH	station not sampled							
WA99-0029	GRAYS HARBOR	1.83	0.5	1.83	no mid-water PAR		no Terrestrial PAR		1.5
WA99-0030	WILLAPA BAY	0.55	0.5	0.54	9.0	0.55	cannot calculate		not measured
WA99-0031	WILLAPA BAY	no Submerged PAR							1.5
WA99-0032	WILLAPA BAY	station not sampled							
WA99-0033	WILLAPA BAY	0.98	0.5	2.03	8.0	0.52	16.0	0.40	3.5

EMAP Station ID	Station Location	Mean Light-Extinct. Coeff. K (1/m)	Surface Depth (m)	Surface Light-Extinct. Coeff. k (1/m)	Mid-Water Depth (m)	Mid-Water Light-Extinct. Coeff. k (1/m)	Bottom Depth* (m)	Bottom Light-Extinct. Coeff. k (1/m)	Secchi Depth (m)
WA99-0034	WILLAPA BAY	no Submerged PAR							2.3
WA99-0035	WILLAPA BAY	1.16	0.5	1.16	no mid-water PAR		1.5	1.17	1.8
WA99-0036	WILLAPA BAY	1.74	0.5	3.71	4.5	0.80	8.5	0.69	2.1
WA99-0037	WILLAPA BAY	station not sampled							
WA99-0038	BAKER BAY	1.39	0.5	1.39	no mid-water PAR		no Terrestrial PAR		1.5
WA99-0039	BAKER BAY	1.72	0.5	1.81	no mid-water PAR		1.0	1.62	1.1
WA99-0040	BAKER BAY	0.19	0.5	0.13	no mid-water PAR		1.0	0.24	1.0 (on seabed)
WA99-0041	GRAYS RIVER	station not sampled							
WA99-0042	BAKER BAY	0.87	0.5	-0.38	4.5	0.83	8.5	0.91	1.7
WA99-0043	GRAYS BAY	1.16	0.5	1.77	2.0	1.11	3.0	0.61	2.0
WA99-0044	GRAYS BAY	0.34	0.5	-0.39	no mid-water PAR		1.0	0.34	2.1 (on seabed)
WA99-0045	GRAYS BAY	0.95	0.5	0.95	no mid-water PAR		no bottom PAR		1.0
WA99-0046	GRAYS BAY	0.74	0.5	0.74	5.5	0.68	10.0	0.79	2.5
WA99-0047	GRAYS BAY	0.72	0.5	0.72	no mid-water PAR		no bottom PAR		0.8 (on seabed)
WA99-0048	COWLITZ RIVER	2.23	0.5	4.33	1.5	1.45	3.0	0.92	2.0
WA99-0049	CARROLLS CHANNEL	1.31	0.5	1.78	2.0	1.10	3.5	1.06	1.7
WA99-0050	MARTIN SLOUGH	2.27	0.5	3.76	3.5	1.65	6.0	1.40	0.9

* Approximately 0.5 m above seabed

Note: Mean light-extinction coefficient is average of surface, middle, and bottom light-extinction coefficients calculated from simultaneous measurements of Submerged PAR (SubPAR) and Terrestrial PAR (TerPAR) at surface, middle, and bottom depths.

Table C-3. Surface photosynthetically-active radiation (PAR), light-extinction coefficient, transmissivity

EMAP Station ID	Station Location	Surface Depth (m)	Surface Submerged PAR (μmol/m²/s)	Surface Terrestrial PAR (μmol/m²/s)	Surface SubPAR as % of TerPAR (%)	Surface Light-Extinct. Coeff. k (1/m)	Depth of Surface Transmiss. Meas. (m)	Surface Transmissivity (%)	Transmissivity at 1m depth (%)
WA99-0001	MAKAH BAY	0.5	70	1426	4.9	6.03	0.5	41.9	42.3
WA99-0002	MAKAH BAY	0.5	114	1490	7.6	5.15	0.5	75.1	75.0
WA99-0003	MAKAH BAY	0.5	158	932	17.0	3.55	0.5	73.4	73.7
WA99-0004	HOKO RIVER	0.5	135	1048	12.8	4.11	0.5	79.0	82.0
WA99-0005	OZETTE RIVER	station not sampled							
WA99-0006	FRESHWATER BAY	0.5	168	1257	13.3	4.03	1.0	72.5	72.5
WA99-0007	FRESHWATER BAY	0.5	126	1572	8.0	5.04	1.0	71.9	71.9
WA99-0008	FRESHWATER BAY	0.5	94	1620	5.8	5.70	0.5	50.3	49.9
WA99-0009	DUNGENESS BAY	0.5	107	200	53.7	1.24	0.5	56.3	60.6
WA99-0010	DISCOVERY BAY	0.5	237	1555	15.3	3.76	0.5	72.1	73.2
WA99-0011	DISCOVERY BAY	0.5	113	270	42.0	1.74	0.5	78.9	82.8
WA99-0012	DISCOVERY BAY	0.5	84	1513	5.5	5.79	1.0	81.9	81.9
WA99-0013	DISCOVERY BAY	0.5	101	1695	5.9	5.64	1.0	68.1	68.1
WA99-0014	DISCOVERY BAY	0.5	101	287	35.2	2.09	0.5	43.6	43.8
WA99-0015	KALALOCH CREEK	0.5	55	177	31.0	2.34	not sampled with CTD		
WA99-0016	RAFT RIVER	0.5	232	1266	18.3	3.40	not sampled with CTD		
WA99-0017	QUINAULT RIVER	0.5	129	706	18.3	3.40	not sampled with CTD		
WA99-0018	QUINAULT RIVER	station not sampled							
WA99-0019	CONNER CREEK	0.5	93	403	23.1	2.93	not sampled with CTD		
WA99-0020	GRAYS HARBOR	0.5	408	644	63.2	0.92	0.5	34.3	35.3
WA99-0021	GRASS CREEK	0.5	96	200	47.7	1.48	0.5	8.4	5.1
WA99-0022	GRAYS HARBOR	0.5	no PAR measurements				0.5	38.7	33.5
WA99-0023	GRAYS HARBOR	0.5	no SubPAR	492			0.5	62.3	61.5
WA99-0024	GRAYS HARBOR	0.5	540	1130	47.8	1.48	0.5	48.1	48.0
WA99-0025	GRAYS HARBOR	0.5	no SubPAR	690			0.5	38.4	37.9
WA99-0026	GRAYS HARBOR	0.5	no SubPAR	185			0.5	63.9	63.9
WA99-0027	BEARDSLEE SLOUGH	0.5	202	400	50.6	1.36	0.5	42.4	41.8
WA99-0028	BEARDSLEE SLOUGH	station not sampled							
WA99-0029	GRAYS HARBOR	0.5	201	503	40.0	1.83	0.5	44.5	44.0
WA99-0030	WILLAPA BAY	0.5	1009	1324	76.2	0.54	0.5	59.6	59.8
WA99-0031	WILLAPA BAY	0.5	no SubPAR	687			0.5	41.9	41.5
WA99-0032	WILLAPA BAY	station not sampled							
WA99-0033	WILLAPA BAY	0.5	484	1334	36.3	2.03	0.5	68.2	68.0
WA99-0034	WILLAPA BAY	0.5	no SubPAR	674			0.5	56.0	55.9

EMAP Station ID	Station Location	Surface Depth (m)	Surface Submerged PAR (µmol/m²/s)	Surface Terrestrial PAR (µmol/m²/s)	Surface SubPAR as % of TerPAR (%)	Surface Light-Extinct. Coeff. k (1/m)	Depth of Surface Transmiss. Meas. (m)	Surface Transmissivity (%)	Transmissivity at 1m depth (%)
WA99-0035	WILLAPA BAY	0.5	178	317	56.0	1.16	0.5	44.7	42.8
WA99-0036	WILLAPA BAY	0.5	163	1043	15.6	3.71	0.5	50.4	52.7
WA99-0037	WILLAPA BAY	station not sampled							
WA99-0038	BAKER BAY	0.5	329	657	50.0	1.39	0.5	40.4	39.9
WA99-0039	BAKER BAY	0.5	130	322	40.5	1.81	0.5	22.6	23.0
WA99-0040	BAKER BAY	0.5	1606	1716	93.6	0.13	0.5	52.3	52.9
WA99-0041	GRAYS RIVER	station not sampled							
WA99-0042	BAKER BAY	0.5	1422	1174	121.1	-0.38	0.5	38.2	37.3
WA99-0043	GRAYS BAY	0.5	678	1644	41.2	1.77	0.5	51.9	51.4
WA99-0044	GRAYS BAY	0.5	1002	827	121.2	-0.39	0.5	57.7	58.4
WA99-0045	GRAYS BAY	0.5	192	308	62.3	0.95	0.5	59.4	59.3
WA99-0046	GRAYS BAY	0.5	175	253	69.1	0.74	0.5	54.8	54.8
WA99-0047	GRAYS BAY	0.5	194	278	69.7	0.72	0.5	64.9	64.9
WA99-0048	COWLITZ RIVER	0.5	181	1572	11.5	4.33	0.5	42.2	51.4
WA99-0049	CARROLLS CHANNEL	0.5	464	1131	41.0	1.78	0.5	40.7	40.0
WA99-0050	MARTIN SLOUGH	0.5	160	1051	15.3	3.76	0.5	16.5	16.7

Table C-4. Mid-water photosynthetically-active radiation (PAR), light-extinction coefficient

EMAP Station ID	Station Location	Mid-Water Depth (m)	Mid-Water Submerged PAR (µmol/m²/s)	Mid-Water Terrestrial PAR (µmol/m²/s)	Mid-Water Light-Extinction Coefficient k (1/m)
WA99-0001	MAKAH BAY	10.0	18	1355	0.43
WA99-0002	MAKAH BAY	4.5	186	1457	0.46
WA99-0003	MAKAH BAY	5.0	135	998	0.40
WA99-0004	HOKO RIVER	2.5	182	940	0.66
WA99-0005	OZETTE RIVER	station not sampled			
WA99-0006	FRESHWATER BAY	10.0	82	1333	0.28
WA99-0007	FRESHWATER BAY	11.0	106	1570	0.25
WA99-0008	FRESHWATER BAY	7.0	257	1620	0.26
WA99-0009	DUNGENESS BAY	no mid-water PAR			
WA99-0010	DISCOVERY BAY	3.5	463	1472	0.33
WA99-0011	DISCOVERY BAY	11.0	12	260	0.28
WA99-0012	DISCOVERY BAY	9.0	94	1558	0.31
WA99-0013	DISCOVERY BAY	10.0	55	1744	0.34
WA99-0014	DISCOVERY BAY	no mid-water PAR			
WA99-0015	KALALOCH CREEK	no mid-water PAR			
WA99-0016	RAFT RIVER	no mid-water PAR			
WA99-0017	QUINAULT RIVER	no mid-water PAR			
WA99-0018	QUINAULT RIVER	station not sampled			
WA99-0019	CONNER CREEK	no mid-water PAR			
WA99-0020	GRAYS HARBOR	2.0	115	646	0.86
WA99-0021	GRASS CREEK	no mid-water PAR			
WA99-0022	GRAYS HARBOR	no PAR measurements			
WA99-0023	GRAYS HARBOR	no mid-water PAR			
WA99-0024	GRAYS HARBOR	2.5	320	1169	0.52
WA99-0025	GRAYS HARBOR	3.5	no SubPAR	690	
WA99-0026	GRAYS HARBOR	6.0	no SubPAR	188	
WA99-0027	BEARDSLEE SLOUGH	no mid-water PAR			
WA99-0028	BEARDSLEE SLOUGH	station not sampled			
WA99-0029	GRAYS HARBOR	no mid-water PAR			
WA99-0030	WILLAPA BAY	9.0	9	1314	0.55
WA99-0031	WILLAPA BAY	2.0	no SubPAR	725	
WA99-0032	WILLAPA BAY	station not sampled			
WA99-0033	WILLAPA BAY	8.0	23	1533	0.52
WA99-0034	WILLAPA BAY	1.0	no SubPAR	656	
WA99-0035	WILLAPA BAY	no mid-water PAR			
WA99-0036	WILLAPA BAY	4.5	28	1044	0.80
WA99-0037	WILLAPA BAY	station not sampled			
WA99-0038	BAKER BAY	no mid-water PAR			
WA99-0039	BAKER BAY	no mid-water PAR			
WA99-0040	BAKER BAY	no mid-water PAR			
WA99-0041	GRAYS RIVER	station not sampled			
WA99-0042	BAKER BAY	4.5	43	1760	0.83
WA99-0043	GRAYS BAY	2.0	178	1642	1.11
WA99-0044	GRAYS BAY	no mid-water PAR			
WA99-0045	GRAYS BAY	no mid-water PAR			
WA99-0046	GRAYS BAY	5.5	6	255	0.68
WA99-0047	GRAYS BAY	no mid-water PAR			
WA99-0048	COWLITZ RIVER	1.5	179	1569	1.45
WA99-0049	CARROLLS CHANNEL	2.0	101	910	1.10
WA99-0050	MARTIN SLOUGH	3.5	5	1590	1.65

Table C-5. Bottom photosynthetically-active radiation (PAR), light-extinction coefficient, transmissivity

EMAP Station ID	Station Location	Bottom Depth* (m)	Bottom Submerged PAR (µmol/m²/s)	Bottom Terrestrial PAR (µmol/m²/s)	Bottom Light-Extinct. Coeff. k (1/m)	Depth of Bottom Transmiss. Meas. (m)	Bottom Transmissivity (%)
WA99-0001	MAKAH BAY	18.5	2	1367	0.37	19.5	21.7
WA99-0002	MAKAH BAY	7.5	99	1511	0.36	8.5	70.6
WA99-0003	MAKAH BAY	9.5	21	912	0.39	9.5	66.7
WA99-0004	HOKO RIVER	4.5	257	1054	0.31	4.5	86.7
WA99-0005	OZETTE RIVER	station not sampled					
WA99-0006	FRESHWATER BAY	19.5	11	1228	0.24	20.5	78.1
WA99-0007	FRESHWATER BAY	22.0	19	1579	0.20	21.5	71.6
WA99-0008	FRESHWATER BAY	12.5	54	1631	0.27	14.0	49.5
WA99-0009	DUNGENESS BAY	2.0	51	200	0.69	3.0	63.4
WA99-0010	DISCOVERY BAY	6.0	251	1472	0.30	5.0	75.7
WA99-0011	DISCOVERY BAY	23.0	1	263	0.23	22.0	85.5
WA99-0012	DISCOVERY BAY	17.0	24	1534	0.25	18.0	87.6
WA99-0013	DISCOVERY BAY	19.0	18	1787	0.24	20.0	12.4
WA99-0014	DISCOVERY BAY	1.5	47	285	1.20	2.5	54.9
WA99-0015	KALALOCH CREEK	no bottom PAR				not sampled with CTD	
WA99-0016	RAFT RIVER	no bottom PAR				not sampled with CTD	
WA99-0017	QUINAULT RIVER	no bottom PAR				not sampled with CTD	
WA99-0018	QUINAULT RIVER	station not sampled					
WA99-0019	CONNER CREEK	no bottom PAR				not sampled with CTD	
WA99-0020	GRAYS HARBOR	3.5	18	648	1.03	4.0	11.3
WA99-0021	GRASS CREEK	1.0	18	201	2.44	2.0	1.5
WA99-0022	GRAYS HARBOR	no PAR measurements				5.5	1.0
WA99-0023	GRAYS HARBOR	13.0	no SubPAR	682		14.0	49.8
WA99-0024	GRAYS HARBOR	5.0	94	1002	0.47	5.0	56.4
WA99-0025	GRAYS HARBOR	6.5	no SubPAR	690		8.0	5.9
WA99-0026	GRAYS HARBOR	12.5	no SubPAR	190		13.0	67.6
WA99-0027	BEARDSLEE SLOUGH	1.0	101	399	1.37	2.5	41.3
WA99-0028	BEARDSLEE SLOUGH	station not sampled					
WA99-0029	GRAYS HARBOR	1.0	80	no TerPAR		2.5	43.2
WA99-0030	WILLAPA BAY	17.5	0	1222	cannot calculate	17.0	40.8
WA99-0031	WILLAPA BAY	3.0	no SubPAR	776		4.0	39.9
WA99-0032	WILLAPA BAY	station not sampled					
WA99-0033	WILLAPA BAY	16.0	2	1459	0.40	16.0	61.7
WA99-0034	WILLAPA BAY	2.5	no SubPAR	622		3.5	53.5
WA99-0035	WILLAPA BAY	1.5	59	341	1.17	2.5	39.6

EMAP Station ID	Station Location	Bottom Depth* (m)	Bottom Submerged PAR (µmol/m²/s)	Bottom Terrestrial PAR (µmol/m²/s)	Bottom Light-Extinct. Coeff. k (1/m)	Depth of Bottom Transmiss. Meas. (m)	Bottom Transmissivity (%)
WA99-0036	WILLAPA BAY	8.5	3	1013	0.69	9.0	51.6
WA99-0037	WILLAPA BAY	station not sampled					
WA99-0038	BAKER BAY	1.0	231	no TerPAR		2.0	33.4
WA99-0039	BAKER BAY	1.0	67	339	1.62	2.5	36.4
WA99-0040	BAKER BAY	1.0	1363	1730	0.24	1.0	52.9
WA99-0041	GRAYS RIVER	station not sampled					
WA99-0042	BAKER BAY	8.5	1	1185	0.91	8.5	35.7
WA99-0043	GRAYS BAY	3.0	270	1675	0.61	4.0	50.5
WA99-0044	GRAYS BAY	1.0	574	808	0.34	2.5	57.3
WA99-0045	GRAYS BAY	no bottom PAR				1.0	59.3
WA99-0046	GRAYS BAY	10.0	0	276	0.79	10.5	58.4
WA99-0047	GRAYS BAY	no bottom PAR				0.5	64.9
WA99-0048	COWLITZ RIVER	3.0	97	1525	0.92	3.5	51.3
WA99-0049	CARROLLS CHANNEL	3.5	32	1298	1.06	4.0	39.4
WA99-0050	MARTIN SLOUGH	6.0	0	954	1.40	6.5	11.9

* Approximately 0.5 m above seabed

Table C-6. Water-column mean TSS, chlorophyll-*a* , phaeopigments, dissolved nutrients, N:P ratio

EMAP Station ID	Station Location	TSS (mg/L)	Chl-a (µg/L)	Phaeo (µg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0001	MAKAH BAY	5.3	12.9	3.8	6.42	2.96	144.17	43.32	1275.35	10.97	1.40	7.85
WA99-0002	MAKAH BAY	3.7	3.0	6.0	18.42	4.89	206.01	49.03	1053.86	16.38	1.58	10.36
WA99-0003	MAKAH BAY	5.0	2.3	8.2	24.52	5.45	234.70	53.14	1119.81	18.90	1.71	11.03
WA99-0004	HOKO RIVER	3.0	1.1	1.3	11.12	4.33	347.85	64.52	1408.29	25.95	2.08	12.47
WA99-0005	OZETTE RIVER	station not sampled										
WA99-0006	FRESHWATER BAY	4.0	3.8	1.6	2.41	3.58	355.06	64.87	1395.82	25.79	2.09	12.32
WA99-0007	FRESHWATER BAY	4.0	5.6	1.7	2.18	4.11	330.74	60.72	1340.88	24.07	1.96	12.29
WA99-0008	FRESHWATER BAY	4.3	6.0	1.3	2.62	4.19	318.08	58.99	1296.25	23.21	1.90	12.19
WA99-0009	DUNGENESS BAY	4.0	4.0	2.5	30.37	3.74	94.06	44.99	1172.49	9.15	1.45	6.31
WA99-0010	DISCOVERY BAY	6.7	3.6	1.3	10.12	4.77	192.43	48.39	1227.65	14.81	1.56	9.49
WA99-0011	DISCOVERY BAY	2.7	6.3	1.0	7.76	4.26	164.45	44.30	1165.52	12.60	1.43	8.82
WA99-0012	DISCOVERY BAY	3.7	3.9	0.5	14.52	3.35	104.93	39.45	1136.96	8.77	1.27	6.89
WA99-0013	DISCOVERY BAY	3.5	3.3	1.0	44.83	3.58	142.44	51.40	1394.06	13.63	1.66	8.22
WA99-0014	DISCOVERY BAY	8.0	31.1	3.5	0.65	1.14	2.22	29.44	1267.09	0.29	0.95	0.30
WA99-0015	KALALOCH CREEK	4.0	0.9	1.3	9.77	0.00	12.58	4.21	876.43	1.60	0.14	11.76
WA99-0016	RAFT RIVER	7.5	4.7	8.3	20.69	0.62	3.53	9.65	372.04	1.77	0.31	5.70
WA99-0017	QUINAULT RIVER	40.0	9.2	10.6	12.05	0.16	1.94	3.73	865.95	1.01	0.12	8.40
WA99-0018	QUINAULT RIVER	station not sampled										
WA99-0019	CONNER CREEK	3.0	3.2	4.5	48.01	1.65	0.00	43.71	4233.71	3.55	1.41	2.52
WA99-0020	GRAYS HARBOR	11.3	4.5	2.3	16.53	2.33	66.92	33.34	1714.33	6.13	1.08	5.70
WA99-0021	GRASS CREEK	35.5	4.1	4.6	9.53	0.91	5.88	22.15	1791.86	1.17	0.71	1.63
WA99-0022	GRAYS HARBOR	16.3	3.8	3.2	44.51	3.83	67.39	32.31	1841.11	8.27	1.04	7.93
WA99-0023	GRAYS HARBOR	6.0	4.9	2.2	25.17	2.71	65.01	33.24	1520.61	6.63	1.07	6.19
WA99-0024	GRAYS HARBOR	7.0	3.5	1.8	14.29	3.22	163.59	42.94	1518.45	12.94	1.39	9.34
WA99-0025	GRAYS HARBOR	13.7	2.9	2.2	57.35	4.76	84.62	29.42	1908.15	10.48	0.95	11.04
WA99-0026	GRAYS HARBOR	5.3	7.6	2.7	19.43	3.13	101.29	33.76	1372.01	8.85	1.09	8.12
WA99-0027	BEARDSLEE SLOUGH	7.5	4.0	2.1	12.82	1.54	16.53	26.48	1868.69	2.21	0.85	2.58
WA99-0028	BEARDSLEE SLOUGH	station not sampled										
WA99-0029	GRAYS HARBOR	6.0	8.1	1.6	24.45	0.84	35.03	13.48	1462.09	4.31	0.43	9.91
WA99-0030	WILLAPA BAY	9.0	14.3	9.3	5.04	2.86	110.61	46.30	1155.84	8.47	1.49	5.67
WA99-0031	WILLAPA BAY	8.7	4.3	2.7	7.52	0.70	0.70	19.82	1273.51	0.64	0.64	1.00
WA99-0032	WILLAPA BAY	station not sampled										
WA99-0033	WILLAPA BAY	6.0	15.6	4.3	2.08	2.69	130.68	47.25	1104.52	9.68	1.52	6.35
WA99-0034	WILLAPA BAY	7.3	6.4	3.6	2.24	0.19	1.21	19.10	968.35	0.26	0.62	0.42
WA99-0035	WILLAPA BAY	11.0	1.4	2.7	11.78	1.05	0.00	37.78	935.20	0.92	1.22	0.75

EMAP Station ID	Station Location	TSS (mg/L)	Chl-a (µg/L)	Phaeo (µg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0036	WILLAPA BAY	9.3	0.6	0.7	2.77	0.46	0.00	43.57	1153.37	0.23	1.41	0.16
WA99-0037	WILLAPA BAY	station not sampled										
WA99-0038	BAKER BAY	6.0	2.2	2.2	51.07	2.24	111.66	24.63	1391.16	11.78	0.79	14.83
WA99-0039	BAKER BAY	15.0	3.2	4.2	43.81	2.11	117.57	24.30	1002.67	11.68	0.78	14.90
WA99-0040	BAKER BAY	5.5	2.1	2.4	51.34	1.52	102.48	22.71	3130.84	11.10	0.73	15.15
WA99-0041	GRAYS RIVER	station not sampled										
WA99-0042	BAKER BAY	8.7	3.8	4.4	39.03	1.67	102.42	20.32	1339.09	10.22	0.66	15.59
WA99-0043	GRAYS BAY	4.0	3.5	2.9	15.19	0.82	54.91	8.43	4094.41	5.07	0.27	18.63
WA99-0044	GRAYS BAY	4.0	3.9	1.7	12.17	0.69	55.68	8.66	3954.65	4.90	0.28	17.53
WA99-0045	GRAYS BAY	3.0	4.8	2.2	12.88	0.35	85.96	9.58	4208.84	7.09	0.31	22.93
WA99-0046	GRAYS BAY	3.0	3.4	3.1	13.23	0.78	79.07	8.91	4091.12	6.65	0.29	23.14
WA99-0047	GRAYS BAY	2.0	4.0	2.3	11.92	0.42	96.52	10.93	3183.20	7.78	0.35	22.05
WA99-0048	COWLITZ RIVER	6.0	1.2	0.6	7.72	0.00	35.03	0.53	5992.28	3.05	0.02	178.62
WA99-0049	CARROLLS CHANNEL	8.0	7.0	2.1	15.78	0.91	96.13	10.01	3915.87	8.06	0.32	24.96
WA99-0050	MARTIN SLOUGH	11.8	12.7	2.9	11.19	0.55	49.08	3.88	3763.87	4.34	0.13	34.68

Table C-7. Surface TSS, chlorophyll-*a* , phaeopigments, dissolved nutrients, N:P ratio

EMAP Station ID	Station Location	Depth Sampled (m)	TSS (mg/L)	Chl-a (µg/L)	Phaeo (µg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0001	MAKAH BAY	0.5	5	28.9	0.0	0.00	0.95	0.00	11.80	1124.78	0.07	0.38	0.18
WA99-0002	MAKAH BAY	0.5	3	2.4	3.7	18.97	5.20	182.90	46.21	999.74	14.79	1.49	9.92
WA99-0003	MAKAH BAY	0.5	5	0.0	6.2	24.67	5.54	230.00	52.61	1121.08	18.59	1.70	10.95
WA99-0004	HOKO RIVER	0.5	5	1.0	1.2	11.80	4.38	349.35	63.11	1459.73	26.11	2.04	12.83
WA99-0005	OZETTE RIVER	station not sampled											
WA99-0006	FRESHWATER BAY	0.5	3	4.2	0.8	5.22	4.28	266.19	53.80	1224.32	19.69	1.74	11.35
WA99-0007	FRESHWATER BAY	0.5	3	6.1	1.1	2.98	4.44	300.94	56.69	1290.92	22.03	1.83	12.04
WA99-0008	FRESHWATER BAY	0.5	2	6.7	0.9	2.98	4.43	301.19	55.97	1260.35	22.04	1.81	12.21
WA99-0009	DUNGENESS BAY	0.5	4	1.7	1.8	28.14	3.55	81.05	43.42	1258.03	8.05	1.40	5.75
WA99-0010	DISCOVERY BAY	0.5	6	3.0	1.2	10.80	4.71	187.21	47.87	1222.62	14.48	1.54	9.38
WA99-0011	DISCOVERY BAY	0.5	3	7.5	1.4	4.29	3.59	103.41	37.02	1139.70	7.95	1.19	6.66
WA99-0012	DISCOVERY BAY	0.5	3	7.2	0.9	4.82	1.66	17.42	26.85	1122.34	1.71	0.87	1.97
WA99-0013	DISCOVERY BAY	0.5	3.5	7.5	1.4	2.92	0.51	0.00	24.43	1346.75	0.25	0.79	0.31
WA99-0014	DISCOVERY BAY	0.5	7	34.7	4.0	0.82	1.17	2.83	31.79	1273.39	0.34	1.03	0.34
WA99-0015	KALALOCH CREEK	0.5	4	0.9	1.3	9.77	0.00	12.58	4.21	876.43	1.60	0.14	11.76
WA99-0016	RAFT RIVER	0.5	7.5	4.7	8.3	20.69	0.62	3.53	9.65	372.04	1.77	0.31	5.70
WA99-0017	QUINAULT RIVER	0.5	40	9.2	10.6	12.05	0.16	1.94	3.73	865.95	1.01	0.12	8.40
WA99-0018	QUINAULT RIVER	station not sampled											
WA99-0019	CONNER CREEK	0.5	3	3.2	4.5	48.01	1.65	0.00	43.71	4233.71	3.55	1.41	2.52
WA99-0020	GRAYS HARBOR	0.5	8	4.5	1.8	13.03	1.68	34.88	27.87	1760.40	3.54	0.90	3.94
WA99-0021	GRASS CREEK	0.5	31	4.5	4.1	9.53	0.98	6.86	22.30	1763.49	1.24	0.72	1.73
WA99-0022	GRAYS HARBOR	0.5	7	3.0	1.7	49.60	3.92	62.06	31.59	1948.04	8.26	1.02	8.10
WA99-0023	GRAYS HARBOR	0.5	6	5.4	1.8	11.35	2.24	35.03	27.56	1627.82	3.47	0.89	3.91
WA99-0024	GRAYS HARBOR	0.5	6	0.0	0.0	16.25	3.22	39.37	26.63	1747.48	4.20	0.86	4.89
WA99-0025	GRAYS HARBOR	0.5	7	3.3	1.8	55.06	5.04	98.49	26.01	1583.43	11.33	0.84	13.50
WA99-0026	GRAYS HARBOR	0.5	5	7.5	2.4	19.75	3.36	47.91	28.80	1841.86	5.07	0.93	5.46
WA99-0027	BEARDSLEE SLOUGH	0.5	7	4.2	2.3	11.63	1.40	13.45	25.09	1969.11	1.89	0.81	2.34
WA99-0028	BEARDSLEE SLOUGH	station not sampled											
WA99-0029	GRAYS HARBOR	0.5	6	6.3	1.4	25.50	0.84	36.01	13.32	1441.30	4.45	0.43	10.37
WA99-0030	WILLAPA BAY	0.5	6	13.0	4.9	2.40	2.54	88.57	41.16	1031.20	6.68	1.33	5.03
WA99-0031	WILLAPA BAY	0.5	9	4.5	2.7	7.85	0.70	1.12	19.82	1276.69	0.69	0.64	1.08
WA99-0032	WILLAPA BAY	station not sampled											
WA99-0033	WILLAPA BAY	0.5	5	15.6	2.5	0.00	2.20	44.54	31.75	845.35	3.34	1.02	3.26
WA99-0034	WILLAPA BAY	0.5	7	6.6	3.3	2.24	0.28	2.24	19.82	1068.26	0.34	0.64	0.53
WA99-0035	WILLAPA BAY	0.5	10.5	1.4	2.8	11.77	1.05	0.00	37.78	933.04	0.92	1.22	0.75

EMAP Station ID	Station Location	Depth Sampled (m)	TSS (mg/L)	Chl-a (µg/L)	Phaeo (µg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0036	WILLAPA BAY	0.5	8	0.0	0.0	2.99	0.42	0.00	43.93	1188.65	0.24	1.42	0.17
WA99-0037	WILLAPA BAY	station not sampled											
WA99-0038	BAKER BAY	0.5	6	2.2	2.3	50.02	2.24	110.82	24.47	1023.60	11.65	0.79	14.76
WA99-0039	BAKER BAY	0.5	14	3.3	4.1	42.08	2.08	117.99	24.12	1144.90	11.58	0.78	14.89
WA99-0040	BAKER BAY	0.5	5	2.1	2.4	51.45	1.52	102.49	22.83	2686.37	11.10	0.74	15.08
WA99-0041	GRAYS RIVER	station not sampled											
WA99-0042	BAKER BAY	0.5	7	4.3	4.4	23.43	1.10	96.20	15.60	1341.42	8.62	0.50	17.14
WA99-0043	GRAYS BAY	0.5	4	3.3	2.9	14.25	1.51	56.26	8.60	4103.76	5.14	0.28	18.54
WA99-0044	GRAYS BAY	0.5	4	3.7	1.7	12.80	0.72	56.03	8.60	3951.70	4.97	0.28	17.91
WA99-0045	GRAYS BAY	0.5	3	4.8	2.2	12.88	0.35	85.96	9.58	4208.84	7.09	0.31	22.93
WA99-0046	GRAYS BAY	0.5	3	3.5	3.1	14.82	0.83	79.55	8.92	4172.49	6.80	0.29	23.63
WA99-0047	GRAYS BAY	0.5	2	4.0	2.3	11.92	0.42	96.52	10.93	3183.20	7.78	0.35	22.05
WA99-0048	COWLITZ RIVER	0.5	6	1.1	0.6	6.46	0.00	34.78	0.14	5193.64	2.95	0.00	652.27
WA99-0049	CARROLLS CHANNEL	0.5	6	6.5	1.8	15.40	1.21	96.35	9.78	3941.96	8.07	0.32	25.58
WA99-0050	MARTIN SLOUGH	0.5	11	19.1	3.2	15.16	0.83	93.50	8.59	3845.80	7.82	0.28	28.22

Table C-8. Mid-water TSS, chlorophyll-*a* , phaeopigments, dissolved nutrients, N:P ratio

EMAP Station ID	Station Location	Depth Sampled (m)	TSS (mg/L)	Chl-a (µg/L)	Phaeo (µg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0001	MAKAH BAY	10	4	7.1	3.8	8.92	4.33	177.32	52.62	1242.27	13.61	1.70	8.02
WA99-0002	MAKAH BAY	4.5	3	3.6	5.7	19.05	4.93	212.63	49.84	1087.08	16.90	1.61	10.51
WA99-0003	MAKAH BAY	5	4	3.3	8.3	26.58	5.53	237.95	53.58	1119.81	19.29	1.73	11.16
WA99-0004	HOKO RIVER	2.5	2	1.2	1.5	11.05	4.38	344.22	64.92	1383.27	25.69	2.09	12.27
WA99-0005	OZETTE RIVER	station not sampled											
WA99-0006	FRESHWATER BAY	10	5	4.2	1.7	2.00	3.56	371.74	67.09	1412.60	26.95	2.16	12.45
WA99-0007	FRESHWATER BAY	11	6	5.8	1.7	1.45	3.98	344.71	62.37	1367.95	25.01	2.01	12.43
WA99-0008	FRESHWATER BAY	7	6	5.8	1.4	2.71	4.10	311.76	58.27	1278.57	22.76	1.88	12.11
WA99-0009	DUNGENESS BAY	no mid-water sample											
WA99-0010	DISCOVERY BAY	3.5	8	3.8	1.5	11.07	4.83	197.66	49.44	1217.83	15.25	1.59	9.57
WA99-0011	DISCOVERY BAY	11	3	6.1	0.8	11.22	4.93	225.48	51.57	1191.34	17.26	1.66	10.38
WA99-0012	DISCOVERY BAY	9	6	0.0	0.0	18.20	4.06	138.31	44.73	1137.90	11.47	1.44	7.95
WA99-0013	DISCOVERY BAY	10	3	1.3	0.3	47.39	4.60	191.37	58.61	1314.46	17.38	1.89	9.19
WA99-0014	DISCOVERY BAY	no mid-water sample											
WA99-0015	KALALOCH CREEK	no mid-water sample											
WA99-0016	RAFT RIVER	no mid-water sample											
WA99-0017	QUINAULT RIVER	no mid-water sample											
WA99-0018	QUINAULT RIVER	station not sampled											
WA99-0019	CONNER CREEK	no mid-water sample											
WA99-0020	GRAYS HARBOR	2	12	4.3	2.1	19.05	2.80	80.00	36.54	1671.64	7.28	1.18	6.17
WA99-0021	GRASS CREEK	no mid-water sample											
WA99-0022	GRAYS HARBOR	3	12	4.7	2.7	37.55	3.78	66.41	31.59	1828.38	7.70	1.02	7.55
WA99-0023	GRAYS HARBOR	6	5	4.7	2.0	30.40	2.80	65.43	34.38	1510.40	7.05	1.11	6.35
WA99-0024	GRAYS HARBOR	2.5	9	5.8	2.4	12.61	3.08	202.30	48.00	1384.28	15.57	1.55	10.06
WA99-0025	GRAYS HARBOR	3.5	14	2.7	2.1	59.96	4.76	80.98	30.66	2006.75	10.41	0.99	10.52
WA99-0026	GRAYS HARBOR	6	5	7.1	2.3	21.30	2.94	95.97	32.21	1196.91	8.59	1.04	8.26
WA99-0027	BEARDSLEE SLOUGH	no mid-water sample											
WA99-0028	BEARDSLEE SLOUGH	station not sampled											
WA99-0029	GRAYS HARBOR	no mid-water sample											
WA99-0030	WILLAPA BAY	9	8	14.4	8.9	5.09	2.86	117.72	46.36	1170.04	8.98	1.50	6.00
WA99-0031	WILLAPA BAY	2	9	4.2	2.7	7.15	0.70	0.70	19.82	1329.50	0.61	0.64	0.96
WA99-0032	WILLAPA BAY	station not sampled											
WA99-0033	WILLAPA BAY	8	6	14.4	4.2	2.83	2.84	162.57	53.85	1214.21	12.02	1.74	6.92
WA99-0034	WILLAPA BAY	1	8	6.4	3.8	2.38	0.14	0.98	19.20	912.36	0.25	0.62	0.40
WA99-0035	WILLAPA BAY	no mid-water sample											

EMAP Station ID	Station Location	Depth Sampled (m)	TSS (mg/L)	Chl-a (µg/L)	Phaeo (µg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0036	WILLAPA BAY	4.5	10	0.8	1.0	2.86	0.48	0.00	43.81	1165.30	0.24	1.41	0.17
WA99-0037	WILLAPA BAY	station not sampled											
WA99-0038	BAKER BAY	no mid-water sample											
WA99-0039	BAKER BAY	no mid-water sample											
WA99-0040	BAKER BAY	no mid-water sample											
WA99-0041	GRAYS RIVER	station not sampled											
WA99-0042	BAKER BAY	4.5	9	3.9	5.1	30.58	1.42	101.16	18.26	1456.85	9.51	0.59	16.15
WA99-0043	GRAYS BAY	2	4	3.3	3.0	16.39	0.41	55.06	9.20	4066.03	5.13	0.30	17.30
WA99-0044	GRAYS BAY	no mid-water sample											
WA99-0045	GRAYS BAY	no mid-water sample											
WA99-0046	GRAYS BAY	5.5	3	3.2	2.9	12.24	0.76	78.08	8.66	4057.04	6.51	0.28	23.29
WA99-0047	GRAYS BAY	no mid-water sample											
WA99-0048	COWLITZ RIVER	1.5	6	1.1	0.6	8.81	0.00	34.76	0.73	6358.45	3.11	0.02	132.16
WA99-0049	CARROLLS CHANNEL	2	8	7.1	2.3	16.43	0.76	96.03	10.25	3908.16	8.09	0.33	24.46
WA99-0050	MARTIN SLOUGH	3.5	10	10.6	2.8	10.21	0.63	49.00	2.63	3770.24	4.27	0.08	50.38

Table C-9. Bottom TSS, chlorophyll-*a* , phaeopigments, dissolved nutrients, N:P ratio

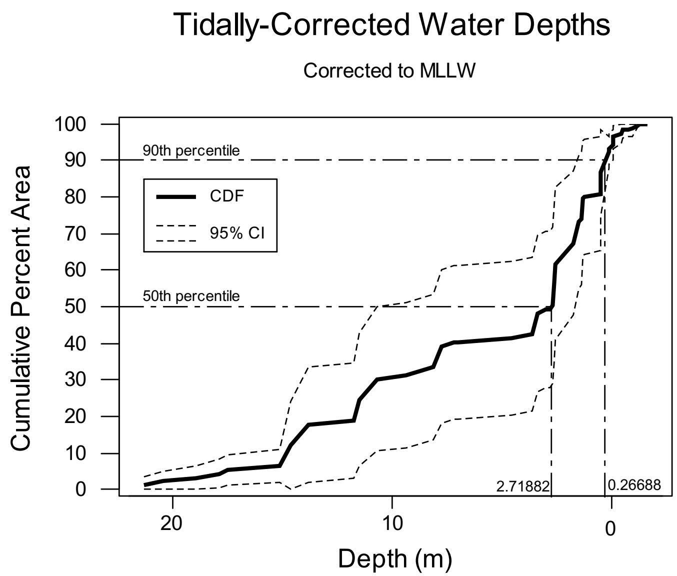
EMAP Station ID	Station Location	Depth Sampled (m)	TSS (µg/L)	Chl-a (µg/L)	Phaeo (mg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0001	MAKAH BAY	18.5	7	2.8	7.5	10.34	3.61	255.19	65.55	1459.00	19.22	2.11	9.09
WA99-0002	MAKAH BAY	7.5	5	3.0	8.5	17.24	4.54	222.51	51.05	1074.77	17.45	1.65	10.60
WA99-0003	MAKAH BAY	9.5	6	3.8	10.1	22.31	5.27	236.15	53.22	1118.55	18.84	1.72	10.97
WA99-0004	HOKO RIVER	4.5	2	1.0	1.2	10.50	4.24	349.99	65.53	1381.88	26.05	2.11	12.32
WA99-0005	OZETTE RIVER	station not sampled											
WA99-0006	FRESHWATER BAY	19.5	4	2.9	2.5	0.00	2.91	427.25	73.73	1550.53	30.73	2.38	12.92
WA99-0007	FRESHWATER BAY	22	3	5.0	2.3	2.10	3.91	346.57	63.09	1363.76	25.18	2.04	12.38
WA99-0008	FRESHWATER BAY	12.5	5	5.4	1.5	2.16	4.03	341.30	62.74	1349.83	24.82	2.02	12.26
WA99-0009	DUNGENESS BAY	2	4	6.2	3.2	32.59	3.93	107.06	46.56	1086.95	10.26	1.50	6.83
WA99-0010	DISCOVERY BAY	6	6	4.0	1.4	8.48	4.76	192.41	47.85	1242.49	14.69	1.54	9.52
WA99-0011	DISCOVERY BAY	23	2	5.4	0.9	11.22	4.93	225.48	51.57	1191.34	17.26	1.66	10.38
WA99-0012	DISCOVERY BAY	17	2	4.5	0.5	20.53	4.32	159.06	46.78	1150.64	13.14	1.51	8.71
WA99-0013	DISCOVERY BAY	19	4	1.1	1.3	84.19	5.63	235.95	71.17	1520.97	23.27	2.30	10.14
WA99-0014	DISCOVERY BAY	1.5	9	27.5	2.9	0.48	1.10	1.61	27.08	1260.78	0.23	0.87	0.26
WA99-0015	KALALOCH CREEK	no bottom sample											
WA99-0016	RAFT RIVER	no bottom sample											
WA99-0017	QUINAULT RIVER	no bottom sample											
WA99-0018	QUINAULT RIVER	station not sampled											
WA99-0019	CONNER CREEK	no bottom sample											
WA99-0020	GRAYS HARBOR	3.5	14	4.7	3.1	17.51	2.52	85.88	35.62	1710.96	7.57	1.15	6.58
WA99-0021	GRASS CREEK	1	40	3.8	5.1	9.53	0.84	4.90	21.99	1820.23	1.09	0.71	1.54
WA99-0022	GRAYS HARBOR	5	30	3.9	5.3	46.37	3.78	73.69	33.76	1746.92	8.85	1.09	8.12
WA99-0023	GRAYS HARBOR	13	7	4.5	3.0	33.76	3.08	94.57	37.78	1423.60	9.39	1.22	7.70
WA99-0024	GRAYS HARBOR	5	6	4.8	3.0	14.01	3.36	249.10	54.20	1423.60	19.03	1.75	10.89
WA99-0025	GRAYS HARBOR	6.5	20	2.8	2.8	57.02	4.48	74.39	31.59	2134.28	9.71	1.02	9.53
WA99-0026	GRAYS HARBOR	12.5	6	8.3	3.4	17.23	3.08	159.99	40.26	1077.25	12.88	1.30	9.92
WA99-0027	BEARDSLEE SLOUGH	1	8	3.9	1.9	14.01	1.68	19.61	27.87	1768.27	2.52	0.90	2.81
WA99-0028	BEARDSLEE SLOUGH	station not sampled											
WA99-0029	GRAYS HARBOR	1	6	9.9	1.7	23.40	0.84	34.04	13.63	1482.87	4.16	0.44	9.47
WA99-0030	WILLAPA BAY	17.5	13	15.6	14.1	7.64	3.17	125.54	51.39	1266.27	9.74	1.66	5.88
WA99-0031	WILLAPA BAY	3	8	4.2	2.7	7.57	0.70	0.28	19.82	1214.33	0.61	0.64	0.96
WA99-0032	WILLAPA BAY	station not sampled											
WA99-0033	WILLAPA BAY	16	7	16.7	6.3	3.41	3.03	184.93	56.15	1253.99	13.67	1.81	7.55
WA99-0034	WILLAPA BAY	2.5	7	6.1	3.8	2.10	0.14	0.42	18.27	924.44	0.19	0.59	0.32
WA99-0035	WILLAPA BAY	1.5	12	1.3	2.7	11.79	1.05	0.00	37.78	937.37	0.92	1.22	0.75

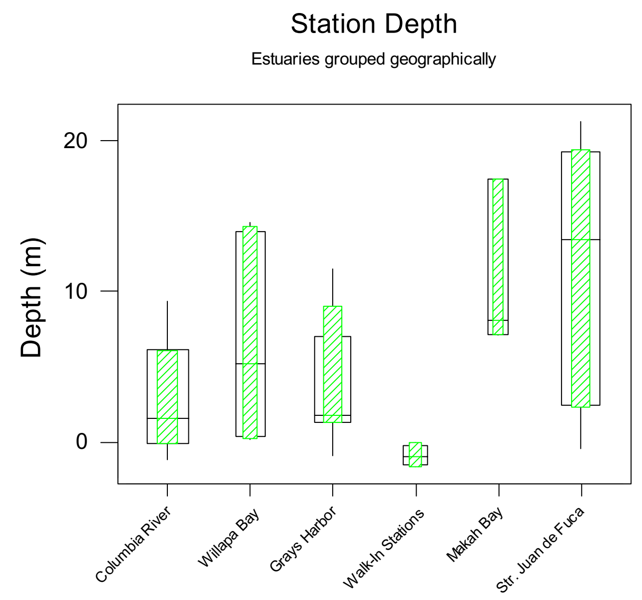
EMAP Station ID	Station Location	Depth Sampled (m)	TSS (µg/L)	Chl-a (µg/L)	Phaeo (mg/L)	Ammonium (µg/L)	Nitrite (µg/L)	Nitrate (µg/L)	Phosphate (µg/L)	Silicic Acid (µg/L)	Total Inorganic N (µM)	Total Inorganic P (µM)	N:P Ratio
WA99-0036	WILLAPA BAY	8.5	10	0.8	1.2	2.46	0.48	0.00	42.97	1106.17	0.21	1.39	0.15
WA99-0037	WILLAPA BAY	station not sampled											
WA99-0038	BAKER BAY	1	6	2.3	2.1	52.12	2.24	112.50	24.78	1758.71	11.92	0.80	14.91
WA99-0039	BAKER BAY	1	16	3.1	4.4	45.54	2.13	117.15	24.47	860.43	11.77	0.79	14.92
WA99-0040	BAKER BAY	1	6	2.1	2.4	51.23	1.51	102.47	22.58	3575.30	11.09	0.73	15.22
WA99-0041	GRAYS RIVER	station not sampled											
WA99-0042	BAKER BAY	8.5	10	3.1	3.7	63.08	2.50	109.90	27.11	1219.00	12.53	0.87	14.33
WA99-0043	GRAYS BAY	3	4	3.9	2.8	14.92	0.53	53.40	7.49	4113.45	4.92	0.24	20.35
WA99-0044	GRAYS BAY	1	4	4.1	1.6	11.54	0.65	55.32	8.71	3957.60	4.82	0.28	17.16
WA99-0045	GRAYS BAY	no bottom sample											
WA99-0046	GRAYS BAY	10	3	3.5	3.2	12.64	0.76	79.58	9.14	4043.84	6.64	0.29	22.53
WA99-0047	GRAYS BAY	no bottom sample											
WA99-0048	COWLITZ RIVER	3	6	1.4	0.7	7.89	0.00	35.56	0.72	6424.74	3.10	0.02	133.63
WA99-0049	CARROLLS CHANNEL	3.5	10	7.3	2.3	15.52	0.75	96.01	10.00	3897.49	8.02	0.32	24.86
WA99-0050	MARTIN SLOUGH	6	15	8.3	2.6	8.19	0.18	4.75	0.43	3675.58	0.94	0.01	67.56

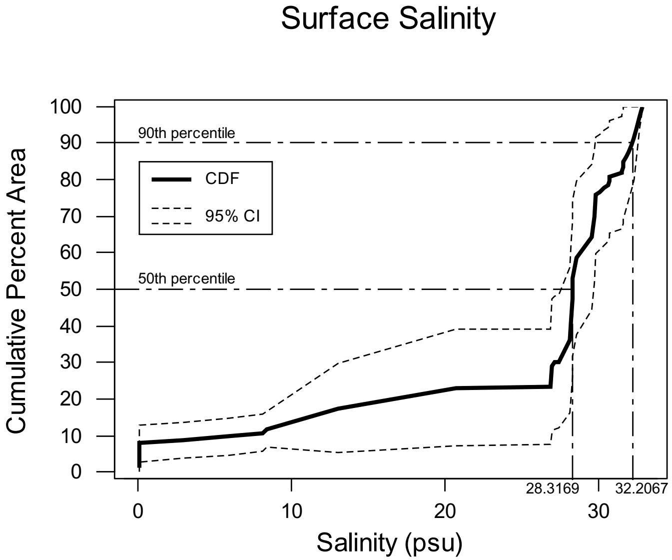
Table C-10. Sediment lithology

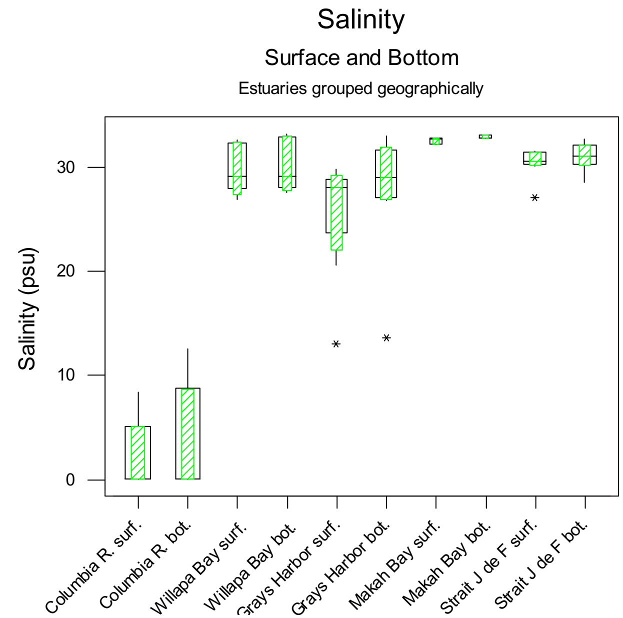
EMAP Station ID	Station Location	Silt-Clay Content (%)	TOC (%)
WA99-0001	MAKAH BAY	6.83	0.46
WA99-0002	MAKAH BAY	0.91	0.22
WA99-0003	MAKAH BAY	1.00	0.18
WA99-0004	HOKO RIVER	1.21	0.10
WA99-0005	OZETTE RIVER	station not sampled	
WA99-0006	FRESHWATER BAY	no sediment sampled	
WA99-0007	FRESHWATER BAY	9.89	0.39
WA99-0008	FRESHWATER BAY	no sediment sampled	
WA99-0009	DUNGENESS BAY	10.10	0.70
WA99-0010	DISCOVERY BAY	57.15	1.72
WA99-0011	DISCOVERY BAY	22.90	0.87
WA99-0012	DISCOVERY BAY	49.82	0.67
WA99-0013	DISCOVERY BAY	86.13	3.24
WA99-0014	DISCOVERY BAY	16.11	0.98
WA99-0015	KALALOCH CREEK	0.00	0.14
WA99-0016	RAFT RIVER	32.60	2.00
WA99-0017	QUINAULT RIVER	5.73	0.37
WA99-0018	QUINAULT RIVER	station not sampled	
WA99-0019	CONNER CREEK	0.00	0.14
WA99-0020	GRAYS HARBOR	14.65	0.54
WA99-0021	GRASS CREEK	4.86	0.17
WA99-0022	GRAYS HARBOR	40.93	0.53
WA99-0023	GRAYS HARBOR	3.10	0.07
WA99-0024	GRAYS HARBOR	1.34	0.07
WA99-0025	GRAYS HARBOR	56.36	1.70
WA99-0026	GRAYS HARBOR	0.00	non-detect
WA99-0027	BEARDSLEE SLOUGH	13.87	0.98
WA99-0028	BEARDSLEE SLOUGH	station not sampled	
WA99-0029	GRAYS HARBOR	1.38	0.15
WA99-0030	WILLAPA BAY	no sediment sampled	
WA99-0031	WILLAPA BAY	14.71	0.86
WA99-0032	WILLAPA BAY	station not sampled	
WA99-0033	WILLAPA BAY	0.00	0.02
WA99-0034	WILLAPA BAY	10.41	0.49
WA99-0035	WILLAPA BAY	34.92	0.11
WA99-0036	WILLAPA BAY	0.00	0.08
WA99-0037	WILLAPA BAY	station not sampled	
WA99-0038	BAKER BAY	7.89	0.35
WA99-0039	BAKER BAY	50.46	1.30
WA99-0040	BAKER BAY	13.90	0.39
WA99-0041	GRAYS RIVER	station not sampled	
WA99-0042	BAKER BAY	0.00	0.09
WA99-0043	GRAYS BAY	19.63	0.81
WA99-0044	GRAYS BAY	0.00	0.22
WA99-0045	GRAYS BAY	1.27	0.27
WA99-0046	GRAYS BAY	1.83	0.27
WA99-0047	GRAYS BAY	0.51	0.06
WA99-0048	COWLITZ RIVER	0.09	0.02
WA99-0049	CARROLLS CHANNEL	2.38	0.21
WA99-0050	MARTIN SLOUGH	17.27	0.85
Notes: (1) Averaged over lab replicates, if any. (2) Non-detects set to zero for EMAP analyses.			

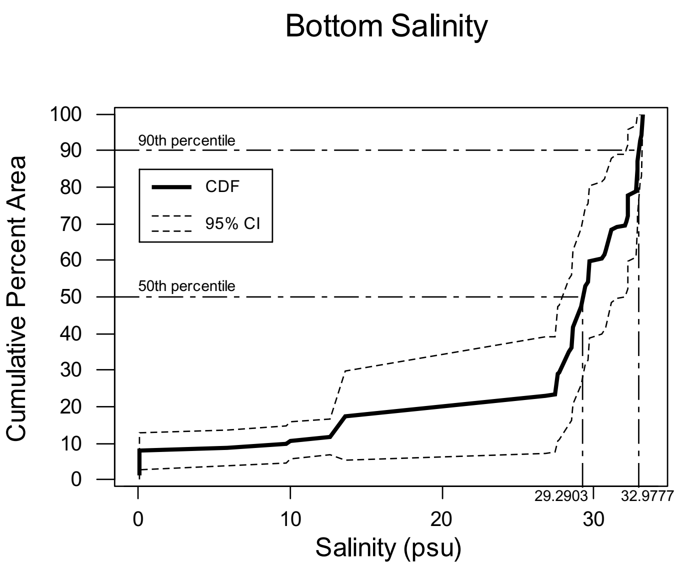
Figure C-1. Hydrographic Profile

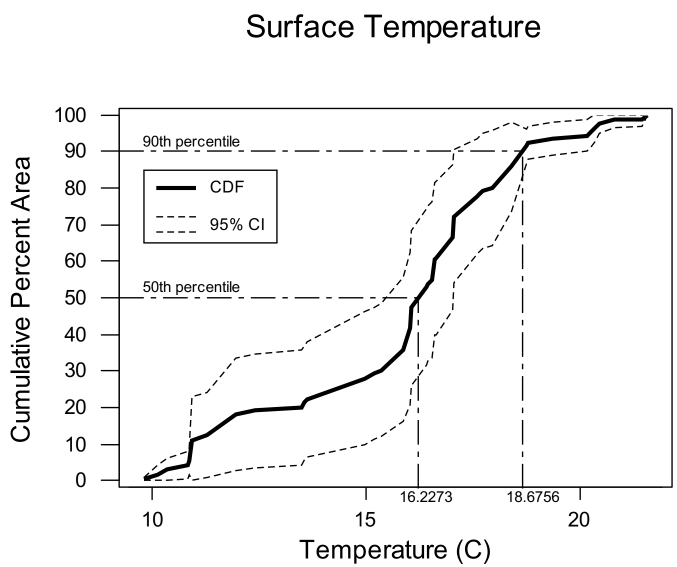




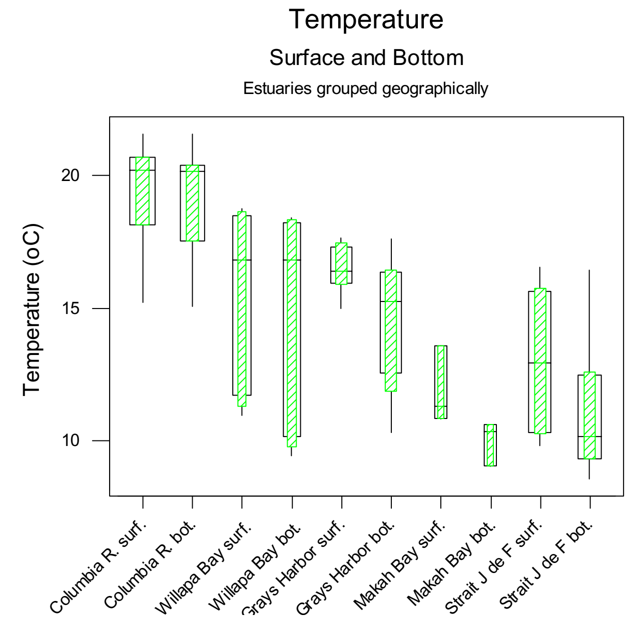

Surface Salinity
90th percentile
50th percentile
CDF
95% CI
Cumulative Percent Area
Salinity (psu)
28.3169
32.2067


Salinity
Surface and Bottom
Estuaries grouped geographically
Salinity (psu)
Columbia R. surf.
Columbia R. bot.
Willapa Bay surf.
Willapa Bay bot.
Grays Harbor surf.
Grays Harbor bot.
Makah Bay surf.
Makah Bay bot.
Strait J de F surf.
Strait J de F bot.

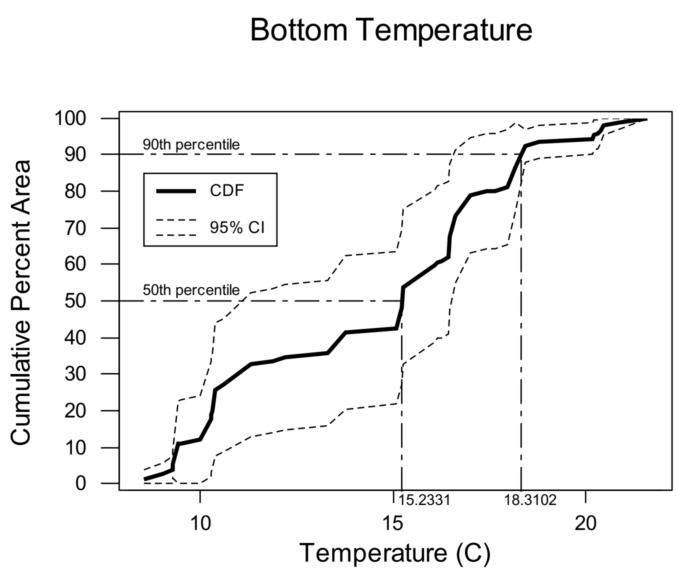

Bottom Salinity
90th percentile
50th percentile
CDF
95% CI
Cumulative Percent Area
Salinity (psu)
29.2903
32.9777



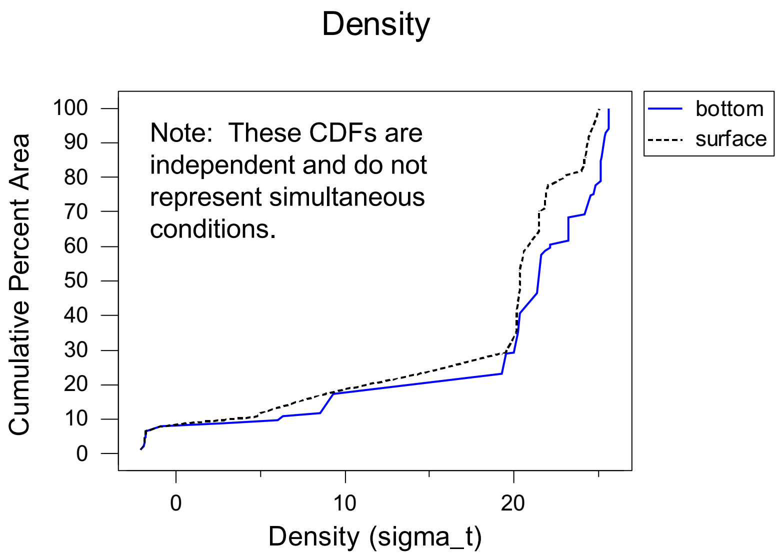
Surface Temperature
90th percentile
50th percentile
CDF
95% CI
Cumulative Percent Area
0
10
20
30
40
50
60
70
80
90
100
10
15
20
16.2273
18.6756
Temperature (C)

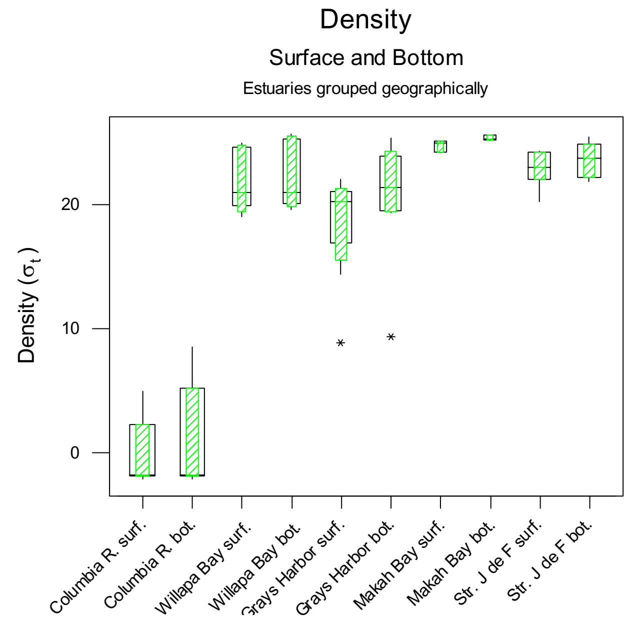


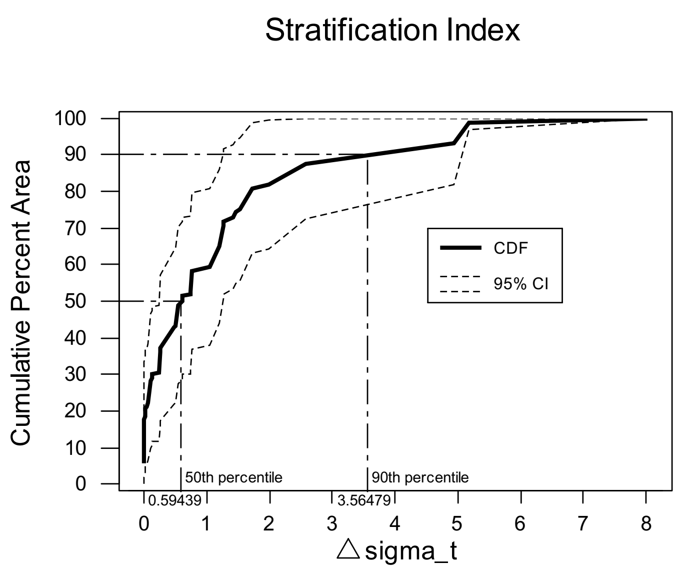
Temperature
Surface and Bottom
Estuaries grouped geographically
Temperature (oC)
10
15
20
Columbia R. surf.
Columbia R. bot.
Willapa Bay surf.
Willapa Bay bot.
Grays Harbor surf.
Grays Harbor bot.
Makah Bay surf.
Makah Bay bot.
Strait J de F surf.
Strait J de F bot.

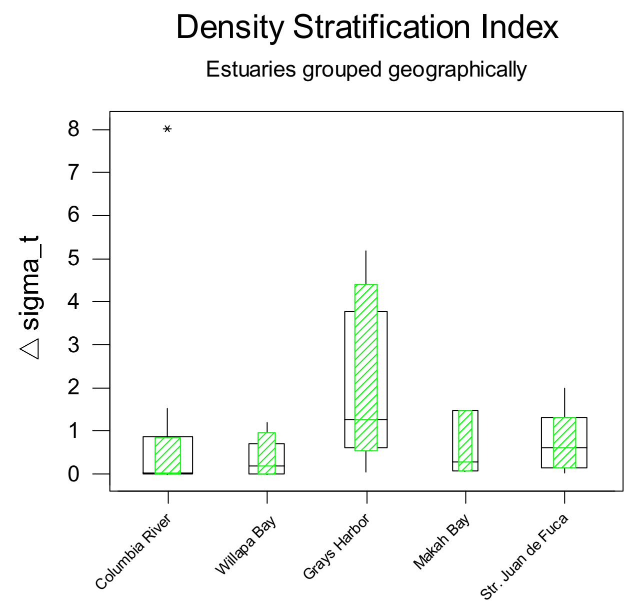


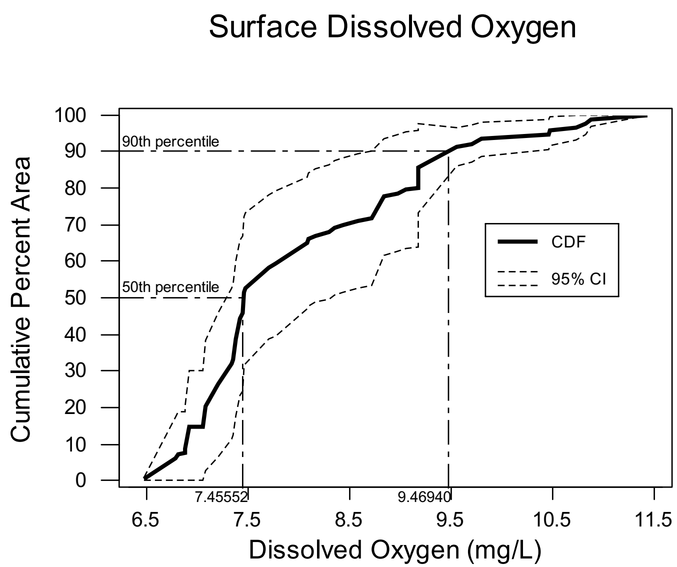
Bottom Temperature
90th percentile
50th percentile
CDF
95% CI
Cumulative Percent Area
0
10
20
30
40
50
60
70
80
90
100
10
15
20
15.2331
18.3102
Temperature (C)


Density
Note: These CDFs are independent and do not represent simultaneous conditions.
bottom
surface
Cumulative Percent Area
Density (sigma_t)

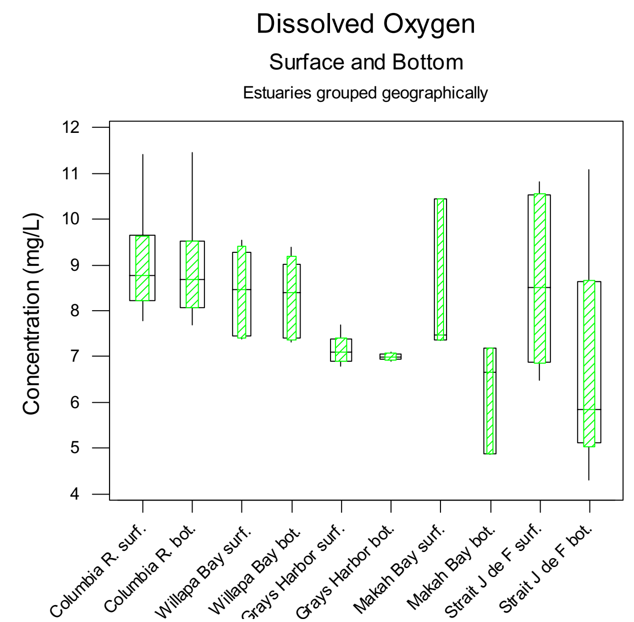

Density
Surface and Bottom
Estuaries grouped geographically
Density (σ_t)
Columbia R. surf.
Columbia R. bot.
Willapa Bay surf.
Willapa Bay bot.
Grays Harbor surf.
Grays Harbor bot.
Makah Bay surf.
Makah Bay bot.
Str. J de F surf.
Str. J de F bot.


Stratification Index
Cumulative Percent Area
CDF
95% CI
50th percentile
90th percentile
0.59439
3.56479
△ sigma_t

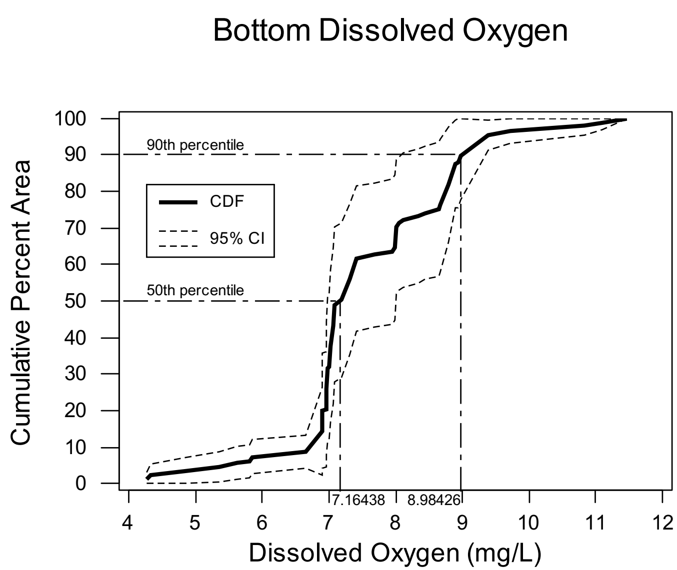

Density Stratification Index
Estuaries grouped geographically
△ sigma_t
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca



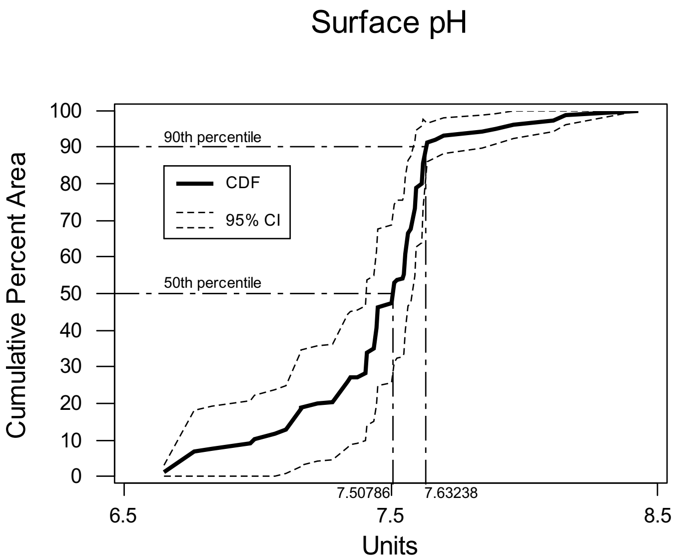
Surface Dissolved Oxygen
Cumulative Percent Area
Dissolved Oxygen (mg/L)
90th percentile
50th percentile
CDF
95% CI
7.45552
9.46940

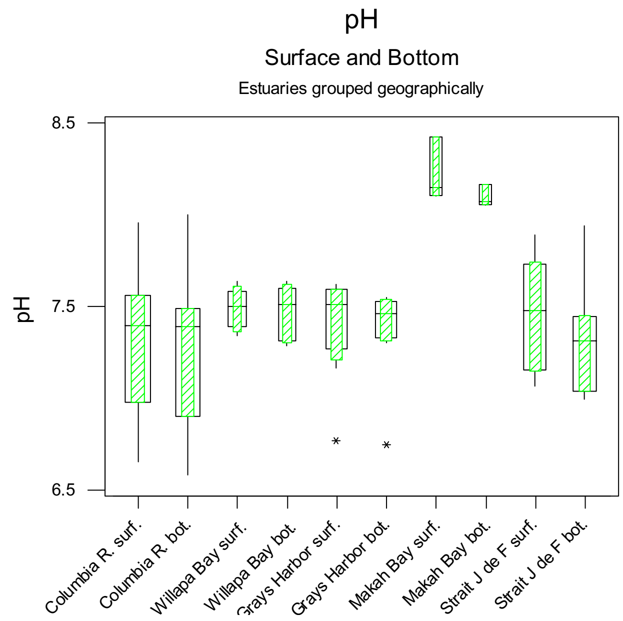


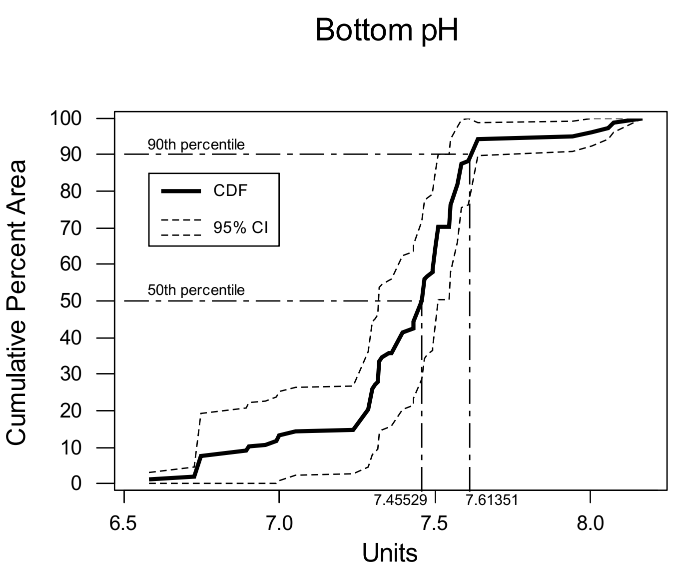
Dissolved Oxygen
Surface and Bottom
Estuaries grouped geographically
Concentration (mg/L)
Columbia R. surf.
Columbia R. bot.
Willapa Bay surf.
Willapa Bay bot.
Grays Harbor surf.
Grays Harbor bot.
Makah Bay surf.
Makah Bay bot.
Strait J de F surf.
Strait J de F bot.

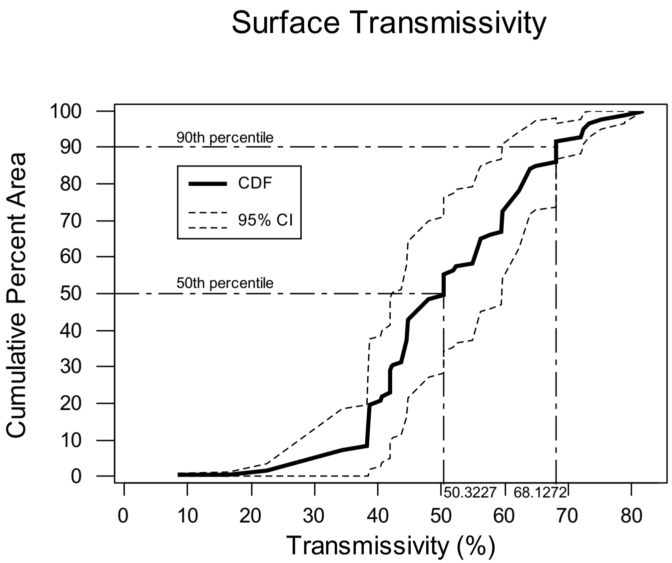


Bottom Dissolved Oxygen
Cumulative Percent Area
Dissolved Oxygen (mg/L)
90th percentile
50th percentile
CDF
95% CI
7.16438
8.98426

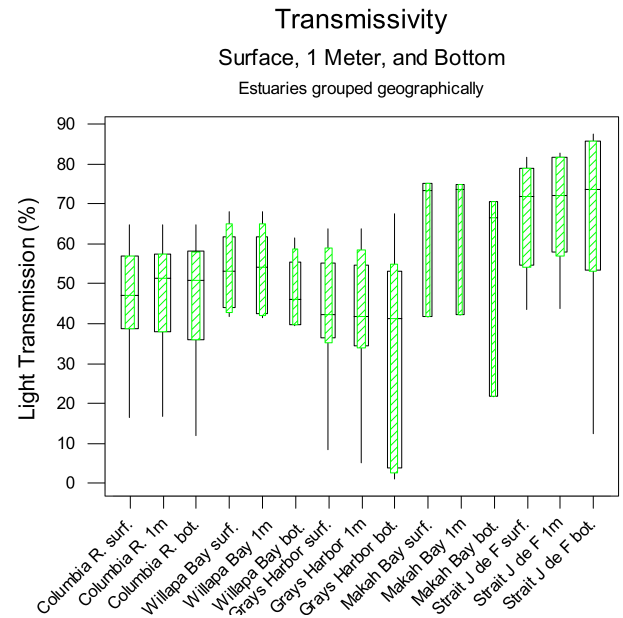

Surface pH
Cumulative Percent Area
90th percentile
50th percentile
CDF
95% CI
7.50786
7.63238
Units


pH
Surface and Bottom
Estuaries grouped geographically
pH
Columbia R. surf.
Columbia R. bot.
Willapa Bay surf.
Willapa Bay bot.
Grays Harbor surf.
Grays Harbor bot.
Makah Bay surf.
Makah Bay bot.
Strait J de F surf.
Strait J de F bot.

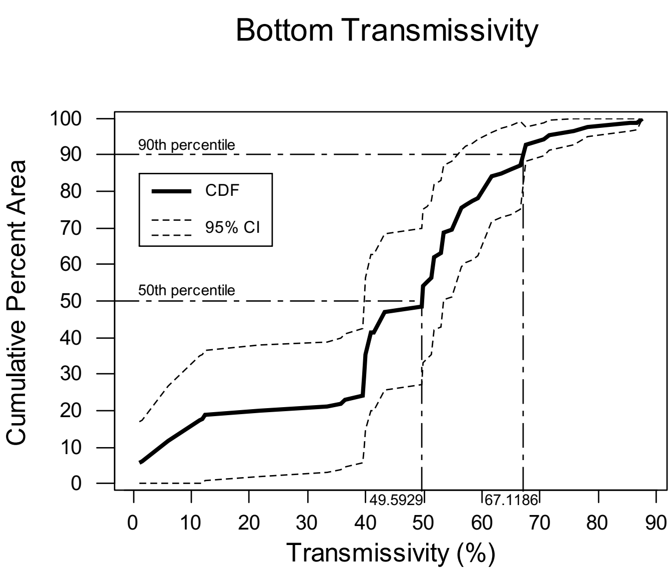

Bottom pH
Cumulative Percent Area
90th percentile
50th percentile
CDF
95% CI
7.45529
7.61351
Units



Surface Transmissivity
Cumulative Percent Area
Transmissivity (%)
90th percentile
50th percentile
CDF
95% CI
50.3227
68.1272

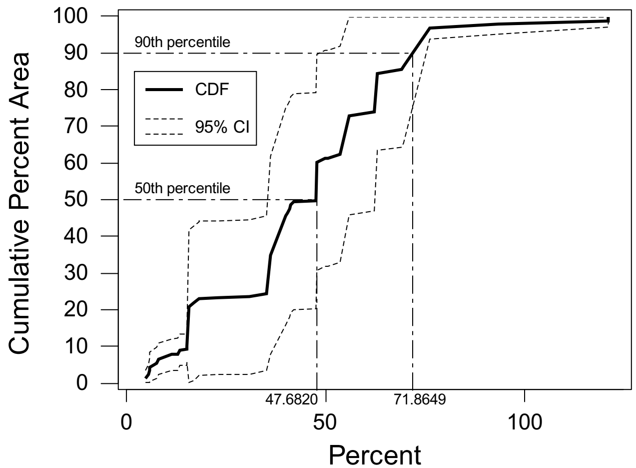


Transmissivity
Surface, 1 Meter, and Bottom
Estuaries grouped geographically
Light Transmission (%)
Columbia R. surf.
Columbia R. 1m
Columbia R. bot.
Willapa Bay surf.
Willapa Bay 1m
Willapa Bay bot.
Grays Harbor surf.
Grays Harbor 1m
Grays Harbor bot.
Makah Bay surf.
Makah Bay 1m
Makah Bay bot.
Strait J de F surf.
Strait J de F 1m
Strait J de F bot.



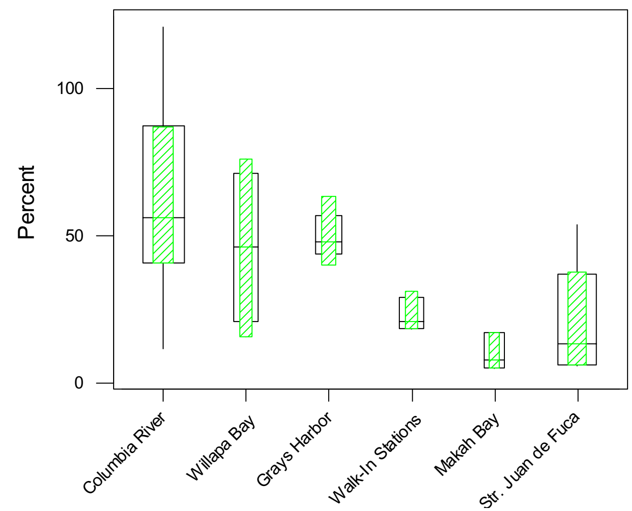
Bottom Transmissivity
Cumulative Percent Area
Transmissivity (%)
90th percentile
50th percentile
CDF
95% CI
49.5929
67.1186

Surface SubPAR as Percent of TerPAR

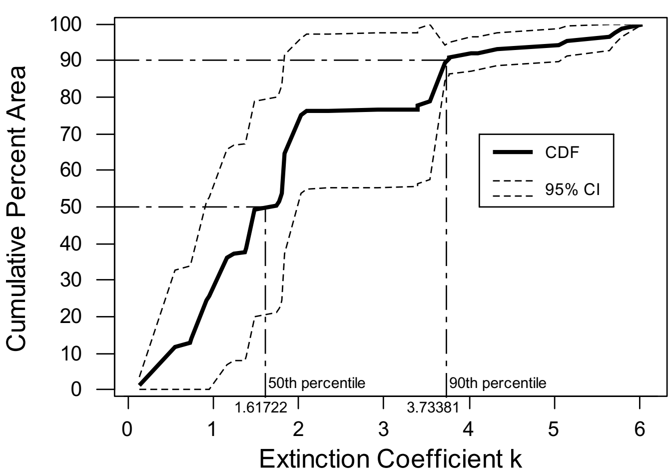


Surface SubPAR as % of TerPAR

Estuaries grouped geographically

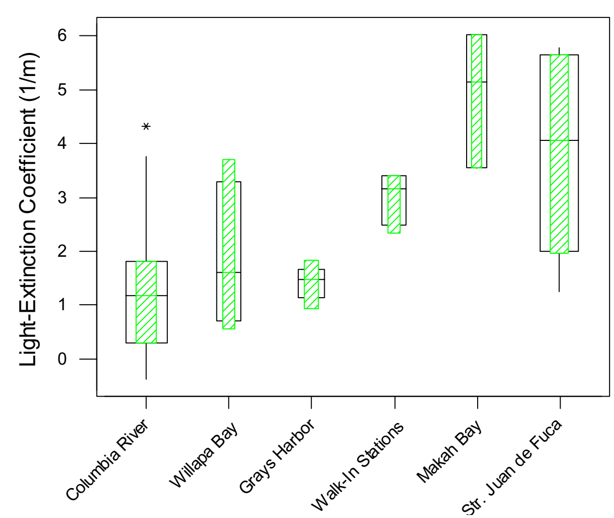


Light Extinction Coefficient k at the Surface

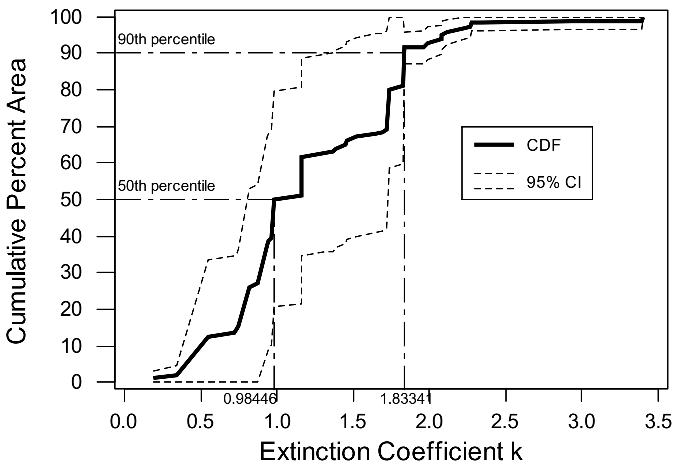


Surface Light-Extinction Coefficient k

Estuaries grouped geographically

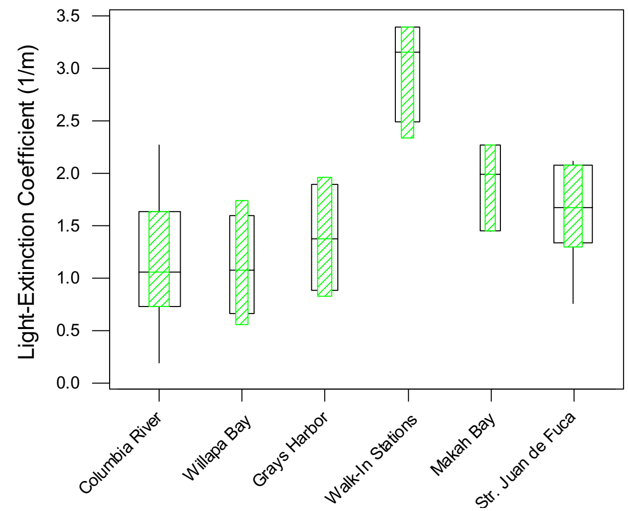


Average Light Extinction Coefficient k



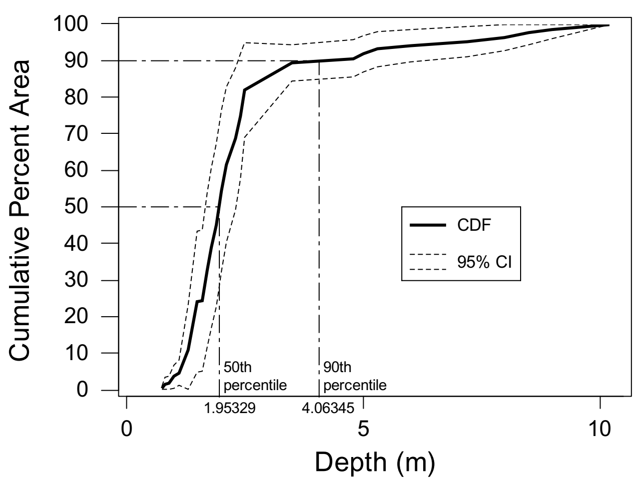
Mean Light-Extinction Coefficient k

Estuaries grouped geographically



Secchi Depth

Excluding walk-in stations



Secchi Depth

Excluding walk-in stations

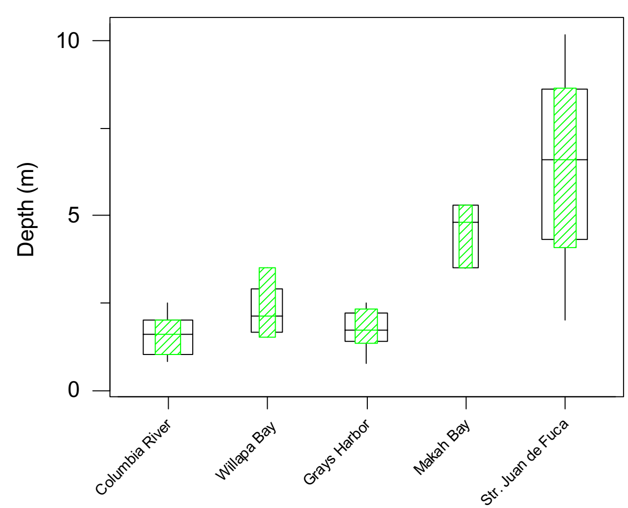
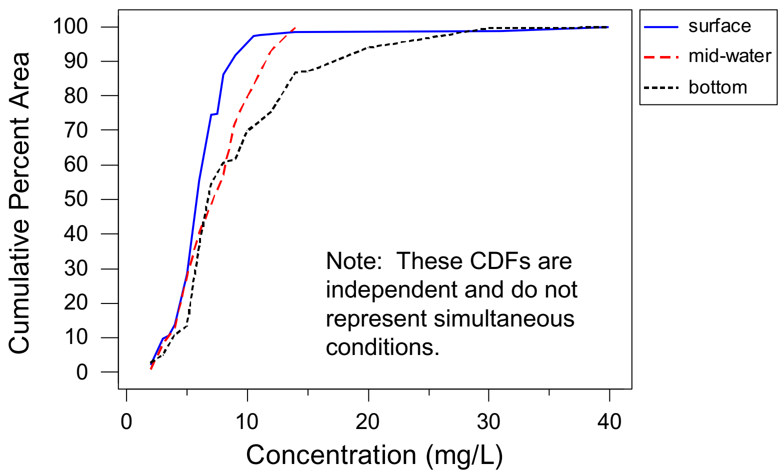
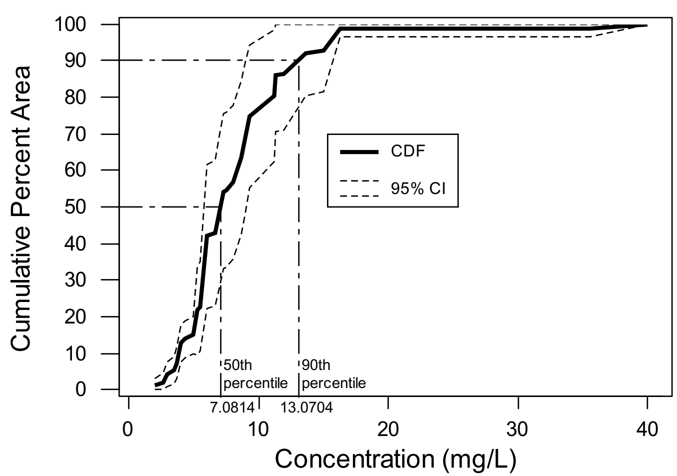


Figure C-2. Water Laboratory Analyses

Total Suspended Solids

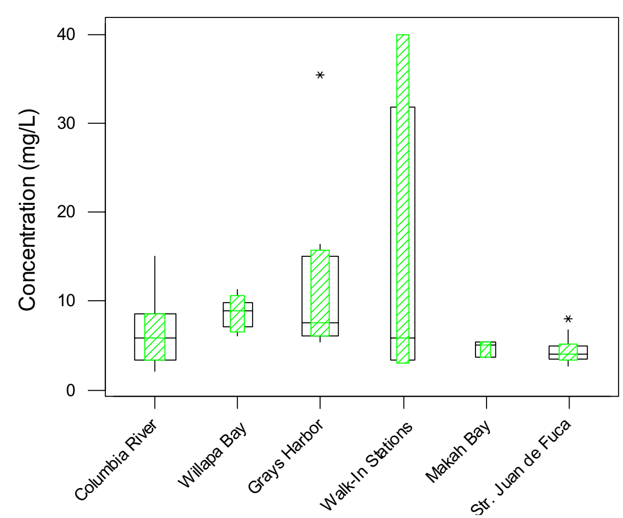


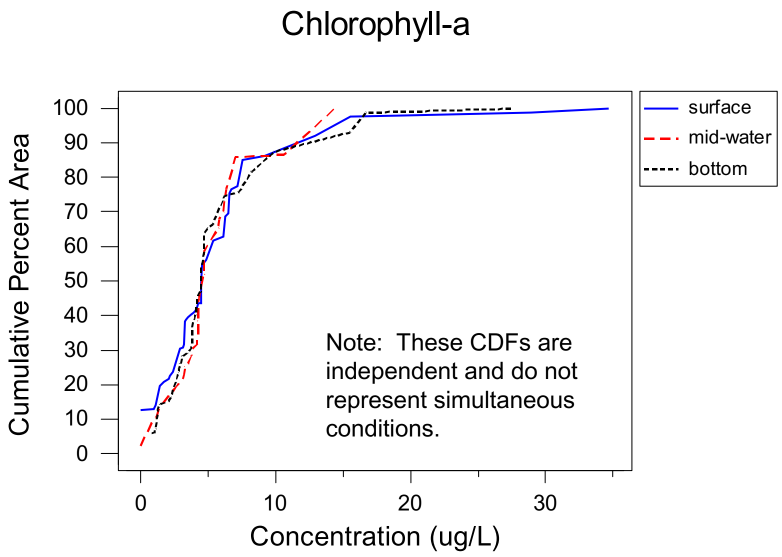
Mean Total Suspended Solids



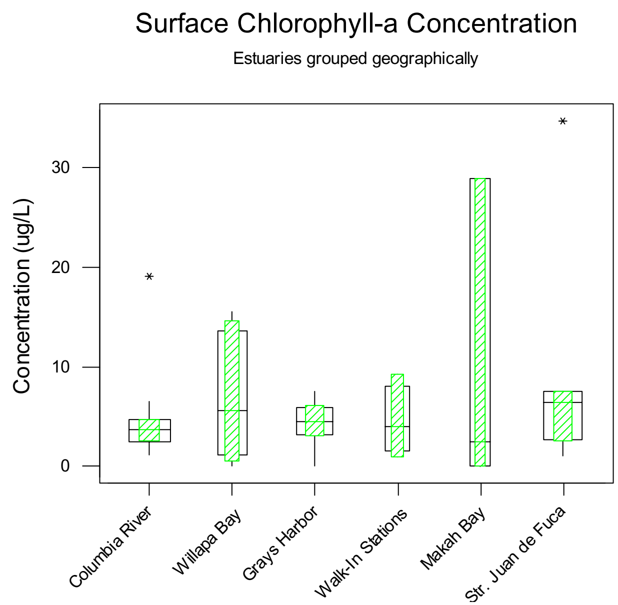
Mean Total Suspended Solids (TSS) Concentration

Estuaries grouped geographically

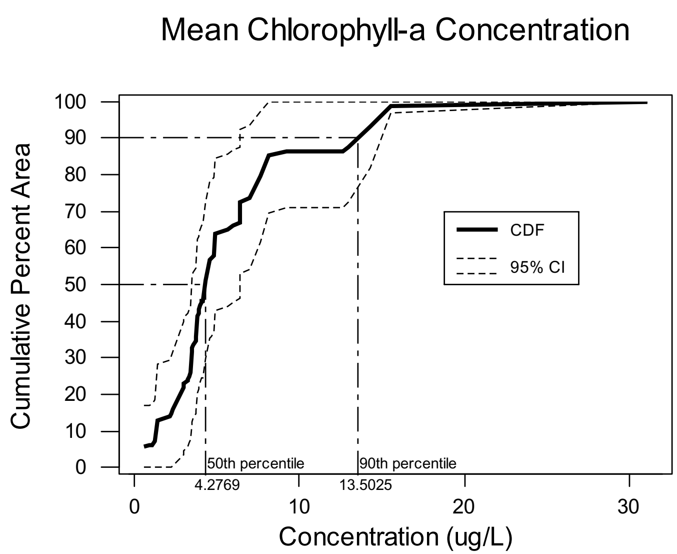




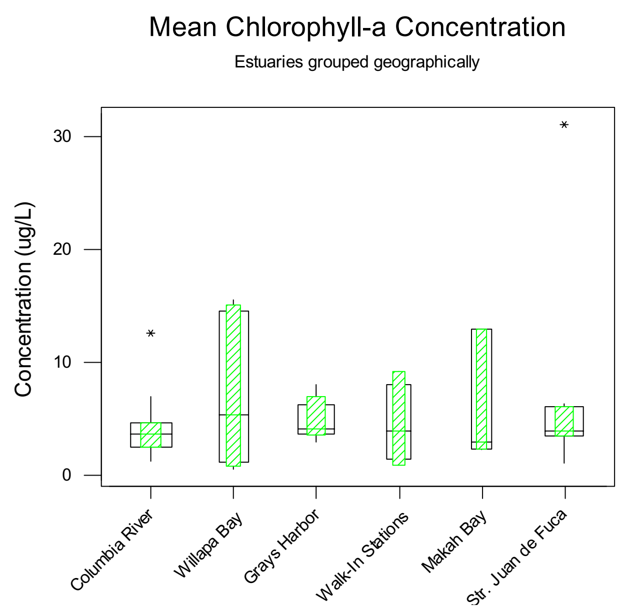
Chlorophyll-a
Cumulative Percent Area
Concentration (ug/L)
surface
mid-water
bottom
Note: These CDFs are independent and do not represent simultaneous conditions.



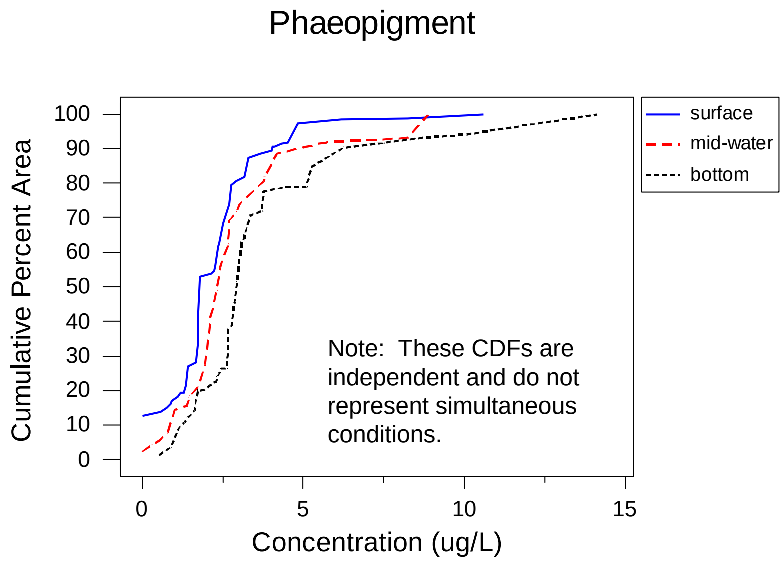
Surface Chlorophyll-a Concentration
Estuaries grouped geographically
Concentration (ug/L)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

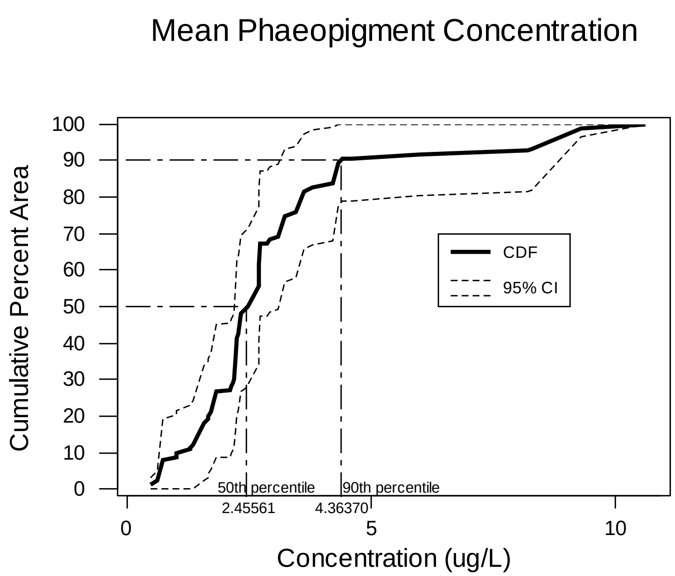


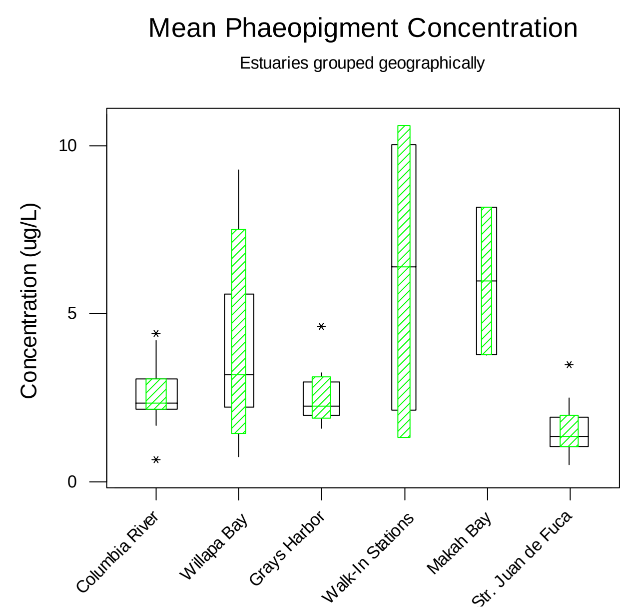
Mean Chlorophyll-a Concentration
Cumulative Percent Area
Concentration (ug/L)
CDF
95% CI
50th percentile
4.2769
90th percentile
13.5025

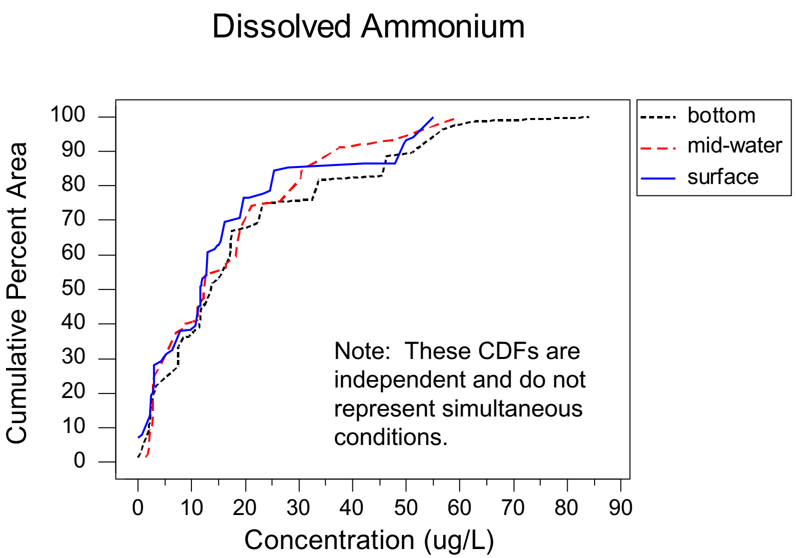


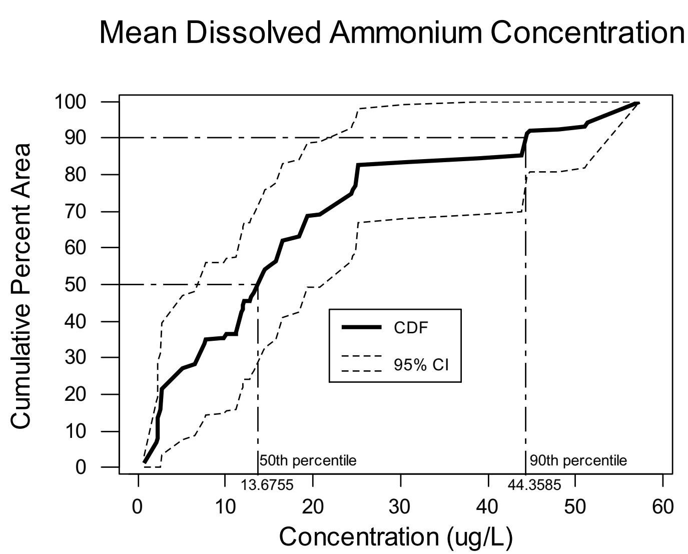
Mean Chlorophyll-a Concentration
Estuaries grouped geographically
Concentration (ug/L)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

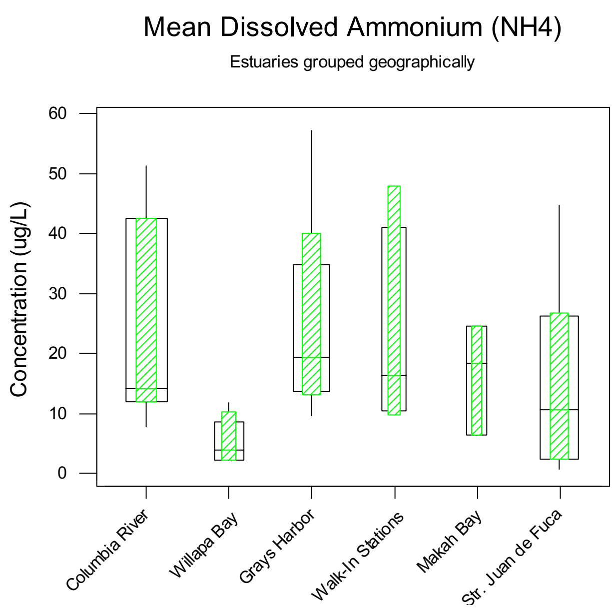

Phaeopigment
Cumulative Percent Area
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
Concentration (ug/L)
surface
mid-water
bottom
Note: These CDFs are independent and do not represent simultaneous conditions.

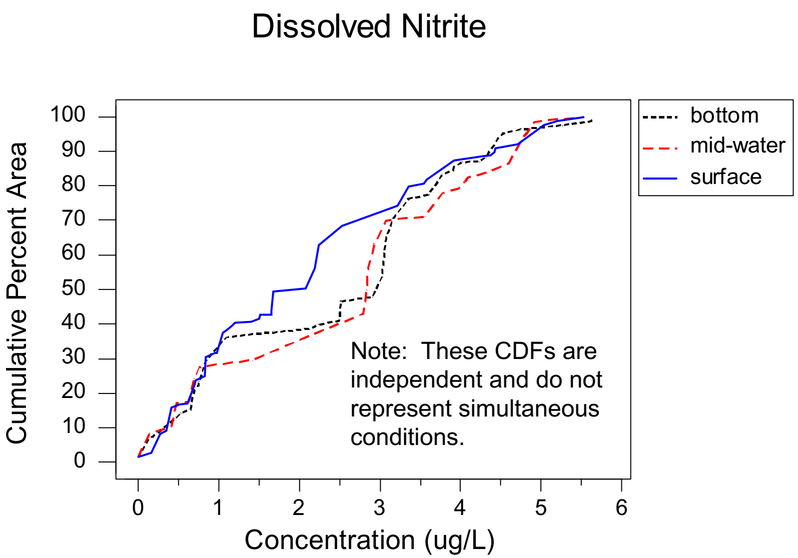

Mean Phaeopigment Concentration
Cumulative Percent Area
0
10
20
30
40
50
60
70
80
90
100
0
5
10
Concentration (ug/L)
CDF
95% CI
50th percentile
2.45561
90th percentile
4.36370

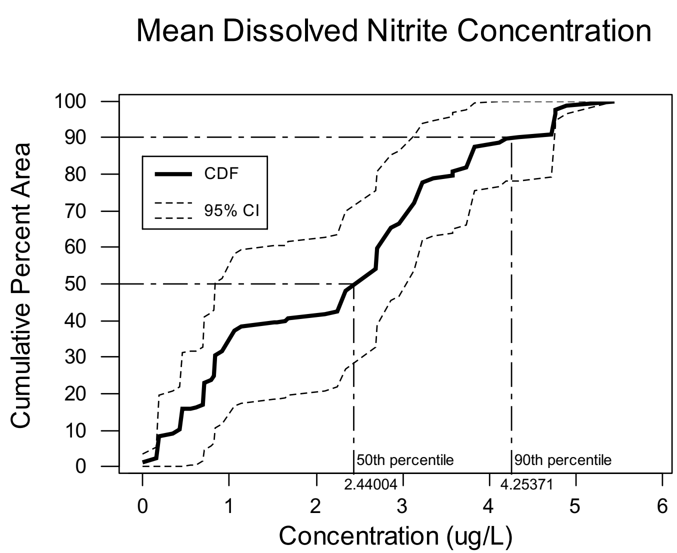

Mean Phaeopigment Concentration
Estuaries grouped geographically
Concentration (ug/L)
0
5
10
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

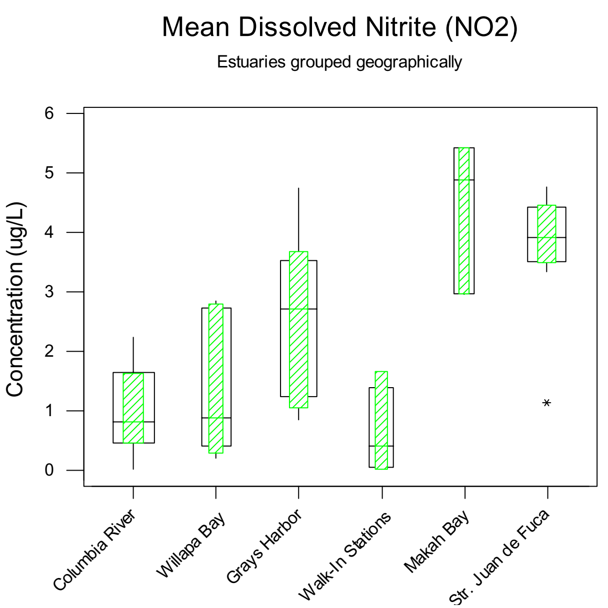

Dissolved Ammonium
Cumulative Percent Area
Concentration (ug/L)
bottom
mid-water
surface
Note: These CDFs are independent and do not represent simultaneous conditions.

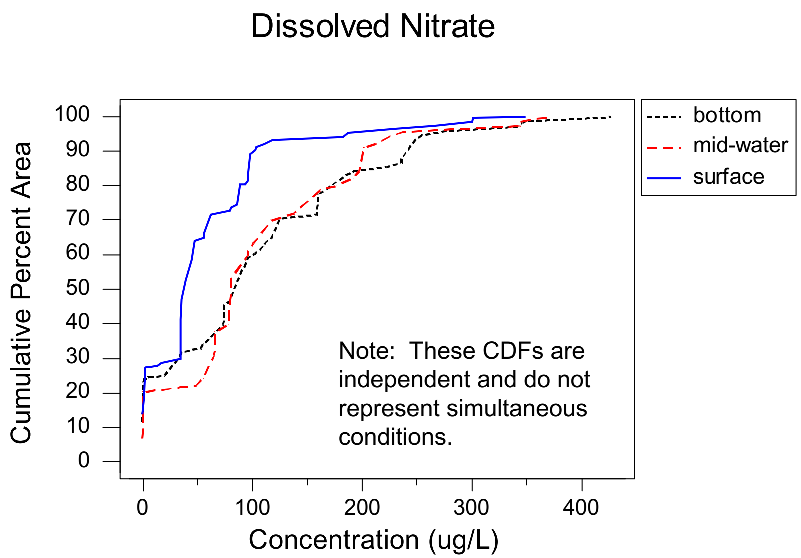

Mean Dissolved Ammonium Concentration
Cumulative Percent Area
Concentration (ug/L)
CDF
95% CI
50th percentile
90th percentile
13.6755
44.3585

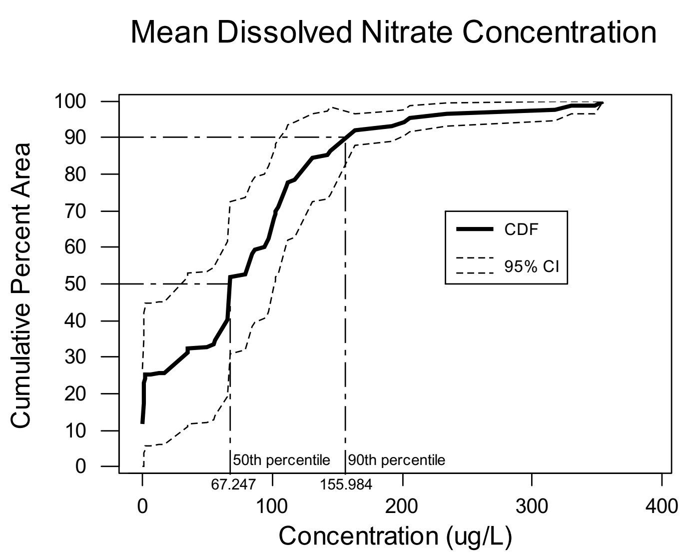

Mean Dissolved Ammonium (NH4)
Estuaries grouped geographically
Concentration (ug/L)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

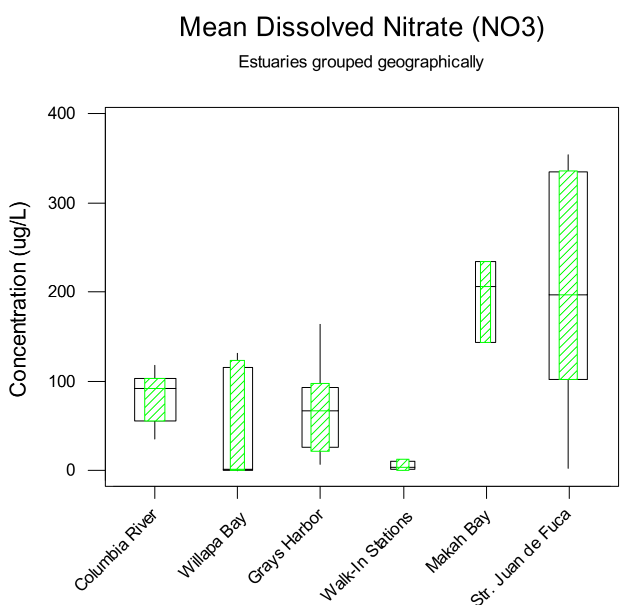

Dissolved Nitrite
Cumulative Percent Area
Concentration (ug/L)
bottom
mid-water
surface
Note: These CDFs are independent and do not represent simultaneous conditions.

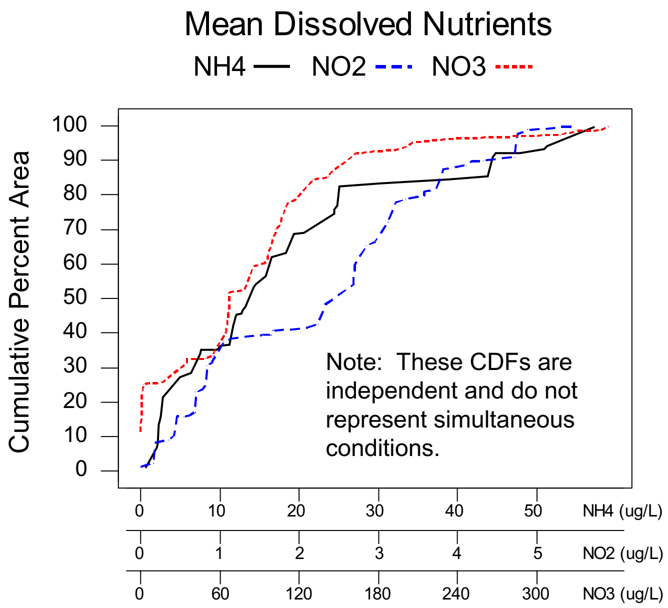

Mean Dissolved Nitrite Concentration
Cumulative Percent Area
Concentration (ug/L)
CDF
95% CI
50th percentile
2.44004
90th percentile
4.25371

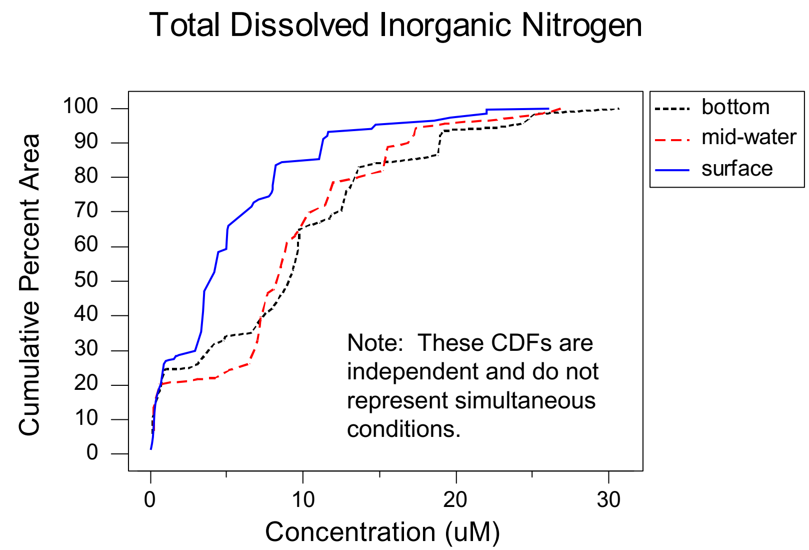

Mean Dissolved Nitrite (NO2)
Estuaries grouped geographically
Concentration (ug/L)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

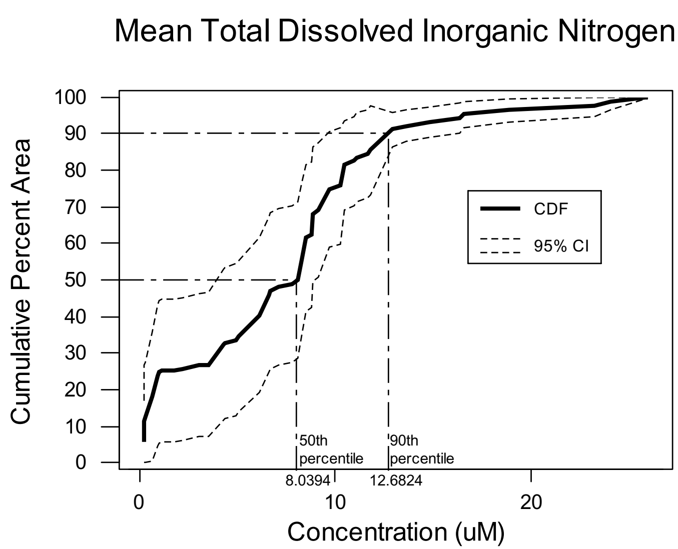

Dissolved Nitrate
Cumulative Percent Area
Concentration (ug/L)
bottom
mid-water
surface
Note: These CDFs are independent and do not represent simultaneous conditions.
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400


Mean Dissolved Nitrate Concentration
Cumulative Percent Area
Concentration (ug/L)
CDF
95% CI
50th percentile
90th percentile
67.247
155.984
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400


Mean Dissolved Nitrate (NO3)
Estuaries grouped geographically
Concentration (ug/L)
0
100
200
300
400
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Mean Dissolved Nutrients
NH4
NO2
NO3
Cumulative Percent Area
0
10
20
30
40
50
60
70
80
90
100
Note: These CDFs are independent and do not represent simultaneous conditions.
0 10 20 30 40 50 NH4 (ug/L)
0 1 2 3 4 5 NO2 (ug/L)
0 60 120 180 240 300 NO3 (ug/L)


Total Dissolved Inorganic Nitrogen
bottom
mid-water
surface
Cumulative Percent Area
0
10
20
30
40
50
60
70
80
90
100
Note: These CDFs are independent and do not represent simultaneous conditions.
0
10
20
30
Concentration (uM)


Mean Total Dissolved Inorganic Nitrogen
Cumulative Percent Area
0
10
20
30
40
50
60
70
80
90
100
CDF
95% CI
50th percentile
90th percentile
8.0394
12.6824
0
10
20
Concentration (uM)

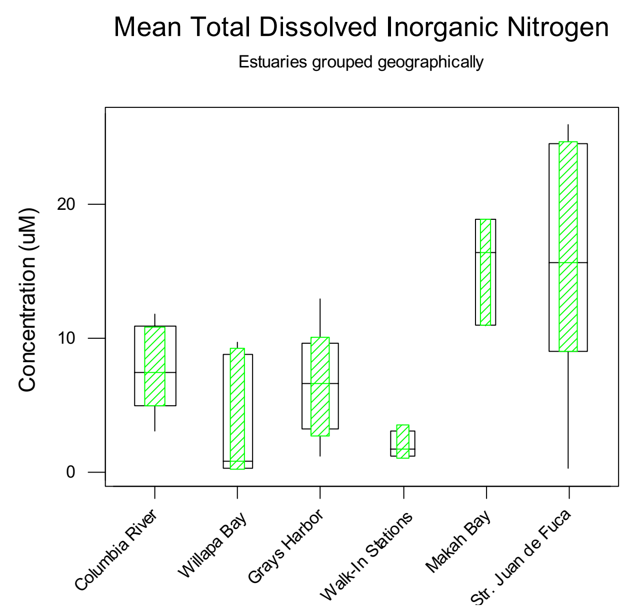
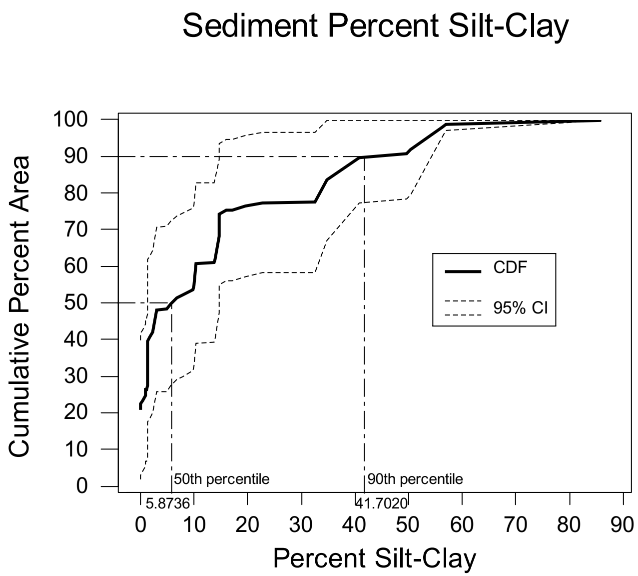
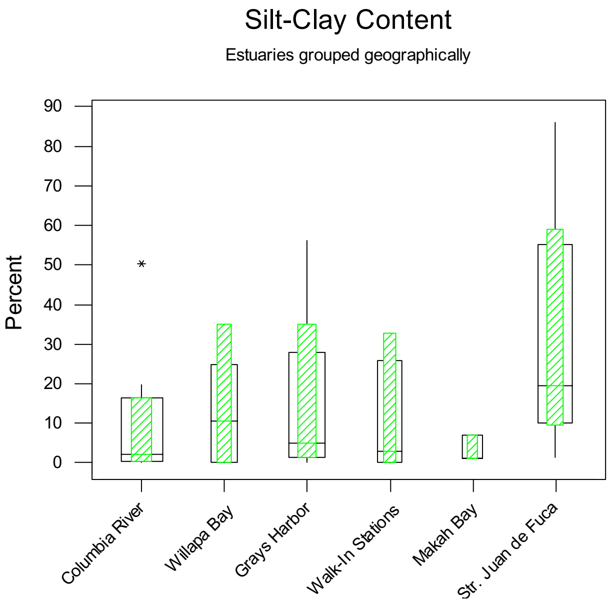
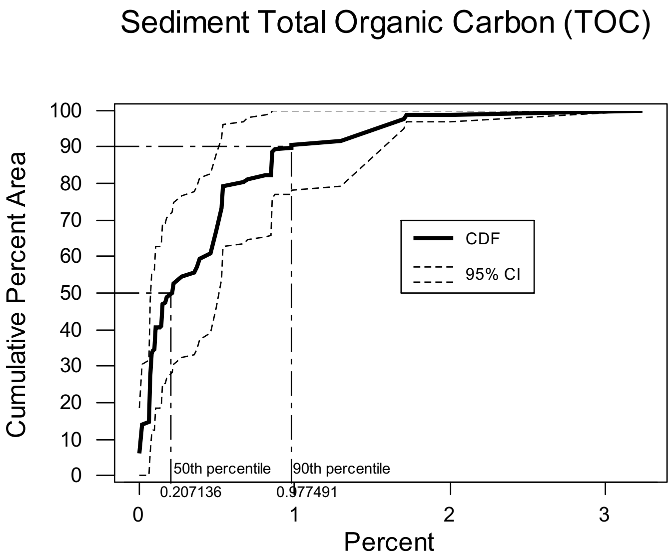

Mean Total Dissolved Inorganic Nitrogen
Estuaries grouped geographically
Concentration (uM)
0
10
20
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

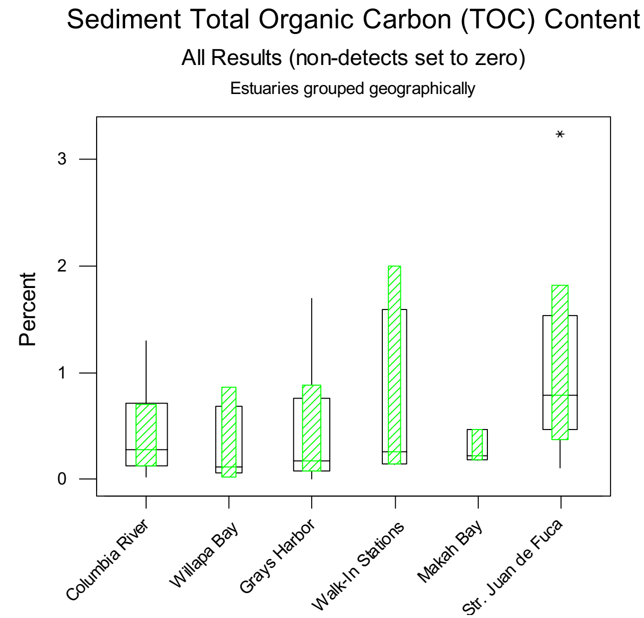
Figure C-3. Sediment Lithology







Sediment Total Organic Carbon (TOC)
Cumulative Percent Area
Percent
CDF
95% CI
50th percentile
90th percentile
0.207136
0.977491
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3



Sediment Total Organic Carbon (TOC) Content
All Results (non-detects set to zero)
Estuaries grouped geographically
Percent
0
1
2
3
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

Appendix D

Abiotic/Pollutant Exposure Condition Indicators

The data tables in this appendix contain the values used in the statistical analyses. The values are the averaged results of lab and/or field replicates, if any. The raw data are available in the national EMAP database or upon request.

The boxplots in Figures D-1 through D-5 group the data for estuaries geographically as shown in Figure B-2 in Appendix B.

Box-and-whisker plots, or boxplots, display median (50th-percentile), 25th-percentile, 75th-percentile, and extreme values of the results, with a 95% confidence interval for the median. Outliers are unusually high or unusually low values. The width of the boxplot is proportional to the number of samples.

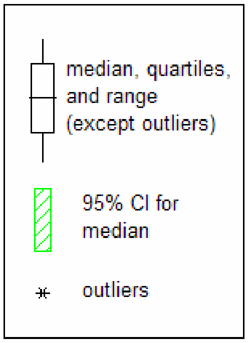


Table D-1. Sediment metals concentrations (µg/g dry weight)

EMAP Station ID	Station Location	Aluminum	Antimony	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Tin	Zinc
WA99-0001	MAKAH BAY	24200	0.25	7.59	0.13	43.1	13.7	28400	8	332	0.024	15.4	ND	0.3	0.95	49.1
WA99-0002	MAKAH BAY	27400	0.21	6.58	0.079	29.8	8	20800	5.6	309	0.014	11.2	ND	0.21	0.7	34.6
WA99-0003	MAKAH BAY	23700	0.24	7.52	0.083	32	9	23500	6.85	327	0.016	12.4	ND	0.22	0.71	38.5
WA99-0004	HOKO RIVER	35100	0.4	3.53	0.12	64.4	20.3	30300	4.42	543	0.027	22.3	ND	0.19	0.78	46.6
WA99-0005	OZETTE RIVER	station not sampled														
WA99-0006	FRESHWATER BAY	no sediment sampled														
WA99-0007	FRESHWATER BAY	31900	0.46	5.64	0.19	53.5	11.4	25300	7.01	368	0.02	22.7	ND	0.23	0.91	43.9
WA99-0008	FRESHWATER BAY	no sediment sampled														
WA99-0009	DUNGENESS BAY	34500	0.32	4.17	0.24	73.4	21.8	27600	6.52	341	0.032	33.3	ND	0.23	1.09	52.5
WA99-0010	DISCOVERY BAY	31400	0.58	6.27	0.5	71.6	27.9	32700	14.4	365	0.07	31.9	0.17	0.48	1.82	76.9
WA99-0011	DISCOVERY BAY	36500	0.61	3.73	0.27	69.8	15.2	27800	10.4	371	0.034	25.5	ND	0.28	1.08	52.3
WA99-0012	DISCOVERY BAY	29900	0.51	3.18	0.27	44.9	7.6	16300	7.88	316	0.021	16.7	ND	0.21	0.84	32
WA99-0013	DISCOVERY BAY	47900	0.59	9.15*	2.31*	76	44.3*	36900	15	337	0.101	37.7	0.22	0.6	2.01	94.2
WA99-0014	DISCOVERY BAY	34500	0.31	4.1	0.49	61.7	13.1	19900	5.18	288	0.033	19	ND	0.22	0.81	35.9
WA99-0015	KALALOCH CREEK	14000	0.24	3.48	0.075	22	6.6	16300	3.89	287	0.0084	7.9	ND	0.12	0.81	29.2
WA99-0016	RAFT RIVER	15300	0.27	5.01	0.24	35.1	16.5	26200	6.24	280	0.017	14.6	0.15	0.29	1.1	56.8
WA99-0017	QUINAULT RIVER	17800	0.31	3.27	0.11	40.2	15.6	22300	7.74	298	0.017	12.9	ND	0.2	1.2	42.3
WA99-0018	QUINAULT RIVER	station not sampled														
WA99-0019	CONNER CREEK	21800	0.24	4.495	0.089	47.25	8.05	26450	5.35	518	0.007	15.85	ND	0.185	0.89	45.35
WA99-0020	GRAYS HARBOR	34900	0.27	4.95	0.18	94.3*	57.1*	46300	6.81	703	0.036	35.5	ND	0.44	2.67	74
WA99-0021	GRASS CREEK	18200	0.27	5.04	0.12	46.9	14.3	26900	6.02	402	0.015	15.2	ND	0.25	1.12	45.5
WA99-0022	GRAYS HARBOR	18400	0.34	5.53	0.22	64.4	28.3	35200	7.56	510	0.028	21.7	ND	0.37	1.33	61.1
WA99-0023	GRAYS HARBOR	22100	0.26	4.51	0.082	41.5	10.8	26700	5.16	501	0.012	16.5	ND	0.21	0.85	46.2
WA99-0024	GRAYS HARBOR	22200	0.27	4.3	0.094	48.7	10.7	27800	5.72	536	0.013	15.5	ND	0.22	0.96	46
WA99-0025	GRAYS HARBOR	34900	0.42	6.4	0.45	82.3*	55.5*	44000	11.4	530	0.056	27	ND	0.59	2.08	80.7
WA99-0026	GRAYS HARBOR	18700	0.26	4.25	0.082	44.8	9.8	27400	5.4	492	0.0097	17	ND	0.21	0.84	45
WA99-0027	BEARDSLEE SLOUGH	11700	0.37	8.02	0.24	59.6	25.5	30800	8.53	307	0.0365	22.7	ND	0.37	1.2	55.1
WA99-0028	BEARDSLEE SLOUGH	station not sampled														
WA99-0029	GRAYS HARBOR	8750	0.3	6.69	0.098	39.1	16.3	27300	5.86	239	0.014	19	ND	0.25	0.99	48.5
WA99-0030	WILLAPA BAY	no sediment sampled														
WA99-0031	WILLAPA BAY	21400	0.35	6.26	0.16	40.4	16.4	28200	10.4	330	0.031	14.7	ND	0.36	1.5	57.9

EMAP Station ID	Station Location	Aluminum	Antimony	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Tin	Zinc
WA99-0032	WILLAPA BAY	station not sampled														
WA99-0033	WILLAPA BAY	15200	0.31	3.84	0.084	22.2	6.9	18700	7.58	289	0.0067	10.7	ND	0.18	0.83	33.9
WA99-0034	WILLAPA BAY	17000	0.305	5.06	0.22	37.25	14.6	25650	9.945	355.5	0.0225	13.95	ND	0.36	1.145	49.55
WA99-0035	WILLAPA BAY	30400	0.29	5.65	0.13	45	9.4	26300	8.04	406	0.0071	15.6	ND	0.25	0.99	45.4
WA99-0036	WILLAPA BAY	11000	0.27	6.8	0.11	21.3	6.9	20500	9.74	393	0.0069	10.6	ND	0.24	0.85	37
WA99-0037	WILLAPA BAY	station not sampled														
WA99-0038	BAKER BAY	17700	0.44	3.9	0.22	37	18.2	28200	15.9	553	0.034	15.1	ND	0.47	1.42	75.7
WA99-0039	BAKER BAY	35400	0.98	7.63	0.854	50.6	37*	38000	25.9	491	0.088	19.2	ND	0.65	2.13	125
WA99-0040	BAKER BAY	18800	0.4	4.32	0.22	37.1	18.6	32100	14	532	0.032	15.7	ND	0.44	1.36	74.3
WA99-0041	GRAYS RIVER	station not sampled														
WA99-0042	BAKER BAY	13000	0.3	2.4	0.1	32.9	14.4	31200	9.82	580	0.0088	16.3	ND	0.32	1.19	58.4
WA99-0043	GRAYS BAY	23100	0.67	18.6*	0.653	68.1	43.8*	65600	21.6	1120	0.033	36.7	0.13	0.81	1.99	147
WA99-0044	GRAYS BAY	39800	0.3	8	0.45	81.6*	52.4*	74000	6.8	706	0.017	49.2	ND	0.92	2.25	129
WA99-0045	GRAYS BAY	38100	0.38	8.13	0.677	83.1*	59*	75200	8.15	1180	0.025	45.5	ND	0.98	2.2	145
WA99-0046	GRAYS BAY	45600	0.45	15.2*	0.651	89.8*	34.2*	61900	11.1	1390	0.02	37.6	ND	0.67	1.71	133
WA99-0047	GRAYS BAY	20600	0.27	2.7	0.23	36.2	22	41500	9.94	723	0.013	18.5	ND	0.44	1.41	82.2
WA99-0048	COWLITZ RIVER	40600	0.14	0.69	0.16	26.7	31.7	49800	6.08	840	ND	21.4	ND	0.49	1.47	84.6
WA99-0049	CARROLLS CHANNEL	38000	0.335	2.75	0.31	37.1	21.55	33950	11.7	662	0.024	18	ND	0.435	1.345	85.95
WA99-0050	MARTIN SLOUGH	24300	0.71	5.15	0.798	40.3	30.5	35200	18	676	0.101	17.7	ND	0.54	1.61	121

Notes: (1) Averaged over lab replicates, if any. (2) Non-detects (ND) set to zero for EMAP analyses. (3) Non-detects (ND) excluded for comparison to sediment quality guidelines. (*) Exceeds Effects Range Low (ERL) sediment quality guideline.

Table D-2. Sediment individual LPAH concentrations - with and without outlier at Station WA99-0050, Lab Rep 4

EMAP Station ID	Station Location	1-Methyl naphthalene	1-Methyl phenanthrene	2,3,5-Trimethyl naphthalene	2,6-Dimethyl naphthalene	2-Methyl naphthalene	Acenaphthene	Acenaph-thylene	Anthracene	Biphenyl	Dibenzo-thiophene	Fluorene	Naphthalene	Phenanthrene	Retene
WA99-0001	MAKAH BAY	158	65	75	89	182	6.2	ND	2.6	46	8.9	40	74	178	118
WA99-0002	MAKAH BAY	95	43	46	49	82	2.8	ND	1.2	21	5.9	20	29	105	82
WA99-0003	MAKAH BAY	100	52	55	3.9	98	4.4	3.3	ND	25	7.6	28	34	139	86
WA99-0004	HOKO RIVER	16.5	12.5	7.3	14.5	24	1.2	ND	0.6	11.5	1.2	5.6	9.4	48	9.35
WA99-0005	OZETTE RIVER	station not sampled													
WA99-0006	FRESHWATER BAY	no sediment sampled													
WA99-0007	FRESHWATER BAY	13.5	5.35	6.45	12.5	15	1.25	0.355	2	3.4	0.935	4.1	7.85	18.5	38
WA99-0008	FRESHWATER BAY	no sediment sampled													
WA99-0009	DUNGENESS BAY	6.6	4.2	3.9	8	8.9	2.5	ND	7.6	2.7	1.6	5.8	6.9	22	31
WA99-0010	DISCOVERY BAY	47	20	23	66	59	4.1	4.8	10	17	4.1	18	36	85	68
WA99-0011	DISCOVERY BAY	17	8.3	10	26	23	1.6	1.9	3.8	6.4	2.3	7.1	14	34	27
WA99-0012	DISCOVERY BAY	6.1	3.8	3.8	17	8.8	ND	ND	2.3	2.8	0.93	3.2	7.3	15	23
WA99-0013	DISCOVERY BAY	47	22	26	78	54	5.8	6.6	15	20	6.5	20	38	93	69
WA99-0014	DISCOVERY BAY	10	2.9	4.8	7	12	1.5	ND	2.7	5	0.83	2.5	10	16	15
WA99-0015	KALALOCH CREEK	4.4	3.7	2.1	5.2	11	0.64	1.1	69	4.7	1.1	8.4	4.3	37	10
WA99-0016	RAFT RIVER	94	25	31	98	191	ND	ND	4.3	1.8	0.7	23	62	110	57
WA99-0017	QUINAULT RIVER	6.8	3.2	3.4	6.6	16	0.8	ND	1	7.1	ND	3.4	7.6	17	27
WA99-0018	QUINAULT RIVER	station not sampled													
WA99-0019	CONNER CREEK	1.1	1.1	0.88	2	2.6	ND	ND	ND	0.98	0.24	1.2	ND	4.6	3.4
WA99-0020	GRAYS HARBOR	6.3	4.7	5.6	5.3	8.9	1.1	1.1	1.3	3.2	1.2	2.8	7.6	17	27
WA99-0021	GRASS CREEK	2.3	1.9	1.7	2.6	3.9	0.65	0.91	0.9	1	0.12	1.7	4.5	6.7	12
WA99-0022	GRAYS HARBOR	6.25	3.25	3.05	5.95	9.35	1.35	2.75	2.7	3.25	0.86	4.3	12.5	13.5	21
WA99-0023	GRAYS HARBOR	1.3	1.15	1.2	1.85	2.6	ND	ND	0.7	ND	0.049	1.02	ND	4.1	5
WA99-0024	GRAYS HARBOR	1.195	1.1	0.95	1.25	2.2	0.39	ND	0.9	ND	0.125	1.14	1.5	4.3	3.8
WA99-0025	GRAYS HARBOR	20	10	7.3	17	37	43	19	27	18	14	43	65	155	150
WA99-0026	GRAYS HARBOR	0.47	0.99	0.76	0.58	ND	ND	ND	ND	ND	ND	0.53	ND	2.3	2
WA99-0027	BEARDSLEE SLOUGH	4.1	1.8	1.8	7.1	6.2	ND	ND	0.9	1.2	ND	1.8	5.4	6.6	79
WA99-0028	BEARDSLEE SLOUGH	station not sampled													
WA99-0029	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.6

EMAP Station ID	Station Location	1-Methyl naphthalene	1-Methyl phenanthrene	2,3,5-Trimethyl naphthalene	2,6-Dimethyl naphthalene	2-Methyl naphthalene	Acenaphthene	Acenaph-thylene	Anthracene	Biphenyl	Dibenzo-thiophene	Fluorene	Naphthalene	Phenanthrene	Retene
WA99-0030	WILLAPA BAY	no sediment sampled													
WA99-0031	WILLAPA BAY	6.2	3.8	3.7	6.5	9.1	1.3	1.9	3.3	3.8	0.93	3.5	11	20	74
WA99-0032	WILLAPA BAY	station not sampled													
WA99-0033	WILLAPA BAY	ND	0.31	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND
WA99-0034	WILLAPA BAY	3.1	1.7	1.6	4.4	5.3	0.9	2.1	1.6	ND	0.15	1.8	8.5	7.6	17
WA99-0035	WILLAPA BAY	ND	0.81	ND	0.62	ND	ND	ND	0.4	ND	ND	0.58	ND	1.6	1.9
WA99-0036	WILLAPA BAY	ND	0.31	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4	2
WA99-0037	WILLAPA BAY	station not sampled													
WA99-0038	BAKER BAY	1.4	3.1	1	2.6	2.8	1.3	2.7	4.5	ND	1.2	3.4	7.2	24	8
WA99-0039	BAKER BAY	9.9	8.5	4.6	12	14	11	13	26	9.4	1.2	17	57	79	87
WA99-0040	BAKER BAY	0.95	1.1	1.2	3.5	2.3	1.8	1.6	2.5	ND	1.2	1.7	5.1	7.3	8.4
WA99-0041	GRAYS RIVER	station not sampled													
WA99-0042	BAKER BAY	ND	0.49	ND	0.34	ND	ND	ND	ND	ND	2.4	ND	ND	1.8	4.6
WA99-0043	GRAYS BAY	2.1	1.5	1.8	2	3.6	1	0.75	1.1	ND	0.6	1.9	5.1	9.9	99
WA99-0044	GRAYS BAY	1.6	0.79	0.82	0.94	3.2	0.53	0.51	0.5	ND	0.095	1	4.1	4.1	6.1
WA99-0045	GRAYS BAY	1.9	1.2	1.2	1.5	3.7	0.7	0.59	0.6	ND	0.11	1.1	4.8	5.8	13
WA99-0046	GRAYS BAY	1.2	0.78	0.8	0.79	2.8	0.62	1.6	0.7	ND	ND	1.3	3.3	3.5	12
WA99-0047	GRAYS BAY	ND	ND	ND	ND	ND	ND	0.76	0.5	ND	ND	ND	ND	1.2	ND
WA99-0048	COWLITZ RIVER	0.13	0.21	ND	0.1	1	0.29	0.32	ND	ND	ND	0.36	ND	1	1.3
WA99-0049	CARROLLS CHANNEL	1.4	0.73	0.34	0.56	3.1	0.76	1.1	0.8	ND	ND	1.1	5.1	3.3	12
WA99-0050 with outlier	MARTIN SLOUGH	27.45	810.25	64.2	165.1	1177.7	29.05	17.63	25111	136.13	606.23	7633	407	16630	1277.3
WA99-0050 w/o outlier	MARTIN SLOUGH	3.93	30.33	1.93	5.47	10.27	4.07	11.83	214.33	11.5	11.63	44	36	439.67	1420.3

Notes: (1) Averaged over lab replicates, if any. (2) Non-detects (ND) set to zero for EMAP analyses. (3) Non-detects (ND) excluded for comparison to ERL and ERM sediment quality guidelines.

Table D-3. Sediment individual HPAH concentrations - with and without outlier at Station WA99-0050, Lab Rep 4

EMAP Station ID	Station Location	Benz(a) anthracene	Benzo(a) pyrene	Benzo(b) fluor- anthene	Benzo[e] pyrene	Benzo (g,h,i) perylene	Benzo(k) fluor- anthene	Chrysene	Dibenz (a,h) anthracene	Fluor- anthene	Indeno (1,2,3-c,d) pyrene	Perylene	Pyrene
WA99-0001	MAKAH BAY	11	ND	25	ND	ND	20	38	ND	28	ND	49	32
WA99-0002	MAKAH BAY	6	ND	15	ND	ND	ND	24	ND	17	ND	19	17
WA99-0003	MAKAH BAY	6.6	ND	18	9	ND	ND	29	ND	20	ND	26	22
WA99-0004	HOKO RIVER	ND	ND	ND	ND	ND	ND	14.5	ND	3.9	ND	12.5	5.05
WA99-0005	OZETTE RIVER	station not sampled											
WA99-0006	FRESHWATER BAY	no sediment sampled											
WA99-0007	FRESHWATER BAY	3.75	3.75	6.35	3.95	4.3	3.4	6.95	0.24	9.7	4	49.5	8.6
WA99-0008	FRESHWATER BAY	no sediment sampled											
WA99-0009	DUNGENESS BAY	7	ND	11	ND	ND	ND	12	ND	43	ND	17	22
WA99-0010	DISCOVERY BAY	21	22	32	20	24	22	38	7.2	65	24	110	56
WA99-0011	DISCOVERY BAY	8.1	9.1	15	9.5	12	10	15	1.1	25	12	53	21
WA99-0012	DISCOVERY BAY	4.6	ND	ND	ND	ND	ND	7.6	ND	14	ND	18	11
WA99-0013	DISCOVERY BAY	34	41	59	36	47	44	56	2.9	117	49	190	105
WA99-0014	DISCOVERY BAY	5.4	ND	ND	ND	ND	ND	7	ND	15	ND	46	13
WA99-0015	KALALOCH CREEK	4.5	6.4	7.4	5.2	ND	7.4	48	ND	4.5	8	9.1	4.2
WA99-0016	RAFT RIVER	9.7	ND	19	11	ND	ND	36	ND	15	ND	66	21
WA99-0017	QUINAULT RIVER	1.7	1	5.5	2.2	1.7	ND	8.1	ND	6.1	ND	23	5.9
WA99-0018	QUINAULT RIVER	station not sampled											
WA99-0019	CONNER CREEK	ND	ND	ND	ND	ND	ND	3.2	ND	2.9	ND	20	2.6
WA99-0020	GRAYS HARBOR	3.2	ND	ND	ND	ND	ND	8.6	ND	8.2	ND	115	8.9
WA99-0021	GRASS CREEK	1.4	1.2	2.2	1.8	1.6	1.6	3.6	ND	5.9	1.5	33	5.7
WA99-0022	GRAYS HARBOR	3.2	ND	ND	ND	ND	ND	5.3	ND	12	ND	560.5	11
WA99-0023	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	2.3	ND	2.45	ND	17.5	2.6
WA99-0024	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	2.8	ND	2.6	ND	28.5	3.1
WA99-0025	GRAYS HARBOR	112	55	63	37	23	58	76	11	276	31	756	245
WA99-0026	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	1.7	ND	1	ND	9.1	1.3
WA99-0027	BEARDSLEE SLOUGH	1.6	ND	ND	ND	ND	ND	3	ND	4.8	ND	56	4.3
WA99-0028	BEARDSLEE SLOUGH	station not sampled											
WA99-0029	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.6	ND
WA99-0030	WILLAPA BAY	no sediment sampled											
WA99-0031	WILLAPA BAY	9	10	11	7.3	8.6	8.7	12	0.95	23	9.5	65	26
WA99-0032	WILLAPA BAY	station not sampled											

EMAP Station ID	Station Location	Benz(a) anthracene	Benzo(a) pyrene	Benzo(b) fluor-anthene	Benzo[e] pyrene	Benzo (g,h,i) perylene	Benzo(k) fluor-anthene	Chrysene	Dibenz (a,h) anthracene	Fluor-anthene	Indeno (1,2,3-c,d) pyrene	Perylene	Pyrene
WA99-0033	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.75
WA99-0034	WILLAPA BAY	2.6	ND	3.7	ND	ND	ND	4	ND	6.5	ND	45	6.9
WA99-0035	WILLAPA BAY	0.72	ND	0.55	0.74	ND	0.61	1.2	ND	1.4	ND	11	1.3
WA99-0036	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	1.1	ND	ND	1
WA99-0037	WILLAPA BAY	station not sampled											
WA99-0038	BAKER BAY	11	15	12	8.9	ND	8.9	15	ND	32	ND	45	33
WA99-0039	BAKER BAY	40	57	39	24	41	43	45	ND	117	50	298	131
WA99-0040	BAKER BAY	6	8	7.8	5.4	ND	6.5	8.4	ND	14	ND	40	15
WA99-0041	GRAYS RIVER	station not sampled											
WA99-0042	BAKER BAY	ND	ND	ND	ND	ND	ND	1.4	ND	1.4	ND	ND	1.5
WA99-0043	GRAYS BAY	2.6	ND	ND	ND	ND	ND	5.2	ND	8.4	ND	410	9.6
WA99-0044	GRAYS BAY	ND	ND	1.7	ND	ND	ND	2.5	ND	2.5	ND	294	4.2
WA99-0045	GRAYS BAY	1.8	ND	4.6	3.3	ND	2	5	ND	4.5	ND	203	7.1
WA99-0046	GRAYS BAY	2.3	8.1	6.6	5.7	7.3	4.7	4.5	ND	3.4	ND	218	4.6
WA99-0047	GRAYS BAY	ND	ND	ND	ND	ND	ND	ND	ND	0.76	ND	6.8	0.64
WA99-0048	COWLITZ RIVER	ND	ND	ND	ND	ND	ND	ND	ND	0.41	ND	ND	0.32
WA99-0049	CARROLLS CHANNEL	1.9	2	2.8	1.8	1.9	1.7	2.9	ND	3.6	2.1	12	3.5
WA99-0050 with outlier	MARTIN SLOUGH	401.5	199.8	142.3	128	72.8	207.5	2465.3	20.98	2163.3	99.3	203.8	1291.5
WA99-0050 w/o outlier	MARTIN SLOUGH	75.3	76.7	84	52	36.7	80.7	450.3	8.63	407.7	43.3	182	338.7

Notes: (1) Averaged over lab replicates, if any. (2) Non-detects (ND) set to zero for EMAP analyses. (3) Non-detects (ND) excluded for comparison to ERL and ERM sediment quality guidelines.

Table D-4. Sediment individual LPAH concentrations - TOC-normalized with and without outlier at Station WA99-0050, Lab Rep 4

EMAP Station ID	Station Location	TOC (%)	2-Methyl-naphthalene (ppm org. C)	Acenaphthene (ppm org. C)	Acenaphthylene (ppm org. C)	Anthracene (ppm org. C)	Fluorene (ppm org. C)	Naphthalene (ppm org. C)	Phenanthrene (ppm org. C)
WA99-0001	MAKAH BAY	0.46	39.57	1.35	0.11*	0.57	8.70	16.09	38.70
WA99-0002	MAKAH BAY	0.22	37.27	1.27	1*	0.55	9.09	13.18	47.73
WA99-0003	MAKAH BAY	0.18	54.44	2.44	1.83	0.27*	15.56	18.89	77.22
WA99-0004	HOKO RIVER	0.10	24.00	1.20	0.5*	0.55	5.60	9.40	48.00
WA99-0005	OZETTE RIVER	station not sampled							
WA99-0006	FRESHWATER BAY	no sediment sampled							
WA99-0007	FRESHWATER BAY	0.39	3.85	0.32	0.18	0.51	1.05	2.01	4.74
WA99-0008	FRESHWATER BAY	no sediment sampled							
WA99-0009	DUNGENESS BAY	0.70	1.27	0.36	0.07*	1.09	0.83	0.99	3.14
WA99-0010	DISCOVERY BAY	1.72	3.43	0.24	0.28	0.58	1.05	2.09	4.94
WA99-0011	DISCOVERY BAY	0.87	2.64	0.18	0.22	0.44	0.82	1.61	3.91
WA99-0012	DISCOVERY BAY	0.67	1.31	0.07*	0.15*	0.34	0.48	1.09	2.24
WA99-0013	DISCOVERY BAY	3.24	1.67	0.18	0.20	0.46	0.62	1.17	2.87
WA99-0014	DISCOVERY BAY	0.98	1.22	0.15	0.05*	0.28	0.26	1.02	1.63
WA99-0015	KALALOCH CREEK	0.14	7.86	0.46	0.79	49.29	6.00	3.07	26.43
WA99-0016	RAFT RIVER	2.00	9.55	0.02*	0.02*	0.22	1.15	3.10	5.50
WA99-0017	QUINAULT RIVER	0.37	4.32	0.22	0.14*	0.27	0.92	2.05	4.59
WA99-0018	QUINAULT RIVER	station not sampled							
WA99-0019	CONNER CREEK	0.14	1.90	0.36*	0.36*	0.39*	0.88	1.17*	3.37
WA99-0020	GRAYS HARBOR	0.54	1.65	0.20	0.20	0.24	0.52	1.41	3.15
WA99-0021	GRASS CREEK	0.17	2.29	0.38	0.54	0.56	1.00	2.65	3.94
WA99-0022	GRAYS HARBOR	0.53	1.76	0.25	0.52	0.51	0.81	2.36	2.55
WA99-0023	GRAYS HARBOR	0.07	3.71	0.71*	0.71*	1.04	1.46	3.14*	5.86
WA99-0024	GRAYS HARBOR	0.07	3.14	1.11	0.8*	1.33	1.63	4.29	6.07
WA99-0025	GRAYS HARBOR	1.70	2.18	2.53	1.12	1.59	2.53	3.82	9.12
WA99-0026	GRAYS HARBOR	non-detect	cannot calculate*	cannot calculate*	cannot calculate*	cannot calculate*	cannot calculate	cannot calculate*	cannot calculate
WA99-0027	BEARDSLEE SLOUGH	0.98	0.63	0.05*	0.05*	0.09	0.18	0.55	0.68
WA99-0028	BEARDSLEE SLOUGH	station not sampled							
WA99-0029	GRAYS HARBOR	0.15	0.33*	0.33*	0.33*	0.33*	0.33*	0.33*	0.33*
WA99-0030	WILLAPA BAY	no sediment sampled							
WA99-0031	WILLAPA BAY	0.86	1.06	0.15	0.22	0.38	0.41	1.28	2.33

EMAP Station ID	Station Location	TOC (%)	2-Methyl-naphthalene (ppm org. C)	Acenaphthene (ppm org. C)	Acenaphthylene (ppm org. C)	Anthracene (ppm org. C)	Fluorene (ppm org. C)	Naphthalene (ppm org. C)	Phenanthrene (ppm org. C)
WA99-0032	WILLAPA BAY	station not sampled							
WA99-0033	WILLAPA BAY	0.02	4.35*	2.4*	2.4*	2.4*	2.4*	4.15*	4.85
WA99-0034	WILLAPA BAY	0.49	1.07	0.18	0.43	0.32	0.36	1.72	1.54
WA99-0035	WILLAPA BAY	0.11	1.09*	0.45*	0.45*	0.38	0.53	0.91*	1.45
WA99-0036	WILLAPA BAY	0.08	1.13*	0.6*	0.6*	0.6*	0.6*	1.1*	1.75
WA99-0037	WILLAPA BAY	station not sampled							
WA99-0038	BAKER BAY	0.35	0.80	0.37	0.77	1.29	0.97	2.06	6.86
WA99-0039	BAKER BAY	1.30	1.08	0.85	1.00	2.00	1.31	4.38	6.08
WA99-0040	BAKER BAY	0.39	0.59	0.46	0.41	0.64	0.44	1.31	1.87
WA99-0041	GRAYS RIVER	station not sampled							
WA99-0042	BAKER BAY	0.09	0.54*	0.54*	0.54*	0.61*	0.54*	1.44*	2.00
WA99-0043	GRAYS BAY	0.81	0.44	0.12	0.09	0.14	0.23	0.63	1.22
WA99-0044	GRAYS BAY	0.22	1.45	0.24	0.23	0.22	0.45	1.86	1.86
WA99-0045	GRAYS BAY	0.27	1.37	0.26	0.22	0.22	0.41	1.78	2.15
WA99-0046	GRAYS BAY	0.27	1.04	0.23	0.59	0.27	0.48	1.22	1.30
WA99-0047	GRAYS BAY	0.06	0.83*	0.83*	1.27	0.80	0.83*	0.83*	2.00
WA99-0048	COWLITZ RIVER	0.02	5.00	1.45	1.60	2.3*	1.80	4.05*	5.00
WA99-0049	CARROLLS CHANNEL	0.21	1.48	0.36	0.52	0.38	0.52	2.43	1.57
WA99-0050 with outlier	MARTIN SLOUGH	0.85	138.55	3.42	2.07	2954.21	898	47.88	1956.44
WA99-0050 w/o outlier	MARTIN SLOUGH	0.85	1.21	0.48	1.39	25.22	5.18	4.24	51.73

* All concentrations were non-detects; therefore, the highest reporting limit (RL) was used as the concentration, per Washington State Department of Ecology (1995).

Table D-5. Sediment individual HPAH concentrations - TOC-normalized with and without outlier at Station WA99-0050, Lab Rep 4

EMAP Station ID	Station Location	TOC (%)	Benz(a) anthracene (ppm org. C)	Benzo(a) pyrene (ppm org. C)	Benzo(g,h,i) perylene (ppm org. C)	Chrysene (ppm org. C)	Dibenz(a,h) anthracene (ppm org. C)	Fluor-anthene (ppm org. C)	Indeno (1,2,3-c,d) pyrene (ppm org. C)	Pyrene (ppm org. C)	Total Benzo-fluoranthenes (ppm org. C)
WA99-0001	MAKAH BAY	0.46	2.39	1.48*	1.80*	8.26	0.48*	6.09	0.78*	6.96	9.78
WA99-0002	MAKAH BAY	0.22	2.73	1.86*	2*	10.91	0.22*	7.73	1.09*	7.73	7.04
WA99-0003	MAKAH BAY	0.18	3.67	2.67*	2.89*	16.11	0.48*	11.11	1.39*	12.22	10.27
WA99-0004	HOKO RIVER	0.10	2*	1*	2.6*	14.50	0.5*	3.90	0.5*	5.05	7.9*
WA99-0005	OZETTE RIVER	station not sampled									
WA99-0006	FRESHWATER BAY	no sediment sampled									
WA99-0007	FRESHWATER BAY	0.39	0.96	0.96	1.10	1.78	0.12	2.49	1.03	2.21	2.50
WA99-0008	FRESHWATER BAY	no sediment sampled									
WA99-0009	DUNGENESS BAY	0.70	1.00	0.7*	0.74*	1.71	0.07*	6.14	0.63*	3.14	2.34
WA99-0010	DISCOVERY BAY	1.72	1.22	1.28	1.40	2.21	0.42	3.78	1.40	3.26	3.14
WA99-0011	DISCOVERY BAY	0.87	0.93	1.05	1.38	1.72	0.13	2.87	1.38	2.41	2.87
WA99-0012	DISCOVERY BAY	0.67	0.69	0.72*	0.81*	1.13	0.07*	2.09	0.88*	1.64	1.88*
WA99-0013	DISCOVERY BAY	3.24	1.05	1.27	1.45	1.73	0.09	3.61	1.51	3.24	3.18
WA99-0014	DISCOVERY BAY	0.98	0.55	0.52*	0.51*	0.71	0.05*	1.53	0.49*	1.33	1.14*
WA99-0015	KALALOCH CREEK	0.14	3.21	4.57	5.29*	34.29	1.14*	3.21	5.71	3.00	10.57
WA99-0016	RAFT RIVER	2.00	0.49	0.38*	0.36*	1.80	0.17*	0.75	0.265*	1.05	0.97
WA99-0017	QUINAULT RIVER	0.37	0.46	0.27	0.46	2.19	0.14*	1.65	0.35*	1.59	1.63
WA99-0018	QUINAULT RIVER	station not sampled									
WA99-0019	CONNER CREEK	0.14	0.81*	0.68*	0.95*	2.34	0.36*	2.12	0.80*	1.90	2.19*
WA99-0020	GRAYS HARBOR	0.54	0.59	0.44*	0.74*	1.59	0.19*	1.52	0.5*	1.65	1.56*
WA99-0021	GRASS CREEK	0.17	0.82	0.71	0.94	2.12	0.29*	3.47	0.88	3.35	2.24
WA99-0022	GRAYS HARBOR	0.53	0.60	0.64*	0.64*	1.00	0.19*	2.26	0.55*	2.08	1.25*
WA99-0023	GRAYS HARBOR	0.07	1.43*	0.97*	1.57*	3.29	0.71*	3.50	1.57*	3.71	2.97*
WA99-0024	GRAYS HARBOR	0.07	2.43*	4.57*	6.86*	4.00	1.86*	3.71	9.14*	4.43	8.14*
WA99-0025	GRAYS HARBOR	1.70	6.59	3.24	1.35	4.47	0.65	16.24	1.82	14.41	7.12
WA99-0026	GRAYS HARBOR	non-detect	cannot calculate*	cannot calculate*	cannot calculate*	cannot calculate	cannot calculate*	cannot calculate	cannot calculate*	cannot calculate	cannot calculate*
WA99-0027	BEARDSLEE SLOUGH	0.98	0.16	0.17*	0.22*	0.31	0.05*	0.49	0.18*	0.44	0.42*
WA99-0028	BEARDSLEE SLOUGH	station not sampled									
WA99-0029	GRAYS HARBOR	0.15	0.33*	0.33*	0.33*	0.33*	0.33*	0.33*	0.33*	0.33*	0.67*
WA99-0030	WILLAPA BAY	no sediment sampled									

EMAP Station ID	Station Location	TOC (%)	Benz(a) anthracene (ppm org. C)	Benzo(a) pyrene (ppm org. C)	Benzo(g,h,i) perylene (ppm org. C)	Chrysene (ppm org. C)	Dibenz(a,h) anthracene (ppm org. C)	Fluor-anthene (ppm org. C)	Indeno (1,2,3-c,d) pyrene (ppm org. C)	Pyrene (ppm org. C)	Total Benzo-fluoranthenes (ppm org. C)
WA99-0031	WILLAPA BAY	0.86	1.05	1.16	1.00	1.40	0.11	2.67	1.10	3.02	2.29
WA99-0032	WILLAPA BAY	station not sampled									
WA99-0033	WILLAPA BAY	0.02	2.6*	2.4*	2.4*	4.25*	2.4*	3.05*	2.4*	3.75	4.8*
WA99-0034	WILLAPA BAY	0.49	0.53	0.71*	0.77*	0.81	0.10*	1.32	0.81*	1.40	1.32
WA99-0035	WILLAPA BAY	0.11	0.65	0.49*	0.82*	1.09	0.45*	1.27	0.77*	1.18	1.05
WA99-0036	WILLAPA BAY	0.08	0.96*	1.38*	1.25*	1.75*	0.6*	1.38	0.6*	1.25	2.35*
WA99-0037	WILLAPA BAY	station not sampled									
WA99-0038	BAKER BAY	0.35	3.14	4.29	2.86*	4.29	0.54*	9.14	3.43*	9.43	5.97
WA99-0039	BAKER BAY	1.30	3.08	4.38	3.15	3.46	0.17*	9.00	3.85	10.08	6.31
WA99-0040	BAKER BAY	0.39	1.54	2.05	1.79*	2.15	0.13*	3.59	2.05*	3.85	3.67
WA99-0041	GRAYS RIVER	station not sampled									
WA99-0042	BAKER BAY	0.09	0.84*	1.11*	0.54*	1.56	0.54*	1.56	0.54*	1.67	1.54*
WA99-0043	GRAYS BAY	0.81	0.32	0.49*	0.54*	0.64	0.06*	1.04	0.43*	1.19	1.11*
WA99-0044	GRAYS BAY	0.22	0.45*	0.73*	1.14*	1.14	0.24*	1.14	0.73*	1.91	1.23
WA99-0045	GRAYS BAY	0.27	0.67	0.67*	1.63*	1.85	0.21*	1.67	1.04*	2.63	2.44
WA99-0046	GRAYS BAY	0.27	0.85	3.00	2.70	1.67	0.21*	1.26	2.52*	1.70	4.19
WA99-0047	GRAYS BAY	0.06	1.03*	2.67*	3.33*	1.35*	0.83*	1.27	3.67*	1.07	3.2*
WA99-0048	COWLITZ RIVER	0.02	2.3*	2.2*	2.3*	2.65*	2.3*	2.05	2.3*	1.60	4.6*
WA99-0049	CARROLLS CHANNEL	0.21	0.90	0.95	0.90	1.38	0.20*	1.71	1.00	1.67	2.14
WA99-0050 with outlier	MARTIN SLOUGH	0.85	8.86	9.02	4.31	52.98	1.02	47.96	5.10	39.84	41.15
WA99-0050 w/o outlier	MARTIN SLOUGH	0.85	47.24	23.50	8.56	290.03	2.47	254.50	11.68	151.94	41.15

* All concentrations were non-detects; therefore, the highest reporting limit (RL) was used as the concentration, per Washington State Department of Ecology (1995).

Table D-6. Sediment Total PAH concentrations, with and without outlier at Station WA99-0050, Lab Rep 4

EMAP Station ID	Station Location	EMAP Total LPAH (ng/g)	EMAP Total HPAH (ng/g)	EMAP Total PAH (ng/g)	TOC (%)	SQS/CSL Total LPAH (ppm org. C)	SQS/CSL Total HPAH (ppm org. C)	ERL/ERM Total LPAH (ng/g)	ERL/ERM Total HPAH (ng/g)	ERL/ERM Total PAH (ng/g)
WA99-0001	MAKAH BAY	746.7	154	900.7	0.46	65.5	38.02	482.8	109	591.8
WA99-0002	MAKAH BAY	394.9	79	473.9	0.22	72.82	41.3	240	64	304
WA99-0003	MAKAH BAY	411.2	95.6	506.8	0.18	116.21	60.8	306.7	77.6	384.3
WA99-0004	HOKO RIVER	104.25	23.45	127.7	0.1	65.25	37.95	88.75	23.45	112.2
WA99-0005	OZETTE RIVER	station not sampled								
WA99-0006	FRESHWATER BAY	no sediment sampled								
WA99-0007	FRESHWATER BAY	72.69	51.04	123.73	0.39	8.82	13.15	49.41	33.23	82.64
WA99-0008	FRESHWATER BAY	no sediment sampled								
WA99-0009	DUNGENESS BAY	58.7	95	153.7	0.7	6.47	16.48	53.7	84	137.7
WA99-0010	DISCOVERY BAY	309	311.2	620.2	1.72	9.18	18.09	216.9	209.2	426.1
WA99-0011	DISCOVERY BAY	121.4	128.3	249.7	0.87	7.17	14.75	85.4	79.3	164.7
WA99-0012	DISCOVERY BAY	56.03	37.2	93.23	0.67	4.37	9.91	36.6	37.2	73.8
WA99-0013	DISCOVERY BAY	338.9	554.9	893.8	3.24	5.51	17.13	232.4	355.9	588.3
WA99-0014	DISCOVERY BAY	59.23	40.4	99.63	0.98	3.39	6.84	44.7	40.4	85.1
WA99-0015	KALALOCH CREEK	115.64	90.4	206.04	0.14	86.03	71	131.44	67.6	199.04
WA99-0016	RAFT RIVER	530.8	100.7	631.5	2	10.01	6.23	390.3	81.7	472
WA99-0017	QUINAULT RIVER	55.89	30	85.89	0.37	8.19	8.74	45.79	22.8	68.59
WA99-0018	QUINAULT RIVER	station not sampled								
WA99-0019	CONNER CREEK	10.1	8.7	18.8	0.13667	6.52	12.15	8.4	8.7	17.1
WA99-0020	GRAYS HARBOR	49.1	28.9	78	0.54	5.72	8.78	39.8	28.9	68.7
WA99-0021	GRASS CREEK	22.23	24.7	46.93	0.17	9.07	14.82	19.31	17.8	37.11
WA99-0022	GRAYS HARBOR	55.56	33.45	89.01	0.53	7	9.21	46.45	31.5	77.95
WA99-0023	GRAYS HARBOR	9.90	7.35	17.25	0.07	12.94	19.73	8.46	7.35	15.81
WA99-0024	GRAYS HARBOR	10.78	12.2	22.98	0.07	15.23	45.14	12.3	10.2	22.5
WA99-0025	GRAYS HARBOR	320.3	950	1270.3	1.7	20.71	55.88	389	775	1164
WA99-0026	GRAYS HARBOR	3.33	4	7.33	non-detect	cannot calculate	cannot calculate	2.83	4	6.83
WA99-0027	BEARDSLEE SLOUGH	30.3	13.7	44	0.98	1.60	2.44	20.9	13.7	34.6
WA99-0028	BEARDSLEE SLOUGH	station not sampled								
WA99-0029	GRAYS HARBOR	0 (all non-detect)	0 (all non-detect)	0 (all non-detect)	0.15	2 (max RL used)	3.33 (max RL used)	all non-detect	all non-detect	all non-detect
WA99-0030	WILLAPA BAY	no sediment sampled								

EMAP Station ID	Station Location	EMAP Total LPAH (ng/g)	EMAP Total HPAH (ng/g)	EMAP Total PAH (ng/g)	TOC (%)	SQS/CSL Total LPAH (ppm org. C)	SQS/CSL Total HPAH (ppm org. C)	ERL/ERM Total LPAH (ng/g)	ERL/ERM Total HPAH (ng/g)	ERL/ERM Total PAH (ng/g)
WA99-0031	WILLAPA BAY	55.03	118.75	173.78	0.86	4.77	13.81	50.1	80.95	131.05
WA99-0032	WILLAPA BAY	station not sampled								
WA99-0033	WILLAPA BAY	0.31	0.75	1.06	0.02	18.60	28.05	0.97	0.75	1.72
WA99-0034	WILLAPA BAY	31.15	23.7	54.85	0.49	4.56	7.76	27.8	20	47.8
WA99-0035	WILLAPA BAY	2.43	5.78	8.21	0.11	4.18	7.79	2.6	4.62	7.22
WA99-0036	WILLAPA BAY	0.31	2.1	2.41	0.08	5.25	11.51	1.4	2.1	3.5
WA99-0037	WILLAPA BAY	station not sampled								
WA99-0038	BAKER BAY	31.2	126.9	158.1	0.35	12.31	43.09	45.9	106	151.9
WA99-0039	BAKER BAY	183.6	563	746.6	1.30	15.62	43.48	217	390	607
WA99-0040	BAKER BAY	22.95	65.7	88.65	0.39	5.13	20.82	22.3	51.4	73.7
WA99-0041	GRAYS RIVER	station not sampled								
WA99-0042	BAKER BAY	3.23	4.3	7.53	0.09	5.69	9.91	1.8	4.3	6.1
WA99-0043	GRAYS BAY	21.45	25.8	47.25	0.81	2.44	5.83	23.35	25.8	49.15
WA99-0044	GRAYS BAY	14.08	10.9	24.98	0.22	4.88	8.70	13.93	9.2	23.13
WA99-0045	GRAYS BAY	17.4	25	42.4	0.27	5.03	12.80	17.29	18.4	35.69
WA99-0046	GRAYS BAY	13.91	41.5	55.41	0.27	4.09	18.10	13.84	22.9	36.74
WA99-0047	GRAYS BAY	1.24	1.4	2.64	0.06	6.57	18.42	2.44	1.4	3.84
WA99-0048	COWLITZ RIVER	2.41	0.73	3.14	0.02	16.20	22.30	2.97	0.73	3.7
WA99-0049	CARROLLS CHANNEL	14.99	22.4	37.39	0.21	5.79	10.86	15.26	13.9	29.16
WA99-0050 with outlier	MARTIN SLOUGH	36184.5	7063.98	43248.4	0.85	5862.02***	831.056	51004.9**	6542.23*	57547.1**
WA99-0050 without outlier	MARTIN SLOUGH	385.3	1601.97	1987.27	0.85	88.224	188.467	760.167	1357.3	2117.47

Notes: (*) Exceeds ERL. (**) Exceeds ERL and ERM. (***) Exceeds SQS and CSL.

Table D-7. Sediment total and individual PCB concentrations (ng/g dry weight)

EMAP Station ID	Station Location	TOTAL PCB	PCB 8	PCB 18	PCB 28	PCB 44	PCB 52	PCB 66	PCB 101	PCB 105	PCB 110	PCB 118	PCB 138	PCB 153	PCB 170	PCB 180	PCB 187
WA99-0001	MAKAH BAY	1.84	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.23	0.22	0.3	0.77	0.32
WA99-0002	MAKAH BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0003	MAKAH BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0004	HOKO RIVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0005	OZETTE RIVER	station not sampled															
WA99-0006	FRESHWATER BAY	no sediment sampled															
WA99-0007	FRESHWATER BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0008	FRESHWATER BAY	no sediment sampled															
WA99-0009	DUNGENESS BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0010	DISCOVERY BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0011	DISCOVERY BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0012	DISCOVERY BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0013	DISCOVERY BAY	1.81	ND	ND	ND	ND	0.33	ND	0.31	ND	ND	0.34	0.42	0.41	ND	ND	ND
WA99-0014	DISCOVERY BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0015	KALALOCH CREEK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0016	RAFT RIVER	1.25	ND	ND	ND	ND	ND	ND	0.17	0.16	0.27	0.18	0.33	0.14	ND	ND	ND
WA99-0017	QUINAULT RIVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0018	QUINAULT RIVER	station not sampled															
WA99-0019	CONNER CREEK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0020	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0021	GRASS CREEK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0022	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0023	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0024	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0025	GRAYS HARBOR	4.41	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.49	1.1	0.32	1	1.5
WA99-0026	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0027	BEARDSLEE SLOUGH	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0028	BEARDSLEE SLOUGH	station not sampled															
WA99-0029	GRAYS HARBOR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0030	WILLAPA BAY	no sediment sampled															
WA99-0031	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0032	WILLAPA BAY	station not sampled															
WA99-0033	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

EMAP Station ID	Station Location	TOTAL PCB	PCB 8	PCB 18	PCB 28	PCB 44	PCB 52	PCB 66	PCB 101	PCB 105	PCB 110	PCB 118	PCB 138	PCB 153	PCB 170	PCB 180	PCB 187
WA99-0034	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0035	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0036	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0037	WILLAPA BAY	station not sampled															
WA99-0038	BAKER BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0039	BAKER BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0040	BAKER BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0041	GRAYS RIVER	station not sampled															
WA99-0042	BAKER BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0043	GRAYS BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0044	GRAYS BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0045	GRAYS BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0046	GRAYS BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0047	GRAYS BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0048	COWLITZ RIVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0049	CARROLLS CHANNEL	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WA99-0050	MARTIN SLOUGH	4.9	0.22	0.33	0.66	0.43	0.61	0.59	0.47	0.22	0.4	0.41	0.32	0.24	ND	ND	ND

Notes: (1) Averaged over lab replicates, if any. (2) Non-detects (ND) set to zero for EMAP analyses. (3) PCB Congeners 77, 126, 128, 195, 206, and 209 were not detected at any station.

Table D-8. Sediment total and individual DDT concentrations (ng/g dry weight)

EMAP Station ID	Station Location	Total DDT	4,4'-DDD	4,4'-DDE
WA99-0001	MAKAH BAY	non-detect	non-detect	non-detect
WA99-0002	MAKAH BAY	non-detect	non-detect	non-detect
WA99-0003	MAKAH BAY	non-detect	non-detect	non-detect
WA99-0004	HOKO RIVER	non-detect	non-detect	non-detect
WA99-0005	OZETTE RIVER	station not sampled		
WA99-0006	FRESHWATER BAY	no sediment sampled		
WA99-0007	FRESHWATER BAY	non-detect	non-detect	non-detect
WA99-0008	FRESHWATER BAY	no sediment sampled		
WA99-0009	DUNGENESS BAY	non-detect	non-detect	non-detect
WA99-0010	DISCOVERY BAY	0.3	non-detect	0.3
WA99-0011	DISCOVERY BAY	non-detect	non-detect	non-detect
WA99-0012	DISCOVERY BAY	non-detect	non-detect	non-detect
WA99-0013	DISCOVERY BAY	0.66	non-detect	0.66
WA99-0014	DISCOVERY BAY	non-detect	non-detect	non-detect
WA99-0015	KALALOCH CREEK	non-detect	non-detect	non-detect
WA99-0016	RAFT RIVER	non-detect	non-detect	non-detect
WA99-0017	QUINAULT RIVER	non-detect	non-detect	non-detect
WA99-0018	QUINAULT RIVER	station not sampled		
WA99-0019	CONNER CREEK	non-detect	non-detect	non-detect
WA99-0020	GRAYS HARBOR	non-detect	non-detect	non-detect
WA99-0021	GRASS CREEK	non-detect	non-detect	non-detect
WA99-0022	GRAYS HARBOR	non-detect	non-detect	non-detect
WA99-0023	GRAYS HARBOR	non-detect	non-detect	non-detect
WA99-0024	GRAYS HARBOR	non-detect	non-detect	non-detect
WA99-0025	GRAYS HARBOR	non-detect	non-detect	non-detect
WA99-0026	GRAYS HARBOR	non-detect	non-detect	non-detect
WA99-0027	BEARDSLEE SLOUGH	non-detect	non-detect	non-detect
WA99-0028	BEARDSLEE SLOUGH	station not sampled		
WA99-0029	GRAYS HARBOR	non-detect	non-detect	non-detect
WA99-0030	WILLAPA BAY	no sediment sampled		
WA99-0031	WILLAPA BAY	non-detect	non-detect	non-detect
WA99-0032	WILLAPA BAY	station not sampled		
WA99-0033	WILLAPA BAY	non-detect	non-detect	non-detect
WA99-0034	WILLAPA BAY	non-detect	non-detect	non-detect
WA99-0035	WILLAPA BAY	non-detect	non-detect	non-detect
WA99-0036	WILLAPA BAY	non-detect	non-detect	non-detect
WA99-0037	WILLAPA BAY	station not sampled		
WA99-0038	BAKER BAY	0.21	non-detect	0.21
WA99-0039	BAKER BAY	0.49	non-detect	0.49
WA99-0040	BAKER BAY	0.27	non-detect	0.27
WA99-0041	GRAYS RIVER	station not sampled		
WA99-0042	BAKER BAY	non-detect	non-detect	non-detect
WA99-0043	GRAYS BAY	0.32	non-detect	0.32
WA99-0044	GRAYS BAY	non-detect	non-detect	non-detect
WA99-0045	GRAYS BAY	0.43	non-detect	0.43
WA99-0046	GRAYS BAY	0.43	non-detect	0.43
WA99-0047	GRAYS BAY	non-detect	non-detect	non-detect
WA99-0048	COWLITZ RIVER	non-detect	non-detect	non-detect
WA99-0049	CARROLLS CHANNEL	non-detect	non-detect	non-detect
WA99-0050	MARTIN SLOUGH	2.09	0.59	1.5

Notes: (1) Averaged over lab replicates, if any. (2) Non-detects set to zero for EMAP analyses. (3) 2,4'-DDD; 2,4'-DDE; 2,4'-DDT; and 4,4'-DDT were not detected at any station.

Table D-9. Sediment chlorinated pesticide concentrations (ng/g dry weight)

		Hexachlorobenzene	
EMAP Station ID	Station Location	Method SW 8081	Method SW 8270
WA99-0001	MAKAH BAY	non-detect	non-detect
WA99-0002	MAKAH BAY	non-detect	non-detect
WA99-0003	MAKAH BAY	non-detect	non-detect
WA99-0004	HOKO RIVER	non-detect	non-detect
WA99-0005	OZETTE RIVER	station not sampled	
WA99-0006	FRESHWATER BAY	no sediment sampled	
WA99-0007	FRESHWATER BAY	non-detect	non-detect
WA99-0008	FRESHWATER BAY	no sediment sampled	
WA99-0009	DUNGENESS BAY	non-detect	non-detect
WA99-0010	DISCOVERY BAY	0.34	non-detect
WA99-0011	DISCOVERY BAY	non-detect	non-detect
WA99-0012	DISCOVERY BAY	non-detect	non-detect
WA99-0013	DISCOVERY BAY	non-detect	non-detect
WA99-0014	DISCOVERY BAY	non-detect	non-detect
WA99-0015	KALALOCH CREEK	non-detect	non-detect
WA99-0016	RAFT RIVER	non-detect	non-detect
WA99-0017	QUINAULT RIVER	23.1	43
WA99-0018	QUINAULT RIVER	station not sampled	
WA99-0019	CONNER CREEK	non-detect	non-detect
WA99-0020	GRAYS HARBOR	non-detect	non-detect
WA99-0021	GRASS CREEK	non-detect	non-detect
WA99-0022	GRAYS HARBOR	non-detect	non-detect
WA99-0023	GRAYS HARBOR	non-detect	non-detect
WA99-0024	GRAYS HARBOR	non-detect	non-detect
WA99-0025	GRAYS HARBOR	non-detect	non-detect
WA99-0026	GRAYS HARBOR	non-detect	non-detect
WA99-0027	BEARDSLEE SLOUGH	non-detect	non-detect
WA99-0028	BEARDSLEE SLOUGH	station not sampled	
WA99-0029	GRAYS HARBOR	non-detect	non-detect
WA99-0030	WILLAPA BAY	no sediment sampled	
WA99-0031	WILLAPA BAY	non-detect	non-detect
WA99-0032	WILLAPA BAY	station not sampled	
WA99-0033	WILLAPA BAY	non-detect	non-detect
WA99-0034	WILLAPA BAY	non-detect	non-detect
WA99-0035	WILLAPA BAY	non-detect	non-detect
WA99-0036	WILLAPA BAY	non-detect	non-detect
WA99-0037	WILLAPA BAY	station not sampled	
WA99-0038	BAKER BAY	non-detect	non-detect
WA99-0039	BAKER BAY	non-detect	non-detect
WA99-0040	BAKER BAY	non-detect	non-detect
WA99-0041	GRAYS RIVER	station not sampled	
WA99-0042	BAKER BAY	non-detect	non-detect
WA99-0043	GRAYS BAY	non-detect	non-detect
WA99-0044	GRAYS BAY	non-detect	non-detect
WA99-0045	GRAYS BAY	non-detect	non-detect
WA99-0046	GRAYS BAY	non-detect	non-detect
WA99-0047	GRAYS BAY	non-detect	non-detect
WA99-0048	COWLITZ RIVER	non-detect	non-detect
WA99-0049	CARROLLS CHANNEL	non-detect	non-detect
WA99-0050	MARTIN SLOUGH	non-detect	non-detect

Notes: (1) Non-detects set to zero for EMAP analyses. (2) No other non-DDT pesticides were detected at any station.

Table D-10. Sediment toxicity test results

		Amphipod Survival Test (*Ampelisca abdita*)	Sea Urchin Fertilization Test (*Arbacia punctulata*)	Sea Urchin Embryo Development Test (*Arbacia punctulata*)
EMAP Station ID	Station Location	Control-Corrected Survival (%)	Control-Corrected Fertilization (%)	Normal Development (%)
WA99-0001	MAKAH BAY	87.8	101.0	0.0
WA99-0002	MAKAH BAY	83.7	101.4	96.2
WA99-0003	MAKAH BAY	93.9	103.5	99.6
WA99-0004	HOKO RIVER	87.8	100.3	27.2
WA99-0005	OZETTE RIVER	station not sampled	station not sampled	station not sampled
WA99-0006	FRESHWATER BAY	no sediment sampled	no sediment sampled	no sediment sampled
WA99-0007	FRESHWATER BAY	96.9	100.3	9.9
WA99-0008	FRESHWATER BAY	no sediment sampled	no sediment sampled	no sediment sampled
WA99-0009	DUNGENESS BAY	99.0	101.8	9.1
WA99-0010	DISCOVERY BAY	94.9	102.0	62.9
WA99-0011	DISCOVERY BAY	90.8	102.4	24.3
WA99-0012	DISCOVERY BAY	91.8	94.8	0.0
WA99-0013	DISCOVERY BAY	86.7	1.3	0.0
WA99-0014	DISCOVERY BAY	93.9	99.5	0.0
WA99-0015	KALALOCH CREEK	101.1	102.6	98.1
WA99-0016	RAFT RIVER	94.6	61.4	0.0
WA99-0017	QUINAULT RIVER	95.7	97.8	97.9
WA99-0018	QUINAULT RIVER	station not sampled	station not sampled	station not sampled
WA99-0019	CONNER CREEK	102.2	103.5	88.9
WA99-0020	GRAYS HARBOR	102.2	100.7	99.8
WA99-0021	GRASS CREEK	96.7	98.6	100.9
WA99-0022	GRAYS HARBOR	insufficient control survival	102.4	100.7
WA99-0023	GRAYS HARBOR	insufficient control survival	101.8	80.6
WA99-0024	GRAYS HARBOR	87.0	103.7	99.4
WA99-0025	GRAYS HARBOR	insufficient control survival	101.6	91.8
WA99-0026	GRAYS HARBOR	insufficient control survival	104.1	101.1
WA99-0027	BEARDSLEE SLOUGH	93.5	100.7	101.9
WA99-0028	BEARDSLEE SLOUGH	station not sampled	station not sampled	station not sampled
WA99-0029	GRAYS HARBOR	90.2	103.5	101.9
WA99-0030	WILLAPA BAY	no sediment sampled	no sediment sampled	no sediment sampled
WA99-0031	WILLAPA BAY	insufficient control survival	102.9	99.6
WA99-0032	WILLAPA BAY	station not sampled	station not sampled	station not sampled
WA99-0033	WILLAPA BAY	79.8	104.3	101.9
WA99-0034	WILLAPA BAY	insufficient control survival	94.0	80.8
WA99-0035	WILLAPA BAY	95.7	103.5	92.2
WA99-0036	WILLAPA BAY	88.3	102.9	99.2
WA99-0037	WILLAPA BAY	station not sampled	station not sampled	station not sampled
WA99-0038	BAKER BAY	98.9	103.3	100.0
WA99-0039	BAKER BAY	92.4	101.4	103.2
WA99-0040	BAKER BAY	91.3	101.8	96.9
WA99-0041	GRAYS RIVER	station not sampled	station not sampled	station not sampled
WA99-0042	BAKER BAY	94.6	103.3	100.9
WA99-0043	GRAYS BAY	76.1	100.1	100.5
WA99-0044	GRAYS BAY	84.8	95.5	96.9
WA99-0045	GRAYS BAY	56.5	101.8	96.9
WA99-0046	GRAYS BAY	81.5	101.8	98.8
WA99-0047	GRAYS BAY	90.2	102.4	99.2
WA99-0048	COWLITZ RIVER	72.8	102.2	87.0
WA99-0049	CARROLLS CHANNEL	89.7	102.9	92.6
WA99-0050	MARTIN SLOUGH	insufficient control survival	99.5	99.4

Table D-11. Amphipod (*Ampelisca abdita*) survival test results

EMAP Station ID	Station Location	Survival (%)	Negative Control Survival (%)	Control-Corrected Survival (%)
WA99-0001	MAKAH BAY	86	98	87.8
WA99-0002	MAKAH BAY	82	98	83.7
WA99-0003	MAKAH BAY	92	98	93.9
WA99-0004	HOKO RIVER	86	98	87.8
WA99-0005	OZETTE RIVER	station not sampled		
WA99-0006	FRESHWATER BAY	no sediment sampled		
WA99-0007	FRESHWATER BAY	95	98	96.9
WA99-0008	FRESHWATER BAY	no sediment sampled		
WA99-0009	DUNGENESS BAY	97	98	99.0
WA99-0010	DISCOVERY BAY	93	98	94.9
WA99-0011	DISCOVERY BAY	89	98	90.8
WA99-0012	DISCOVERY BAY	90	98	91.8
WA99-0013	DISCOVERY BAY	85	98	86.7
WA99-0014	DISCOVERY BAY	92	98	93.9
WA99-0015	KALALOCH CREEK	93	92	101.1
WA99-0016	RAFT RIVER	87	92	94.6
WA99-0017	QUINAULT RIVER	88	92	95.7
WA99-0018	QUINAULT RIVER	station not sampled		
WA99-0019	CONNER CREEK	94	92	102.2
WA99-0020	GRAYS HARBOR	94	92	102.2
WA99-0021	GRASS CREEK	89	92	96.7
WA99-0022	GRAYS HARBOR	insufficient control survival		
WA99-0023	GRAYS HARBOR	insufficient control survival		
WA99-0024	GRAYS HARBOR	80	92	87.0
WA99-0025	GRAYS HARBOR	insufficient control survival		
WA99-0026	GRAYS HARBOR	insufficient control survival		
WA99-0027	BEARDSLEE SLOUGH	86	92	93.5
WA99-0028	BEARDSLEE SLOUGH	station not sampled		
WA99-0029	GRAYS HARBOR	83	92	90.2
WA99-0030	WILLAPA BAY	no sediment sampled		
WA99-0031	WILLAPA BAY	insufficient control survival		
WA99-0032	WILLAPA BAY	station not sampled		
WA99-0033	WILLAPA BAY	75	94	79.8
WA99-0034	WILLAPA BAY	insufficient control survival		
WA99-0035	WILLAPA BAY	90	94	95.7
WA99-0036	WILLAPA BAY	83	94	88.3
WA99-0037	WILLAPA BAY	station not sampled		
WA99-0038	BAKER BAY	91	92	98.9
WA99-0039	BAKER BAY	85	92	92.4
WA99-0040	BAKER BAY	84	92	91.3
WA99-0041	GRAYS RIVER	station not sampled		
WA99-0042	BAKER BAY	87	92	94.6
WA99-0043	GRAYS BAY	70	92	76.1
WA99-0044	GRAYS BAY	78	92	84.8
WA99-0045	GRAYS BAY	52	92	56.5
WA99-0046	GRAYS BAY	75	92	81.5
WA99-0047	GRAYS BAY	83	92	90.2
WA99-0048	COWLITZ RIVER	67	92	72.8
WA99-0049	CARROLLS CHANNEL	82.5	92	89.7
WA99-0050	MARTIN SLOUGH	insufficient control survival		

Table D-12. Sea urchin (*Arbacia punctulata*) fertilization test results

		100% salinity-adjusted porewater			50% salinity-adjusted porewater			25% salinity-adjusted porewater		
EMAP Station ID	Station Location	Fertilization (%)	Negative Control Fertilization (%)	Control-Corrected Fertilization (%)	Fertilization (%)	Negative Control Fertilization (%)	Control-Corrected Fertilization (%)	Fertilization (%)	Negative Control Fertilization (%)	Control-Corrected Fertilization (%)
WA99-0001	MAKAH BAY	95.4	94.5	101.0	96.2	94.5	101.8	97.6	94.5	103.3
WA99-0002	MAKAH BAY	95.8	94.5	101.4	96.2	94.5	101.8	95.8	94.5	101.4
WA99-0003	MAKAH BAY	97.8	94.5	103.5	97	94.5	102.6	96.6	94.5	102.2
WA99-0004	HOKO RIVER	94.8	94.5	100.3	95.6	94.5	101.2	96.2	94.5	101.8
WA99-0005	OZETTE RIVER	station not sampled			station not sampled			station not sampled		
WA99-0006	FRESHWATER BAY	no sediment sampled			no sediment sampled			no sediment sampled		
WA99-0007	FRESHWATER BAY	94.8	94.5	100.3	96.8	94.5	102.4	94.4	94.5	99.9
WA99-0008	FRESHWATER BAY	no sediment sampled			no sediment sampled			no sediment sampled		
WA99-0009	DUNGENESS BAY	96.2	94.5	101.8	97	94.5	102.6	96.2	94.5	101.8
WA99-0010	DISCOVERY BAY	96.4	94.5	102.0	97.4	94.5	103.1	95.8	94.5	101.4
WA99-0011	DISCOVERY BAY	96.8	94.5	102.4	95.2	94.5	100.7	96.8	94.5	102.4
WA99-0012	DISCOVERY BAY	89.6	94.5	94.8	96	94.5	101.6	97.2	94.5	102.9
WA99-0013	DISCOVERY BAY	1.2	94.5	1.3	4.8	94.5	5.1	71.6	94.5	75.8
WA99-0014	DISCOVERY BAY	94	94.5	99.5	95.8	94.5	101.4	96	94.5	101.6
WA99-0015	KALALOCH CREEK	97	94.5	102.6	98	94.5	103.7	98	94.5	103.7
WA99-0016	RAFT RIVER	58	94.5	61.4	94.8	94.5	100.3	95.4	94.5	101.0
WA99-0017	QUINAULT RIVER	92.4	94.5	97.8	96.4	94.5	102.0	98	94.5	103.7
WA99-0018	QUINAULT RIVER	station not sampled			station not sampled			station not sampled		
WA99-0019	CONNER CREEK	97.8	94.5	103.5	98.2	94.5	103.9	96.2	94.5	101.8
WA99-0020	GRAYS HARBOR	95.2	94.5	100.7	96	94.5	101.6	96.4	94.5	102.0
WA99-0021	GRASS CREEK	93.2	94.5	98.6	95.8	94.5	101.4	96.4	94.5	102.0
WA99-0022	GRAYS HARBOR	96.8	94.5	102.4	96.4	94.5	102.0	97	94.5	102.6
WA99-0023	GRAYS HARBOR	96.2	94.5	101.8	97.2	94.5	102.9	98.2	94.5	103.9
WA99-0024	GRAYS HARBOR	98	94.5	103.7	96.2	94.5	101.8	97.6	94.5	103.3
WA99-0025	GRAYS HARBOR	96	94.5	101.6	95.6	94.5	101.2	97.2	94.5	102.9
WA99-0026	GRAYS HARBOR	98.4	94.5	104.1	96.4	94.5	102.0	96.6	94.5	102.2
WA99-0027	BEARDSLEE SLOUGH	95.2	94.5	100.7	96.8	94.5	102.4	96	94.5	101.6
WA99-0028	BEARDSLEE SLOUGH	station not sampled			station not sampled			station not sampled		
WA99-0029	GRAYS HARBOR	97.8	94.5	103.5	98.2	94.5	103.9	97	94.5	102.6

		100% salinity-adjusted porewater			50% salinity-adjusted porewater			25% salinity-adjusted porewater		
EMAP Station ID	Station Location	Fertilization (%)	Negative Control Fertilization (%)	Control-Corrected Fertilization (%)	Fertilization (%)	Negative Control Fertilization (%)	Control-Corrected Fertilization (%)	Fertilization (%)	Negative Control Fertilization (%)	Control-Corrected Fertilization (%)
WA99-0030	WILLAPA BAY	no sediment sampled			no sediment sampled			no sediment sampled		
WA99-0031	WILLAPA BAY	97.2	94.5	102.9	97.2	94.5	102.9	98.8	94.5	104.6
WA99-0032	WILLAPA BAY	station not sampled			station not sampled			station not sampled		
WA99-0033	WILLAPA BAY	98.6	94.5	104.3	95.8	94.5	101.4	97.2	94.5	102.9
WA99-0034	WILLAPA BAY	88.8	94.5	94.0	97.8	94.5	103.5	96.8	94.5	102.4
WA99-0035	WILLAPA BAY	97.8	94.5	103.5	97	94.5	102.6	98	94.5	103.7
WA99-0036	WILLAPA BAY	97.2	94.5	102.9	95.8	94.5	101.4	97.4	94.5	103.1
WA99-0037	WILLAPA BAY	station not sampled			station not sampled			station not sampled		
WA99-0038	BAKER BAY	97.6	94.5	103.3	97	94.5	102.6	97.8	94.5	103.5
WA99-0039	BAKER BAY	95.8	94.5	101.4	95.8	94.5	101.4	97.4	94.5	103.1
WA99-0040	BAKER BAY	96.2	94.5	101.8	98	94.5	103.7	95.8	94.5	101.4
WA99-0041	GRAYS RIVER	station not sampled			station not sampled			station not sampled		
WA99-0042	BAKER BAY	97.6	94.5	103.3	97.6	94.5	103.3	98.4	94.5	104.1
WA99-0043	GRAYS BAY	94.6	94.5	100.1	95.8	94.5	101.4	96	94.5	101.6
WA99-0044	GRAYS BAY	90.2	94.5	95.5	96.2	94.5	101.8	97.2	94.5	102.9
WA99-0045	GRAYS BAY	96.2	94.5	101.8	95.4	94.5	101.0	97.6	94.5	103.3
WA99-0046	GRAYS BAY	96.2	94.5	101.8	96.8	94.5	102.4	97	94.5	102.6
WA99-0047	GRAYS BAY	96.8	94.5	102.4	96.4	94.5	102.0	95.6	94.5	101.2
WA99-0048	COWLITZ RIVER	96.6	94.5	102.2	96.8	94.5	102.4	96.6	94.5	102.2
WA99-0049	CARROLLS CHANNEL	97.2	94.5	102.9	98.6	94.5	104.3	97.8	94.5	103.5
WA99-0050	MARTIN SLOUGH	94	94.5	99.5	94.6	94.5	100.1	96.2	94.5	101.8

Table D-13. Sea urchin (*Arbacia punctulata*) embryo development test results

		100% salinity-adjusted porewater			50% salinity-adjusted porewater			25% salinity-adjusted porewater		
EMAP Station ID	Station Location	Normal Devel. (%)	Negative Control Normal Devel. (%)	Control-Corrected Normal Devel. (%)	Normal Devel. (%)	Negative Control Normal Devel. (%)	Control-Corrected Normal Devel. (%)	Normal Devel. (%)	Negative Control Normal Devel. (%)	Control-Corrected Normal Devel. (%)
WA99-0001	MAKAH BAY	0	94.8	0.0	8.2	94.8	8.7	93.2	94.8	98.3
WA99-0002	MAKAH BAY	91.2	94.8	96.2	94.6	94.8	99.8	93.6	94.8	98.8
WA99-0003	MAKAH BAY	94.4	94.8	99.6	93.8	94.8	99.0	94.8	94.8	100.0
WA99-0004	HOKO RIVER	25.8	94.8	27.2	93.2	94.8	98.3	94	94.8	99.2
WA99-0005	OZETTE RIVER	station not sampled			station not sampled			station not sampled		
WA99-0006	FRESHWATER BAY	no sediment sampled			no sediment sampled			no sediment sampled		
WA99-0007	FRESHWATER BAY	9.4	94.8	9.9	92.4	94.8	97.5	94.6	94.8	99.8
WA99-0008	FRESHWATER BAY	no sediment sampled			no sediment sampled			no sediment sampled		
WA99-0009	DUNGENESS BAY	8.6	94.8	9.1	96.2	94.8	101.5	95.4	94.8	100.7
WA99-0010	DISCOVERY BAY	59.6	94.8	62.9	94	94.8	99.2	95.4	94.8	100.7
WA99-0011	DISCOVERY BAY	23	94.8	24.3	92.6	94.8	97.7	94.4	94.8	99.6
WA99-0012	DISCOVERY BAY	0	94.8	0.0	81	94.8	85.5	90.4	94.8	95.4
WA99-0013	DISCOVERY BAY	0	94.8	0.0	1.6	94.8	1.7	95.4	94.8	100.7
WA99-0014	DISCOVERY BAY	0	94.8	0.0	90.2	94.8	95.2	95.4	94.8	100.7
WA99-0015	KALALOCH CREEK	93	94.8	98.1	95.4	94.8	100.7	93	94.8	98.1
WA99-0016	RAFT RIVER	0	94.8	0.0	24.8	94.8	26.2	94	94.8	99.2
WA99-0017	QUINAULT RIVER	92.8	94.8	97.9	90.6	94.8	95.6	94	94.8	99.2
WA99-0018	QUINAULT RIVER	station not sampled			station not sampled			station not sampled		
WA99-0019	CONNER CREEK	84.2	94.8	88.9	91.2	94.8	96.2	90.4	94.8	95.4
WA99-0020	GRAYS HARBOR	94.6	94.8	99.8	94.2	94.8	99.4	94.6	94.8	99.8
WA99-0021	GRASS CREEK	95.6	94.8	100.9	95	94.8	100.2	95.6	94.8	100.9
WA99-0022	GRAYS HARBOR	95.4	94.8	100.7	97.4	94.8	102.8	97.4	94.8	102.8
WA99-0023	GRAYS HARBOR	76.4	94.8	80.6	96.6	94.8	101.9	97.8	94.8	103.2
WA99-0024	GRAYS HARBOR	94.2	94.8	99.4	95	94.8	100.2	95.2	94.8	100.5
WA99-0025	GRAYS HARBOR	87	94.8	91.8	97	94.8	102.4	95.2	94.8	100.5
WA99-0026	GRAYS HARBOR	95.8	94.8	101.1	95.4	94.8	100.7	95.4	94.8	100.7
WA99-0027	BEARDSLEE SLOUGH	96.6	94.8	101.9	96.4	94.8	101.7	96.2	94.8	101.5
WA99-0028	BEARDSLEE SLOUGH	station not sampled			station not sampled			station not sampled		
WA99-0029	GRAYS HARBOR	96.6	94.8	101.9	94.2	94.8	99.4	95.8	94.8	101.1

		100% salinity-adjusted porewater			50% salinity-adjusted porewater			25% salinity-adjusted porewater		
EMAP Station ID	Station Location	Normal Devel. (%)	Negative Control Normal Devel. (%)	Control-Corrected Normal Devel. (%)	Normal Devel. (%)	Negative Control Normal Devel. (%)	Control-Corrected Normal Devel. (%)	Normal Devel. (%)	Negative Control Normal Devel. (%)	Control-Corrected Normal Devel. (%)
WA99-0030	WILLAPA BAY	no sediment sampled			no sediment sampled			no sediment sampled		
WA99-0031	WILLAPA BAY	94.4	94.8	99.6	97	94.8	102.4	96.2	94.8	101.5
WA99-0032	WILLAPA BAY	station not sampled			station not sampled			station not sampled		
WA99-0033	WILLAPA BAY	96.6	94.8	101.9	96	94.8	101.3	93.8	94.8	99.0
WA99-0034	WILLAPA BAY	76.6	94.8	80.8	94	94.8	99.2	96	94.8	101.3
WA99-0035	WILLAPA BAY	87.4	94.8	92.2	96	94.8	101.3	95.6	94.8	100.9
WA99-0036	WILLAPA BAY	94	94.8	99.2	92.2	94.8	97.3	89.8	94.8	94.8
WA99-0037	WILLAPA BAY	station not sampled			station not sampled			station not sampled		
WA99-0038	BAKER BAY	94.8	94.8	100.0	95.4	94.8	100.7	97	94.8	102.4
WA99-0039	BAKER BAY	97.8	94.8	103.2	95.4	94.8	100.7	95.8	94.8	101.1
WA99-0040	BAKER BAY	91.8	94.8	96.9	96	94.8	101.3	91.4	94.8	96.4
WA99-0041	GRAYS RIVER	station not sampled			station not sampled			station not sampled		
WA99-0042	BAKER BAY	95.6	94.8	100.9	96.2	94.8	101.5	96	94.8	101.3
WA99-0043	GRAYS BAY	95.2	94.8	100.5	96.4	94.8	101.7	93.6	94.8	98.8
WA99-0044	GRAYS BAY	91.8	94.8	96.9	95.4	94.8	100.7	92.4	94.8	97.5
WA99-0045	GRAYS BAY	91.8	94.8	96.9	95.6	94.8	100.9	92.8	94.8	97.9
WA99-0046	GRAYS BAY	93.6	94.8	98.8	92.4	94.8	97.5	92.2	94.8	97.3
WA99-0047	GRAYS BAY	94	94.8	99.2	94	94.8	99.2	92	94.8	97.1
WA99-0048	COWLITZ RIVER	82.4	94.8	87.0	88.4	94.8	93.3	90.8	94.8	95.8
WA99-0049	CARROLLS CHANNEL	87.8	94.8	92.6	85.2	94.8	89.9	89.4	94.8	94.3
WA99-0050	MARTIN SLOUGH	94.2	94.8	99.4	94.6	94.8	99.8	88.6	94.8	93.5

Table D-14. Fish-tissue metals concentrations (µg/g wet weight)

EMAP Station ID	Station Location	Species	Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Selenium	Silver	Tin	Zinc
WA99-0001	MAKAH BAY	no fish sampled													
WA99-0002	MAKAH BAY	sand sole	12	0.88	0.2	1.1	2.9	19	0.058	0.0314	1.2	0.32	ND	ND	17.9
WA99-0003	MAKAH BAY	sand sole	13	1	ND	1.1	ND	18	0.78	0.016	ND	0.41	ND	ND	21
WA99-0004	HOKO RIVER	speckled sanddab	33	1.4	ND	1	1.32	33	0.11	0.018	ND	0.35	0.017	ND	19
WA99-0005	OZETTE RIVER	station not sampled													
WA99-0006	FRESHWATER BAY	speckled sanddab	11	2.1	ND	1.2	1.88	18	ND	0.024	ND	0.41	0.015	0.06	17.8
WA99-0007	FRESHWATER BAY	speckled sanddab	8.9	3.07	0.056	1.2	1.39	13	0.051	0.02	ND	0.39	0.012	0.057	17.3
WA99-0008	FRESHWATER BAY	no fish sampled													
WA99-0009	DUNGENESS BAY	insufficient target species fish obtained													
WA99-0010	DISCOVERY BAY	insufficient target species fish obtained													
WA99-0011	DISCOVERY BAY	no target species obtained													
WA99-0012	DISCOVERY BAY	English sole	114	3.77	0.052	1.3	ND	108	0.31	0.0089	ND	ND	0.015	ND	17.3
WA99-0013	DISCOVERY BAY	English sole	123	2.5	ND	2.2	3.68	156	0.13	0.01	ND	0.32	0.017	0.15	14.7
WA99-0014	DISCOVERY BAY	English sole	160	3.64	ND	1.6	3.99	233	0.1	0.0086	ND	0.31	ND	0.16	17.1
WA99-0015	KALALOCH CREEK	insufficient target species fish obtained													
WA99-0016	RAFT RIVER	starry flounder	109	0.32	ND	1.4	ND	102	0.12	0.017	ND	ND	ND	ND	27.3
WA99-0017	QUINAULT RIVER	no fish sampled													
WA99-0018	QUINAULT RIVER	station not sampled													
WA99-0019	CONNER CREEK	no target species obtained													
WA99-0020	GRAYS HARBOR	insufficient target species fish obtained													
WA99-0021	GRASS CREEK	English sole	47	0.35	ND	1	ND	59.3	0.079	0.0042	ND	0.34	ND	ND	21.8
WA99-0022	GRAYS HARBOR	insufficient target species fish obtained													
WA99-0023	GRAYS HARBOR	insufficient target species fish obtained													
WA99-0024	GRAYS HARBOR	insufficient target species fish obtained													
WA99-0025	GRAYS HARBOR	insufficient target species fish obtained													
WA99-0026	GRAYS HARBOR	insufficient target species fish obtained													
WA99-0027	BEARDSLEE SLOUGH	English sole	175	0.88	ND	1	2.25	233	0.13	0.0089	ND	0.63	ND	ND	20.8
WA99-0028	BEARDSLEE SLOUGH	station not sampled													
WA99-0029	GRAYS HARBOR	insufficient target species fish obtained													
WA99-0030	WILLAPA BAY	no fish sampled													
WA99-0031	WILLAPA BAY	English sole	186	0.65	ND	1	ND	210	0.24	0.0075	ND	0.5	ND	ND	20.2

EMAP Station ID	Station Location	Species	Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Selenium	Silver	Tin	Zinc
WA99-0032	WILLAPA BAY	station not sampled													
WA99-0033	WILLAPA BAY	no fish sampled													
WA99-0034	WILLAPA BAY	English sole	95.4	1.1	ND	1.3	1.92	114	0.84	0.0098	ND	0.6	ND	0.054	18.9
WA99-0035	WILLAPA BAY	no fish sampled													
WA99-0036	WILLAPA BAY	English sole	101	0.97	ND	0.75	1.33	135	0.11	0.011	ND	0.56	ND	ND	19.9
WA99-0037	WILLAPA BAY	station not sampled													
WA99-0038	BAKER BAY	starry flounder	96.3	ND	ND	1.2	3.73	152	0.17	0.017	ND	0.3	ND	0.14	25.3
WA99-0039	BAKER BAY	insufficient target species fish obtained													
WA99-0040	BAKER BAY	English sole	73.5	0.36	ND	0.75	2.67	99.7	0.099	0.016	ND	0.34	ND	0.083	20.8
WA99-0041	GRAYS RIVER	station not sampled													
WA99-0042	BAKER BAY	English sole	108	ND	ND	0.78	1.3	124	0.19	0.016	ND	0.41	0.27	ND	22.4
WA99-0043	GRAYS BAY	starry flounder	48	ND	0.052	0.87	0.83	66.4	0.084	0.013	ND	0.34	ND	ND	26.4
WA99-0044	GRAYS BAY	starry flounder	76	ND	ND	0.67	0.61	151	0.19	0.011	ND	0.32	ND	ND	32.1
WA99-0045	GRAYS BAY	no fish kept for tissue analyses													
WA99-0046	GRAYS BAY	starry flounder	37	ND	ND	0.49	2.12	46	0.054	0.012	ND	ND	ND	0.072	27.1
WA99-0047	GRAYS BAY	starry flounder	24.5	ND	ND	0.445	3.115	30	0.07	0.013	ND	0.155	ND	0.12	28.45
WA99-0048	COWLITZ RIVER	starry flounder	34.2	ND	ND	0.635	2.39	14	0.08	0.026	ND	ND	ND	0.0815	22.4
WA99-0049	CARROLLS CHANNEL	starry flounder	24	ND	ND	0.54	0.59	37	0.24	0.021	ND	0.46	ND	ND	29.2
WA99-0050	MARTIN SLOUGH	starry flounder	16	ND	ND	0.38	1.46	23	0.061	18	ND	0.46	ND	ND	23.5

Notes: (1) Averaged over lab replicates, if any. (2) NDs set to zero for EMAP analyses.

Table D-15. Fish-tissue PCB concentrations (ng/g wet weight)

EMAP Station ID	Station Location	PCB 18	PCB 28	PCB 44	PCB 52	PCB 66	PCB 101	PCB 105	PCB 118	PCB 126	PCB 128	PCB 138	PCB 153	PCB 180	PCB 187	PCB 195	PCB 206	Total PCB
WA99-0001	MAKAH BAY	no fish sampled																
WA99-0002	MAKAH BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.145	0.24	0.17	0.125	ND	ND	0.68
WA99-0003	MAKAH BAY	ND	ND	ND	ND	ND	0.11	ND	0.098	ND	ND	0.2	0.34	0.2	ND	ND	ND	0.948
WA99-0004	HOKO RIVER	ND	ND	ND	ND	ND	0.23	ND	0.19	ND	ND	0.29	0.44	0.14	0.14	ND	ND	1.43
WA99-0005	OZETTE RIVER	station not sampled																
WA99-0006	FRESHWATER BAY	ND	ND	ND	ND	ND	0.25	ND	0.21	ND	ND	0.32	0.5	0.16	0.17	ND	ND	1.61
WA99-0007	FRESHWATER BAY	ND	ND	ND	ND	ND	0.27	ND	0.21	ND	ND	0.33	0.53	0.18	0.19	ND	ND	1.71
WA99-0008	FRESHWATER BAY	no fish sampled																
WA99-0009	DUNGENESS BAY	insufficient target species fish obtained																
WA99-0010	DISCOVERY BAY	insufficient target species fish obtained																
WA99-0011	DISCOVERY BAY	no target species obtained																
WA99-0012	DISCOVERY BAY	ND	ND	ND	ND	ND	0.25	ND	0.19	ND	ND	0.33	0.56	0.19	0.26	ND	ND	1.78
WA99-0013	DISCOVERY BAY	ND	0.12	0.2	ND	0.098	0.61	0.11	0.4	ND	0.095	0.62	0.99	0.33	0.42	ND	ND	3.993
WA99-0014	DISCOVERY BAY	ND	ND	ND	ND	ND	0.085	ND	ND	ND	ND	0.18	0.28	0.088	0.089	ND	ND	0.722
WA99-0015	KALALOCH CREEK																	
WA99-0016	RAFT RIVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.11	0.13	ND	ND	ND	ND	0.24
WA99-0017	QUINAULT RIVER	no fish sampled																
WA99-0018	QUINAULT RIVER	station not sampled																
WA99-0019	CONNER CREEK	no target species obtained																
WA99-0020	GRAYS HARBOR	insufficient target species fish obtained																
WA99-0021	GRASS CREEK	ND	ND	ND	ND	ND	0.12	ND	ND	ND	ND	0.19	0.37	0.15	0.23	ND	ND	1.06
WA99-0022	GRAYS HARBOR	insufficient target species fish obtained																
WA99-0023	GRAYS HARBOR	insufficient target species fish obtained																
WA99-0024	GRAYS HARBOR	insufficient target species fish obtained																
WA99-0025	GRAYS HARBOR	insufficient target species fish obtained																
WA99-0026	GRAYS HARBOR	insufficient target species fish obtained																
WA99-0027	BEARDSLEE SLOUGH	ND	ND	ND	ND	ND	0.16	ND	0.096	ND	ND	0.23	0.44	0.12	0.26	ND	ND	1.306
WA99-0028	BEARDSLEE SLOUGH	station not sampled																
WA99-0029	GRAYS HARBOR	insufficient target species fish obtained																
WA99-0030	WILLAPA BAY	no fish sampled																
WA99-0031	WILLAPA BAY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.092	0.11	ND	ND	ND	ND	0.202
WA99-0032	WILLAPA BAY	station not sampled																
WA99-0033	WILLAPA BAY	no fish sampled																
WA99-0034	WILLAPA BAY	ND	ND	ND	ND	ND	0.18	ND	0.14	ND	ND	0.25	0.4	ND	0.18	ND	ND	1.15
WA99-0035	WILLAPA BAY	no fish sampled																
WA99-0036	WILLAPA BAY	ND	ND	ND	ND	ND	0.11	ND	0.11	ND	ND	0.19	0.34	0.1	0.18	ND	ND	1.03

EMAP Station ID	Station Location	PCB 18	PCB 28	PCB 44	PCB 52	PCB 66	PCB 101	PCB 105	PCB 118	PCB 126	PCB 128	PCB 138	PCB 153	PCB 180	PCB 187	PCB 195	PCB 206	Total PCB
WA99-0037	WILLAPA BAY	station not sampled																
WA99-0038	BAKER BAY	ND	0.21	0.2	0.66	0.605	1.25	0.395	1.3	ND	0.38	1.65	2.35	0.98	0.9	ND	ND	10.88
WA99-0039	BAKER BAY	insufficient target species fish obtained																
WA99-0040	BAKER BAY	ND	0.093	0.12	0.26	0.28	0.7	0.2	0.61	ND	0.19	0.83	1.2	0.46	0.53	ND	ND	5.473
WA99-0041	GRAYS RIVER	station not sampled																
WA99-0042	BAKER BAY	ND	0.11	0.12	0.27	0.26	0.71	0.18	0.6	ND	0.17	0.78	1.1	0.43	0.49	ND	ND	5.22
WA99-0043	GRAYS BAY	ND	0.15	0.18	0.57	0.51	1.3	0.4	1	ND	0.33	1.4	1.8	0.67	0.76	ND	ND	9.07
WA99-0044	GRAYS BAY	ND	0.14	0.078	0.38	0.33	0.71	0.23	0.63	ND	0.21	0.89	1.2	0.48	0.53	ND	ND	5.808
WA99-0045	GRAYS BAY	no fish kept for tissue analyses																
WA99-0046	GRAYS BAY	ND	0.23	0.29	0.81	1.2	1.8	0.54	1.4	ND	0.47	1.9	2.4	1	0.93	ND	ND	12.97
WA99-0047	GRAYS BAY	ND	0.26	0.3	0.98	0.83	2.2	0.7	1.9	ND	0.6	2.5	3.3	1.3	1.3	ND	ND	16.17
WA99-0048	COWLITZ RIVER	0.32	1.6	2.1	7.7	4	17	4.8	18	ND	3.2	15	16	4.6	3.2	0.24	0.22	97.98
WA99-0049	CARROLLS CHANNEL	0.91	3.4	4	11	6	20	6.2	19	0.26	3.7	17	17	4.4	3.5	0.23	0.28	116.9
WA99-0050	MARTIN SLOUGH	0.51	1.2	1.6	3.7	2.8	4.3	1.4	3.5	0.3	0.9	3.4	4.9	1.9	1.7	ND	ND	32.11

Notes: (1) Averaged over lab replicates, if any. (2) Non-detects (ND) set to zero for EMAP analyses. (3) PCB Congeners 8, 170, and 209 were not detected at any station.

Table D-16. Fish-tissue individual and Total DDT concentrations (ng/g wet weight)

EMAP Station ID	Station Location	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT
WA99-0001	MAKAH BAY	no fish sampled						
WA99-0002	MAKAH BAY	ND	ND	ND	ND	0.84	ND	0.84
WA99-0003	MAKAH BAY	ND	ND	ND	ND	0.89	ND	0.89
WA99-0004	HOKO RIVER	ND	ND	ND	ND	1.9	ND	1.9
WA99-0005	OZETTE RIVER	station not sampled						
WA99-0006	FRESHWATER BAY	ND	ND	ND	ND	1.6	ND	1.6
WA99-0007	FRESHWATER BAY	ND	ND	ND	ND	1.6	ND	1.6
WA99-0008	FRESHWATER BAY	no fish sampled						
WA99-0009	DUNGENESS BAY	insufficient target species fish obtained						
WA99-0010	DISCOVERY BAY	insufficient target species fish obtained						
WA99-0011	DISCOVERY BAY	no target species obtained						
WA99-0012	DISCOVERY BAY	ND	ND	ND	ND	0.78	ND	0.78
WA99-0013	DISCOVERY BAY	ND	ND	ND	0.15	1.7	ND	1.85
WA99-0014	DISCOVERY BAY	ND	ND	ND	ND	0.38	ND	0.38
WA99-0015	KALALOCH CREEK	insufficient target species fish obtained						
WA99-0016	RAFT RIVER	ND	ND	ND	0.12	0.57	ND	0.69
WA99-0017	QUINAULT RIVER	no fish sampled						
WA99-0018	QUINAULT RIVER	station not sampled						
WA99-0019	CONNER CREEK	no target species obtained						
WA99-0020	GRAYS HARBOR	insufficient target species fish obtained						
WA99-0021	GRASS CREEK	ND	ND	ND	ND	0.34	ND	0.34
WA99-0022	GRAYS HARBOR	insufficient target species fish obtained						
WA99-0023	GRAYS HARBOR	insufficient target species fish obtained						
WA99-0024	GRAYS HARBOR	insufficient target species fish obtained						
WA99-0025	GRAYS HARBOR	insufficient target species fish obtained						
WA99-0026	GRAYS HARBOR	insufficient target species fish obtained						
WA99-0027	BEARDSLEE SLOUGH	ND	ND	ND	0.2	0.89	ND	1.09
WA99-0028	BEARDSLEE SLOUGH	station not sampled						
WA99-0029	GRAYS HARBOR	insufficient target species fish obtained						
WA99-0030	WILLAPA BAY	no fish sampled						
WA99-0031	WILLAPA BAY	ND	ND	ND	ND	0.48	ND	0.48
WA99-0032	WILLAPA BAY	station not sampled						
WA99-0033	WILLAPA BAY	no fish sampled						
WA99-0034	WILLAPA BAY	ND	ND	ND	0.27	1.6	ND	1.87
WA99-0035	WILLAPA BAY	no fish sampled						
WA99-0036	WILLAPA BAY	ND	ND	ND	ND	0.9	ND	0.9
WA99-0037	WILLAPA BAY	station not sampled						
WA99-0038	BAKER BAY	0.34	0.31	0.74	4.55	27.5	2.3	35.74
WA99-0039	BAKER BAY	insufficient target species fish obtained						
WA99-0040	BAKER BAY	0.48	0.2	0.23	2.7	13	0.81	17.42
WA99-0041	GRAYS RIVER	station not sampled						
WA99-0042	BAKER BAY	0.37	0.18	0.16	2.8	12	0.84	16.35
WA99-0043	GRAYS BAY	0.52	0.35	0.79	4.1	29	1.9	36.66
WA99-0044	GRAYS BAY	0.23	0.19	0.31	3.2	17	0.99	21.92
WA99-0045	GRAYS BAY	no fish kept for tissue analyses						
WA99-0046	GRAYS BAY	0.88	0.5	1.3	6.8	41	3	53.48
WA99-0047	GRAYS BAY	0.78	0.59	1.6	6.4	53	3.3	65.67
WA99-0048	COWLITZ RIVER	1.4	ND	9.7	14	130	12	168.3
WA99-0049	CARROLLS CHANNEL	1.2	ND	5.2	11	94	7.9	119.3
WA99-0050	MARTIN SLOUGH	1.2	0.91	2.1	11	70	4.9	90.11

Notes: (1) Averaged over lab replicates, if any. (2) Non-detects (ND) set to zero for EMAP analyses.

Table D-17. Fish-tissue pesticide, Total DDT, and Total PCB concentrations (ng/g wet weight)

EMAP Station ID		Species	alpha-Chlordane	Hexachloro-benzene	trans-Nonachlor	Total DDT	Total PCB
WA99-0001	MAKAH BAY	no fish sampled					
WA99-0002	MAKAH BAY	sand sole	ND	ND	ND	0.84	0.68
WA99-0003	MAKAH BAY	sand sole	ND	ND	ND	0.89	0.948
WA99-0004	HOKO RIVER	speckled sanddab	ND	0.21	0.21	1.9	1.43
WA99-0005	OZETTE RIVER	station not sampled					
WA99-0006	FRESHWATER BAY	speckled sanddab	ND	0.28	0.2	1.6	1.61
WA99-0007	FRESHWATER BAY	speckled sanddab	ND	0.24	0.19	1.6	1.71
WA99-0008	FRESHWATER BAY	no fish sampled					
WA99-0009	DUNGENESS BAY	insufficient target species fish obtained					
WA99-0010	DISCOVERY BAY	insufficient target species fish obtained					
WA99-0011	DISCOVERY BAY	no target species obtained					
WA99-0012	DISCOVERY BAY	English sole	ND	0.15	ND	0.78	1.78
WA99-0013	DISCOVERY BAY	English sole	ND	0.17	0.16	1.85	3.993
WA99-0014	DISCOVERY BAY	English sole	ND	ND	ND	0.38	0.722
WA99-0015	KALALOCH CREEK	insufficient target species fish obtained					
WA99-0016	RAFT RIVER	starry flounder	ND	0.14	ND	0.69	0.24
WA99-0017	QUINAULT RIVER	no fish sampled					
WA99-0018	QUINAULT RIVER	station not sampled					
WA99-0019	CONNER CREEK	no target species obtained					
WA99-0020	GRAYS HARBOR	insufficient target species fish obtained					
WA99-0021	GRASS CREEK	English sole	ND	ND	ND	0.34	1.06
WA99-0022	GRAYS HARBOR	insufficient target species fish obtained					
WA99-0023	GRAYS HARBOR	insufficient target species fish obtained					
WA99-0024	GRAYS HARBOR	insufficient target species fish obtained					
WA99-0025	GRAYS HARBOR	insufficient target species fish obtained					
WA99-0026	GRAYS HARBOR	insufficient target species fish obtained					
WA99-0027	BEARDSLEE SLOUGH	English sole	ND	ND	ND	1.09	1.306
WA99-0028	BEARDSLEE SLOUGH	station not sampled					
WA99-0029	GRAYS HARBOR	insufficient target species fish obtained					
WA99-0030	WILLAPA BAY	no fish sampled					
WA99-0031	WILLAPA BAY	English sole	ND	ND	ND	0.48	0.202
WA99-0032	WILLAPA BAY	station not sampled					
WA99-0033	WILLAPA BAY	no fish sampled					
WA99-0034	WILLAPA BAY	English sole	ND	ND	ND	1.87	1.15
WA99-0035	WILLAPA BAY	no fish sampled					
WA99-0036	WILLAPA BAY	English sole	ND	ND	ND	0.9	1.03
WA99-0037	WILLAPA BAY	station not sampled					
WA99-0038	BAKER BAY	starry flounder	0.555	0.605	1.25	35.74	10.88
WA99-0039	BAKER BAY	insufficient target species fish obtained					
WA99-0040	BAKER BAY	English sole	ND	0.35	0.56	17.42	5.473
WA99-0041	GRAYS RIVER	station not sampled					
WA99-0042	BAKER BAY	English sole	ND	0.26	0.44	16.35	5.22
WA99-0043	GRAYS BAY	starry flounder	0.42	0.55	0.93	36.66	9.07
WA99-0044	GRAYS BAY	starry flounder	0.28	0.45	0.63	21.92	5.808
WA99-0045	GRAYS BAY	no fish kept for tissue analyses					
WA99-0046	GRAYS BAY	starry flounder	0.74	0.77	1.5	53.48	12.97
WA99-0047	GRAYS BAY	starry flounder	0.64	0.83	1.9	65.67	16.17
WA99-0048	COWLITZ RIVER	starry flounder	1.4	1.6	4.1	168.3	97.98
WA99-0049	CARROLLS CHANNEL	starry flounder	0.82	1.6	2.6	119.3	116.88
WA99-0050	MARTIN SLOUGH	starry flounder	0.88	1.9	2	90.11	32.11

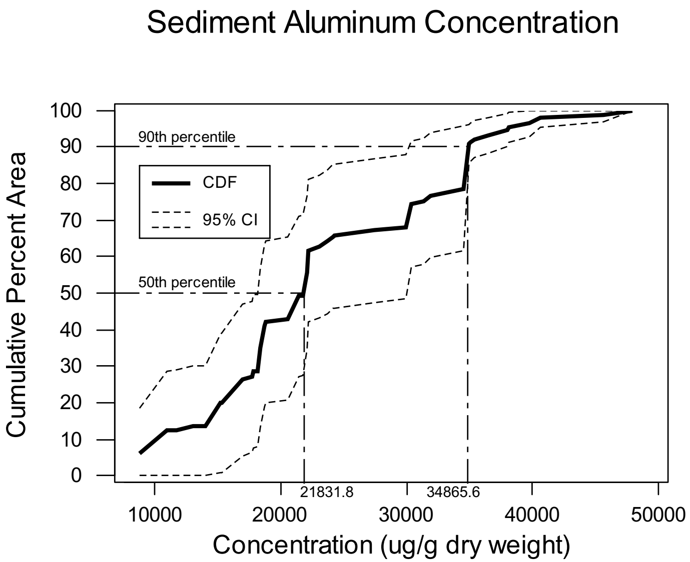
Notes: (1) Averaged over lab replicates, if any. (2) Non-detects set to zero for EMAP analyses. (3) No other pesticides were detected at any station.

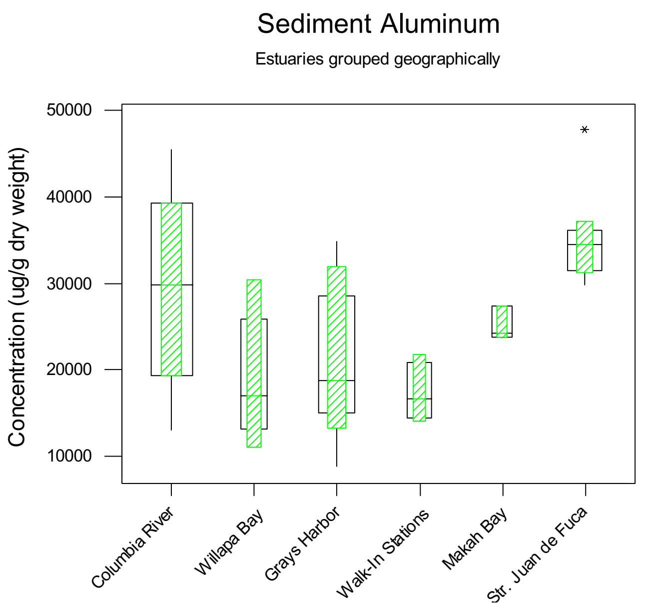
Table D-18. Marine debris and submerged aquatic vegetation

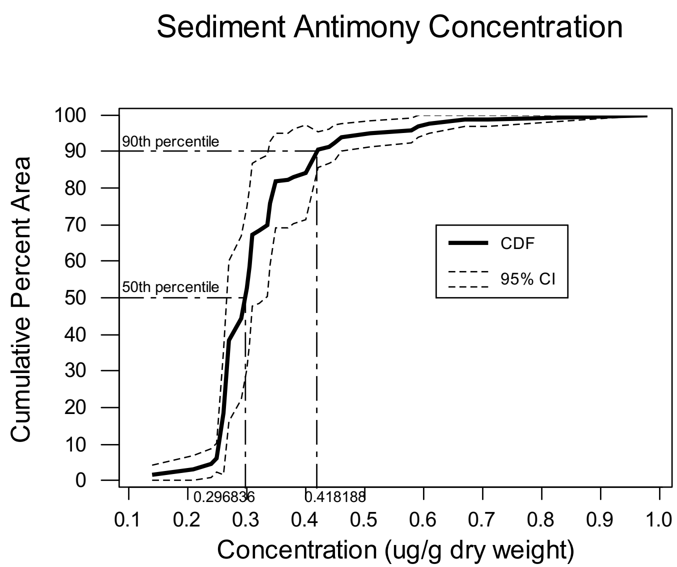
EMAP Station ID	Station Location	Observations
WA99-0002	MAKAH BAY	Rocks in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Trawl hung up hard on boulders on bottom. Abandoned site for fishing because of too many rocks. Sediment grabs taken 0.27 nautical miles from station where WQ samples acquired due to rocky bottom at other coordinates.
WA99-0003	MAKAH BAY	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg).
WA99-0004	HOKO RIVER	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). SAV (submerged aquatic vegetation) present in grab.
WA99-0006	FRESHWATER BAY	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Station rejected for sediment due to rocky substrate.
WA99-0007	FRESHWATER BAY	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg).
WA99-0008	FRESHWATER BAY	Marine Vegetation in trawl - estimate abundance high (> 100), weight high (>10 Kg). Lots of bullwhip kelp and other kelp. One trawl stopped due to too much kelp. Station rejected for sediment due to gravel substrate.
WA99-0009	DUNGENESS BAY	Terrestrial & Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). sea lettuce, abundant woody debris.
WA99-0010	DISCOVERY BAY	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Lots of macroalgae.
WA99-0011	DISCOVERY BAY	Marine Vegetation in trawl - estimate abundance high (> 100), weight high (>10 Kg). Trawl hung up on bottom. Lot of kelp.
WA99-0012	DISCOVERY BAY	Marine Vegetation in trawl - estimate abundance high (> 100), weight high (>10 Kg). Probably 2,000 lbs of various types of kelp -- it took 1 hour of 3 people working to clear the net of all the kelp.
WA99-0013	DISCOVERY BAY	Terrestrial & Marine Vegetation in trawl - estimate abundance high (T), low (M) (> 100 (T), 2 to 10 (M)), weight high (T), low (M) (>10 Kg (T), 0.2-1.0 Kg (M)). Large hunks of wood, with sea lettuce, in trawl.
WA99-0014	DISCOVERY BAY	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg).
WA99-0016	RAFT RIVER	Walk-in station - station within intertidal area. Tribal fish nets are cleaned on beaches where we sampled.
WA99-0017	QUINAULT RIVER	Walk-in station - station within intertidal area. Tribal fish nets are cleaned on beaches where we sampled.
WA99-0020	GRAYS HARBOR	Marine Vegetation in trawl - estimate abundance moderate (10 to100), weight moderate (1.1-10 Kg). Sea lettuce in trawl. Woody debris in grab.
WA99-0021	GRASS CREEK	Marine Vegetation in trawl - estimate abundance high (> 100), weight high (>10 Kg). Sea lettuce in trawl.
WA99-0022	GRAYS HARBOR	Marine Vegetation in trawl - estimate abundance high (> 100), weight high (>10 Kg). Sea lettuce in trawl.
WA99-0023	GRAYS HARBOR	Marine Vegetation in trawl - estimate abundance high (> 100), weight high (>10 Kg). Sea lettuce in trawl. Substrate in grab is mix of sand and shell hash.
WA99-0024	GRAYS HARBOR	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Sea lettuce in trawl.
WA99-0027	BEARDSLEE SLOUGH	Terrestrial Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). One strand Zostera sp. in grab.
WA99-0031	WILLAPA BAY	Woody debris in grab.

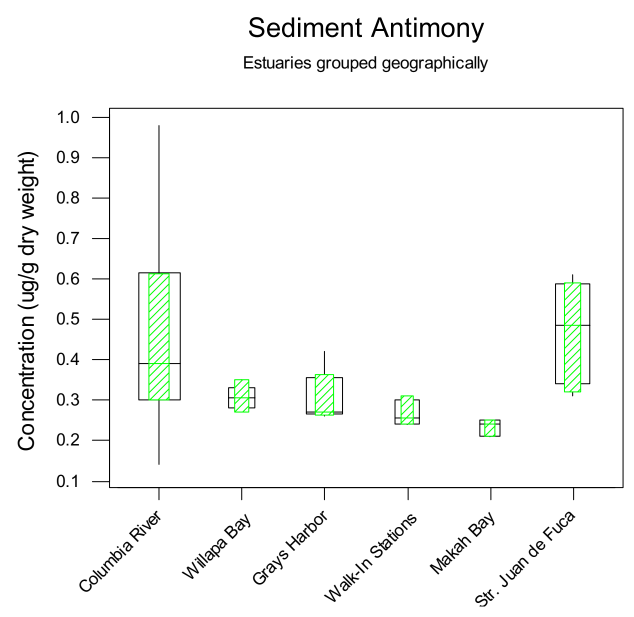
EMAP Station ID	Station Location	Observations
WA99-0034	WILLAPA BAY	Ripped net, big hole; lots of eel grass in trawl. Small woody debris present in grab.
WA99-0038	BAKER BAY	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Sea lettuce in trawl.
WA99-0039	BAKER BAY	Obstruction - nothing caught in trawl. Woody debris in grab.
WA99-0042	BAKER BAY	Shell fragments present in grab.
WA99-0043	GRAYS BAY	Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Mixed sand and wood substrate in grab.
WA99-0044	GRAYS BAY	Terrestrial & Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Wood chips, green algae in net.
WA99-0046	GRAYS BAY	Terrestrial & Marine Vegetation in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Green algae, wood chips in net.
WA99-0048	COWLITZ RIVER	Pumice/ash from Mount St Helens in grab sample.
WA99-0049	CARROLLS CHANNEL	Metal Debris in trawl - estimate abundance low (2 to 10), weight low (0.2-1.0 Kg). Steel cable; snagged net twice.
WA99-0050	MARTIN SLOUGH	Snagged net twice. Woody debris abundant in grab.

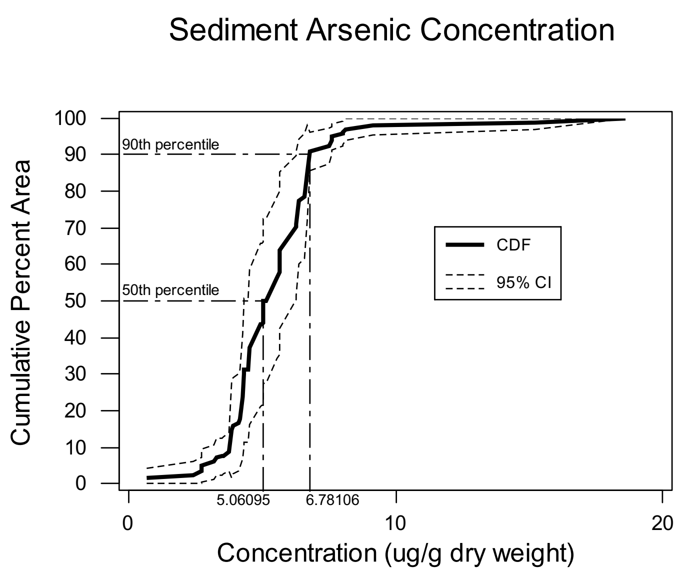
Figure D-1. Sediment Metals

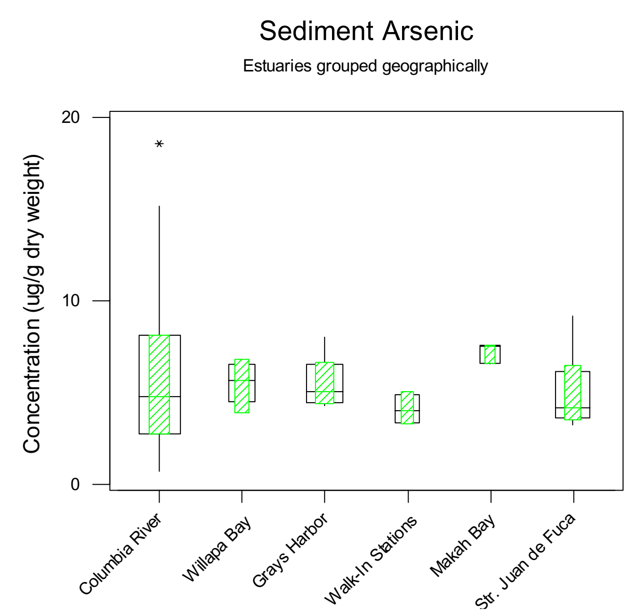


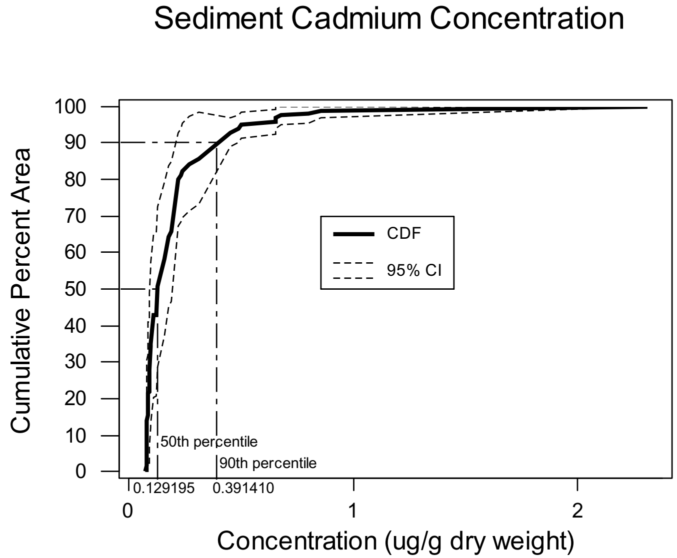


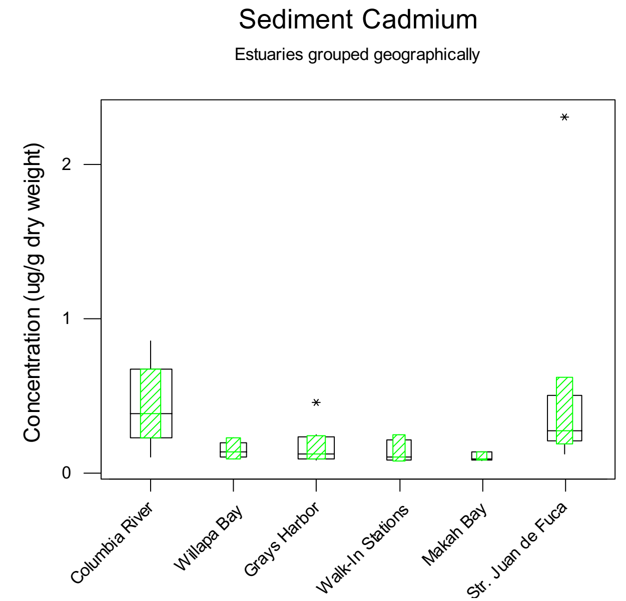

Sediment Antimony Concentration
Cumulative Percent Area
90th percentile
50th percentile
CDF
95% CI
0.296836
0.418188
Concentration (ug/g dry weight)

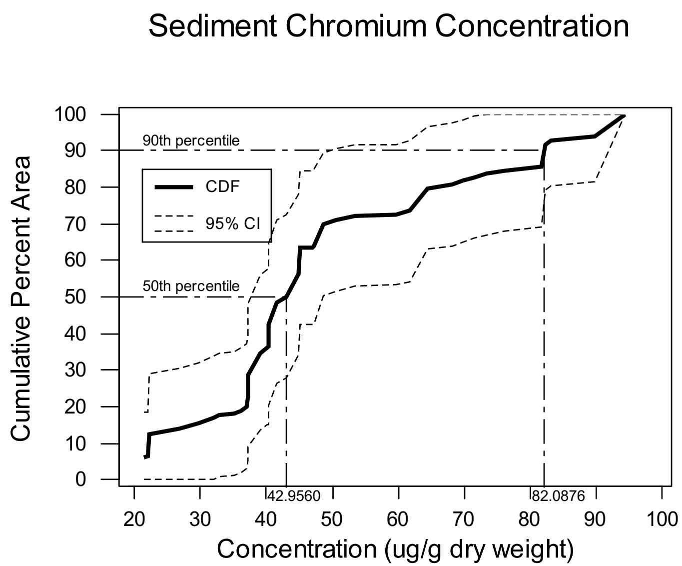

Sediment Antimony
Estuaries grouped geographically
Concentration (ug/g dry weight)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

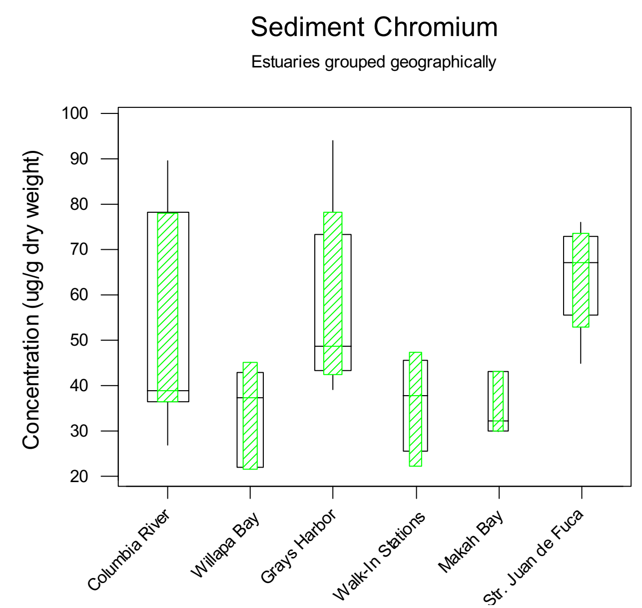

Sediment Arsenic Concentration
Cumulative Percent Area
90th percentile
50th percentile
CDF
95% CI
5.06095
6.78106
Concentration (ug/g dry weight)


Sediment Arsenic
Estuaries grouped geographically
Concentration (ug/g dry weight)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

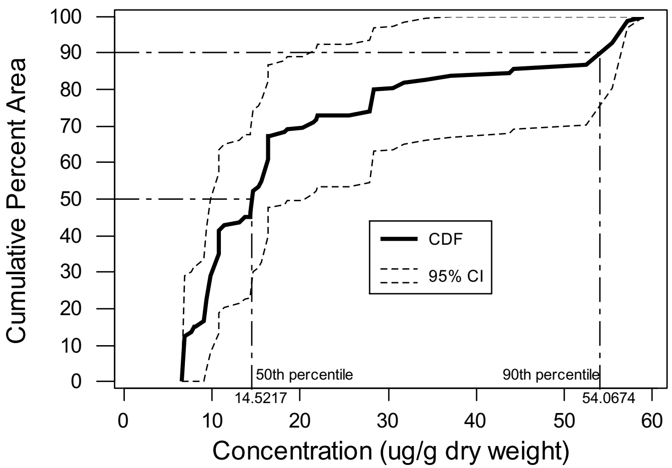

Sediment Cadmium Concentration
Cumulative Percent Area
CDF
95% CI
50th percentile
90th percentile
0.129195
0.391410
Concentration (ug/g dry weight)


Sediment Cadmium
Estuaries grouped geographically
Concentration (ug/g dry weight)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sediment Chromium Concentration
Cumulative Percent Area
90th percentile
50th percentile
CDF
95% CI
42.9560
82.0876
Concentration (ug/g dry weight)

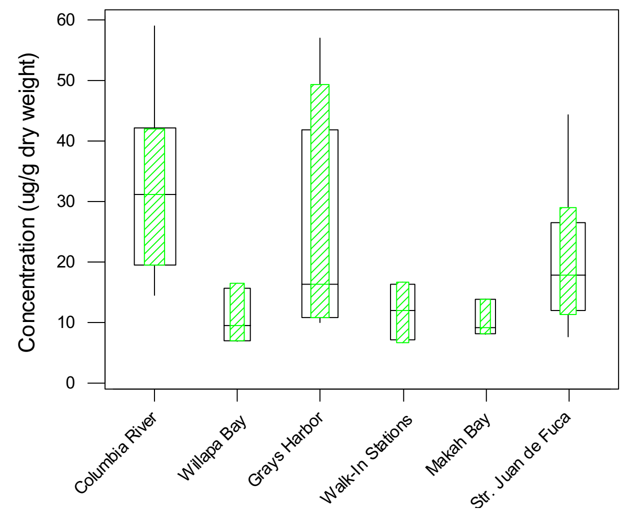

Sediment Chromium
Estuaries grouped geographically
Concentration (ug/g dry weight)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

Sediment Copper Concentration

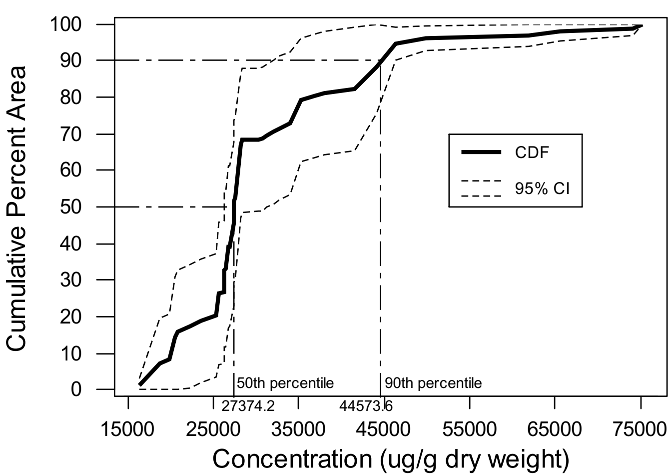


Sediment Copper

Estuaries grouped geographically

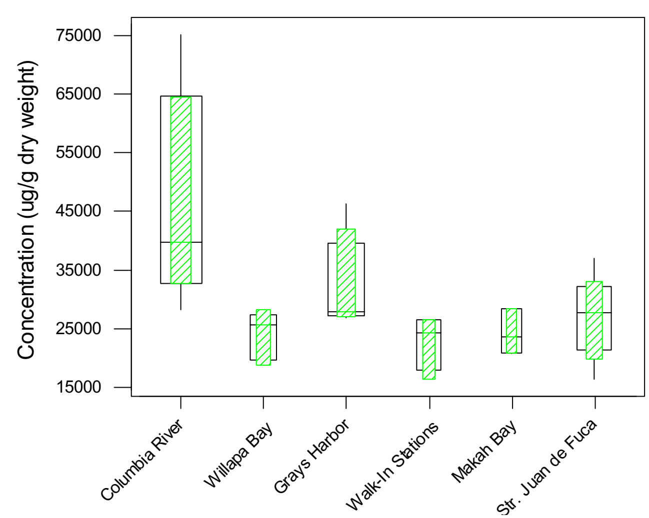


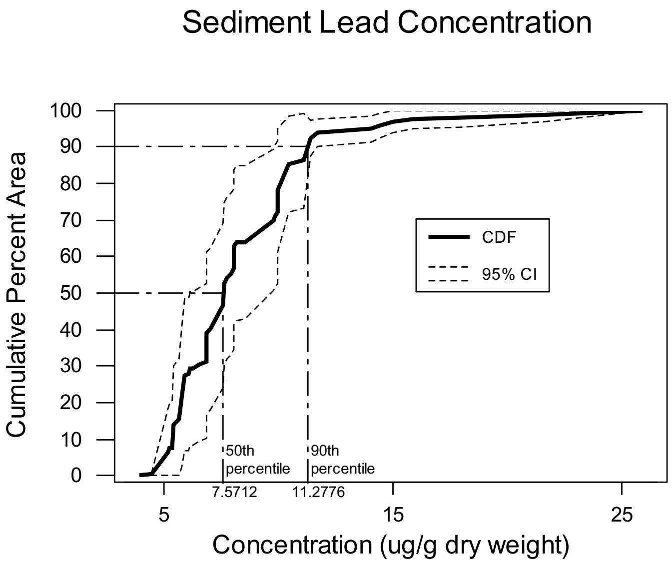
Sediment Iron Concentration

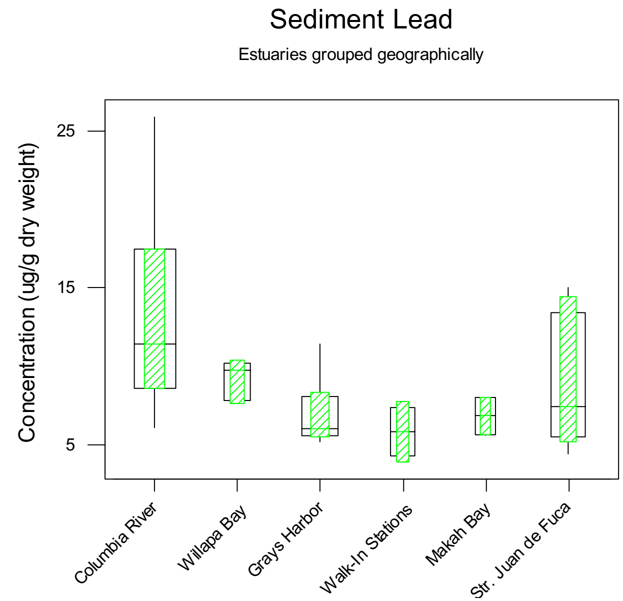


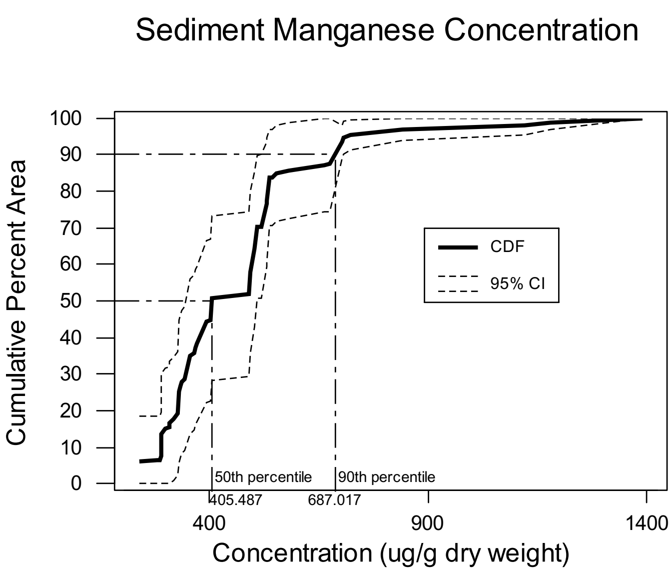
Sediment Iron

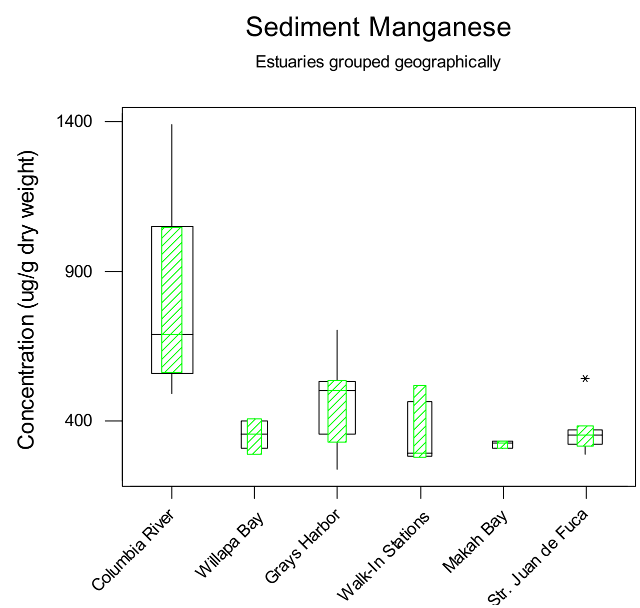
Estuaries grouped geographically

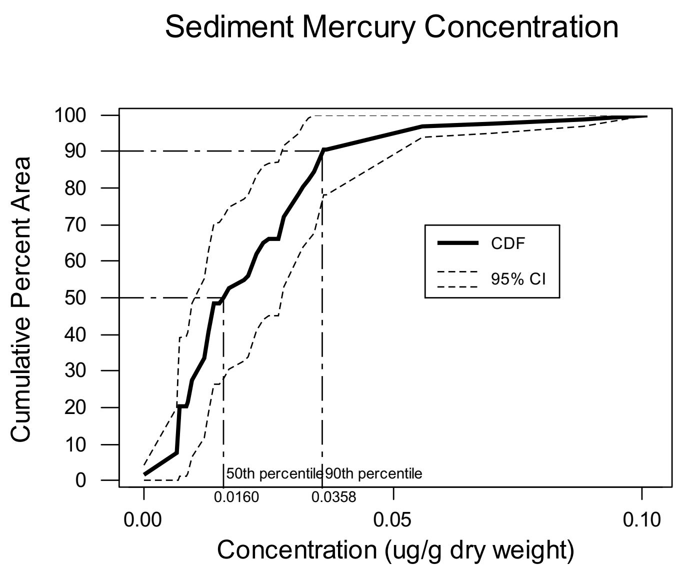


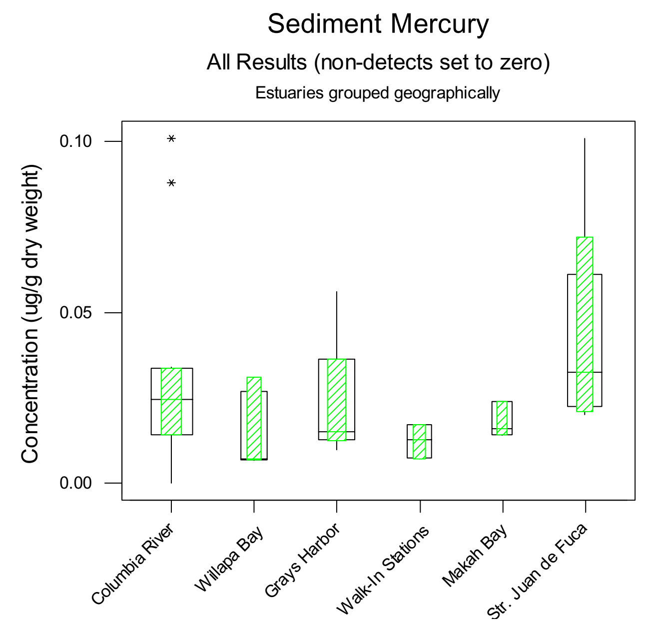

Sediment Lead Concentration
Cumulative Percent Area
100
90
80
70
60
50
40
30
20
10
0
CDF
95% CI
50th percentile
90th percentile
7.5712
11.2776
5
15
25
Concentration (ug/g dry weight)

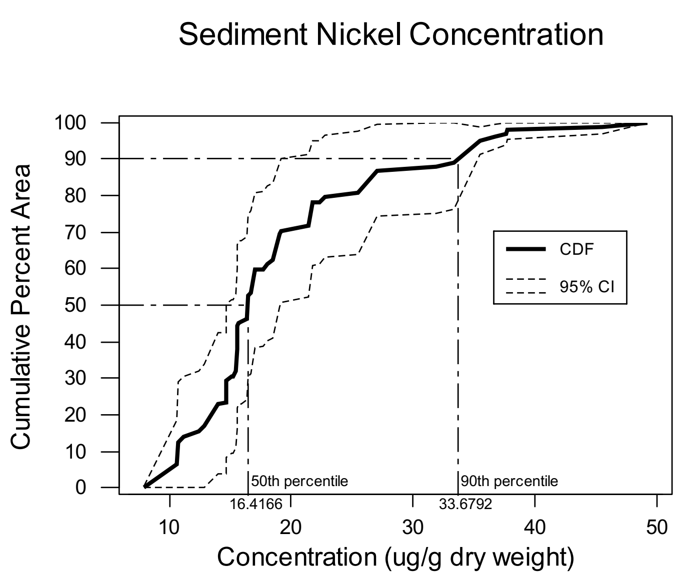

Sediment Lead
Estuaries grouped geographically
Concentration (ug/g dry weight)
25
15
5
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

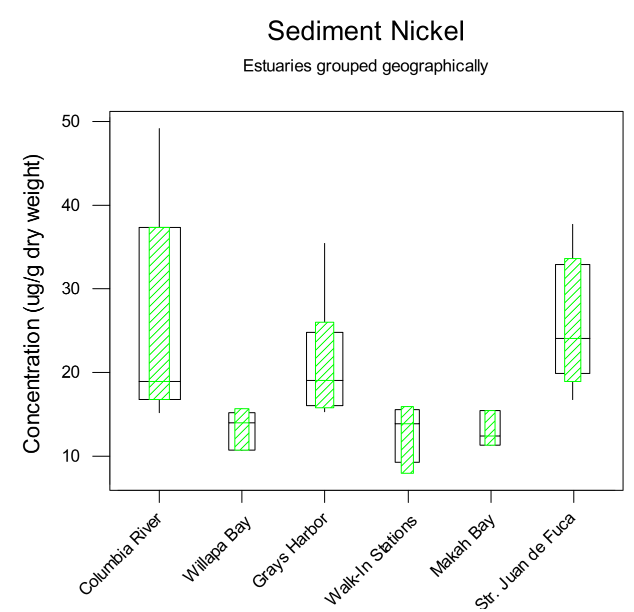

Sediment Manganese Concentration
Cumulative Percent Area
100
90
80
70
60
50
40
30
20
10
0
CDF
95% CI
50th percentile
90th percentile
405.487
687.017
400
900
1400
Concentration (ug/g dry weight)

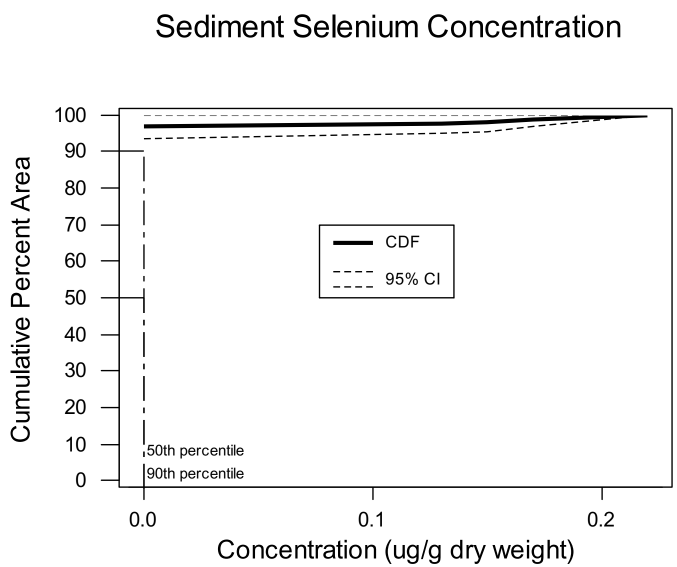

Sediment Manganese
Estuaries grouped geographically
Concentration (ug/g dry weight)
1400
900
400
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

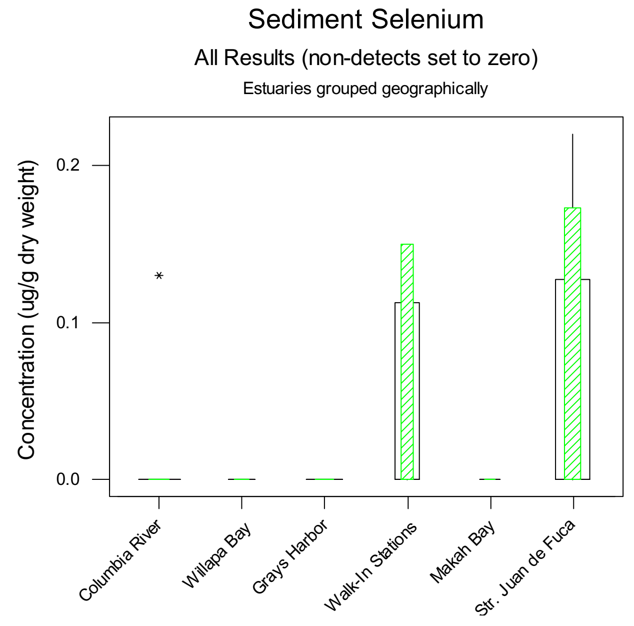

Sediment Mercury Concentration
Cumulative Percent Area
100
90
80
70
60
50
40
30
20
10
0
CDF
95% CI
50th percentile
90th percentile
0.0160
0.0358
0.00
0.05
0.10
Concentration (ug/g dry weight)

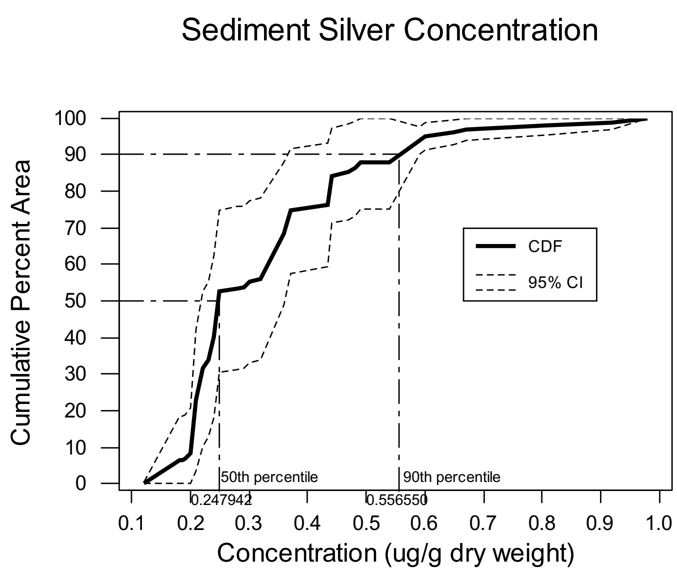

Sediment Mercury
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g dry weight)
0.10
0.05
0.00
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

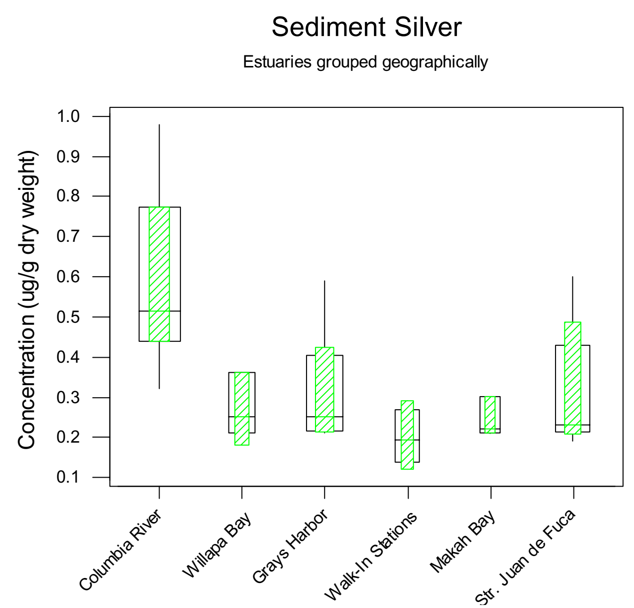

Sediment Nickel Concentration
Cumulative Percent Area
100
90
80
70
60
50
40
30
20
10
0
CDF
95% CI
50th percentile
90th percentile
16.4166
33.6792
10
20
30
40
50
Concentration (ug/g dry weight)

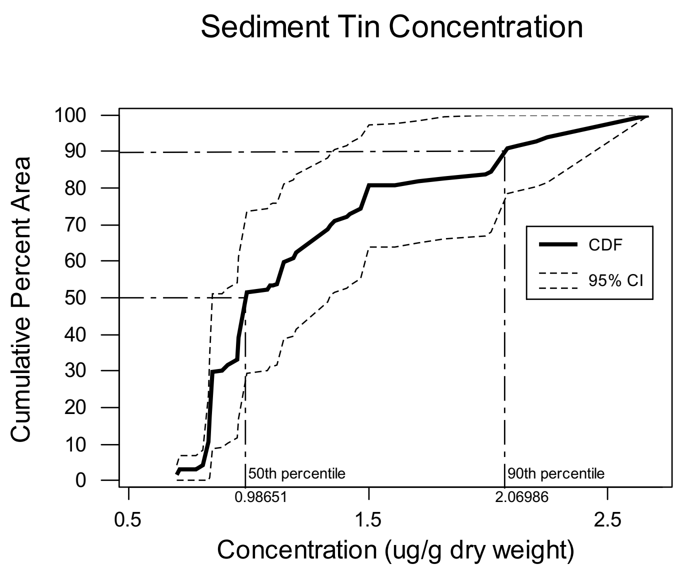

Sediment Nickel
Estuaries grouped geographically
Concentration (ug/g dry weight)
50
40
30
20
10
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

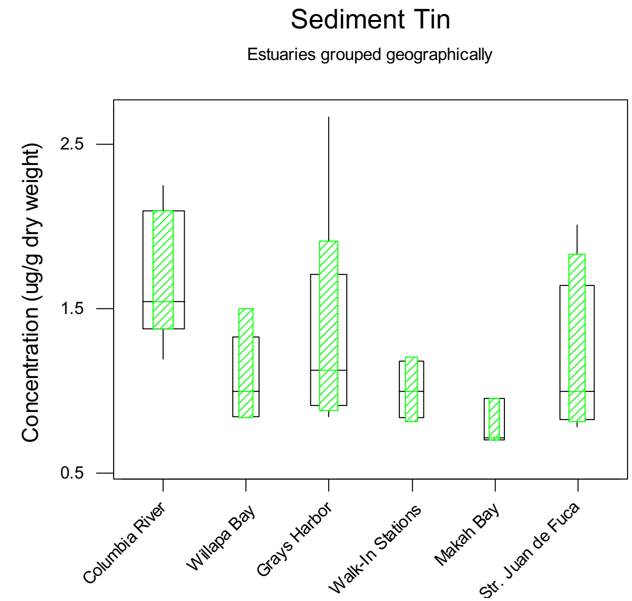

Sediment Selenium Concentration
Cumulative Percent Area
Concentration (ug/g dry weight)
CDF
95% CI
50th percentile
90th percentile
0.0
0.1
0.2
100
90
80
70
60
50
40
30
20
10
0

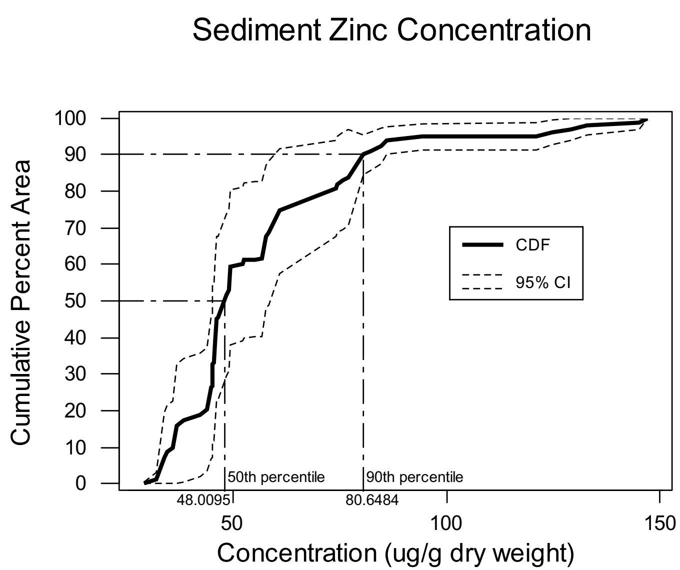

Sediment Selenium
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g dry weight)
0.2
0.1
0.0
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sediment Silver Concentration
Cumulative Percent Area
Concentration (ug/g dry weight)
CDF
95% CI
50th percentile
90th percentile
0.247942
0.556550
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
100
90
80
70
60
50
40
30
20
10
0


Sediment Silver
Estuaries grouped geographically
Concentration (ug/g dry weight)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sediment Tin Concentration
Cumulative Percent Area
Concentration (ug/g dry weight)
CDF
95% CI
50th percentile
90th percentile
0.98651
2.06986
0.5
1.5
2.5
0
10
20
30
40
50
60
70
80
90
100


Sediment Tin
Estuaries grouped geographically
Concentration (ug/g dry weight)
0.5
1.5
2.5
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sediment Zinc Concentration
Cumulative Percent Area
Concentration (ug/g dry weight)
CDF
95% CI
50th percentile
90th percentile
48.0095
80.6484
50
100
150
0
10
20
30
40
50
60
70
80
90
100

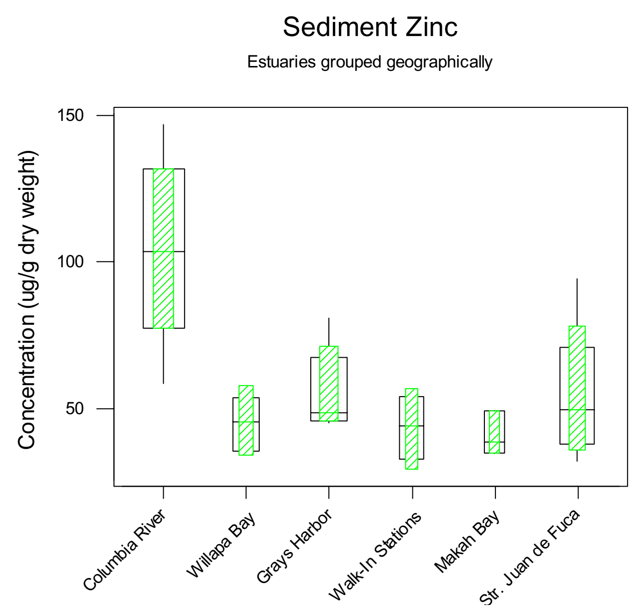
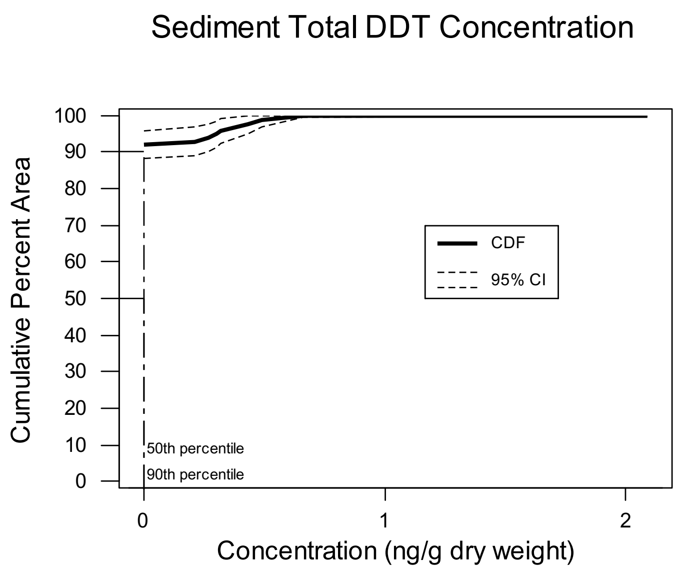
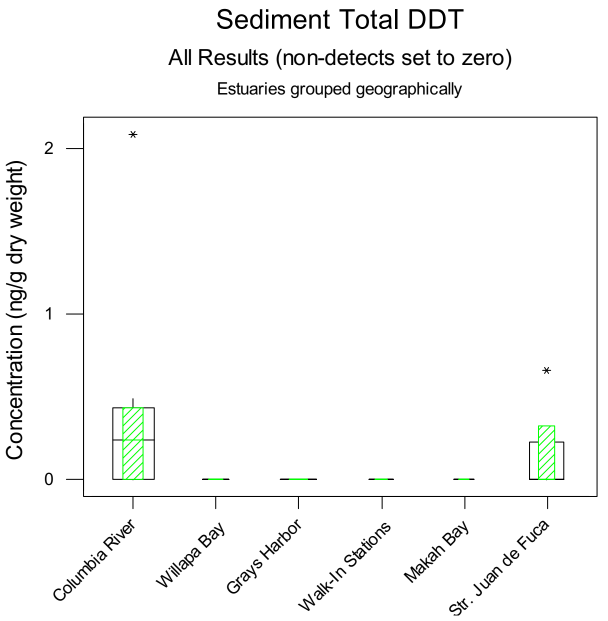
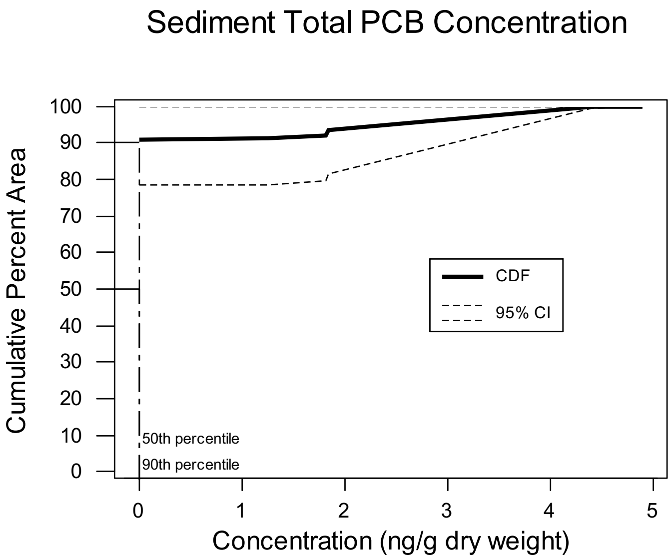

Sediment Zinc
Estuaries grouped geographically
Concentration (ug/g dry weight)
50
100
150
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

Figure D-2. Sediment Total DDT and Total PCB






Sediment Total PCB Concentration
Cumulative Percent Area
Concentration (ng/g dry weight)
CDF
95% CI
50th percentile
90th percentile
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5

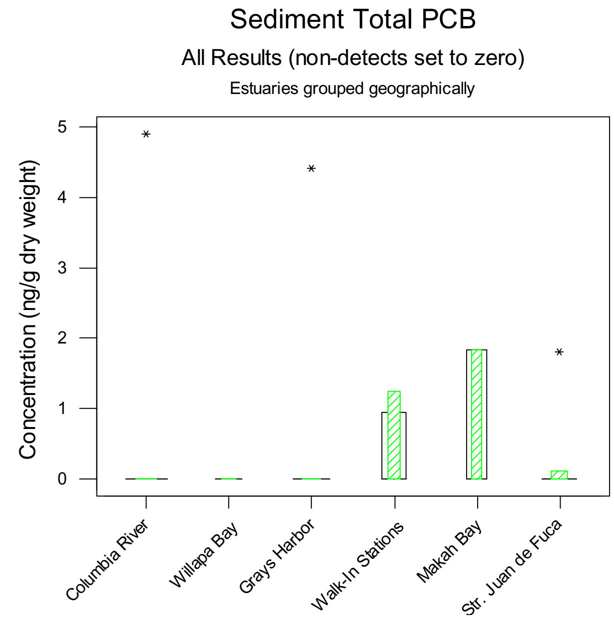
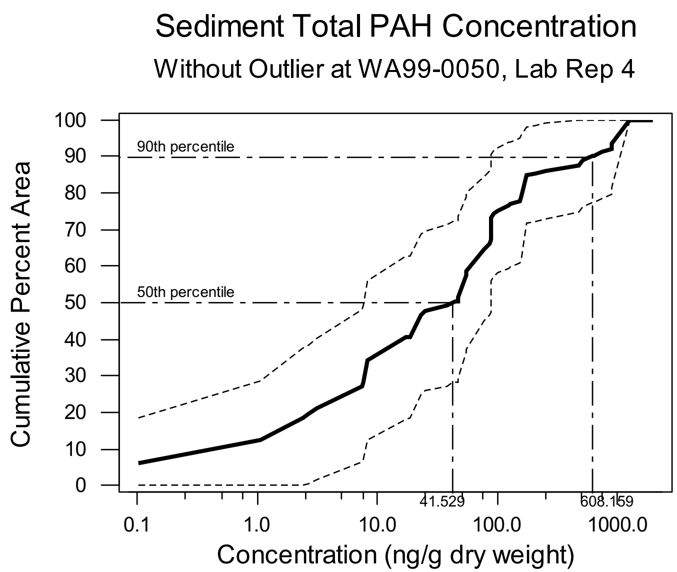
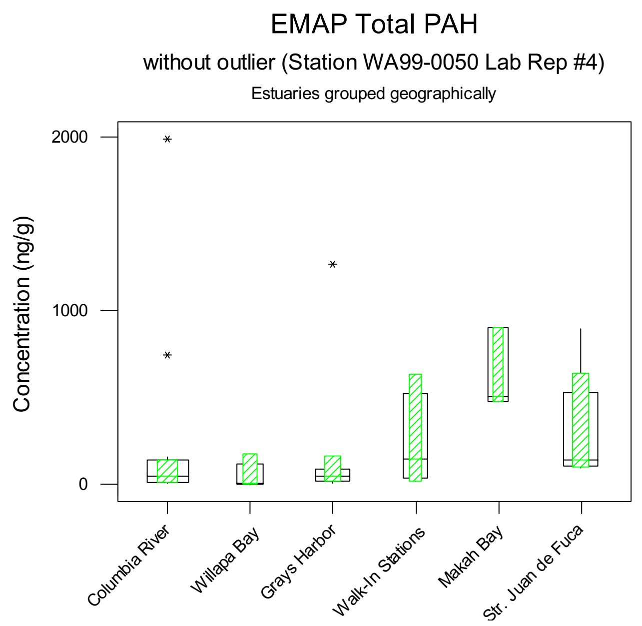
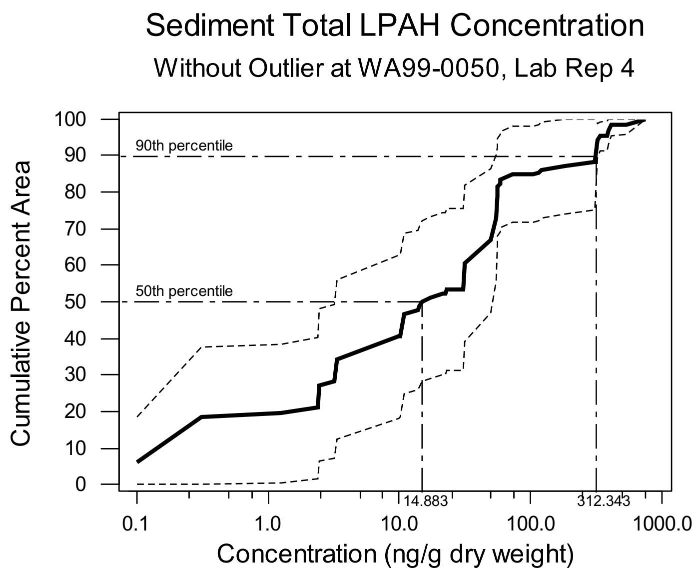

Sediment Total PCB
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ng/g dry weight)
0
1
2
3
4
5
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

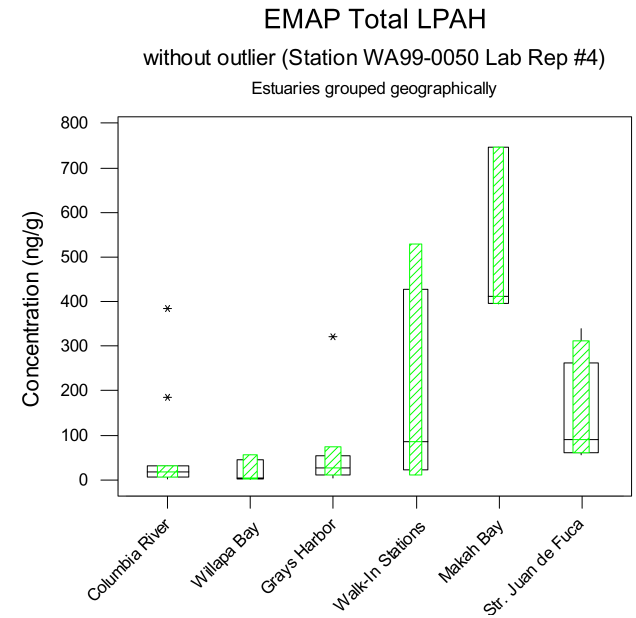
Figure D-3. Sediment Total PAHs



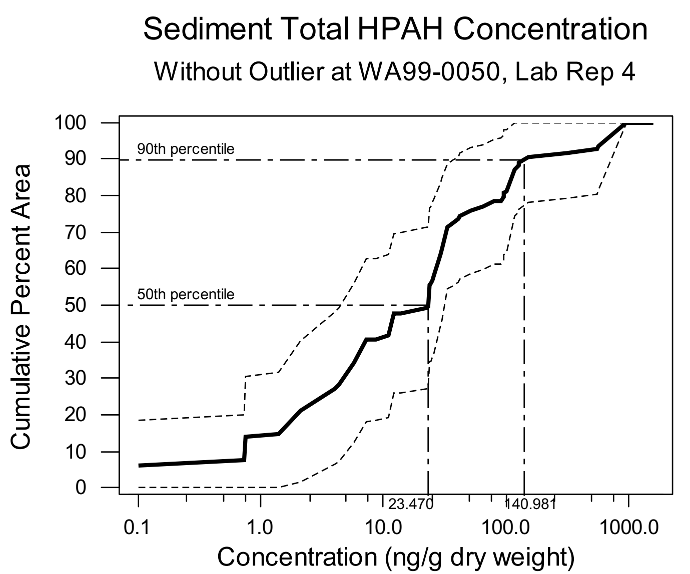




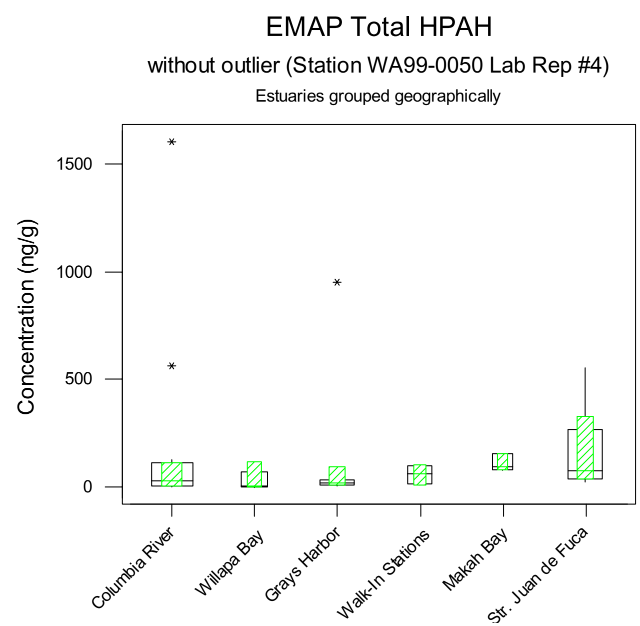
Sediment Total LPAH Concentration
Without Outlier at WA99-0050, Lab Rep 4
90th percentile
50th percentile
Cumulative Percent Area
14.883
312.343
0.1
1.0
10.0
100.0
1000.0
Concentration (ng/g dry weight)



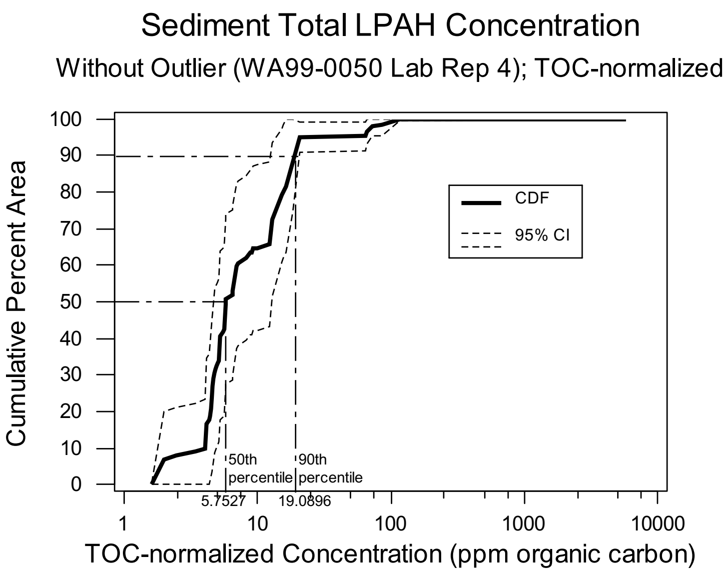
EMAP Total LPAH
without outlier (Station WA99-0050 Lab Rep #4)
Estuaries grouped geographically
Concentration (ng/g)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

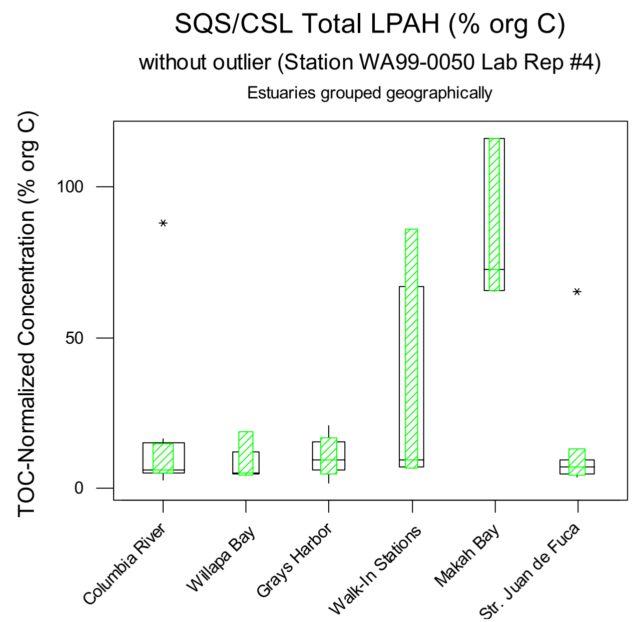


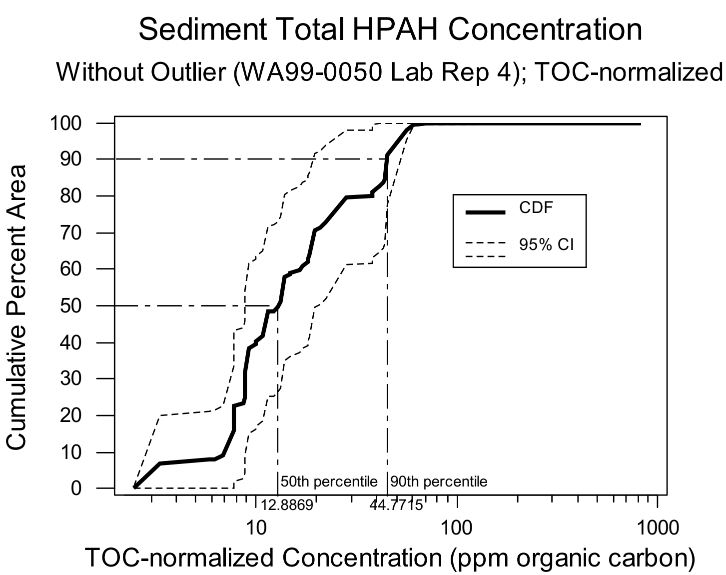
Sediment Total HPAH Concentration
Without Outlier at WA99-0050, Lab Rep 4
90th percentile
50th percentile
Cumulative Percent Area
23.470
140.981
0.1
1.0
10.0
100.0
1000.0
Concentration (ng/g dry weight)

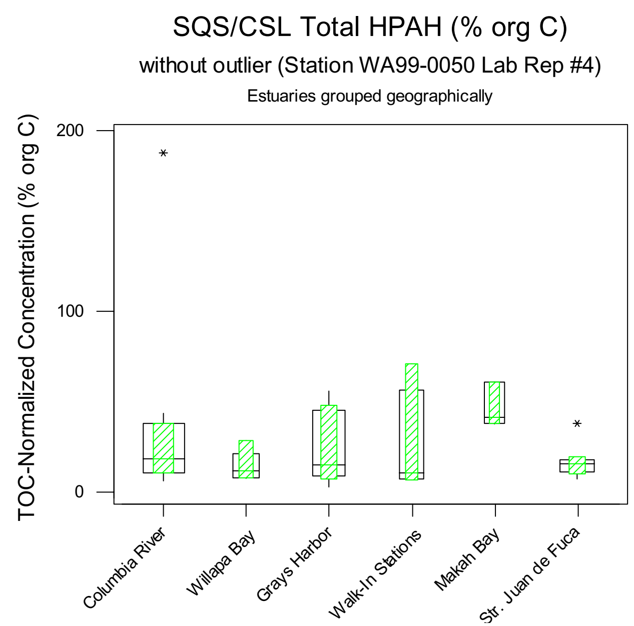


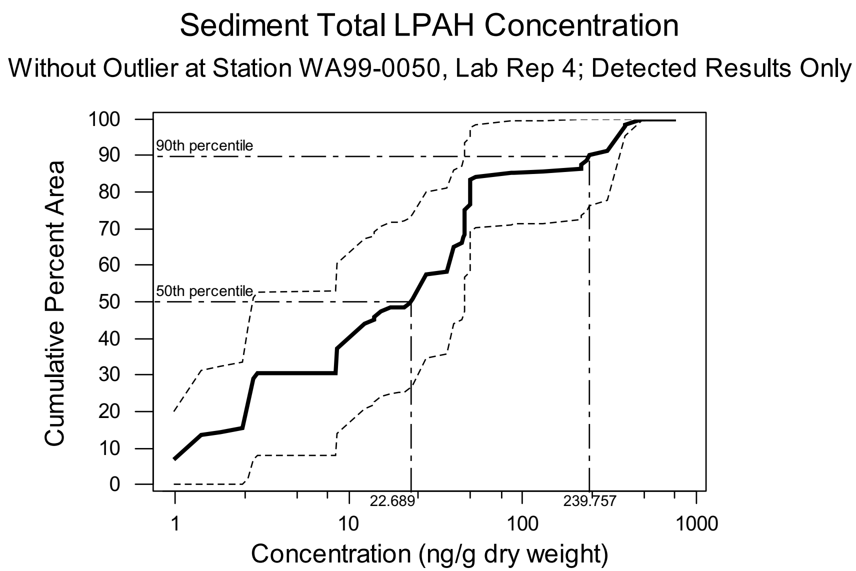
EMAP Total HPAH
without outlier (Station WA99-0050 Lab Rep #4)
Estuaries grouped geographically
Concentration (ng/g)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

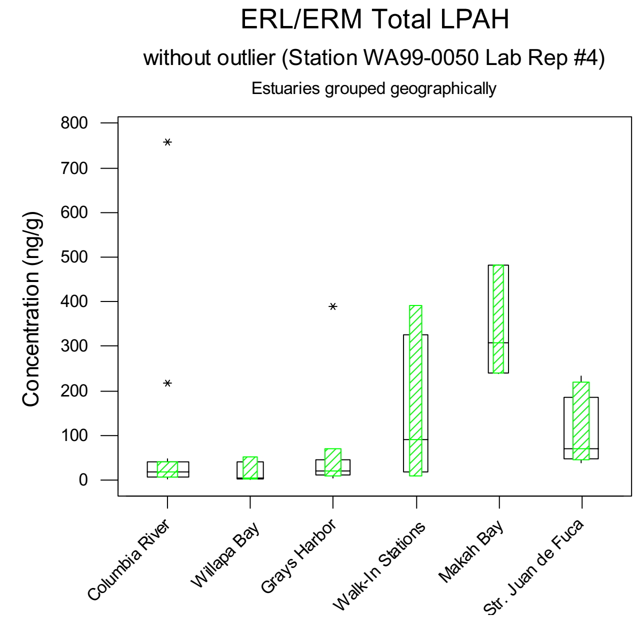

Sediment Total LPAH Concentration
Without Outlier (WA99-0050 Lab Rep 4); TOC-normalized
Cumulative Percent Area
CDF
95% CI
50th percentile
90th percentile
5.7527
19.0896
TOC-normalized Concentration (ppm organic carbon)

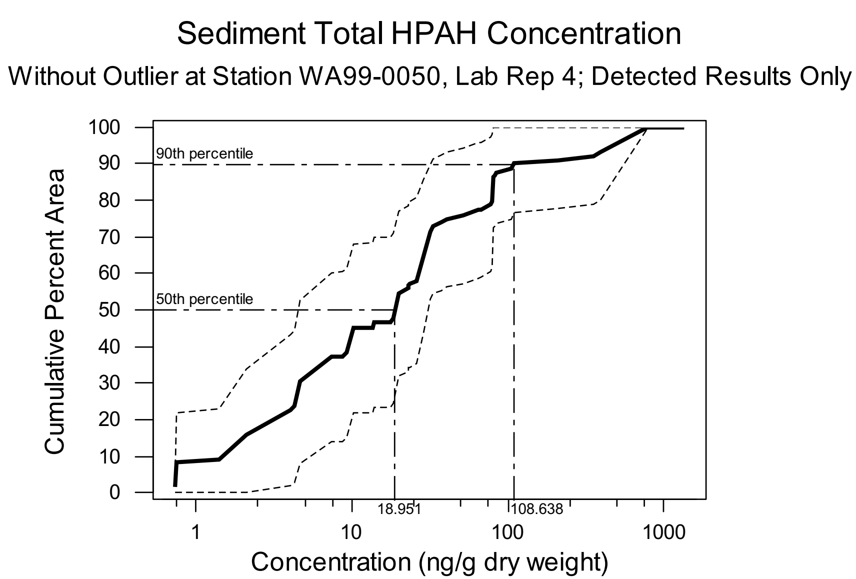

SQS/CSL Total LPAH (% org C)
without outlier (Station WA99-0050 Lab Rep #4)
Estuaries grouped geographically
TOC-Normalized Concentration (% org C)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

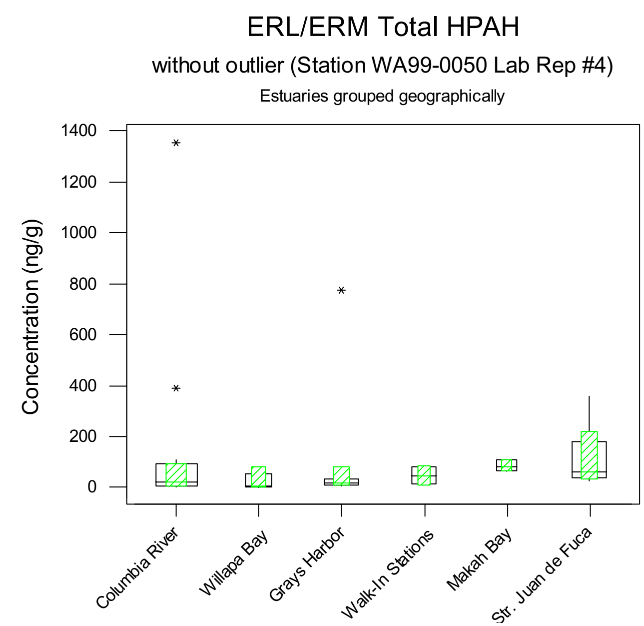

Sediment Total HPAH Concentration
Without Outlier (WA99-0050 Lab Rep 4); TOC-normalized
Cumulative Percent Area
CDF
95% CI
50th percentile
90th percentile
12.8869
44.7715
TOC-normalized Concentration (ppm organic carbon)

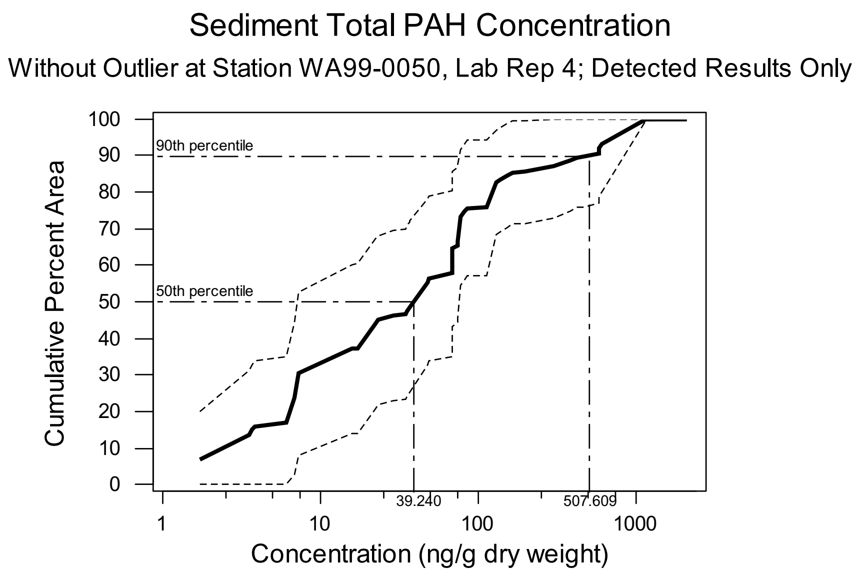

SQS/CSL Total HPAH (% org C)
without outlier (Station WA99-0050 Lab Rep #4)
Estuaries grouped geographically
TOC-Normalized Concentration (% org C)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sediment Total LPAH Concentration
Without Outlier at Station WA99-0050, Lab Rep 4; Detected Results Only
90th percentile
50th percentile
Cumulative Percent Area
22.689
239.757
Concentration (ng/g dry weight)


ERL/ERM Total LPAH
without outlier (Station WA99-0050 Lab Rep #4)
Estuaries grouped geographically
Concentration (ng/g)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sediment Total HPAH Concentration
Without Outlier at Station WA99-0050, Lab Rep 4; Detected Results Only
90th percentile
50th percentile
Cumulative Percent Area
18.951
108.638
Concentration (ng/g dry weight)


ERL/ERM Total HPAH
without outlier (Station WA99-0050 Lab Rep #4)
Estuaries grouped geographically
Concentration (ng/g)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sediment Total PAH Concentration
Without Outlier at Station WA99-0050, Lab Rep 4; Detected Results Only
Cumulative Percent Area
90th percentile
50th percentile
39.240
507.609
Concentration (ng/g dry weight)

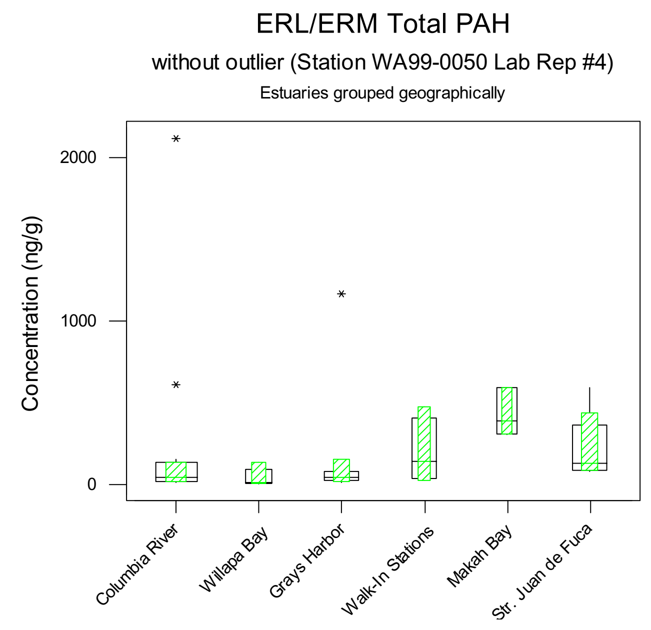
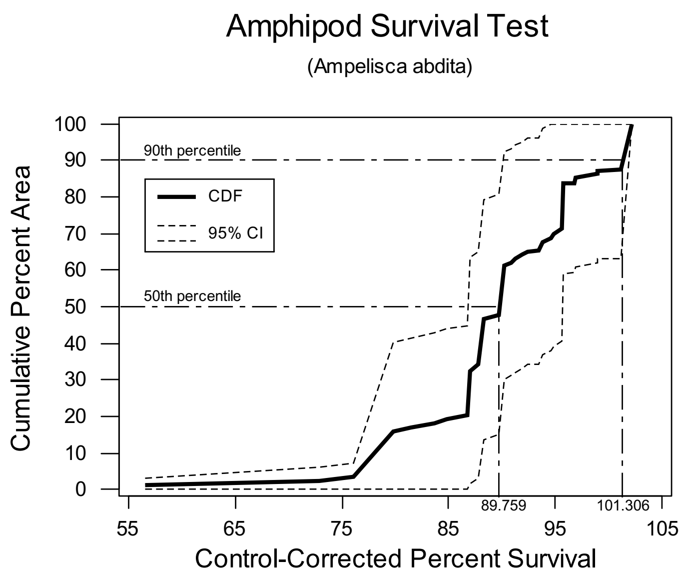
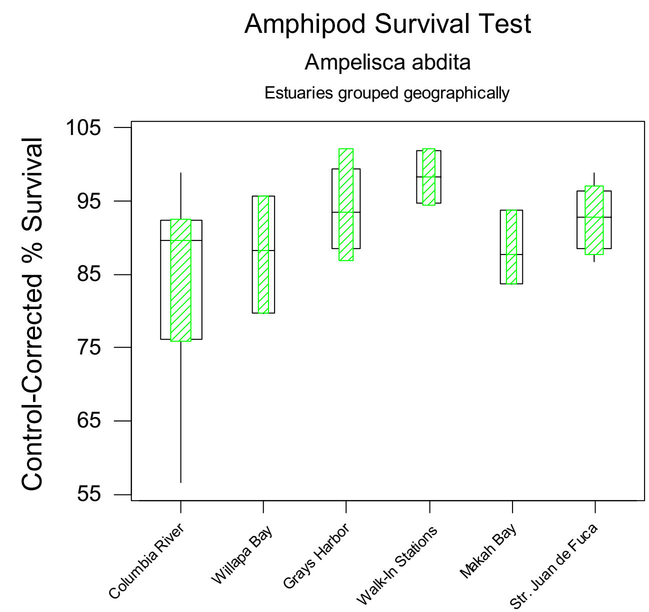
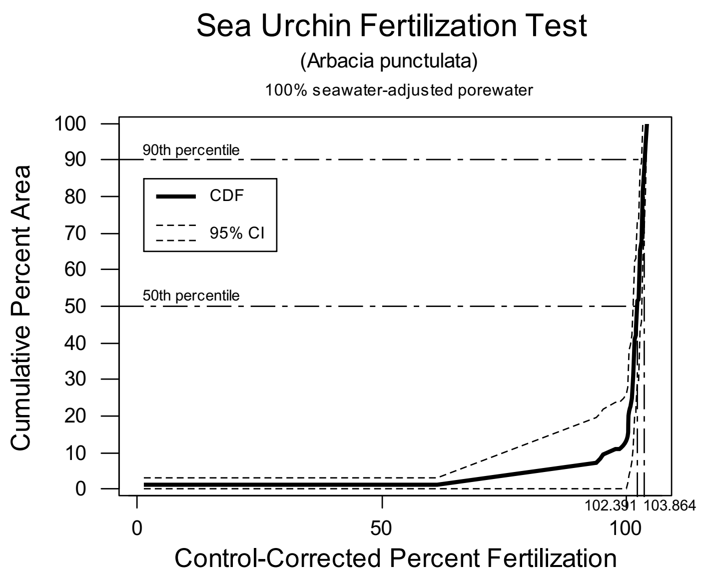
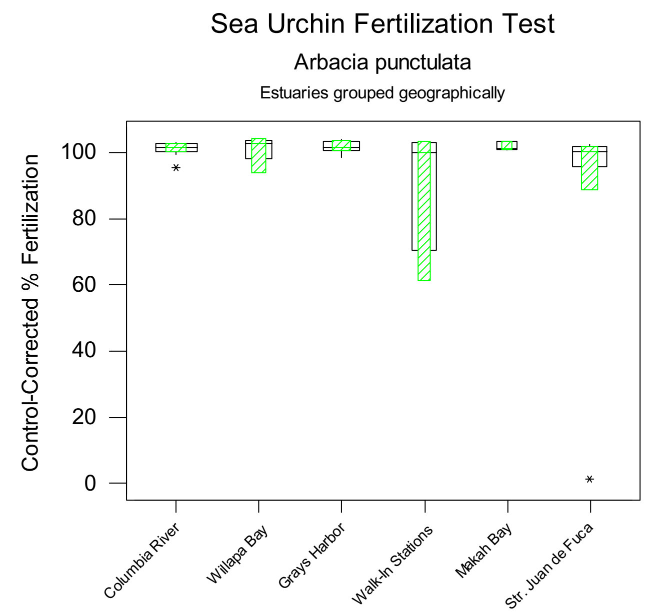

ERL/ERM Total PAH
without outlier (Station WA99-0050 Lab Rep #4)
Estuaries grouped geographically
Concentration (ng/g)
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

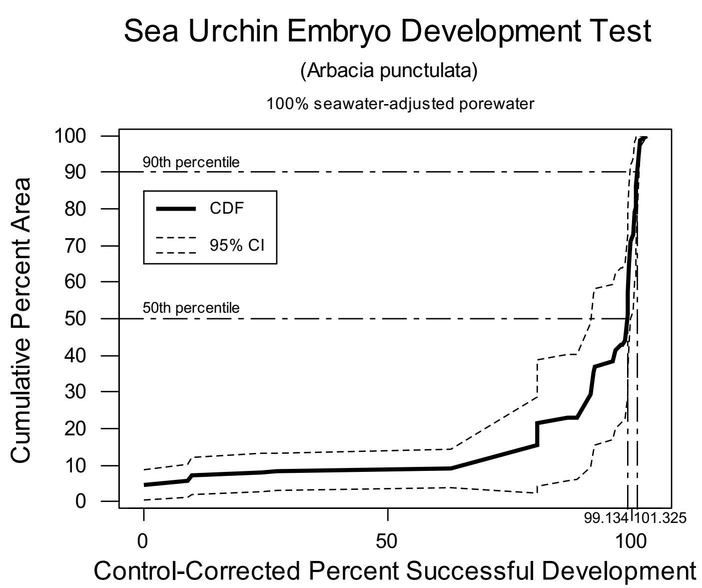
Figure D-4. Sediment Toxicity






Sea Urchin Fertilization Test
(Arbacia punctulata)
100% seawater-adjusted porewater
Cumulative Percent Area
90th percentile
50th percentile
CDF
95% CI
102.391
103.864
Control-Corrected Percent Fertilization


Sea Urchin Fertilization Test
Arbacia punctulata
Estuaries grouped geographically
Control-Corrected % Fertilization
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca


Sea Urchin Embryo Development Test
(Arbacia punctulata)
100% seawater-adjusted porewater
Cumulative Percent Area
90th percentile
50th percentile
CDF
95% CI
99.134
101.325
Control-Corrected Percent Successful Development

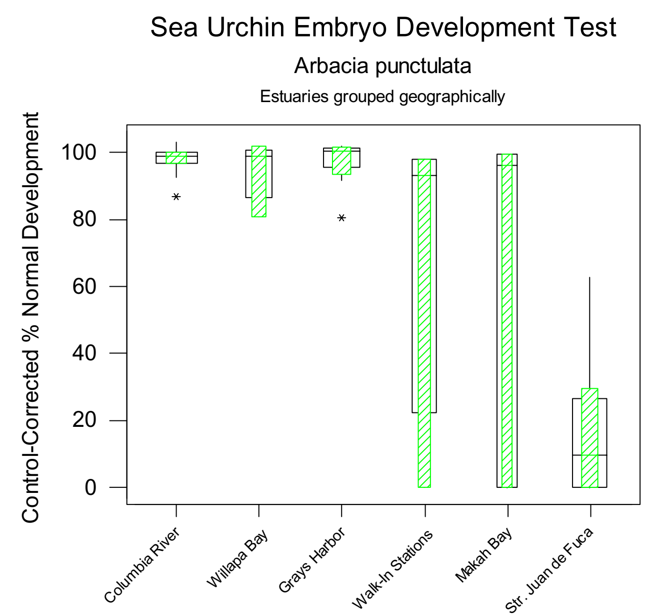
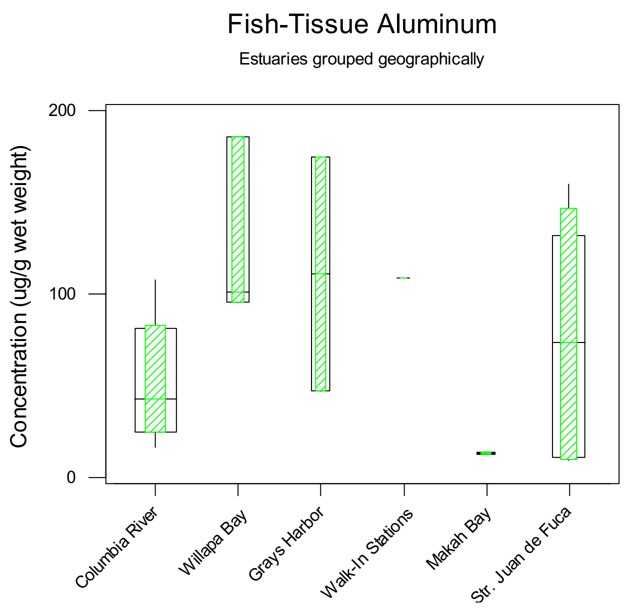
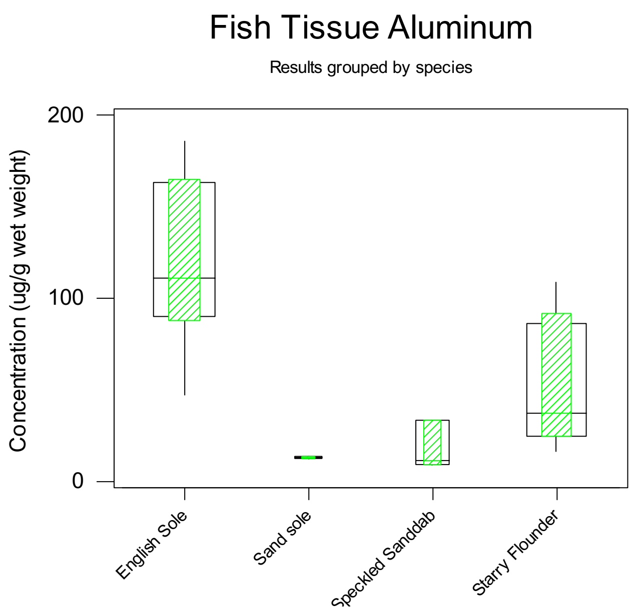
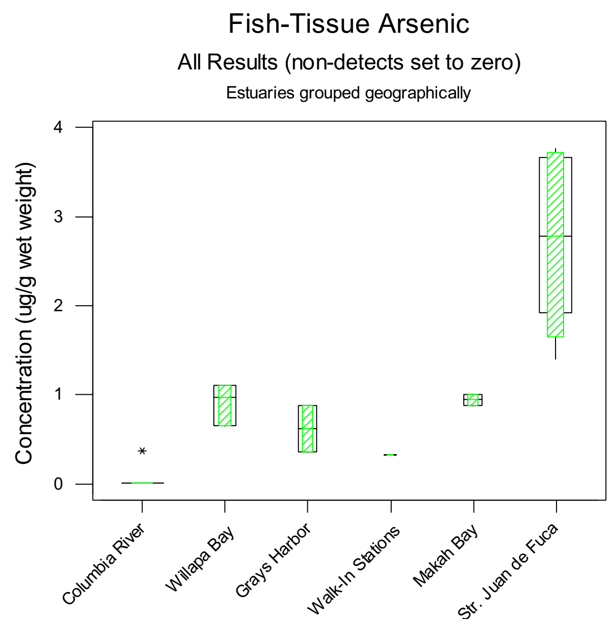
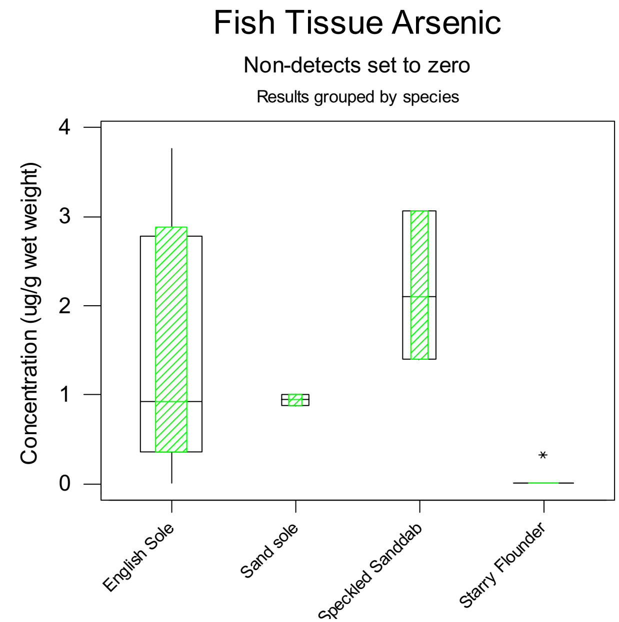

Sea Urchin Embryo Development Test
Arbacia punctulata
Estuaries grouped geographically
Control-Corrected % Normal Development
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

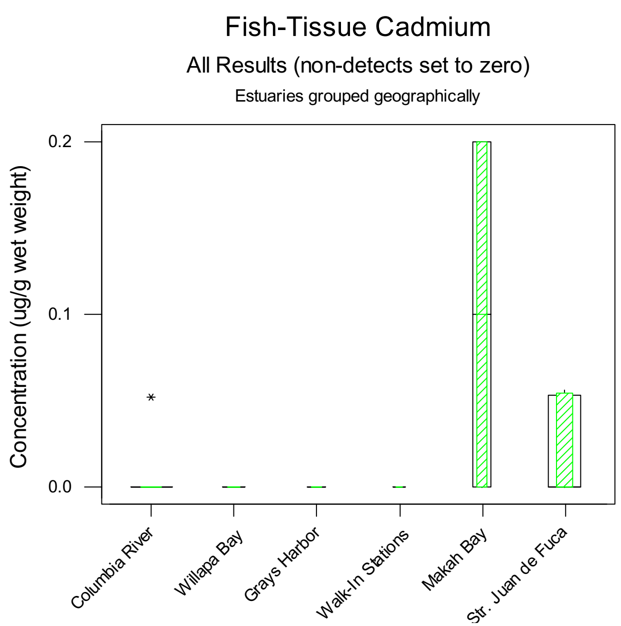
Figure D-5. Fish-Tissue Chemistry

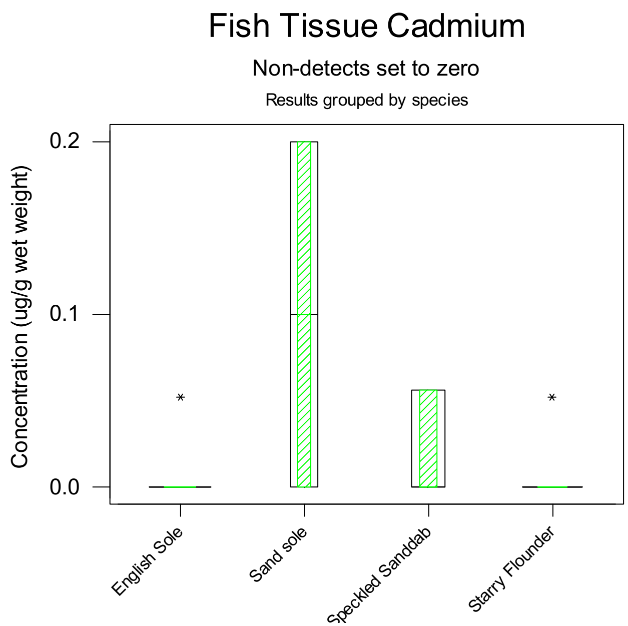


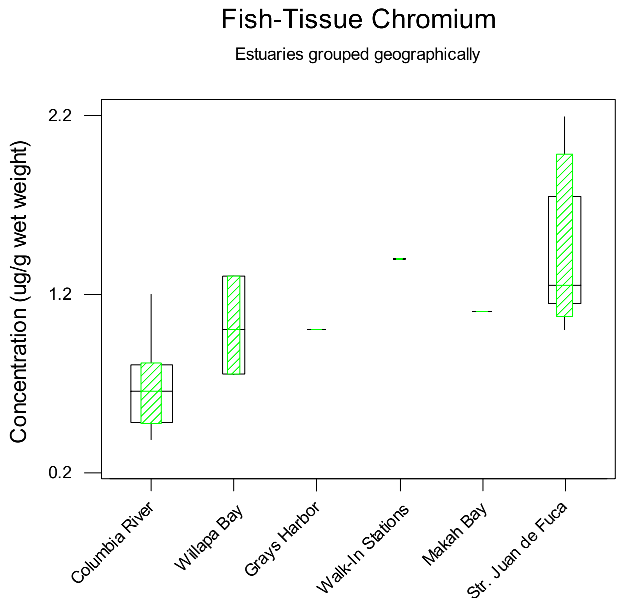


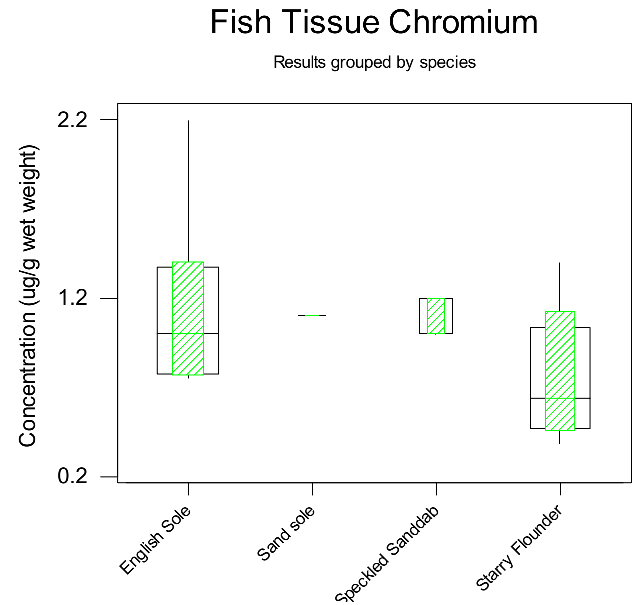

Fish-Tissue Arsenic
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
0
1
2
3
4
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

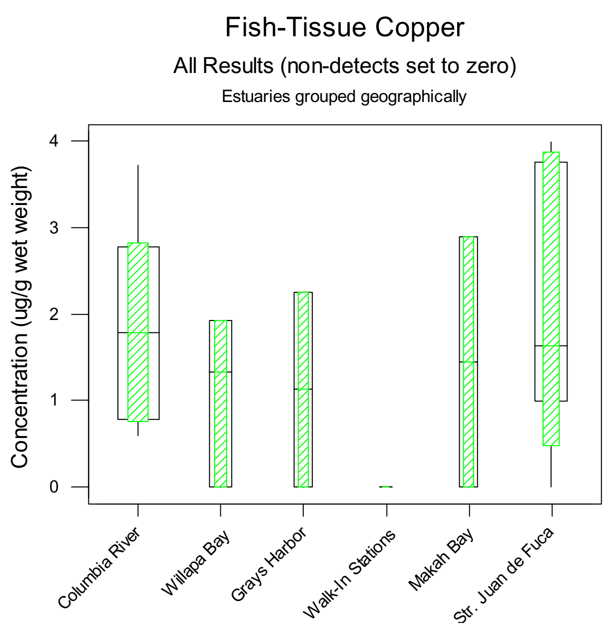

Fish Tissue Arsenic
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
0
1
2
3
4
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

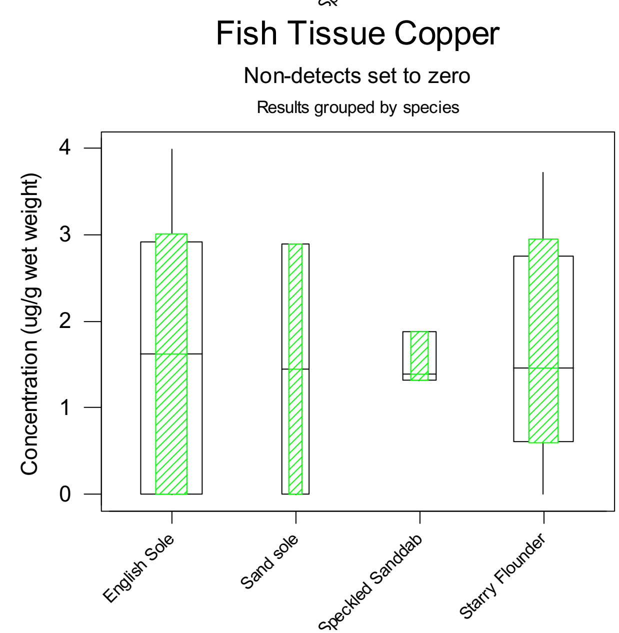

Fish-Tissue Cadmium
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
0.0
0.1
0.2
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

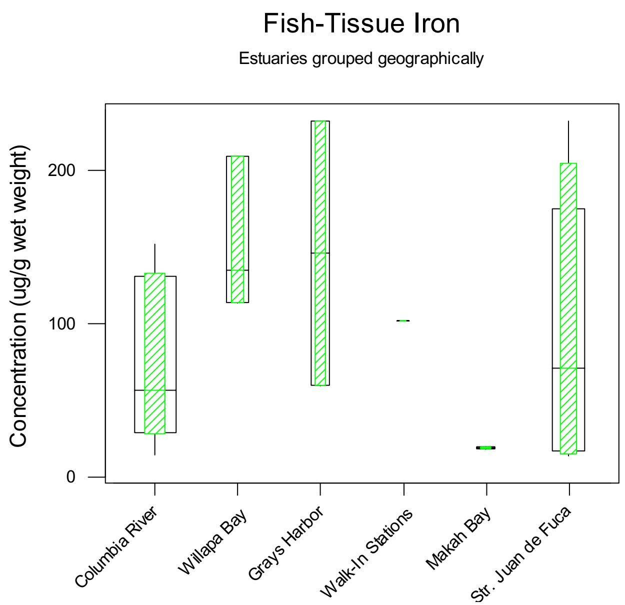

Fish Tissue Cadmium
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
0.0
0.1
0.2
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

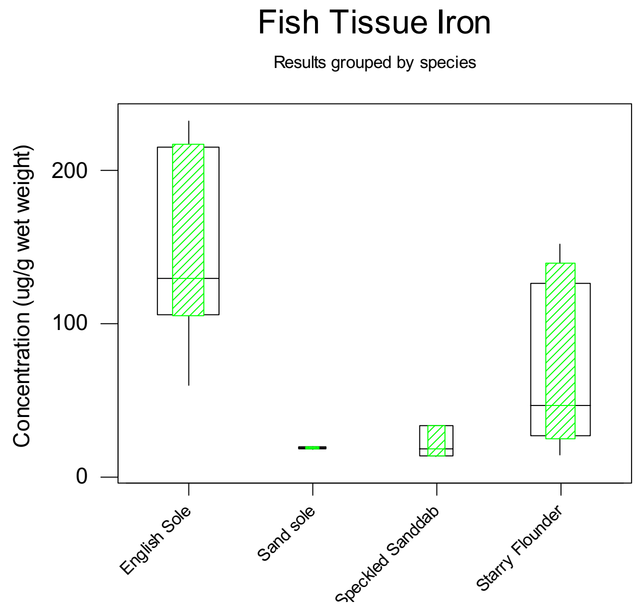

Fish-Tissue Chromium
Estuaries grouped geographically
Concentration (ug/g wet weight)
2.2
1.2
0.2
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

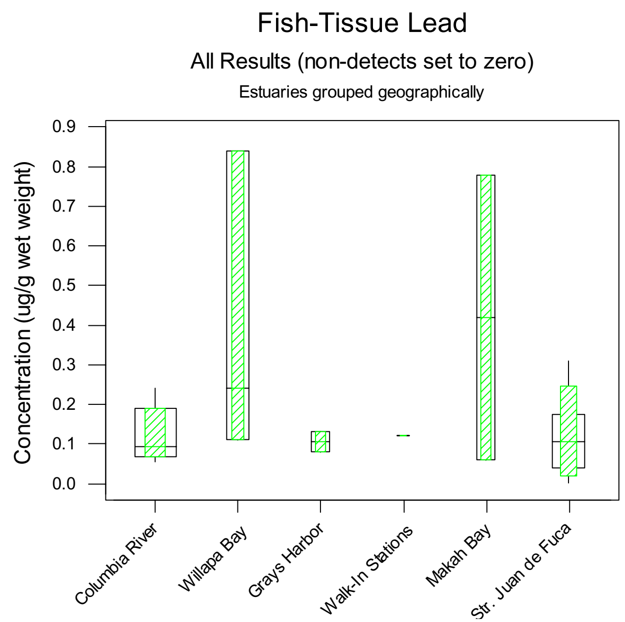

Fish Tissue Chromium
Results grouped by species
Concentration (ug/g wet weight)
2.2
1.2
0.2
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

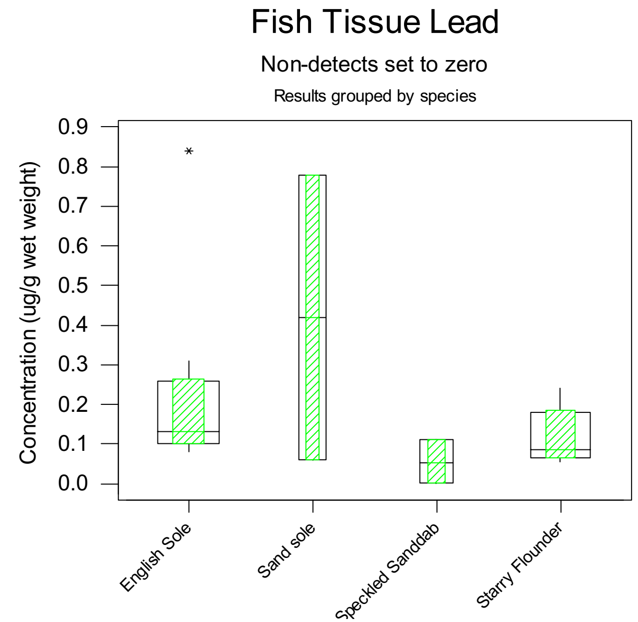

Fish-Tissue Copper
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
4
3
2
1
0
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

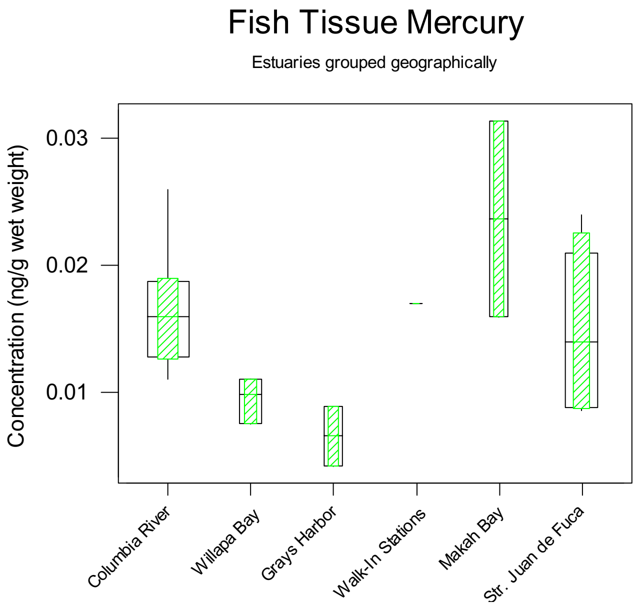

Fish Tissue Copper
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
4
3
2
1
0
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

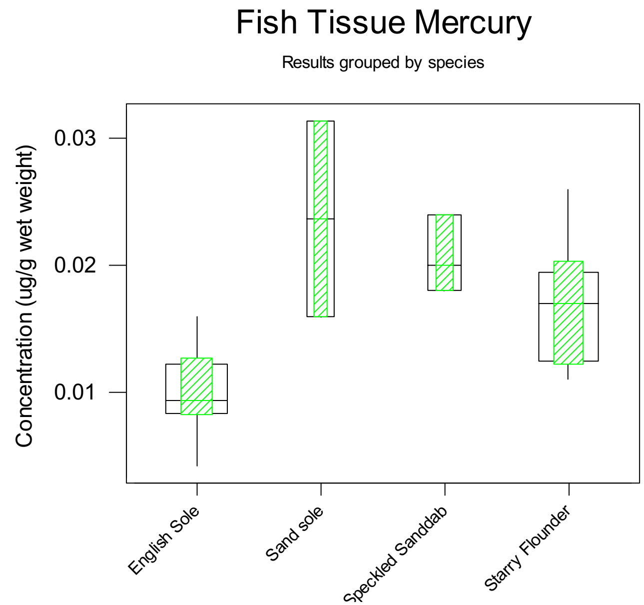

Fish-Tissue Iron
Estuaries grouped geographically
Concentration (ug/g wet weight)
0
100
200
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

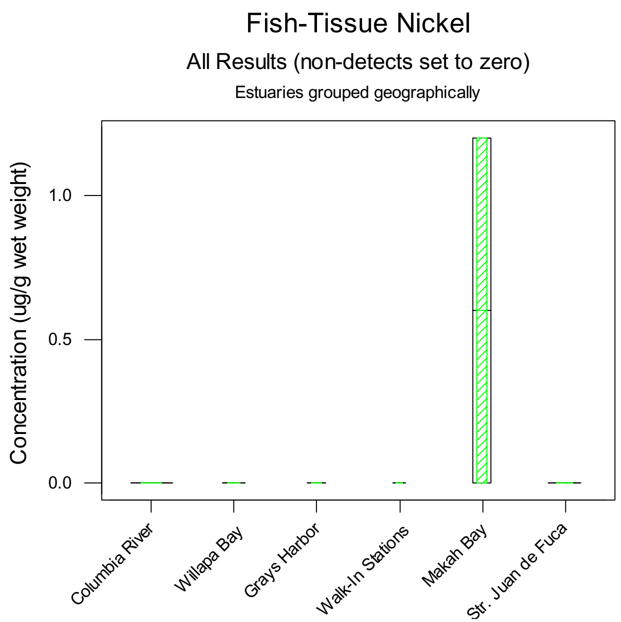

Fish Tissue Iron
Results grouped by species
Concentration (ug/g wet weight)
0
100
200
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

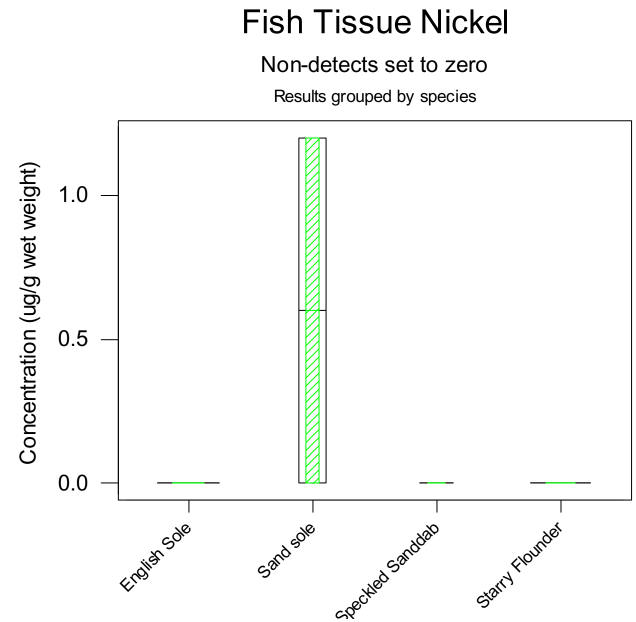

Fish-Tissue Lead
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

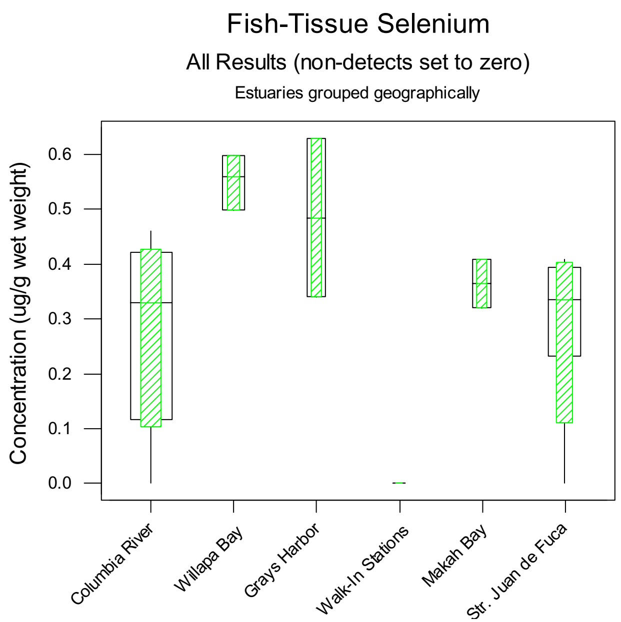

Fish Tissue Lead
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

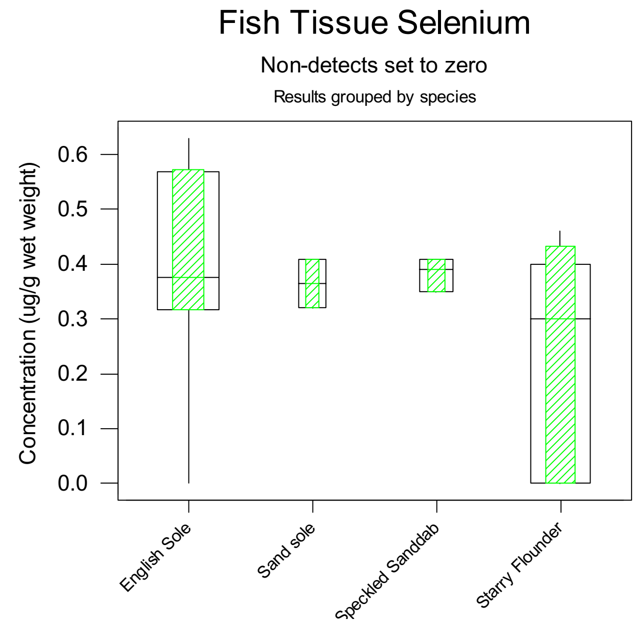

Fish Tissue Mercury
Estuaries grouped geographically
Concentration (ng/g wet weight)
0.03
0.02
0.01
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

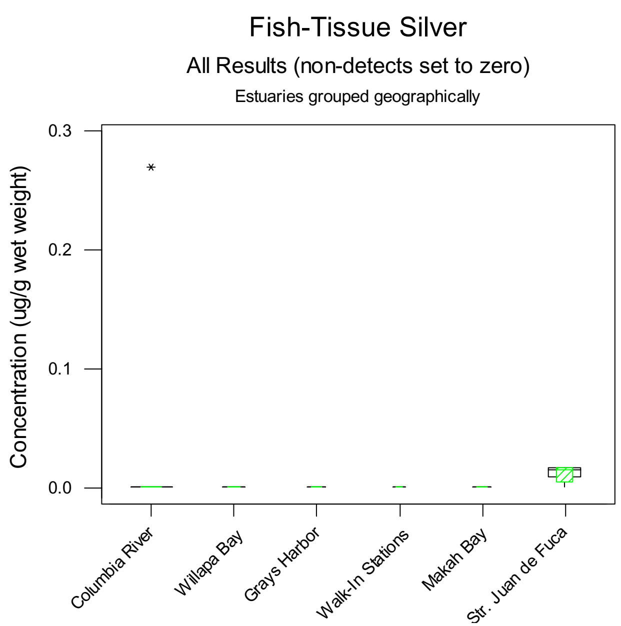

Fish Tissue Mercury
Results grouped by species
Concentration (ug/g wet weight)
0.03
0.02
0.01
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

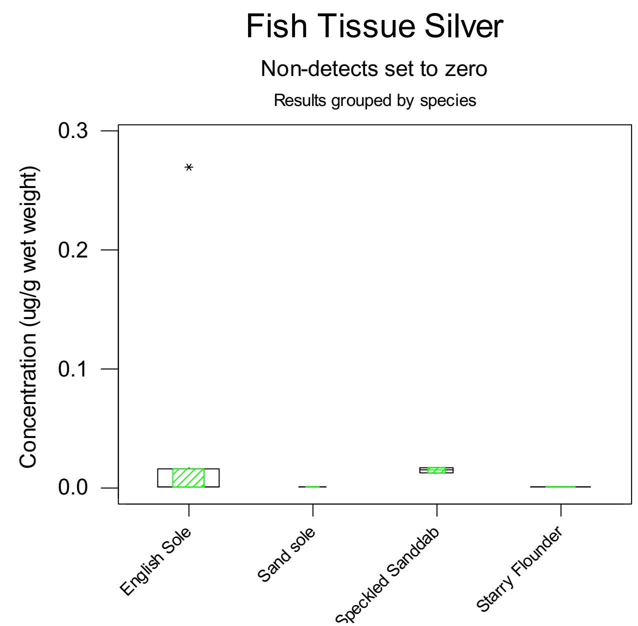

Fish-Tissue Nickel
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
1.0
0.5
0.0
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

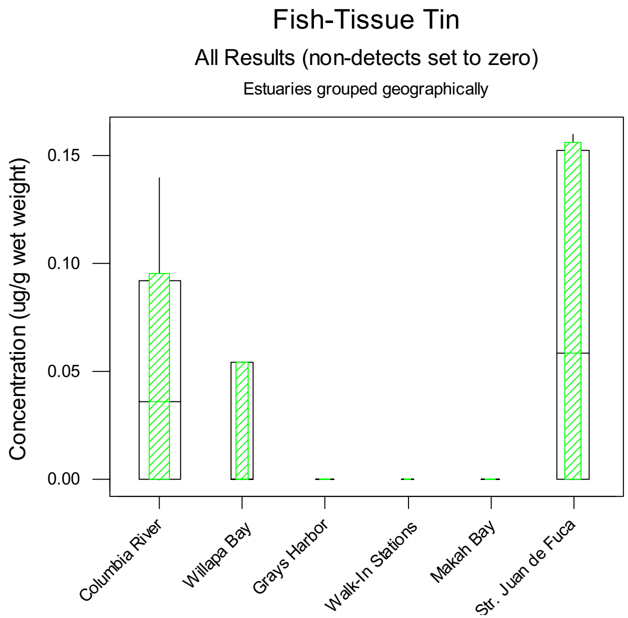

Fish Tissue Nickel
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
1.0
0.5
0.0
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

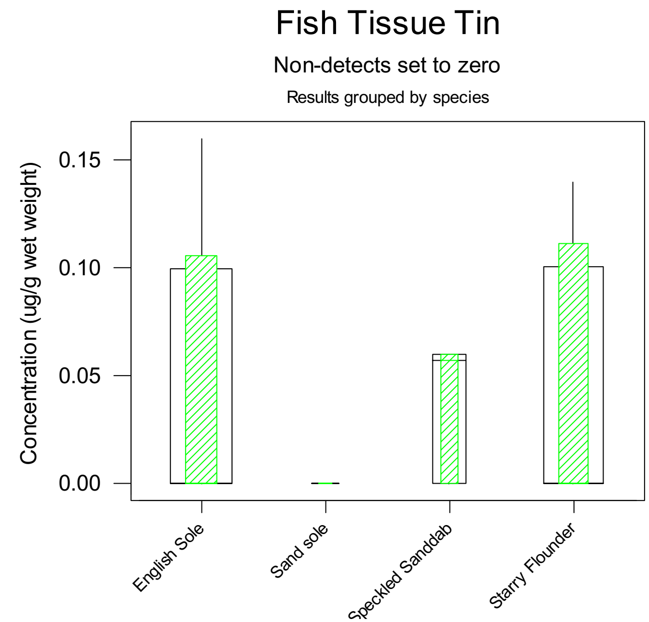

Fish-Tissue Selenium
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

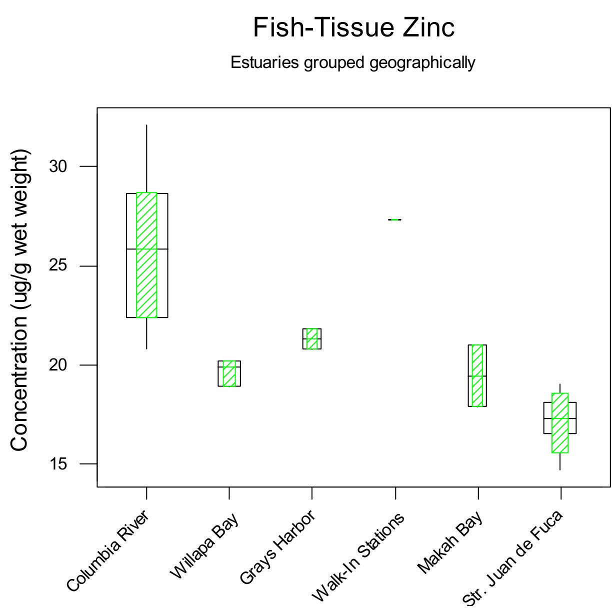

Fish Tissue Selenium
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
English Sole
Sand sole
Speckled Sanddab
Starry Flounder

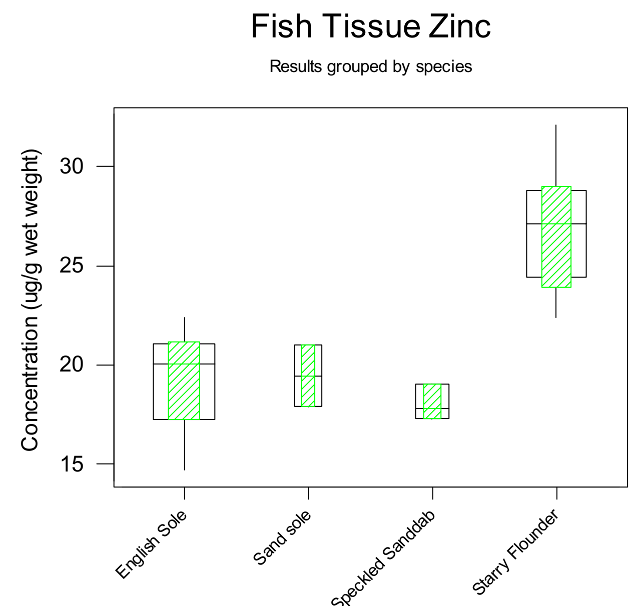

Fish-Tissue Silver
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
0.0
0.1
0.2
0.3
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

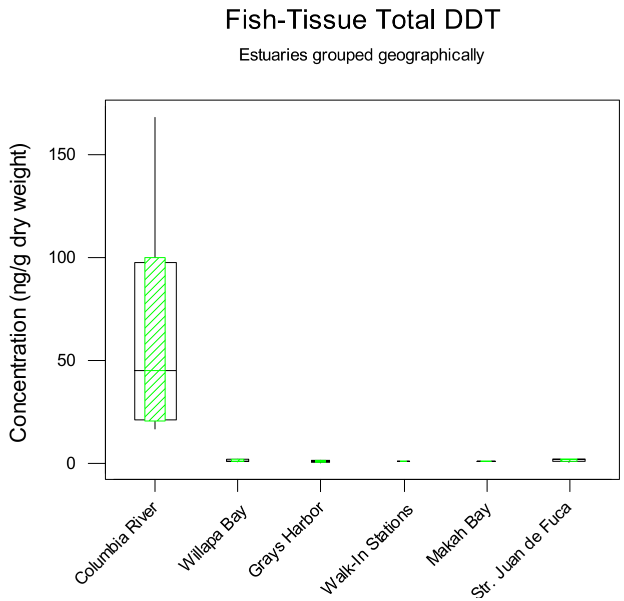

Fish Tissue Silver
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
0.0
0.1
0.2
0.3
English Sole
Sand sole
Speckled Sanddab
Starry Flounder


Fish-Tissue Tin
All Results (non-detects set to zero)
Estuaries grouped geographically
Concentration (ug/g wet weight)
0.00
0.05
0.10
0.15
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

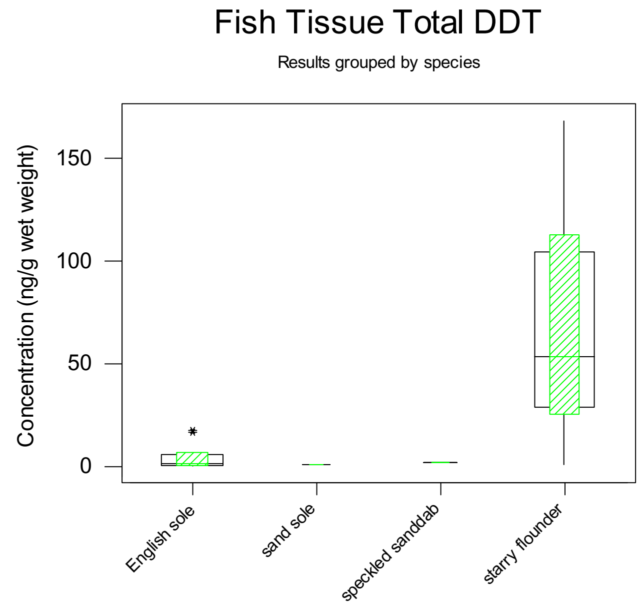

Fish Tissue Tin
Non-detects set to zero
Results grouped by species
Concentration (ug/g wet weight)
0.00
0.05
0.10
0.15
English Sole
Sand sole
Speckled Sanddab
Starry Flounder


Fish-Tissue Zinc
Estuaries grouped geographically
Concentration (ug/g wet weight)
15
20
25
30
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca

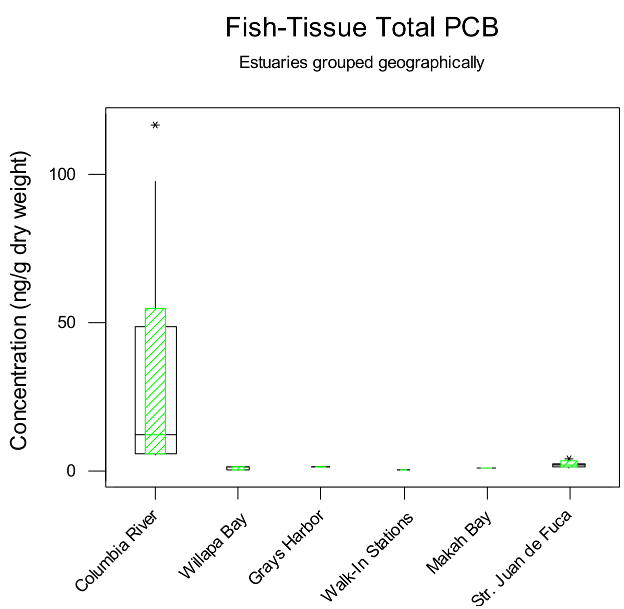

Fish Tissue Zinc
Results grouped by species
Concentration (ug/g wet weight)
15
20
25
30
English Sole
Sand sole
Speckled Sanddab
Starry Flounder



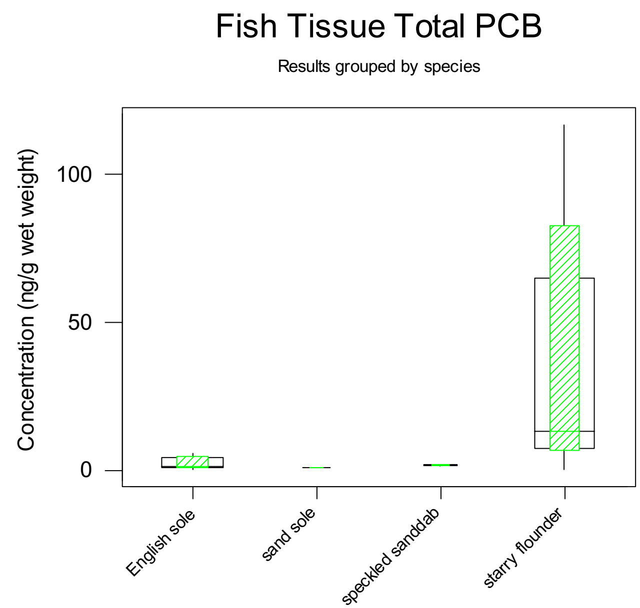
Fish-Tissue Total DDT
Estuaries grouped geographically
Concentration (ng/g dry weight)
0
50
100
150
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca



Fish Tissue Total DDT
Results grouped by species
Concentration (ng/g wet weight)
0
50
100
150
English sole
sand sole
speckled sanddab
starry flounder



Fish-Tissue Total PCB
Estuaries grouped geographically
Concentration (ng/g dry weight)
0
50
100
Columbia River
Willapa Bay
Grays Harbor
Walk-In Stations
Makah Bay
Str. Juan de Fuca



Fish Tissue Total PCB
Results grouped by species
Concentration (ng/g wet weight)
0
50
100
English sole
sand sole
speckled sanddab
starry flounder

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Appendix E

Biotic Condition Indicators

The data tables in this appendix contain the values used in the statistical analyses. The raw data are available in the national EMAP database or upon request.

The graphical summaries in Figures E-1 through E-7 group the data for estuaries geographically as shown in Figure B-2 in Appendix B.

Box-and-whisker plots, or boxplots, display median (50th-percentile), 25th-percentile, 75th-percentile, and extreme values of the results, with a 95% confidence interval for the median. Outliers are unusually high or unusually low values. The width of the boxplot is proportional to the number of samples.

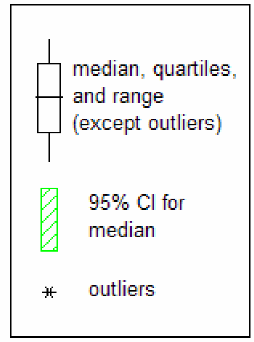


Table E-1. Percent composition of benthic macrofauna taxa (van Veen grabs only)

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
1	***Americorophium salmonis***	**3526**	**19.72%**	
2	***Pygospio elegans***	**2116**	**11.83%**	
3	***Owenia fusiformis***	**1969**	**11.01%**	
4	***Oligochaeta***	**1293**	**7.23%**	
5	***Mediomastus californiensis***	**650**	**3.64%**	
6	***Phyllochaetopterus prolifica***	**562**	**3.14%**	
7	***Mediomastus* sp**	**342**	**1.91%**	
8	***Rochefortia tumida***	**322**	**1.80%**	
9	***Streblospio benedicti***	**306**	**1.71%**	
10	***Aphelochaeta glandaria***	**299**	**1.67%**	
11	*Corbicula fluminea*	282	1.58%	Exotic
12	*Macoma balthica*	273	1.53%	
13	*Axinopsida serricata*	235	1.31%	
14	*Alvania compacta*	191	1.07%	
15	*Magelona sacculata*	170	0.95%	
16	*Tharyx parvus*	134	0.75%	
17	*Neanthes limnicola*	128	0.72%	
18	*Mya arenaria*	125	0.70%	Exotic
19	*Aphelochaeta monilaris*	124	0.69%	
20	*Magelona longicornis*	121	0.68%	
21	*Glycinde polygnatha*	113	0.63%	
22	*Capitella capitata* Cmplx	112	0.63%	
23	*Clinocardium nuttallii*	108	0.60%	
24	*Monocorophium acherusicum*	107	0.60%	Exotic
25	*Leptochelia dubia*	93	0.52%	
26	*Scoloplos armiger armiger*	89	0.50%	
27	*Lumbrineris californiensis*	85	0.48%	
28	*Pholoides asperus*	80	0.45%	
29	*Pseudopolydora kempi*	80	0.45%	Exotic
30	*Sphaerosyllis californiensis*	80	0.45%	
31	*Ophiurida*	79	0.44%	
32	*Hobsonia florida*	76	0.43%	Exotic
33	*Clinocardium* sp	75	0.42%	
34	*Macoma* sp	75	0.42%	
35	*Crepipatella dorsata*	74	0.41%	
36	*Cryptomya californica*	73	0.41%	
37	*Prionospio (Prionospio) steenstrupi*	70	0.39%	
38	*Exogone lourei*	61	0.34%	
39	*Nephtys cornuta*	61	0.34%	
40	*Spiophanes berkeleyorum*	60	0.34%	
41	*Dipolydora socialis*	59	0.33%	
42	*Grandidierella japonica*	59	0.33%	Exotic
43	*Eumida longicornuta*	57	0.32%	
44	*Leitoscoloplos pugettensis*	54	0.30%	
45	*Petaloproctus borealis*	53	0.30%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
46	*Lineidae*	49	0.27%	
47	*Monoporeia affinis*	48	0.27%	
48	*Neanthes* sp	48	0.27%	
49	*Nutricola lordi*	47	0.26%	
50	*Heteromastus filobranchus*	46	0.26%	
51	*Lamprops quadriplicatus*	45	0.25%	
52	*Decamastus gracilis*	44	0.25%	
53	*Polydora cornuta*	41	0.23%	Exotic
54	*Notomastus hemipodus*	40	0.22%	
55	*Sigambra bassi*	38	0.21%	
56	*Macoma yoldiformis*	37	0.21%	
57	*Nephtys caecoides*	36	0.20%	
58	*Phoronidae*	36	0.20%	
59	*Anobothrus gracilis*	35	0.20%	Exotic
60	*Parvilucina tenuisculpta*	34	0.19%	
61	*Spiochaetopterus costarum*	34	0.19%	
62	*Exogone dwisula*	31	0.17%	
63	*Mytilidae*	31	0.17%	
64	*Acila castrensis*	30	0.17%	
65	*Eohaustorius estuarius*	30	0.17%	
66	*Trochochaeta multisetosa*	30	0.17%	Exotic
67	*Amphiodia* sp	28	0.16%	
68	*Eteone columbiensis*	28	0.16%	
69	*Nippoleucon hinumensis*	28	0.16%	Exotic
70	*Paraprionospio pinnata*	28	0.16%	
71	*Monocorophium insidiosum*	26	0.15%	Exotic
72	*Grandifoxus grandis*	25	0.14%	
73	*Nereis procera*	25	0.14%	
74	*Spio butleri*	25	0.14%	
75	*Ampharete labrops*	23	0.13%	
76	*Platynereis bicanaliculata*	23	0.13%	
77	*Polydora limicola*	23	0.13%	
78	*Astyris gausapata*	22	0.12%	
79	*Chironomidae*	22	0.12%	
80	*Tellina nuculoides*	22	0.12%	
81	*Nephtys ferruginea*	21	0.12%	
82	*Photis parvidons*	21	0.12%	
83	*Photis* sp	21	0.12%	
84	*Euclymeninae*	20	0.11%	
85	*Archaeomysis grebnitzkii*	19	0.11%	
86	*Heterophoxus conlanae*	19	0.11%	
87	*Asabellides sibirica*	18	0.10%	
88	*Glycera macrobranchia*	18	0.10%	
89	*Halcampa decemtentaculata*	18	0.10%	
90	*Scoletoma luti*	18	0.10%	
91	*Eusarsiella zostericola*	17	0.10%	Exotic
92	*Lumbrineridae*	17	0.10%	
93	*Odostomia* sp	17	0.10%	
94	*Protomedeia prudens*	17	0.10%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
95	*Siliqua* sp	17	0.10%	
96	*Ampelisca careyi*	16	0.09%	
97	*Cyclocardia ventricosa*	16	0.09%	
98	*Macoma golikovi*	16	0.09%	
99	*Ophelia assimilis*	16	0.09%	
100	*Actiniidae*	15	0.08%	
101	*Macoma nasuta*	15	0.08%	
102	*Tetrastemma candidum*	15	0.08%	
103	*Typosyllis caeca*	15	0.08%	
104	*Armandia brevis*	14	0.08%	
105	*Barantolla nr americana*	14	0.08%	
106	*Cumella vulgaris*	14	0.08%	
107	*Ischyrocerus* sp	14	0.08%	
108	*Manayunkia aestuarina*	14	0.08%	Exotic
109	*Pseudopolydora paucibranchiata*	14	0.08%	Exotic
110	*Terebellides* sp	14	0.08%	
111	*Cerebratulus montgomeryi*	13	0.07%	
112	*Euclymeninae* sp A	13	0.07%	
113	*Scoloplos armiger alaskensis*	13	0.07%	
114	*Terebellides californica*	13	0.07%	
115	*Chironomidae*	12	0.07%	
116	*Tetrastemma* sp	12	0.07%	
117	*Ampelisca lobata*	11	0.06%	
118	*Ampelisca pugetica*	11	0.06%	
119	*Gattyana cirrosa*	11	0.06%	
120	*Manayunkia speciosa*	11	0.06%	Exotic
121	*Saccoglossus* sp	11	0.06%	
122	*Solamen columbianum*	11	0.06%	
123	*Ampithoe valida*	10	0.06%	Exotic
124	*Aphelochaeta* sp	10	0.06%	
125	*Desdimelita desdichada*	10	0.06%	
126	*Enteropneusta*	10	0.06%	
127	*Eulalia californiensis*	10	0.06%	
128	*Photis brevipes*	10	0.06%	
129	*Scolelepis squamata*	10	0.06%	
130	*Americorophium spinicorne*	9	0.05%	
131	*Aoroides* sp	9	0.05%	
132	*Diastylopsis dawsoni*	9	0.05%	
133	*Dipolydora caulleryi*	9	0.05%	Exotic
134	*Macoma carlottensis*	9	0.05%	
135	*Magelona* sp	9	0.05%	
136	*Olivella pycna*	9	0.05%	
137	*Pectinaria granulata*	9	0.05%	
138	*Phoronopsis harmeri*	9	0.05%	
139	*Rhepoxynius abronius*	9	0.05%	
140	*Themiste pyroides*	9	0.05%	
141	*Carinoma mutabilis*	8	0.04%	
142	*Cirratulus multioculatus*	8	0.04%	
143	*Crangon* sp	8	0.04%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
144	*Eudorella pacifica*	8	0.04%	
145	*Euphilomedes producta*	8	0.04%	
146	*Glycera nana*	8	0.04%	
147	*Glycinde* sp	8	0.04%	
148	*Hydrobiidae*	8	0.04%	
149	*Prionospio (Minuspio) lighti*	8	0.04%	
150	*Spiophanes bombyx*	8	0.04%	
151	*Cardiomya pectinata*	7	0.04%	
152	*Cerebratulus californiensis*	7	0.04%	
153	*Cirratulidae*	7	0.04%	
154	*Dendraster excentricus*	7	0.04%	
155	*Eobrolgus* sp	7	0.04%	
156	*Galathowenia oculata*	7	0.04%	
157	*Heteromastus* sp	7	0.04%	
158	*Lepidasthenia berkeleyae*	7	0.04%	
159	*Nuculana minuta*	7	0.04%	
160	*Podarkeopsis glabrus*	7	0.04%	
161	*Rhynchospio glutaea*	7	0.04%	
162	*Sinelobus stanfordi*	7	0.04%	Exotic
163	*Amphipholis* sp	6	0.03%	
164	*Boccardia pugettensis*	6	0.03%	
165	*Cerebratulus* sp	6	0.03%	
166	*Eumida* sp	6	0.03%	
167	*Euphilomedes carcharodonta*	6	0.03%	
168	*Glycera americana*	6	0.03%	
169	*Lirularia lirulata*	6	0.03%	
170	*Lumbrineris limicola*	6	0.03%	
171	*Oregonia gracilis*	6	0.03%	
172	*Pentamera lissoplaca*	6	0.03%	
173	*Pherusa plumosa*	6	0.03%	
174	*Phyllodoce groenlandica*	6	0.03%	
175	*Pilargis maculata*	6	0.03%	
176	*Pinnixa schmitti*	6	0.03%	
177	*Proceraea cornuta*	6	0.03%	
178	*Rhabdocoela*	6	0.03%	
179	*Sigalion spinosus*	6	0.03%	
180	*Sternaspis cf fossor*	6	0.03%	
181	*Ampelisca agassizi*	5	0.03%	
182	*Ascidiacea*	5	0.03%	
183	*Byblis millsi*	5	0.03%	
184	*Clausidium vancouverense*	5	0.03%	
185	*Crangon franciscorum*	5	0.03%	
186	*Diastylis santamariensis*	5	0.03%	
187	*Eogammarus confervicolus* Cmplx	5	0.03%	
188	*Eteone lighti*	5	0.03%	
189	*Eteone* sp	5	0.03%	
190	*Eudistylia catharinae*	5	0.03%	
191	*Eyakia robusta*	5	0.03%	
192	*Haminaea vesicula*	5	0.03%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
193	*Kurtzia arteaga*	5	0.03%	
194	*Leptochiton rugatus*	5	0.03%	
195	*Lumbrineris* sp	5	0.03%	
196	*Majoxiphalus major*	5	0.03%	
197	*Mandibulophoxus mayi*	5	0.03%	
198	*Melanochlamys diomedea*	5	0.03%	
199	*Monocorophium californianum*	5	0.03%	
200	*Neosabellaria cementarium*	5	0.03%	
201	*Nephtys caeca*	5	0.03%	
202	*Nutricola tantilla*	5	0.03%	
203	*Phyllodoce* sp	5	0.03%	
204	*Pista elongata*	5	0.03%	
205	*Polycirrus* sp I	5	0.03%	
206	*Praxillella pacifica*	5	0.03%	
207	*Rutiderma lomae*	5	0.03%	
208	*Sabaco elongatus*	5	0.03%	Exotic
209	*Amphiodia urtica*	4	0.02%	
210	*Aphelochaeta tigrina*	4	0.02%	
211	*Aricidea (Acmira) lopezi*	4	0.02%	
212	*Caecidotea racovitzai*	4	0.02%	Exotic
213	*Caprella laeviuscula*	4	0.02%	
214	*Ennucula tenuis*	4	0.02%	
215	*Eualus subtilis*	4	0.02%	
216	*Gammaropsis thompsoni*	4	0.02%	
217	*Golfingia vulgaris*	4	0.02%	
218	*Harmothoinae*	4	0.02%	
219	*Heterophoxus ellisi*	4	0.02%	
220	*Lyonsia californica*	4	0.02%	
221	*Notomastus latericeus*	4	0.02%	
222	*Oenopota* sp	4	0.02%	
223	*Ophelina acuminata*	4	0.02%	
224	*Ophiodromus pugettensis*	4	0.02%	
225	*Phyllochaetopterus pottsi*	4	0.02%	
226	*Psammonyx longimerus*	4	0.02%	
227	*Rhodine bitorquata*	4	0.02%	
228	*Saxidomus giganteus*	4	0.02%	
229	*Scionella japonica*	4	0.02%	
230	*Turbonilla* sp	4	0.02%	
231	*Ampharete acutifrons*	3	0.02%	
232	*Ampharetidae*	3	0.02%	
233	*Apistobranchus ornatus*	3	0.02%	
234	*Bivalvia*	3	0.02%	
235	*Bowerbankia gracilis*	3	0.02%	Exotic Colonial
236	*Caulleriella pacifica*	3	0.02%	
237	*Chaetozone acuta*	3	0.02%	
238	*Chaetozone nr setosa*	3	0.02%	
239	*Chironomidae*	3	0.02%	
240	*Compsomyax subdiaphana*	3	0.02%	
241	*Edwardsia sipunculoides*	3	0.02%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
242	*Euchone incolor*	3	0.02%	
243	*Exogone molesta*	3	0.02%	
244	*Glycinde armigera*	3	0.02%	
245	*Haliophasma geminatum*	3	0.02%	
246	*Harmothoe multisetosa*	3	0.02%	
247	*Hirudinea*	3	0.02%	
248	*Lanassa venusta*	3	0.02%	Exotic
249	*Mesochaetopterus taylori*	3	0.02%	
250	*Molgula pugetiensis*	3	0.02%	
251	*Monticellina tesselata*	3	0.02%	
252	*Naineris uncinata*	3	0.02%	
253	*Nassarius mendicus*	3	0.02%	
254	*Pagurus* sp	3	0.02%	
255	*Pinnixa* sp	3	0.02%	
256	*Pista brevibranchiata*	3	0.02%	
257	*Podocopida*	3	0.02%	
258	*Polycirrus* sp	3	0.02%	
259	*Syllis elongata*	3	0.02%	
260	*Tecticeps pugettensis*	3	0.02%	
261	*Tellina modesta*	3	0.02%	
262	*Tresus sp*	3	0.02%	
263	*Tubulanus polymorphus*	3	0.02%	
264	*Adontorhina cyclia*	2	0.01%	
265	*Amphissa columbiana*	2	0.01%	
266	*Barentsia benedeni*	2	0.01%	Exotic Colonial
267	*Bivalvia* sp 1	2	0.01%	
268	*Cancer oregonensis*	2	0.01%	
269	*Caprella californica*	2	0.01%	
270	*Celleporella hyalina*	2	0.01%	Colonial
271	*Chaetozone* sp	2	0.01%	
272	*Circeis spirillum*	2	0.01%	Exotic
273	*Coullana canadensis*	2	0.01%	Exotic
274	*Crangon alaskensis*	2	0.01%	
275	*Cylichna attonsa*	2	0.01%	
276	*Dendrobeania lichenoides*	2	0.01%	Colonial
277	*Dipolydora quadrilobata*	2	0.01%	Exotic
278	*Eobrolgus chumashi*	2	0.01%	
279	*Eupolymnia heterobranchia*	2	0.01%	
280	*Hexagenia* sp	2	0.01%	
281	*Levinsenia gracilis*	2	0.01%	
282	*Magelona pitelkai*	2	0.01%	
283	*Mediomastus ambiseta*	2	0.01%	
284	*Megalomma splendida*	2	0.01%	
285	*Membranipora* sp	2	0.01%	Colonial
286	*Mopalia* sp	2	0.01%	
287	*Neotrypaea californiensis*	2	0.01%	
288	*Nephtys* sp	2	0.01%	
289	*Nicomache personata*	2	0.01%	
290	*Olivella baetica*	2	0.01%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
291	*Olivella biplicata*	2	0.01%	
292	*Onuphidae*	2	0.01%	
293	*Onuphis iridescens*	2	0.01%	
294	*Paleanotus bellis*	2	0.01%	
295	*Pectinaria californiensis*	2	0.01%	
296	*Pholoe glabra*	2	0.01%	
297	*Physella* sp	2	0.01%	
298	*Polycirrus californicus*	2	0.01%	
299	*Polyplacophora*	2	0.01%	
300	*Protothaca staminea*	2	0.01%	
301	*Sabellidae*	2	0.01%	
302	*Sabelliphilidae*	2	0.01%	
303	*Sthenelais berkeleyi*	2	0.01%	
304	*Tellina* sp	2	0.01%	
305	*Tenonia priops*	2	0.01%	
306	*Tetrastemma nigrifrons*	2	0.01%	
307	*Thelepus setosus*	2	0.01%	
308	*Abietinaria* sp	1	0.01%	Colonial
309	*Acarina*	1	0.01%	
310	*Achelia alaskensis*	1	0.01%	
311	*Achelia echinata*	1	0.01%	Exotic
312	*Aglaja ocelligera*	1	0.01%	
313	*Ampharete cf crassiseta*	1	0.01%	
314	*Amphiporus* sp	1	0.01%	
315	*Amphitrite edwardsi*	1	0.01%	Exotic
316	*Anchicolurus occidentalis*	1	0.01%	
317	*Anonyx cf lilljeborgi*	1	0.01%	
318	*Araphura cuspirostris*	1	0.01%	
319	*Argissa hamatipes*	1	0.01%	
320	*Aricidea* sp	1	0.01%	
321	*Balanus crenatus*	1	0.01%	
322	*Boltenia villosa*	1	0.01%	
323	*Bougainvilliidae*	1	0.01%	Colonial
324	*Caecum occidentale*	1	0.01%	
325	*Caecum* sp	1	0.01%	
326	*Campanulariidae*	1	0.01%	Colonial
327	*Campylaspis hartae*	1	0.01%	
328	*Caprella* sp	1	0.01%	
329	*Caulibugula ciliata*	1	0.01%	Colonial
330	*Cellaria mandibulata*	1	0.01%	Colonial
331	*Ceratopogonidae*	1	0.01%	
332	*Chaetozone bansei*	1	0.01%	
333	*Chapperiopsis patula*	1	0.01%	Colonial
334	*Chironomidae*	1	0.01%	
335	*Chlamys hastata*	1	0.01%	
336	*Cossura pygodactylata*	1	0.01%	
337	*Crisia* sp	1	0.01%	Colonial
338	*Cyclostomata*	1	0.01%	Colonial
339	*Cylindroleberididae*	1	0.01%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
340	*Deflexilodes similis*	1	0.01%	
341	*Demonax* sp	1	0.01%	
342	*Dendrochirotida*	1	0.01%	
343	*Diaphana californica*	1	0.01%	
344	*Dichonemertes hartmanae*	1	0.01%	
345	*Diopatra* sp	1	0.01%	
346	*Discorsopagurus schmitti*	1	0.01%	
347	*Disporella fimbriata*	1	0.01%	Colonial
348	*Ectinosoma* sp	1	0.01%	
349	*Electra crustulenta arctica*	1	0.01%	Colonial
350	*Eohaustorius washingtonianus*	1	0.01%	
351	*Eranno bicirrata*	1	0.01%	
352	*Eteone fauchaldi*	1	0.01%	
353	*Eudistylia polymorpha*	1	0.01%	
354	*Eudistylia* sp	1	0.01%	
355	*Euphysa ruthae*	1	0.01%	
356	*Eurystomella bilabiata*	1	0.01%	Colonial
357	*Eusyllis habei*	1	0.01%	
358	*Gastropoda* sp 4	1	0.01%	
359	*Gattyana treadwelli*	1	0.01%	
360	*Geminosyllis ohma*	1	0.01%	Exotic
361	*Gnathopleustes* sp	1	0.01%	
362	*Grantiidae*	1	0.01%	Colonial
363	*Harmothoe extenuata*	1	0.01%	
364	*Heptacarpus kincaidi*	1	0.01%	
365	*Hesperonoe complanata*	1	0.01%	
366	*Heteromastus filiformis*	1	0.01%	
367	*Heterophoxus oculatus group*	1	0.01%	
368	*Heteropodarke heteromorpha*	1	0.01%	
369	*Heteropora pacifica*	1	0.01%	Colonial
370	*Hiatella arctica*	1	0.01%	
371	*Hoplonemertea*	1	0.01%	
372	*Humilaria kennerlyi*	1	0.01%	
373	*Hyas lyratus*	1	0.01%	
374	*Idanthyrsus saxicavus*	1	0.01%	
375	*Lagenipora socialis*	1	0.01%	Colonial
376	*Laonice cirrata*	1	0.01%	Exotic
377	*Lepidasthenia longicirrata*	1	0.01%	
378	*Levinsenia oculata*	1	0.01%	
379	*Longipedia* sp	1	0.01%	
380	*Lophopanopeus bellus*	1	0.01%	
381	*Macoma elimata*	1	0.01%	
382	*Macoma inquinata*	1	0.01%	
383	*Macoma secta*	1	0.01%	
384	*Mandibulophoxus gilesi*	1	0.01%	
385	*Margarites* sp	1	0.01%	
386	*Microphthalmus sczelkowii*	1	0.01%	
387	*Micrura alaskensis*	1	0.01%	
388	*Micrura* sp	1	0.01%	

Order of Dominance	Taxon	Total Number of Individuals	% of Total	Species Classification
389	*Modiolus* sp	1	0.01%	
390	*Molpadia intermedia*	1	0.01%	
391	*Monostylifera*	1	0.01%	
392	*Monticellina secunda*	1	0.01%	
393	*Narpus* sp	1	0.01%	
394	*Neomysis mercedis*	1	0.01%	
395	*Nephtys californiensis*	1	0.01%	
396	*Nereididae*	1	0.01%	
397	*Nereis* sp	1	0.01%	
398	*Nolella stipata*	1	0.01%	Colonial
399	*Obelia longissima*	1	0.01%	Colonial
400	*Oplorhiza gracilis*	1	0.01%	Colonial
401	*Pachynus cf barnardi*	1	0.01%	
402	*Parandalia fauveli*	1	0.01%	
403	*Paraonella platybranchia*	1	0.01%	
404	*Phoronis* sp	1	0.01%	
405	*Phoxocephalidae*	1	0.01%	
406	*Phyllodoce cuspidata*	1	0.01%	
407	*Pinnotheridae*	1	0.01%	
408	*Pista wui*	1	0.01%	
409	*Polydora websteri*	1	0.01%	Exotic
410	*Pontogeneia rostrata*	1	0.01%	Exotic
411	*Pulsellum salishorum*	1	0.01%	
412	*Rocinela belliceps*	1	0.01%	
413	*Scalibregma inflatum*	1	0.01%	
414	*Scyphozoa*	1	0.01%	
415	*Solen sicarius*	1	0.01%	
416	*Solidobalanus hesperius*	1	0.01%	
417	*Spio filicornis*	1	0.01%	
418	*Spirontocaris ochotensis*	1	0.01%	
419	*Streblosoma* sp B	1	0.01%	
420	*Styela gibbsii*	1	0.01%	
421	*Tellina bodegensis*	1	0.01%	
422	*Terebellidae*	1	0.01%	
423	*Thyasira flexuosa*	1	0.01%	
424	*Thysanocardia nigra*	1	0.01%	
425	*Trichobranchus glacialis*	1	0.01%	
426	*Tubulanus cingulatus*	1	0.01%	
427	*Tubulipora* sp	1	0.01%	Colonial
428	*Venerupis philippinarum*	1	0.01%	Exotic
429	*Yoldia hyperborea*	1	0.01%	
430	*Yoldia seminuda*	1	0.01%	
431	*Yoldia* sp	1	0.01%	
	TOTAL	17881	100.00%	

Table E-2. Benthic infauna by station. Top 10 abundant taxa in bold.

WA99-0001 MAKAH BAY	
Count	Taxon
14	**Ampelisca careyi**
8	**Diastylopsis dawsoni**
7	**Rhepoxynius abronius**
4	**Olivella pycna**
2	**Olivella biplicata**
2	**Tecticeps pugettensis**
1	**Anchicolurus occidentalis**
1	**Chaetozone bansei**
1	**Eurystomella bilabiata**
1	**Glycinde armigera**
1	**Heteropora pacifica**
1	**Naineris uncinata**
1	**Notomastus hemipodus**
44	**TOTAL**

WA99-0002 MAKAH BAY	
Count	Taxon
7	**Eohaustorius estuarius**
5	**Glycera macrobranchia**
4	**Psammonyx longimerus**
2	**Naineris uncinata**
1	**Aphelochaeta sp**
1	**Nephtys caecoides**
1	**Tetrastemma sp**
21	**TOTAL**

WA99-0003 MAKAH BAY	
Count	Taxon
13	**Eohaustorius estuarius**
6	**Sigalion spinosus**
5	**Olivella pycna**
4	**Mandibulophoxus mayi**
3	**Dendraster excentricus**
2	**Ampelisca careyi**
2	**Majoxiphalus major**
1	**Diastylopsis dawsoni**
1	**Macoma secta**
1	**Nephtys caecoides**
1	**Phoxocephalidae**
1	**Rhepoxynius abronius**
1	**Scoloplos armiger armiger**
41	**TOTAL**

WA99-0004 HOKO RIVER	
Count	Taxon
8	**Archaeomysis grebnitzkii**
6	**Armandia brevis**
5	**Rhynchospio glutaea**
3	**Majoxiphalus major**
2	**Olivella baetica**
1	**Capitella capitata Cmplx**
1	**Crangon alaskensis**
1	**Crangon sp**
1	**Eobrolgus chumashi**
1	**Glycinde polygnatha**
1	**Leitoscoloplos pugettensis**
1	**Magelona sacculata**
1	**Mandibulophoxus mayi**
1	**Paraonella platybranchia**
1	**Rhepoxynius abronius**
1	**Scoloplos armiger armiger**
1	**Spiophanes bombyx**
1	**Tecticeps pugettensis**
1	**Tellina bodegensis**
1	**Tellina modesta**
39	**TOTAL**

WA99-0007 FRESHWATER BAY			
Count	Taxon	Count	Taxon
100	**Phyllochaetopterus prolifica**	2	Polycirrus sp
42	**Magelona longicornis**	2	Sthenelais berkeleyi
38	**Nutricola lordi**	1	Alvania compacta
28	**Axinopsida serricata**	1	Ampharete cf crassiseta
21	**Photis parvidons**	1	Amphipholis sp
20	**Photis sp**	1	Amphiporus sp
17	**Protomedeia prudens**	1	Anonyx cf lilljeborgi
13	**Cyclocardia ventricosa**	1	Argissa hamatipes
12	**Dipolydora socialis**	1	Campylaspis hartae
11	**Rochefortia tumida**	1	Cancer oregonensis
10	Desdimelita desdichada	1	Caulleriella pacifica
9	Decamastus gracilis	1	Cellaria mandibulata
9	Ischyrocerus sp	1	Chaetozone acuta
9	Photis brevipes	1	Clinocardium nuttallii
7	Heterophoxus conlanae	1	Crangon sp
7	Mediomastus californiensis	1	Cyclostomata
7	Mya arenaria	1	Cylindroleberididae
7	Prionospio (Prionospio) steenstrupi	1	Deflexilodes similis
6	Boccardia pugettensis	1	Discorsopagurus schmitti
6	Eudorella pacifica	1	Disporella fimbriata
6	Parvilucina tenuisculpta	1	Eteone lighti
6	Spiochaetopterus costarum	1	Eualus subtilis
5	Ampelisca agassizi	1	Euclymeninae sp A
5	Aphelochaeta glandaria	1	Eumida sp
5	Byblis millsi	1	Galathowenia oculata
5	Exogone lourei	1	Heptacarpus kincaidi
5	Eyakia robusta	1	Hiatella arctica
5	Monocorophium californianum	1	Laonice cirrata
5	Nephtys ferruginea	1	Leitoscoloplos pugettensis
4	Diastylis santamariensis	1	Lirularia lirulata
4	Euclymeninae	1	Lumbrineris limicola
4	Eudistylia catharinae	1	Lumbrineris sp
4	Eumida longicornuta	1	Lyonsia californica
4	Heterophoxus ellisi	1	Macoma elimata
4	Lumbrineris californiensis	1	Macoma inquinata
4	Macoma golikovi	1	Monticellina secunda
4	Nephtys caecoides	1	Notomastus latericeus
4	Nuculana minuta	1	Nutricola tantilla
4	Sabaco elongatus	1	Onuphis iridescens
3	Apistobranchus ornatus	1	Ophelina acuminata
3	Gammaropsis thompsoni	1	Pholoides asperus
3	Glycinde polygnatha	1	Phyllochaetopterus pottsi
3	Haliophasma geminatum	1	Phyllodoce cuspidata
3	Molgula pugetiensis	1	Phyllodoce sp
3	Pectinaria granulata	1	Praxillella pacifica
3	Typosyllis caeca	1	Proceraea cornuta
2	Adontorhina cyclia	1	Protothaca staminea
2	Ampelisca pugetica	1	Rhodine bitorquata
2	Amphissa columbiana	1	Rocinela belliceps
2	Aoroides sp	1	Sabellidae
2	Aphelochaeta sp	1	Scalibregma inflatum
2	Chaetozone nr setosa	1	Scoletoma luti
2	Chaetozone sp	1	Spiophanes berkeleyorum
2	Circeis spirillum	1	Spiophanes bombyx
2	Hobsonia florida	1	Spirontocaris ochotensis
2	Megalomma splendida	1	Tetrastemma nigrifrons
2	Nicomache personata	1	Thyasira flexuosa
2	Oregonia gracilis	1	Thysanocardia nigra
2	Polycirrus californicus	**573**	**TOTAL**

WA99-0009 DUNGENESS BAY	
Count	Taxon
289	**Aphelochaeta glandaria**
63	**Owenia fusiformis**
56	**Capitella capitata Cmplx**
42	**Oligochaeta**
29	**Leitoscoloplos pugettensis**
22	**Mediomastus sp**
20	**Ampharete labrops**
10	**Leptochelia dubia**
10	**Prionospio (Prionospio) steenstrupi**
9	**Axinopsida serricata**
8	Exogone lourei
8	Macoma nasuta
6	Glycinde polygnatha
5	Clinocardium sp
5	Lirularia lirulata
5	Mediomastus californiensis
4	Nutricola lordi
4	Nutricola tantilla
3	Ampharete acutifrons
3	Aricidea (Acmira) lopezi
3	Armandia brevis
3	Dipolydora socialis
3	Eteone lighti
2	Dipolydora quadrilobata
2	Glycinde sp
2	Pseudopolydora paucibranchiata
2	Pygospio elegans
2	Rhynchospio glutaea
1	Ampelisca pugetica
1	Ampharetidae
1	Carinoma mutabilis
1	Chaetozone nr setosa
1	Crangon sp
1	Diastylis santamariensis
1	Eobrolgus chumashi
1	Euphilomedes carcharodonta
1	Gnathopleustes sp
1	Lamprops quadriplicatus
1	Melanochlamys diomedea
1	Micrura alaskensis
1	Neanthes limnicola
1	Nephtys caecoides
1	Notomastus hemipodus
1	Ophelina acuminata
1	Pista wui
1	Scoloplos armiger armiger
1	Spio filicornis
1	Tellina modesta
640	**TOTAL**

WA99-0010 DISCOVERY BAY	
Count	Taxon
157	**Axinopsida serricata**
46	**Heteromastus filobranchus**
45	**Spiophanes berkeleyorum**
29	**Trochochaeta multisetosa**
21	**Rochefortia tumida**
13	**Sigambra bassi**
12	**Scoletoma luti**
8	**Macoma carlottensis**
7	**Euclymeninae sp A**
7	**Lepidasthenia berkeleyae**
7	**Nereis procera**
6	Glycera nana
5	Lumbrineris limicola
5	Spiophanes bombyx
4	Astyris gausapata
4	Heteromastus sp
4	Praxillella pacifica
4	Sternaspis cf fossor
3	Nephtys ferruginea
3	Paraprionospio pinnata
3	Pinnixa sp
2	Levinsenia gracilis
1	Amphiodia urtica
1	Aphelochaeta sp
1	Aricidea (Acmira) lopezi
1	Compsomyax subdiaphana
1	Crepipatella dorsata
1	Cylichna attonsa
1	Ennucula tenuis
1	Eteone lighti
1	Eteone sp
1	Gattyana treadwelli
1	Glycera americana
1	Glycinde armigera
1	Heteromastus filiformis
1	Heterophoxus oculatus group
1	Leptochelia dubia
1	Levinsenia oculata
1	Molpadia intermedia
1	Nuculana minuta
1	Nutricola lordi
1	Oligochaeta
1	Ophelina acuminata
1	Parvilucina tenuisculpta
1	Pectinaria granulata
1	Pilargis maculata
1	Podarkeopsis glabrus
1	Prionospio (Minuspio) lighti
1	Tenonia priops
422	**TOTAL**

WA99-0011 DISCOVERY BAY					
Count	Taxon	Count	Taxon	Count	Taxon
67	**Crepipatella dorsata**	3	Harmothoe multisetosa	1	Eudistylia catharinae
60	**Pholoides asperus**	3	Heterophoxus conlanae	1	Eudistylia polymorpha
53	**Petaloproctus borealis**	3	Monticellina tesselata	1	Eudistylia sp
50	**Magelona longicornis**	3	Oenopota sp	1	Eudorella pacifica
45	**Alvania compacta**	3	Owenia fusiformis	1	Gammaropsis thompsoni
28	**Macoma yoldiformis**	3	Parvilucina tenuisculpta	1	Geminosyllis ohma
28	**Phyllochaetopterus prolifica**	3	Pectinaria granulata	1	Glycera americana
26	**Mya arenaria**	3	Phoronopsis harmeri	1	Harmothoe extenuata
23	**Lumbrineris californiensis**	3	Pista elongata	1	Harmothoinae
23	**Rochefortia tumida**	3	Proceraea cornuta	1	Heteromastus sp
22	Acila castrensis	3	Rhodine bitorquata	1	Humilaria kennerlyi
21	Prionospio (Prionospio) steenstrupi	2	Chaetozone acuta	1	Idanthyrsus saxicavus
20	Anobothrus gracilis	2	Dipolydora socialis	1	Lagenipora socialis
16	Lineidae	2	Glycera nana	1	Lepidasthenia longicirrata
14	Euclymeninae	2	Glycinde polygnatha	1	Margarites sp
13	Odostomia sp	2	Lanassa venusta	1	Mediomastus sp
12	Astyris gausapata	2	Lyonsia californica	1	Micrura sp
12	Macoma golikovi	2	Mesochaetopterus taylori	1	Modiolus sp
12	Notomastus hemipodus	2	Nassarius mendicus	1	Nereis procera
12	Sphaerosyllis californiensis	2	Nuculana minuta	1	Nereis sp
11	Lumbrineridae	2	Nutricola lordi	1	Nolella stipata
11	Terebellides sp	2	Pilargis maculata	1	Notomastus latericeus
10	Eulalia californiensis	2	Pinnixa schmitti	1	Obelia longissima
10	Nephtys ferruginea	2	Pista brevibranchiata	1	Onuphidae
9	Gattyana cirrosa	2	Polyplacophora	1	Onuphis iridescens
9	Paraprionospio pinnata	2	Sabelliphilidae	1	Ophiodromus pugettensis
8	Cirratulus multioculatus	2	Sternaspis cf fossor	1	Ophiurida
8	Euphilomedes producta	2	Thelepus setosus	1	Oplorhiza gracilis
7	Asabellides sibirica	2	Themiste pyroides	1	Pagurus sp
7	Cardiomya pectinata	2	Turbonilla sp	1	Paleanotus bellis
7	Eumida longicornuta	1	Amphitrite edwardsi	1	Pholoe glabra
7	Solamen columbianum	1	Araphura cuspirostris	1	Phoronidae
7	Terebellides californica	1	Armandia brevis	1	Phoronis sp
5	Ampelisca lobata	1	Balanus crenatus	1	Photis sp
5	Amphipholis sp	1	Barentsia benedeni	1	Pinnotheridae
5	Ascidiacea	1	Bougainvilliidae	1	Platynereis bicanaliculata
5	Axinopsida serricata	1	Bowerbankia gracilis	1	Podocopida
5	Galathowenia oculata	1	Campanulariidae	1	Polycirrus sp
5	Leptochiton rugatus	1	Caulibugula ciliata	1	Polydora limicola
5	Neosabellaria cementarium	1	Caulleriella pacifica	1	Polydora websteri
4	Aphelochaeta sp	1	Chlamys hastata	1	Pulsellum salishorum
4	Aphelochaeta tigrina	1	Cirratulidae	1	Rutiderma lomae
4	Golfingia vulgaris	1	Compsomyax subdiaphana	1	Sabellidae
4	Kurtzia arteaga	1	Cossura pygodactylata	1	Scoletoma luti
4	Scionella japonica	1	Crangon sp	1	Streblosoma sp B
4	Spiochaetopterus costarum	1	Demonax sp	1	Tetrastemma candidum
3	Aphelochaeta glandaria	1	Dendrobeania lichenoides	1	Trichobranchus glacialis
3	Cyclocardia ventricosa	1	Dendrochirotida	1	Trochochaeta multisetosa
3	Decamastus gracilis	1	Dichonemertes hartmanae	1	Tubulanus cingulatus
3	Euchone incolor	1	Diopatra sp	1	Typosyllis caeca
3	Exogone dwisula	1	Edwardsia sipunculoides	1	Yoldia seminuda
3	Exogone lourei	1	Ennucula tenuis	**893**	**TOTAL**
3	Exogone molesta	1	Eranno bicirrata		

WA99-0012 DISCOVERY BAY			
Count	Taxon	Count	Taxon
434	**Phyllochaetopterus prolifica**	2	Aphelochaeta glandaria
140	**Alvania compacta**	2	Ennucula tenuis
119	**Rochefortia tumida**	2	Eteone sp
78	**Ophiurida**	2	Euclymeninae
57	**Lumbrineris californiensis**	2	Euphilomedes carcharodonta
57	**Mya arenaria**	2	Eupolymnia heterobranchia
43	**Eumida longicornuta**	2	Gattyana cirrosa
42	**Dipolydora socialis**	2	Glycera americana
35	**Axinopsida serricata**	2	Harmothoinae
30	**Prionospio (Prionospio) steenstrupi**	2	Leitoscoloplos pugettensis
28	Amphiodia sp	2	Leptochelia dubia
28	Exogone dwisula	2	Mediomastus ambiseta
26	Magelona longicornis	2	Mopalia sp
22	Polydora limicola	2	Notomastus latericeus
21	Spiochaetopterus costarum	2	Pagurus sp
19	Pholoides asperus	2	Pectinaria californiensis
15	Anobothrus gracilis	2	Pista elongata
14	Nereis procera	2	Podarkeopsis glabrus
13	Parvilucina tenuisculpta	2	Podocopida
13	Platynereis bicanaliculata	2	Proceraea cornuta
11	Asabellides sibirica	2	Turbonilla sp
11	Typosyllis caeca	1	Aglaja ocelligera
10	Glycinde polygnatha	1	Armandia brevis
10	Owenia fusiformis	1	Barentsia benedeni
10	Spiophanes berkeleyorum	1	Boltenia villosa
9	Heterophoxus conlanae	1	Cancer oregonensis
9	Lineidae	1	Capitella capitata Cmplx
9	Mediomastus californiensis	1	Caulleriella pacifica
9	Paraprionospio pinnata	1	Celleporella hyalina
8	Ampelisca pugetica	1	Cerebratulus montgomeryi
8	Sigambra bassi	1	Cerebratulus sp
7	Acila castrensis	1	Chapperiopsis patula
7	Aoroides sp	1	Cirratulidae
7	Carinoma mutabilis	1	Clinocardium nuttallii
7	Eobrolgus sp	1	Crisia sp
7	Macoma yoldiformis	1	Cylichna attonsa
7	Themiste pyroides	1	Dendrobeania lichenoides
6	Ampelisca lobata	1	Diaphana californica
6	Crepipatella dorsata	1	Edwardsia sipunculoides
6	Lumbrineridae	1	Eudorella pacifica
6	Nephtys cornuta	1	Eusyllis habei
6	Pentamera lissoplaca	1	Galathowenia oculata
6	Pherusa plumosa	1	Grantiidae
6	Phyllodoce groenlandica	1	Hyas lyratus
6	Terebellides californica	1	Kurtzia arteaga
5	Astyris gausapata	1	Lanassa venusta
5	Euclymeninae sp A	1	Lophopanopeus bellus
5	Eumida sp	1	Lyonsia californica
5	Ischyrocerus sp	1	Macoma carlottensis
5	Polycirrus sp I	1	Mesochaetopterus taylori
4	Eteone columbiensis	1	Microphthalmus sczelkowii
4	Lumbrineris sp	1	Nereididae
4	Mediomastus sp	1	Oenopota sp
4	Notomastus hemipodus	1	Ophelina acuminata
4	Odostomia sp	1	Pachynus cf barnardi
4	Oregonia gracilis	1	Paleanotus bellis
4	Phyllodoce sp	1	Parandalia fauveli
4	Pinnixa schmitti	1	Pholoe glabra
4	Rutiderma lomae	1	Phoronopsis harmeri
4	Scoletoma luti	1	Pista brevibranchiata
4	Solamen columbianum	1	Prionospio (Minuspio) lighti
3	Amphiodia urtica	1	Pygospio elegans
3	Eualus subtilis	1	Saxidomus giganteus
3	Monocorophium acherusicum	1	Styela gibbsii
3	Nephtys ferruginea	1	Terebellidae
3	Ophiodromus pugettensis	1	Tetrastemma nigrifrons
3	Phyllochaetopterus pottsi	1	Tubulanus polymorphus
3	Pilargis maculata	1	Tubulipora sp
3	Syllis elongata	1	Yoldia hyperborea
3	Terebellides sp	1	Yoldia sp
2	Ampharetidae	**1617**	**TOTAL**

WA99-0013 DISCOVERY BAY	
Count	Taxon
46	**Nephtys cornuta**
7	**Paraprionospio pinnata**
3	**Parvilucina tenuisculpta**
2	**Sigambra bassi**
1	**Compsomyax subdiaphana**
59	**TOTAL**

WA99-0014 DISCOVERY BAY	
Count	Taxon
1890	**Owenia fusiformis**
348	**Oligochaeta**
148	**Rochefortia tumida**
84	**Monocorophium acherusicum**
71	**Macoma sp**
63	**Mediomastus sp**
54	**Mediomastus californiensis**
48	**Clinocardium nuttallii**
47	**Clinocardium sp**
45	**Exogone lourei**
32	Decamastus gracilis
23	Glycinde polygnatha
22	Notomastus hemipodus
21	Leitoscoloplos pugettensis
20	Lineidae
17	Capitella capitata Cmplx
16	Leptochelia dubia
15	Sigambra bassi
9	Platynereis bicanaliculata
8	Cumella vulgaris
8	Parvilucina tenuisculpta
8	Pseudopolydora paucibranchiata
7	Cerebratulus californiensis
6	Nippoleucon hinumensis
5	Alvania compacta
5	Grandidierella japonica
5	Haminaea vesicula
5	Phoronopsis harmeri
5	Prionospio (Minuspio) lighti
4	Melanochlamys diomedea
4	Podarkeopsis glabrus
4	Spiophanes berkeleyorum
3	Ampharete labrops
3	Cryptomya californica
3	Eumida longicornuta
3	Euphilomedes carcharodonta
3	Macoma nasuta
3	Magelona longicornis
3	Nereis procera
3	Spiochaetopterus costarum
2	Bivalvia
2	Cerebratulus montgomeryi
2	Glycera americana
2	Macoma yoldiformis
2	Nephtys cornuta
2	Nutricola lordi
2	Pectinaria granulata
2	Prionospio (Prionospio) steenstrupi
2	Tellina sp
2	Tubulanus polymorphus
1	Acila castrensis
1	Astyris gausapata
1	Axinopsida serricata
1	Ectinosoma sp
1	Edwardsia sipunculoides
1	Eteone sp
1	Longipedia sp
1	Lumbrineris californiensis
1	Nephtys caecoides
1	Nephtys sp
1	Onuphidae
1	Protothaca staminea
1	Solidobalanus hesperius
1	Tellina modesta
1	Tenonia priops
3106	**TOTAL**

WA99-0020 GRAYS HARBOR	
Count	Taxon
12	**Mediomastus sp**
9	**Cryptomya californica**
8	**Nephtys caecoides**
4	**Scolelepis squamata**
3	**Nippoleucon hinumensis**
3	**Oligochaeta**
1	**Capitella capitata Cmplx**
1	**Clinocardium nuttallii**
1	**Hesperonoe complanata**
1	**Macoma balthica**
1	**Neotrypaea californiensis**
1	**Owenia fusiformis**
1	**Siliqua sp**
46	**TOTAL**

WA99-0021 GRASS CREEK	
Count	Taxon
34	**Phoronidae**
23	**Cryptomya californica**
11	**Barantolla nr americana**
8	**Mediomastus sp**
7	**Clinocardium nuttallii**
6	**Lamprops quadriplicatus**
4	**Nephtys caecoides**
3	**Glycinde sp**
3	**Oligochaeta**
2	**Eohaustorius estuarius**
2	**Nephtys caeca**
1	Bowerbankia gracilis
1	Capitella capitata Cmplx
1	Cerebratulus montgomeryi
1	Harmothoinae
1	Macoma nasuta
1	Membranipora sp
1	Mya arenaria
1	Scolelepis squamata
1	Tharyx parvus
112	**TOTAL**

WA99-0022 GRAYS HARBOR	
Count	Taxon
18	**Cryptomya californica**
9	**Dipolydora caulleryi**
7	**Lamprops quadriplicatus**
6	**Nephtys caecoides**
5	**Clausidium vancouverense**
5	**Glycinde polygnatha**
5	**Scolelepis squamata**
3	**Clinocardium nuttallii**
3	**Polydora cornuta**
2	**Aphelochaeta sp**
2	**Monocorophium acherusicum**
1	Barantolla nr americana
1	Capitella capitata Cmplx
1	Caprella laeviuscula
1	Caprella sp
1	Cerebratulus sp
1	Eogammarus confervicolus CMPLX
1	Eohaustorius estuarius
1	Glycinde armigera
1	Glycinde sp
1	Macoma balthica
1	Neotrypaea californiensis
1	Tharyx parvus
77	**TOTAL**

WA99-0023 GRAYS HARBOR	
Count	Taxon
141	**Magelona sacculata**
11	**Mytilidae**
8	**Scoloplos armiger armiger**
7	**Clinocardium nuttallii**
5	**Glycera macrobranchia**
5	**Spio butleri**
4	**Siliqua sp**
3	**Archaeomysis grebnitzkii**
3	**Lamprops quadriplicatus**
3	**Magelona sp**
2	Glycinde polygnatha
1	Caecum occidentale
1	Caecum sp
1	Cryptomya californica
1	Electra crustulenta arctica
1	Glycinde sp
1	Grandidierella japonica
1	Heteropodarke heteromorpha
1	Lineidae
1	Nassarius mendicus
1	Oligochaeta
1	Ophelia assimilis
1	Saxidomus giganteus
1	Tresus sp
205	**TOTAL**

WA99-0024 GRAYS HARBOR	
Count	Taxon
10	**Scoloplos armiger armiger**
5	**Glycera macrobranchia**
4	**Siliqua sp**
3	**Mediomastus sp**
2	**Grandifoxus grandis**
2	**Magelona sacculata**
1	**Bowerbankia gracilis**
1	**Glycinde polygnatha**
1	**Lamprops quadriplicatus**
29	**TOTAL**

WA99-0025 GRAYS HARBOR	
Count	Taxon
10	**Polydora cornuta**
5	**Glycinde polygnatha**
3	**Macoma balthica**
2	**Mya arenaria**
1	**Americorophium salmonis**
1	**Nippoleucon hinumensis**
1	**Streblospio benedicti**
1	**Tetrastemma sp**
24	**TOTAL**

WA99-0026 GRAYS HARBOR	
Count	Taxon
26	**Magelona sacculata**
21	**Tellina nuculoides**
9	**Scoloplos armiger armiger**
7	**Spio butleri**
6	**Magelona sp**
5	**Grandifoxus grandis**
4	**Ophelia assimilis**
2	**Archaeomysis grebnitzkii**
2	**Glycinde polygnatha**
2	**Lamprops quadriplicatus**
2	**Nephtys caecoides**
1	Clinocardium nuttallii
1	Eogammarus confervicolus CMPLX
1	Glycera macrobranchia
1	Mytilidae
1	Oligochaeta
1	Siliqua sp
1	Spiophanes bombyx
93	**TOTAL**

WA99-0027 BEARDSLEE SLOUGH	
Count	Taxon
388	**Oligochaeta**
301	**Streblospio benedicti**
68	**Sphaerosyllis californiensis**
63	**Leptochelia dubia**
63	**Pseudopolydora kempi**
60	**Americorophium salmonis**
60	**Hobsonia florida**
58	**Pygospio elegans**
40	**Tharyx parvus**
26	**Monocorophium insidiosum**
22	Mya arenaria
21	Capitella capitata Cmplx
21	Polydora cornuta
18	Halcampa decemtentaculata
18	Nippoleucon hinumensis
14	Manayunkia aestuarina
12	Chironomidae
10	Ampithoe valida
8	Eusarsiella zostericola
8	Grandidierella japonica
8	Scoloplos armiger alaskensis
7	Sinelobus stanfordi
7	Tetrastemma sp
6	Clinocardium sp
6	Cumella vulgaris
6	Glycinde polygnatha
6	Nephtys cornuta
6	Rhabdocoela
5	Americorophium spinicorne
4	Monocorophium acherusicum
3	Macoma sp
2	Coullana canadensis
2	Crangon franciscorum
1	Bivalvia
1	Eteone sp
1	Euphysa ruthae
1	Hoplonemertea
1	Membranipora sp
1	Monostylifera
1	Pseudopolydora paucibranchiata
1354	**TOTAL**

WA99-0029 GRAYS HARBOR	
Count	Taxon
5	**Eohaustorius estuarius**
5	**Mya arenaria**
3	**Tetrastemma sp**
1	**Acarina**
1	**Actiniidae**
1	**Archaeomysis grebnitzkii**
1	**Crangon franciscorum**
1	**Eogammarus confervicolus CMPLX**
1	**Grandifoxus grandis**
1	**Leptochelia dubia**
1	**Nephtys sp**
21	**TOTAL**

WA99-0031 WILLAPA BAY	
Count	Taxon
124	**Aphelochaeta monilaris**
40	**Tharyx parvus**
36	**Mediomastus californiensis**
29	**Mediomastus sp**
25	**Oligochaeta**
17	**Clinocardium sp**
16	**Glycinde polygnatha**
14	**Monocorophium acherusicum**
10	**Enteropneusta**
10	**Saccoglossus sp**
9	Eusarsiella zostericola
8	Cerebratulus montgomeryi
5	Cirratulidae
5	Clinocardium nuttallii
4	Pseudopolydora kempi
4	Scoloplos armiger alaskensis
3	Crangon sp
3	Mya arenaria
2	Archaeomysis grebnitzkii
2	Lamprops quadriplicatus
2	Mytilidae
2	Nephtys caeca
2	Streblospio benedicti
1	Abietinaria sp
1	Capitella capitata Cmplx
1	Macoma balthica
1	Macoma sp
1	Polydora cornuta
1	Pseudopolydora paucibranchiata
1	Sabaco elongatus
1	Solen sicarius
1	Tresus sp
381	**TOTAL**

WA99-0033 WILLAPA BAY	
Count	Taxon
53	**Scoloplos armiger armiger**
11	**Ophelia assimilis**
10	**Capitella capitata Cmplx**
4	**Dendraster excentricus**
4	**Siliqua sp**
4	**Spio butleri**
2	**Clinocardium nuttallii**
2	**Grandifoxus grandis**
2	**Magelona pitelkai**
1	**Archaeomysis grebnitzkii**
1	**Eteone columbiensis**
1	**Eteone fauchaldi**
1	**Glycera macrobranchia**
1	**Mandibulophoxus gilesi**
1	**Nephtys californiensis**
1	**Tellina nuculoides**
99	**TOTAL**

WA99-0034 WILLAPA BAY	
Count	Taxon
539	**Mediomastus californiensis**
195	**Mediomastus sp**
42	**Tharyx parvus**
32	**Clinocardium nuttallii**
30	**Glycinde polygnatha**
26	**Oligochaeta**
16	**Cryptomya californica**
14	**Lamprops quadriplicatus**
12	**Grandidierella japonica**
7	**Nephtys caecoides**
4	Cerebratulus sp
4	Polydora cornuta
3	Armandia brevis
3	Caprella laeviuscula
3	Scoloplos armiger armiger
3	Siliqua sp
2	Caprella californica
2	Macoma balthica
2	Macoma nasuta
2	Owenia fusiformis
2	Saxidomus giganteus
1	Achelia alaskensis
1	Achelia echinata
1	Celleporella hyalina
1	Cerebratulus montgomeryi
1	Crangon alaskensis
1	Glycinde sp
1	Grandifoxus grandis
1	Lineidae
1	Photis brevipes
1	Pontogeneia rostrata
1	Prionospio (Minuspio) lighti
1	Pseudopolydora paucibranchiata
1	Scoloplos armiger alaskensis
1	Tresus sp
957	**TOTAL**

WA99-0035 WILLAPA BAY	
Count	Taxon
10	**Tharyx parvus**
6	**Lamprops quadriplicatus**
5	**Oligochaeta**
3	**Mediomastus sp**
3	**Pseudopolydora kempi**
1	**Aricidea sp**
1	**Cryptomya californica**
1	**Glycinde polygnatha**
1	**Lineidae**
1	**Macoma balthica**
1	**Macoma nasuta**
1	**Nephtys caeca**
1	**Pseudopolydora paucibranchiata**
1	**Saccoglossus sp**
36	**TOTAL**

WA99-0036 WILLAPA BAY	
Count	Taxon
3	**Grandifoxus grandis**
3	**Lamprops quadriplicatus**
3	**Scoloplos armiger armiger**
2	**Barantolla nr americana**
2	**Capitella capitata Cmplx**
1	**Archaeomysis grebnitzkii**
1	**Cryptomya californica**
1	**Glycera macrobranchia**
1	**Lineidae**
1	**Oligochaeta**
1	**Phoronidae**
1	**Scyphozoa**
1	**Venerupis philippinarum**
21	**TOTAL**

WA99-0038 BAKER BAY	
Count	Taxon
32	**Macoma balthica**
10	**Americorophium salmonis**
4	**Grandidierella japonica**
3	**Neanthes sp**
2	**Eohaustorius estuarius**
1	**Pygospio elegans**
52	**TOTAL**

WA99-0039 BAKER BAY	
Count	Taxon
148	**Pygospio elegans**
122	**Macoma balthica**
76	**Americorophium salmonis**
66	**Neanthes limnicola**
14	**Hobsonia florida**
4	**Oligochaeta**
3	**Americorophium spinicorne**
2	**Heteromastus sp**
1	**Crangon franciscorum**
1	**Crangon sp**
1	**Eteone columbiensis**
1	**Grandidierella japonica**
1	**Mediomastus sp**
1	**Mya arenaria**
1	**Neanthes sp**
1	**Polydora cornuta**
1	**Pseudopolydora kempi**
1	**Tetrastemma candidum**
445	**TOTAL**

WA99-0040 BAKER BAY	
Count	Taxon
1905	**Pygospio elegans**
491	**Americorophium salmonis**
110	**Macoma balthica**
52	**Neanthes limnicola**
28	**Grandidierella japonica**
22	**Eteone columbiensis**
18	**Oligochaeta**
13	**Tetrastemma candidum**
9	**Pseudopolydora kempi**
2	**Eogammarus confervicolus CMPLX**
2	**Streblospio benedicti**
1	Crangon franciscorum
1	Mya arenaria
1	Nephtys caecoides
1	Nephtys cornuta
1	Polydora cornuta
2657	**TOTAL**

WA99-0042 BAKER BAY	
Count	Taxon
17	Mytilidae
14	Actiniidae
11	Grandifoxus grandis
9	Spio butleri
1	Americorophium salmonis
1	Archaeomysis grebnitzkii
1	Cryptomya californica
1	Eohaustorius washingtonianus
1	Pygospio elegans
56	TOTAL

WA99-0043 GRAYS BAY	
Count	Taxon
463	Americorophium salmonis
44	Neanthes sp
16	Oligochaeta
4	Corbicula fluminea
2	Chironomidae
2	Hirudinea
1	Neanthes limnicola
532	TOTAL

WA99-0044 GRAYS BAY	
Count	Taxon
154	Americorophium salmonis
37	Corbicula fluminea
2	Physella sp
1	Ceratopogonidae
1	Chironomidae
1	Gastropoda sp 4
1	Hirudinea
1	Oligochaeta
198	TOTAL

WA99-0045 GRAYS BAY	
Count	Taxon
347	Americorophium salmonis
59	Corbicula fluminea
48	Monoporeia affinis
3	Chironomidae
3	Hydrobiidae
460	TOTAL

WA99-0046 GRAYS BAY	
Count	Taxon
973	Americorophium salmonis
54	Corbicula fluminea
2	Hydrobiidae
1	Americorophium spinicorne
1	Chironomidae
1	Mediomastus sp
1	Narpus sp
1033	TOTAL

WA99-0047 GRAYS BAY	
Count	Taxon
682	Americorophium salmonis
123	Corbicula fluminea
4	Oligochaeta
809	TOTAL

WA99-0048 COWLITZ RIVER	
Count	Taxon
3	Americorophium salmonis
3	TOTAL

WA99-0049 CARROLLS CHANNEL	
Count	Taxon
155	Americorophium salmonis
12	Oligochaeta
3	Corbicula fluminea
3	Hydrobiidae
1	Chironomidae
1	Neomysis mercedis
175	TOTAL

WA99-0050 MARTIN SLOUGH	
Count	Taxon
394	Oligochaeta
110	Americorophium salmonis
18	Chironomidae
11	Manayunkia speciosa
8	Neanthes limnicola
4	Caecidotea racovitzai
2	Bivalvia sp 1
2	Corbicula fluminea
2	Hexagenia sp
551	TOTAL

WALK-IN STATIONS (BELOW) -- Not included in species counts

WA99-0015 KALALOCH CREEK	
Count	Taxon
13	Chironomidae
13	TOTAL

WA99-0016 RAFT RIVER	
Count	Taxon
72	Oligochaeta
9	Owenia fusiformis
2	Chironomidae
1	Eteone columbiensis
1	Pseudopolydora paucibranchiata
85	TOTAL

WA99-0017 QUINAULT RIVER	
Count	Taxon
2	Neanthes limnicola
2	Owenia fusiformis
1	Gastropoda sp 3
5	TOTAL

WA99-0019 CONNER CREEK	
Count	Taxon
51	Americorophium salmonis
41	Chironomidae
15	Oligochaeta
3	Neanthes limnicola
3	Physella sp
1	Callibaetis sp
1	Cecidomyiidae
1	Coenagrionidae
1	Ephydridae
1	Haliplus sp
118	TOTAL

Table E-3. Benthic infauna community diversity indicators

EMAP Station ID	Station Location	Taxa Richness (# taxa)	Shannon-Weiner Diversity H'	Pielou's Evenness J'	Swartz' Dominance* (# taxa)	Dominance Standardized by Taxa Richness (%)
WA99-0001	MAKAH BAY	13	2.98319	0.229476	4	0.30769
WA99-0002	MAKAH BAY	7	2.4275	0.346786	3	0.42857
WA99-0003	MAKAH BAY	13	3.11414	0.239549	5	0.38462
WA99-0004	HOKO RIVER	20	3.80145	0.190072	11	0.55
WA99-0005	OZETTE RIVER	station not sampled				
WA99-0006	FRESHWATER BAY	no sediment sampled				
WA99-0007	FRESHWATER BAY	117	5.52149	0.047192	30	0.25641
WA99-0008	FRESHWATER BAY	no sediment sampled				
WA99-0009	DUNGENESS BAY	48	3.29174	0.068578	6	0.125
WA99-0010	DISCOVERY BAY	49	3.64843	0.074458	7	0.14286
WA99-0011	DISCOVERY BAY	157	5.98813	0.038141	34	0.21656
WA99-0012	DISCOVERY BAY	141	4.94101	0.035043	19	0.13475
WA99-0013	DISCOVERY BAY	5	1.12857	0.225714	1	0.2
WA99-0014	DISCOVERY BAY	65	2.57891	0.039676	3	0.04615
WA99-0015	KALALOCH CREEK	walk-in station -- non-standard sample				
WA99-0016	RAFT RIVER	walk-in station -- non-standard sample				
WA99-0017	QUINAULT RIVER	walk-in station -- non-standard sample				
WA99-0018	QUINAULT RIVER	station not sampled				
WA99-0019	CONNER CREEK	walk-in station -- non-standard sample				
WA99-0020	GRAYS HARBOR	13	3.06577	0.235828	5	0.38462
WA99-0021	GRASS CREEK	20	3.27396	0.163698	6	0.3
WA99-0022	GRAYS HARBOR	23	3.83707	0.166829	8	0.34783
WA99-0023	GRAYS HARBOR	24	2.13867	0.089111	3	0.125
WA99-0024	GRAYS HARBOR	9	2.7344	0.303822	4	0.44444
WA99-0025	GRAYS HARBOR	8	2.43564	0.304455	3	0.375
WA99-0026	GRAYS HARBOR	18	3.25152	0.18064	6	0.33333
WA99-0027	BEARDSLEE SLOUGH	40	3.64872	0.091218	8	0.2
WA99-0028	BEARDSLEE SLOUGH	station not sampled				
WA99-0029	GRAYS HARBOR	11	3.06021	0.278201	6	0.54545
WA99-0030	WILLAPA BAY	no sediment sampled				
WA99-0031	WILLAPA BAY	32	3.63197	0.113499	7	0.21875
WA99-0032	WILLAPA BAY	station not sampled				
WA99-0033	WILLAPA BAY	16	2.53993	0.158746	4	0.25
WA99-0034	WILLAPA BAY	35	2.3211	0.066317	2	0.05714
WA99-0035	WILLAPA BAY	14	3.22969	0.230692	5	0.35714
WA99-0036	WILLAPA BAY	13	3.52257	0.270967	8	0.61538
WA99-0037	WILLAPA BAY	station not sampled				
WA99-0038	BAKER BAY	6	1.70094	0.283489	2	0.33333
WA99-0039	BAKER BAY	18	2.38333	0.132407	3	0.16667
WA99-0040	BAKER BAY	16	1.37326	0.085828	2	0.125
WA99-0041	GRAYS RIVER	station not sampled				
WA99-0042	BAKER BAY	9	2.4257	0.269522	3	0.33333
WA99-0043	GRAYS BAY	7	0.75449	0.107785	1	0.14286
WA99-0044	GRAYS BAY	8	0.99383	0.124228	1	0.125
WA99-0045	GRAYS BAY	5	1.12174	0.224348	1	0.2
WA99-0046	GRAYS BAY	7	0.36011	0.051444	1	0.14286
WA99-0047	GRAYS BAY	3	0.65873	0.219577	1	0.33333
WA99-0048	COWLITZ RIVER	1	0	0	1	1
WA99-0049	CARROLLS CHANNEL	6	0.70648	0.117746	1	0.16667
WA99-0050	MARTIN SLOUGH	9	1.31253	0.145837	2	0.22222

* Swartz' Dominance is the number of taxa accounting for at least 75% of the total abundance.

Table E-4. Infauna abundance (individuals/0.1 m²) – total and major taxonomic groups

EMAP Station ID	Station Location	Annelida	Arthropoda	Echinodermata	Mollusca	Misc. Taxa	Total Abundance
WA99-0001	MAKAH BAY	4	32	0	6	2	44
WA99-0002	MAKAH BAY	9	11	0	0	1	21
WA99-0003	MAKAH BAY	8	24	3	6	0	41
WA99-0004	HOKO RIVER	18	17	0	4	0	39
WA99-0005	OZETTE RIVER	no sediment sampled					
WA99-0006	FRESHWATER BAY	station not sampled					
WA99-0007	FRESHWATER BAY	287	151	1	125	9	573
WA99-0008	FRESHWATER BAY	no sediment sampled					
WA99-0009	DUNGENESS BAY	584	17	0	37	2	640
WA99-0010	DISCOVERY BAY	218	5	2	197	0	422
WA99-0011	DISCOVERY BAY	504	30	7	305	47	893
WA99-0012	DISCOVERY BAY	977	73	115	414	38	1617
WA99-0013	DISCOVERY BAY	55	0	0	4	0	59
WA99-0014	DISCOVERY BAY	2589	125	0	355	37	3106
WA99-0015	KALALOCH CREEK	walk-in station -- non-standard sample					
WA99-0016	RAFT RIVER	walk-in station -- non-standard sample					
WA99-0017	QUINAULT RIVER	walk-in station -- non-standard sample					
WA99-0018	QUINAULT RIVER	station not sampled					
WA99-0019	CONNER CREEK	walk-in station -- non-standard sample					
WA99-0020	GRAYS HARBOR	30	4	0	12	0	46
WA99-0021	GRASS CREEK	35	8	0	32	37	112
WA99-0022	GRAYS HARBOR	35	19	0	22	1	77
WA99-0023	GRAYS HARBOR	168	7	0	28	2	205
WA99-0024	GRAYS HARBOR	21	3	0	4	1	29
WA99-0025	GRAYS HARBOR	16	2	0	5	1	24
WA99-0026	GRAYS HARBOR	59	10	0	24	0	93
WA99-0027	BEARDSLEE SLOUGH	1056	231	0	32	35	1354
WA99-0028	BEARDSLEE SLOUGH	station not sampled					
WA99-0029	GRAYS HARBOR	1	11	0	5	4	21
WA99-0030	WILLAPA BAY	no sediment sampled					
WA99-0031	WILLAPA BAY	291	30	0	31	29	381
WA99-0032	WILLAPA BAY	station not sampled					
WA99-0033	WILLAPA BAY	84	4	4	7	0	99
WA99-0034	WILLAPA BAY	855	37	0	58	7	957
WA99-0035	WILLAPA BAY	25	6	0	3	2	36
WA99-0036	WILLAPA BAY	9	7	0	2	3	21
WA99-0037	WILLAPA BAY	station not sampled					
WA99-0038	BAKER BAY	4	16	0	32	0	52
WA99-0039	BAKER BAY	239	82	0	123	1	445
WA99-0040	BAKER BAY	2011	522	0	111	13	2657
WA99-0041	GRAYS RIVER	station not sampled					
WA99-0042	BAKER BAY	10	14	0	18	14	56
WA99-0043	GRAYS BAY	63	465	0	4	0	532
WA99-0044	GRAYS BAY	2	156	0	40	0	198
WA99-0045	GRAYS BAY	0	398	0	62	0	460
WA99-0046	GRAYS BAY	1	976	0	56	0	1033
WA99-0047	GRAYS BAY	4	682	0	123	0	809
WA99-0048	COWLITZ RIVER	0	3	0	0	0	3
WA99-0049	CARROLLS CHANNEL	12	157	0	6	0	175
WA99-0050	MARTIN SLOUGH	413	134	0	4	0	551

Table E-5. Percent composition of fish species, standard trawls only (1st successful trawl)

Order of Dominance	Species	Common Name	Total Abundance	% of Total
1	***Pleuronectes vetulus***	**English sole**	**565**	**44.31%**
2	***Cymatogaster aggregata***	**shiner perch**	**219**	**17.18%**
3	***Citharichthys stigmaeus***	**speckled sanddab**	**129**	**10.12%**
4	***Platichthys stellatus***	**starry flounder**	**88**	**6.90%**
5	***Gasterosteus aculeatus***	**three-spine stickleback**	**75**	**5.88%**
6	***Spirinchus thaleichthys***	**longfin smelt**	**45**	**3.53%**
7	***Leptocottus armatus***	**Pacific staghorn sculpin**	**35**	**2.75%**
8	***Psettichthys melanostictus***	**sand sole**	**19**	**1.49%**
9	***Chitonotus pugetensis***	**roughback sculpin**	**13**	**1.02%**
10	***Pomoxis* sp.**	**crappie**	**11**	**0.86%**
11	*Lumpenus sagitta*	snake prickleback	9	0.71%
12	*Microgadus proximus*	Pacific tomcod	8	0.63%
13	*Oncorhynchus tshawytscha*	chinook salmon	8	0.63%
14	*Hyperprosopon argenteum*	walleye surfperch	6	0.47%
15	*Artedius fenestralis*	padded sculpin	5	0.39%
16	*Sarritor frenatus*	sawback poacher	5	0.39%
17	*Citharichthys sordidus*	Pacific sanddab	4	0.31%
18	*Enophrys bison*	buffalo sculpin	3	0.24%
19	*Hydrolagus colliei*	spotted ratfish	3	0.24%
20	*Icelus spiniger*	thorny sculpin	3	0.24%
21	*Phanerodon furcatus*	white seaperch	3	0.24%
22	*Pholis ornata*	saddleback gunnel	3	0.24%
23	*Hexagrammos stelleri*	whitespotted greenling	2	0.16%
24	*Hyperprosopon anale*	spotfin seaperch	2	0.16%
25	*Microstomus pacificus*	Dover sole	2	0.16%
26	*Pleuronectes bilineatus*	rock sole	2	0.16%
27	*Porichthys notatus*	plainfin midshipman	2	0.16%
28	*Syngnathus leptorhynchus*	bay pipefish	2	0.16%
29	*Gadus macrocephalus*	Pacific cod	1	0.08%
30	*Ophiodon elongatus*	lingcod	1	0.08%
31	*Raja binoculata*	big skate	1	0.08%
32	*Sebastes auriculatus*	brown rockfish	1	0.08%
		Total	1275	100.00%

Table E-6. Fish species, abundance, and size distribution, all stations, 1st trawl or seine

EMAP Station ID	Species	Size Class (cm)	Abundance	Number of Individuals	Number of Species
WA99-0002 partial trawl — abandoned due to hanging up on rocks	*Microgadus proximus*	7	1	8	3
	Pleuronectes vetulus	8	1		
	Psettichthys melanostictus	11	1		
		12	2		
		14	1		
		16	1		
		18	1		
WA99-0003	*Hyperprosopon anale*	7	1	11	4
		8	1		
	Microgadus proximus	7	1		
		9	1		
	Pleuronectes vetulus	5	2		
	Psettichthys melanostictus	6	1		
		7	1		
		8	1		
		12	1		
		14	1		
WA99-0004	*Chitonotus pugetensis*	11	1	336	7
	Citharichthys stigmaeus	8	6		
		9	9		
		10	9		
		13	4		
		14	2		
		catch-all	41		
	Hexagrammos stelleri	11	1		
	Leptocottus armatus	13	1		
	Pleuronectes vetulus	5	2		
		6	2		
		7	5		
		8	6		
		9	5		
		10	4		
		11	3		
		12	1		
		19	1		
		30	1		
		catch-all	226		
	Psettichthys melanostictus	23	1		
	Sarritor frenatus	6	2		
		7	3		
WA99-0006	*Citharichthys stigmaeus*	9	1	9	5
		13	1		
		16	1		
	Gadus macrocephalus	12	1		

EMAP Station ID	Species	Size Class (cm)	Abundance	Number of Individuals	Number of Species
	Hydrolagus colliei	38	1		
		42	1		
	Ophiodon elongatus	17	1		
	Pleuronectes bilineatus	32	1		
		38	1		
WA99-0007	*Citharichthys stigmaeus*	11	1	4	3
		17	1		
	Enophrys bison	25	1		
	Hydrolagus colliei	50	1		
WA99-0009	*Cymatogaster aggregata*	6	1	11	3
		11	1		
		13	1		
	Leptocottus armatus	9	1		
	Pleuronectes vetulus	6	3		
		10	1		
		12	3		
WA99-0010	*Citharichthys stigmaeus*	13	1	1	1
WA99-0011 (short trawl due to kelp)	*Enophrys bison*	22	1	1	1
WA99-0012	*Citharichthys stigmaeus*	12	2	17	3
		13	5		
		14	3		
		15	1		
	Leptocottus armatus	6	1		
	Pleuronectes vetulus	11	1		
		14	1		
		15	1		
		16	2		
WA99-0013	*Chitonotus pugetensis*	7	2	110	10
		9	2		
		10	8		
	Citharichthys sordidus	7	1		
		12	1		
		13	1		
		14	1		
	Citharichthys stigmaeus	8	2		
		9	2		
		10	1		
		13	1		
	Icelus spiniger	11	3		
	Leptocottus armatus	8	1		
		9	2		
		10	1		
		11	3		
		13	1		
		14	1		

EMAP Station ID	Species	Size Class (cm)	Abundance	Number of Individuals	Number of Species
	Lumpenus sagitta	8	5		
		9	2		
	Microstomus pacificus	11	1		
		13	1		
	Pleuronectes vetulus	10	1		
		11	5		
		12	10		
		13	10		
		15	2		
		18	1		
		20	1		
		catch-all	35		
	Raja binoculata	27	1		
	Sebastes auriculatus	8	1		
WA99-0014	*Citharichthys stigmaeus*	8	1	308	8
		9	9		
		10	3		
		11	1		
		12	1		
		13	2		
	Cymatogaster aggregata	5	7		
		6	19		
		8	2		
		9	2		
		catch-all	163		
	Leptocottus armatus	6	2		
		8	4		
		9	2		
	Lumpenus sagitta	16	1		
		17	1		
	Microgadus proximus	7	1		
		8	1		
	Phanerodon furcatus	9	1		
	Platichthys stellatus	7	1		
	Pleuronectes vetulus	8	5		
		9	12		
		10	6		
		11	6		
		14	1		
		catch-all	54		
WA99-0015 beach seine	*Oligocottus maculosus*	2	1	85	3
		3	9		
		4	19		
		5	1		
		catch-all	53		
	Platichthys stellatus	6	1		

EMAP Station ID	Species	Size Class (cm)	Abundance	Number of Individuals	Number of Species
	Salmo clarkii	8	1		
WA99-0016 beach seine	*Oligocottus maculosus*	2	16	21	2
		3	3		
		5	1		
	Platichthys stellatus	10	1		
WA99-0019 beach seine	*Gasterosteus aculeatus*	2	10	61	2
		3	13		
		4	4		
		5	2		
		6	1		
		catch-all	29		
	Oncorhynchus tshawytscha	10	1		
		11	1		
WA99-0020	*Citharichthys stigmaeus*	7	1	4	2
	Pleuronectes vetulus	5	1		
		6	1		
		10	1		
WA99-0021	*Citharichthys stigmaeus*	9	1	26	6
	Cymatogaster aggregata	10	4		
		11	4		
		13	1		
	Leptocottus armatus	10	1		
		11	1		
		12	1		
	Platichthys stellatus	15	1		
	Pleuronectes vetulus	7	2		
		8	4		
		9	3		
		14	1		
	Psettichthys melanostictus	13	2		
WA99-0022	*Pleuronectes vetulus*	6	1	1	1
WA99-0023	*Citharichthys stigmaeus*	11	1	4	4
	Enophrys bison	10	1		
	Pholis ornata	13	1		
	Pleuronectes vetulus	12	1		
WA99-0024	*Citharichthys stigmaeus*	6	3	13	2
		7	5		
		8	3		
		9	1		
	Leptocottus armatus	10	1		
WA99-0025	*Microgadus proximus*	18	1	51	4
		19	1		
		22	1		
	Pleuronectes vetulus	12	1		
	Porichthys notatus	11	1		
		12	1		

EMAP Station ID	Species	Size Class (cm)	Abundance	Number of Individuals	Number of Species
	Spirinchus thaleichthys	10	3		
		11	4		
		12	9		
		13	12		
		14	2		
		catch-all	15		
WA99-0026	*Citharichthys stigmaeus*	7	2	3	1
		8	1		
WA99-0027 (trawl #2 used)	*Cymatogaster aggregata*	6	1	7	4
		7	1		
		13	1		
	Leptocottus armatus	12	1		
		14	1		
	Phanerodon furcatus	8	1		
	Pleuronectes vetulus	8	1		
WA99-0029 partial trawl — fouled net	*Cymatogaster aggregata*	6	1	20	5
		7	3		
		10	1		
		11	2		
	Leptocottus armatus	9	1		
		10	1		
		11	1		
		12	1		
	Phanerodon furcatus	9	1		
	Pholis ornata	6	1		
		8	1		
	Pleuronectes vetulus	6	2		
		7	1		
		8	2		
		10	1		
WA99-0031	*Leptocottus armatus*	11	1	3	2
	Pleuronectes vetulus	8	2		
WA99-0034	*Cymatogaster aggregata*	6	1	9	2
		7	1		
		8	1		
	Hyperprosopon argenteum	7	1		
		8	5		
WA99-0036	*Pleuronectes vetulus*	5	3	89	3
		6	5		
		7	12		
		8	6		
		9	4		
		catch-all	52		
	Psettichthys melanostictus	5	4		
		6	1		

EMAP Station ID	Species	Size Class (cm)	Abundance	Number of Individuals	Number of Species
	Syngnathus leptorhynchus	14	1		
		25	1		
WA99-0038	*Platichthys stellatus*	6	1	6	2
		7	1		
		8	1		
		9	1		
		22	1		
	Pleuronectes vetulus	7	1		
WA99-0039	*Leptocottus armatus*	10	1	7	2
	Platichthys stellatus	5	1		
		6	1		
		7	3		
		9	1		
WA99-0040	*Cymatogaster aggregata*	11	1	34	3
	Platichthys stellatus	5	1		
		6	1		
	Pleuronectes vetulus	6	5		
		7	8		
		8	12		
		9	5		
		catch-all	1		
WA99-0042 partial trawl — hung up after 8 minutes	*Hexagrammos stelleri*	12	1	14	4
	Leptocottus armatus	10	1		
		12	1		
		14	1		
	Platichthys stellatus	8	1		
		9	2		
		10	1		
	Pleuronectes vetulus	6	3		
		7	2		
		8	1		
WA99-0043	*Artedius fenestralis*	8	1	6	3
	Gasterosteus aculeatus	6	1		
	Platichthys stellatus	5	2		
		6	2		
WA99-0044	*Gasterosteus aculeatus*	6	4	6	2
	Platichthys stellatus	6	1		
		7	1		
WA99-0045	*Gasterosteus aculeatus*	5	2	40	2
		6	4		
		7	1		
	Platichthys stellatus	5	10		
		6	7		
		7	11		
		8	2		
		catch-all	3		

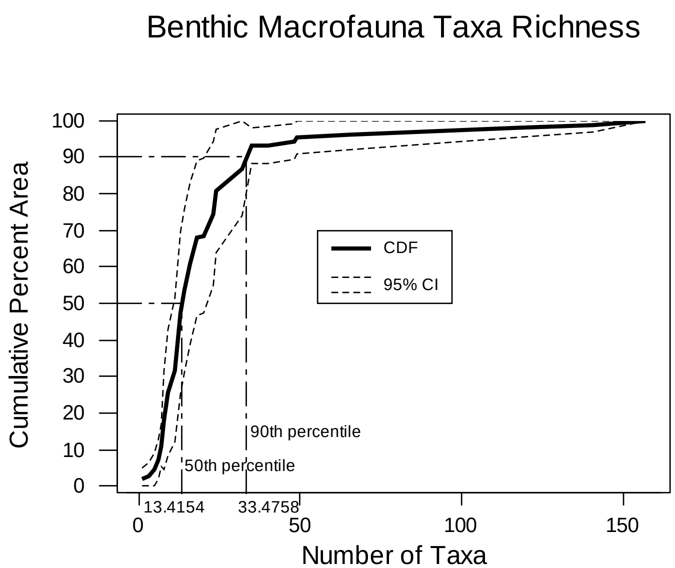
EMAP Station ID	Species	Size Class (cm)	Abundance	Number of Individuals	Number of Species
WA99-0046	*Gasterosteus aculeatus*	6	2	10	2
		7	1		
	Platichthys stellatus	7	3		
		8	1		
		9	1		
		10	1		
		17	1		
WA99-0047	*Gasterosteus aculeatus*	5	1	21	2
	Platichthys stellatus	4	2		
		5	7		
		6	6		
		7	2		
		8	2		
		9	1		
WA99-0048	*Oncorhynchus tshawytscha*	7	1	8	1
		8	1		
		9	6		
WA99-0049	*Platichthys stellatus*	14	1	1	1
WA99-0050	*Artedius fenestralis*	14	2	17	3
		16	2		
	Platichthys stellatus	18	2		
	Pomoxis sp	5	1		
		6	6		
		11	2		
		12	1		
		15	1		

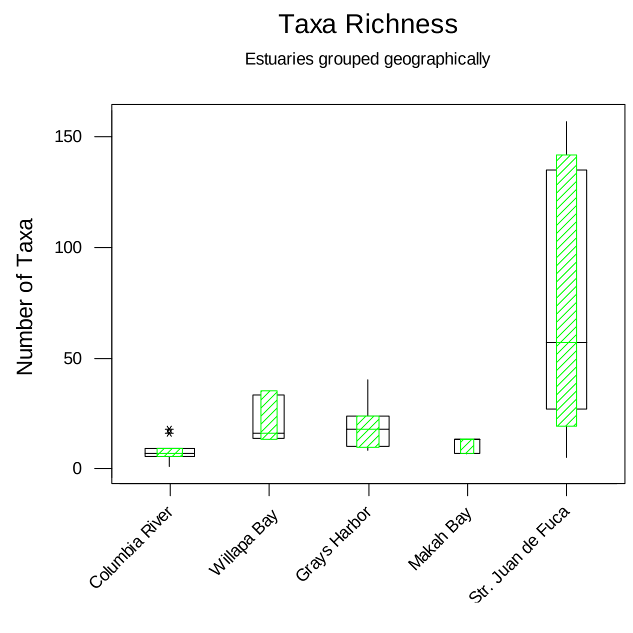
Table E-7. Demersal fish species richness, abundance, and catch per area swept

		All Trawls (includes beach seines)		Complete Standard Trawls Only				
EMAP Station ID	Station Location	Taxa Richness	Total Fish Abundance	Taxa Richness	Total Fish Abundance	Width of Net (ft)	Distance Trawled (m)	Catch per Area Swept (fish/km²)
WA99-0001	MAKAH BAY	no trawling		no trawling				
WA99-0002	MAKAH BAY	3	8	incomplete trawl				
WA99-0003	MAKAH BAY	4	11	4	11	19	393	4833.2
WA99-0004	HOKO RIVER	7	336	7	336	19	409	141855.9
WA99-0005	OZETTE RIVER	station not sampled		station not sampled				
WA99-0006	FRESHWATER BAY	5	9	5	9	19	451	3445.9
WA99-0007	FRESHWATER BAY	3	4	3	4	19	179	3858.7
WA99-0008	FRESHWATER BAY	trawling hindered by kelp		trawling hindered by kelp				
WA99-0009	DUNGENESS BAY	3	11	3	11	19	287	6618.2
WA99-0010	DISCOVERY BAY	1	1	1	1	19	261	661.6
WA99-0011	DISCOVERY BAY	1	1	incomplete trawl				
WA99-0012	DISCOVERY BAY	3	17	3	17	19	337	8710.6
WA99-0013	DISCOVERY BAY	10	110	10	110	19	320	59357.3
WA99-0014	DISCOVERY BAY	8	308	8	308	19	305	174374.2
WA99-0015	KALALOCH CREEK	3	85	non-standard trawl (beach seine)				
WA99-0016	RAFT RIVER	2	21	non-standard trawl (beach seine)				
WA99-0017	QUINAULT RIVER	no trawling		no trawling				
WA99-0018	QUINAULT RIVER	station not sampled		station not sampled				
WA99-0019	CONNER CREEK	2	61	non-standard trawl (beach seine)				
WA99-0020	GRAYS HARBOR	2	4	2	4	19	322	2145.0
WA99-0021	GRASS CREEK	6	26	6	26	19	251	17886.7
WA99-0022	GRAYS HARBOR	1	1	1	1	19	256	674.5
WA99-0023	GRAYS HARBOR	4	4	4	4	19	120	5755.9
WA99-0024	GRAYS HARBOR	2	13	2	13	19	236	9511.8
WA99-0025	GRAYS HARBOR	4	51	4	51	19	250	35225.9
WA99-0026	GRAYS HARBOR	1	3	1	3	19	301	1721.0
WA99-0027	BEARDSLEE SLOUGH	4	7	4	7	19	263	4595.9
WA99-0028	BEARDSLEE SLOUGH	station not sampled		station not sampled				
WA99-0029	GRAYS HARBOR	5	20	incomplete trawl				
WA99-0030	WILLAPA BAY	no trawling		no trawling				

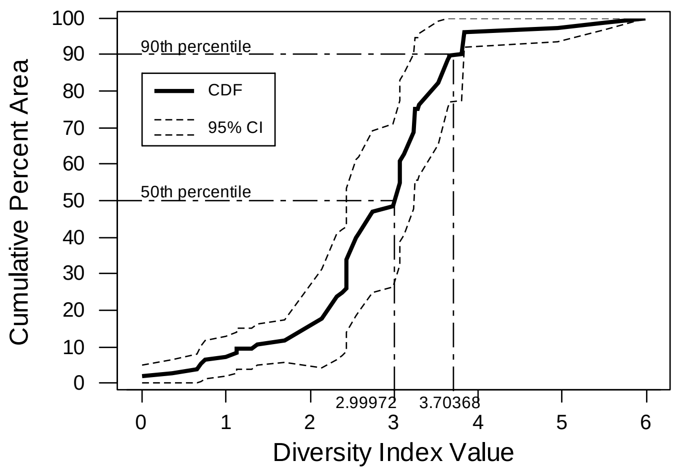
		All Trawls (includes beach seines)		Complete Standard Trawls Only				
EMAP Station ID	Station Location	Taxa Richness	Total Fish Abundance	Taxa Richness	Total Fish Abundance	Width of Net (ft)	Distance Trawled (m)	Catch per Area Swept (fish/km²)
WA99-0031	WILLAPA BAY	2	3	2	3	19	253	2047.5
WA99-0032	WILLAPA BAY	station not sampled		station not sampled				
WA99-0033	WILLAPA BAY	no trawling		no trawling				
WA99-0034	WILLAPA BAY	2	9	2	9	19	426	3648.1
WA99-0035	WILLAPA BAY	no trawling		no trawling				
WA99-0036	WILLAPA BAY	3	89	3	89	19	338	45467.9
WA99-0037	WILLAPA BAY	station not sampled		station not sampled				
WA99-0038	BAKER BAY	2	6	2	6	19	472	2195.0
WA99-0039	BAKER BAY	2	7	2	7	19	238	5078.7
WA99-0040	BAKER BAY	3	34	3	34	19	447	13134.2
WA99-0041	GRAYS RIVER	station not sampled		station not sampled				
WA99-0042	BAKER BAY	4	14	incomplete trawl				
WA99-0043	GRAYS BAY	3	6	3	6	19	370 (est.)	2800.1
WA99-0044	GRAYS BAY	2	6	2	6	19	309	3352.9
WA99-0045	GRAYS BAY	2	40	2	40	19	326	21187.2
WA99-0046	GRAYS BAY	2	10	2	10	19	357	4836.9
WA99-0047	GRAYS BAY	2	21	2	21	19	300	12087.3
WA99-0048	COWLITZ RIVER	1	8	1	8	19	378	3654.5
WA99-0049	CARROLLS CHANNEL	1	1	1	1	19	340	507.9
WA99-0050	MARTIN SLOUGH	3	17	3	17	19	362	8109.1

Figure E-1. Benthic Macrofauna



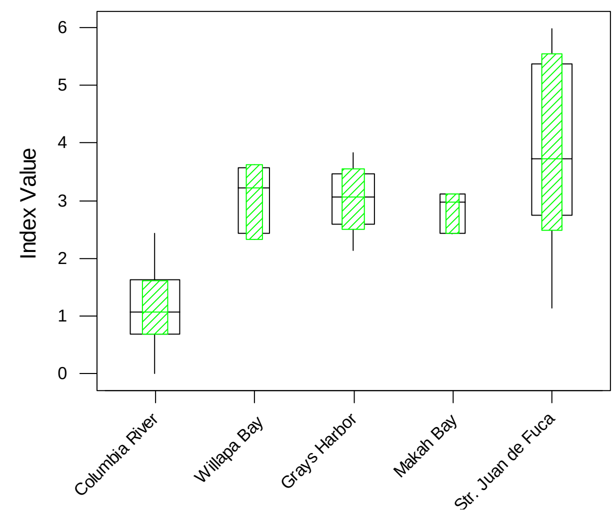


Benthic Macrofauna Shannon-Wiener Diversity (H')

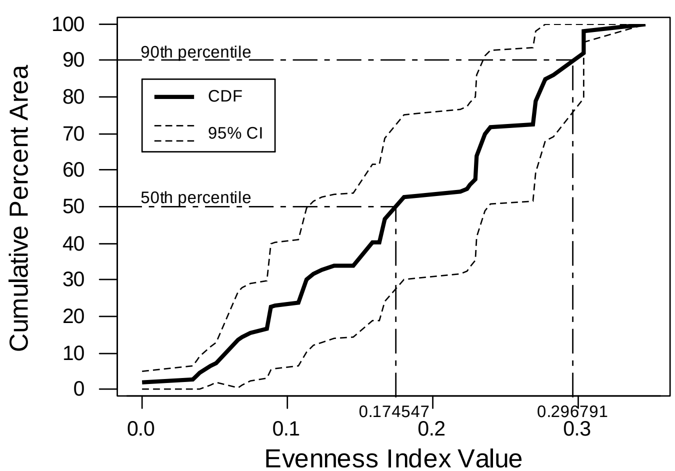


Shannon-Wiener Diversity (H')

Estuaries grouped geographically

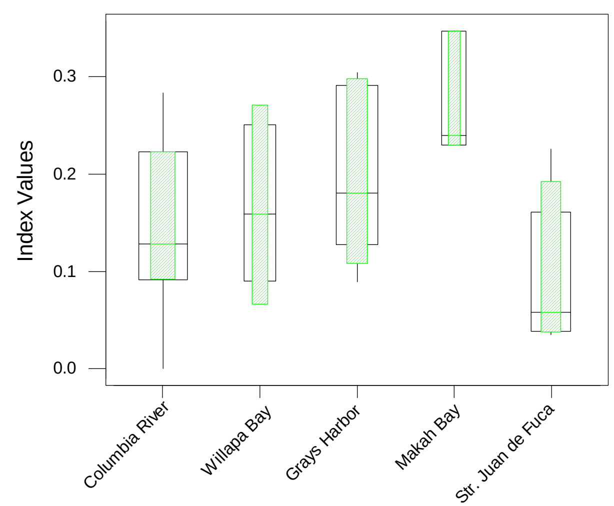


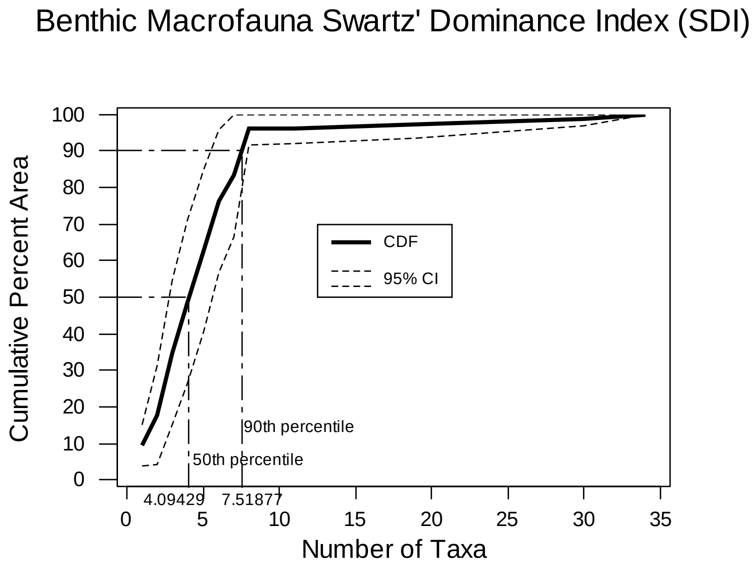
Benthic Macrofauna Pielou's Evenness (J')

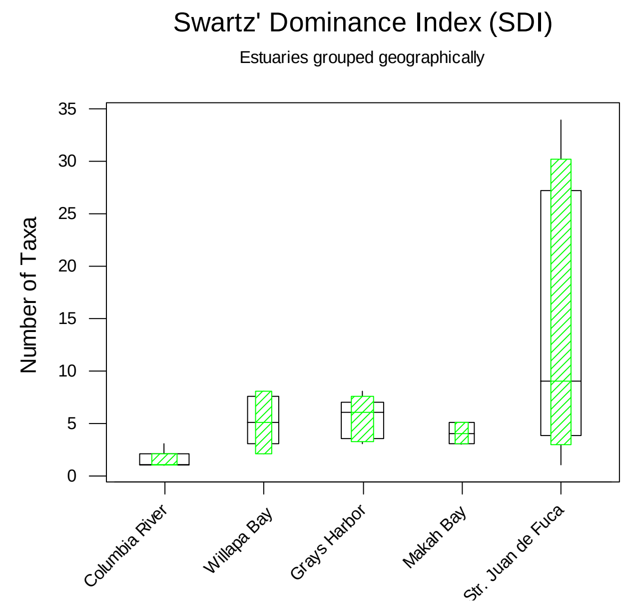


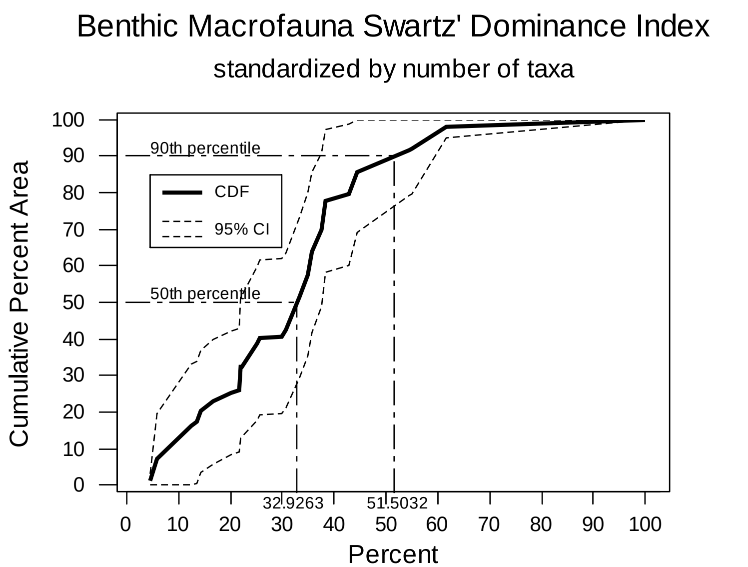
Pielou's Evenness (J')

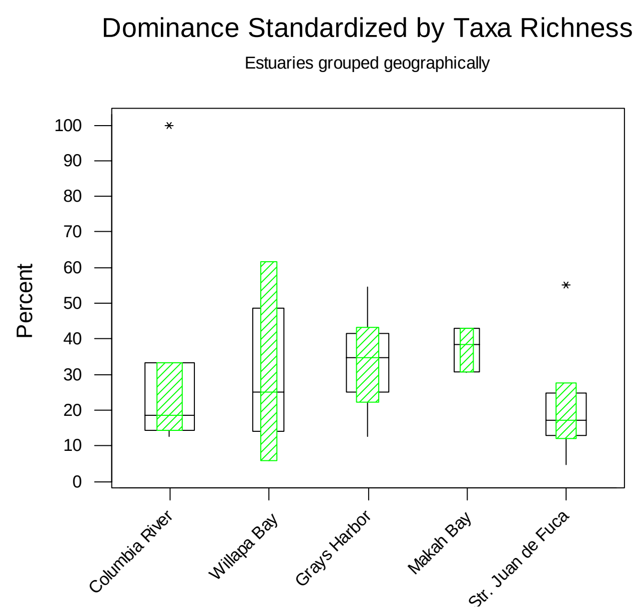
Estuaries grouped geographically

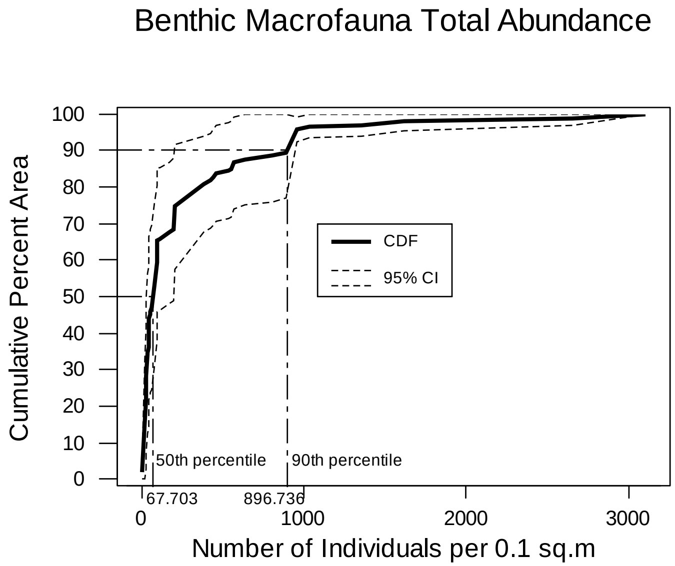


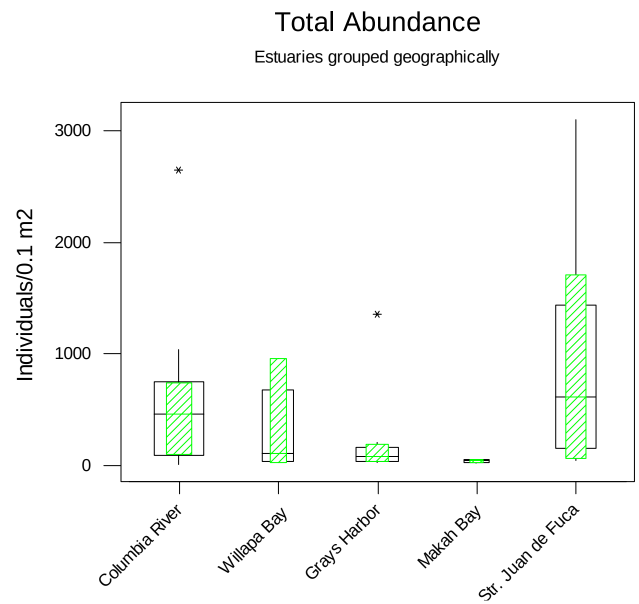

Benthic Macrofauna Swartz' Dominance Index (SDI)
Cumulative Percent Area
Number of Taxa
CDF
95% CI
90th percentile
50th percentile
4.09429
7.51877

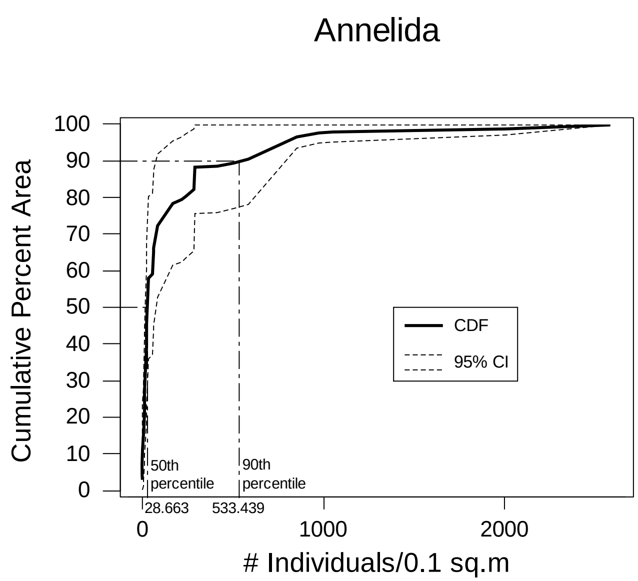

Swartz' Dominance Index (SDI)
Estuaries grouped geographically
Number of Taxa
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca

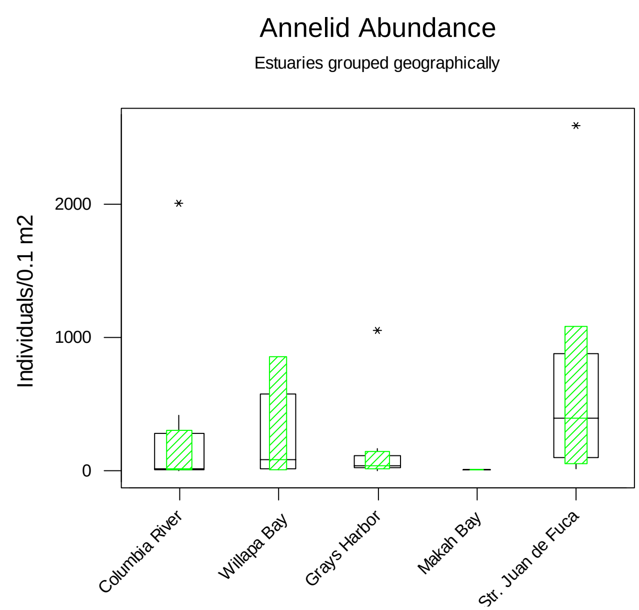

Benthic Macrofauna Swartz' Dominance Index
standardized by number of taxa
Cumulative Percent Area
Percent
90th percentile
50th percentile
CDF
95% CI
32.9263
51.5032

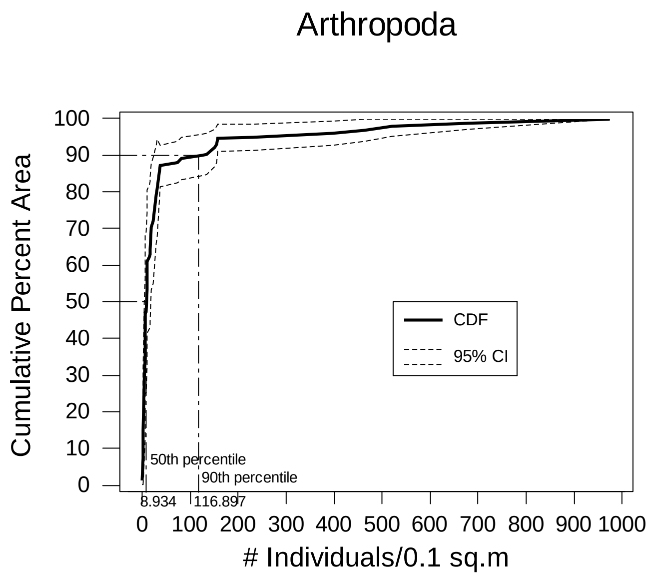

Dominance Standardized by Taxa Richness
Estuaries grouped geographically
Percent
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca

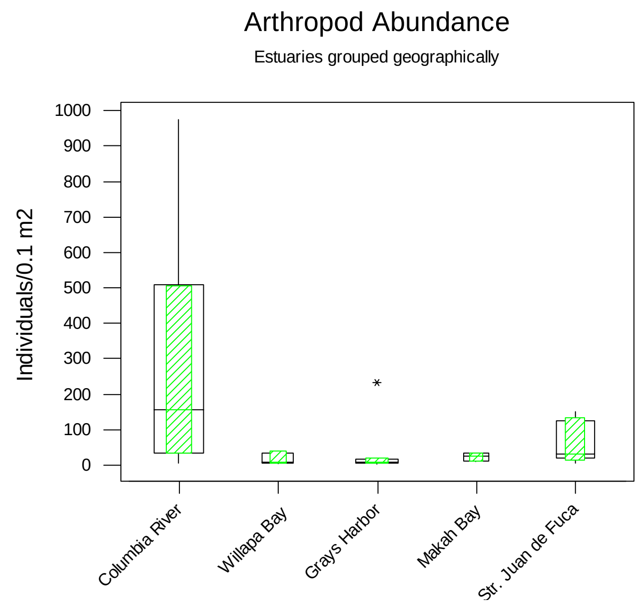

Benthic Macrofauna Total Abundance
Cumulative Percent Area
Number of Individuals per 0.1 sq.m
CDF
95% CI
50th percentile
90th percentile
67.703
896.736

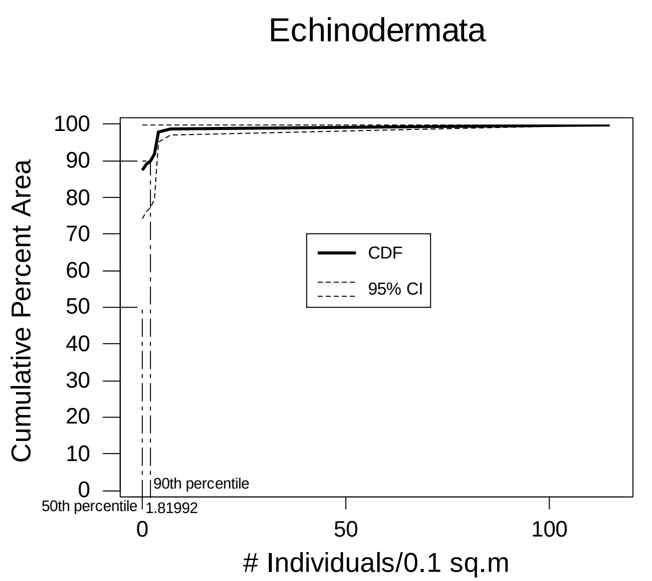

Total Abundance
Estuaries grouped geographically
Individuals/0.1 m2
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca

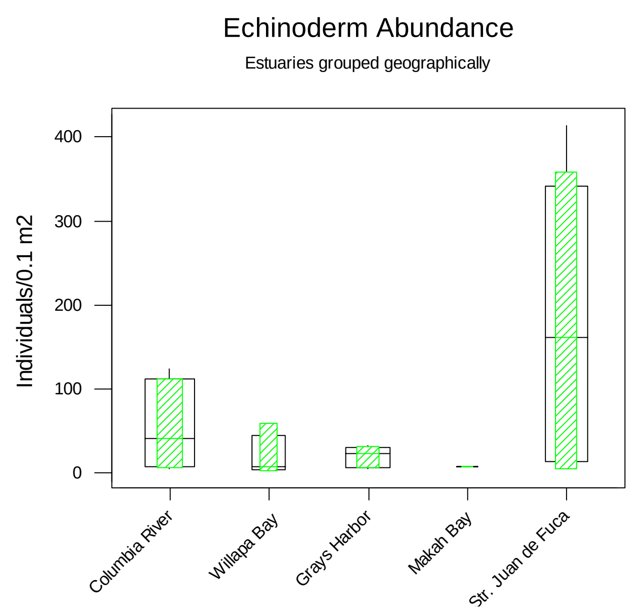

Annelida
Cumulative Percent Area
Individuals/0.1 sq.m
CDF
95% CI
50th percentile
90th percentile
28.663
533.439

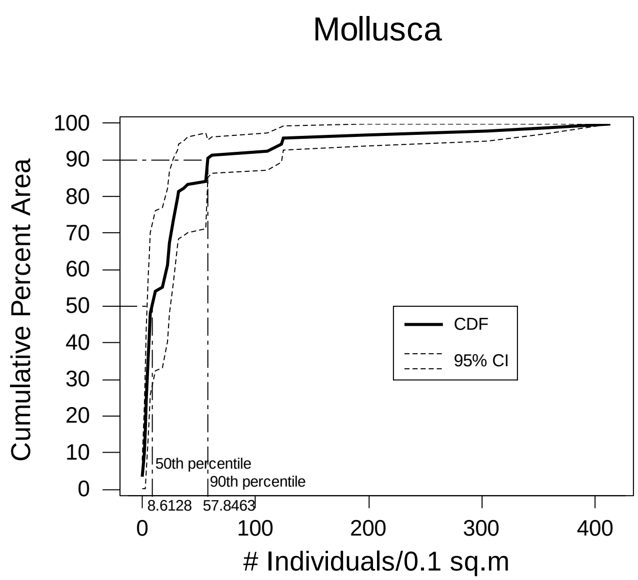

Annelid Abundance
Estuaries grouped geographically
Individuals/0.1 m2
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca

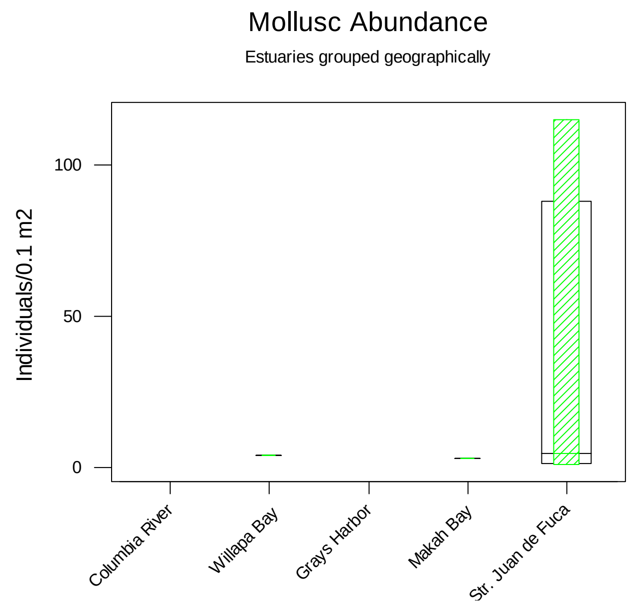

Arthropoda
Cumulative Percent Area
Individuals/0.1 sq.m
CDF
95% CI
50th percentile
90th percentile
8.934
116.897

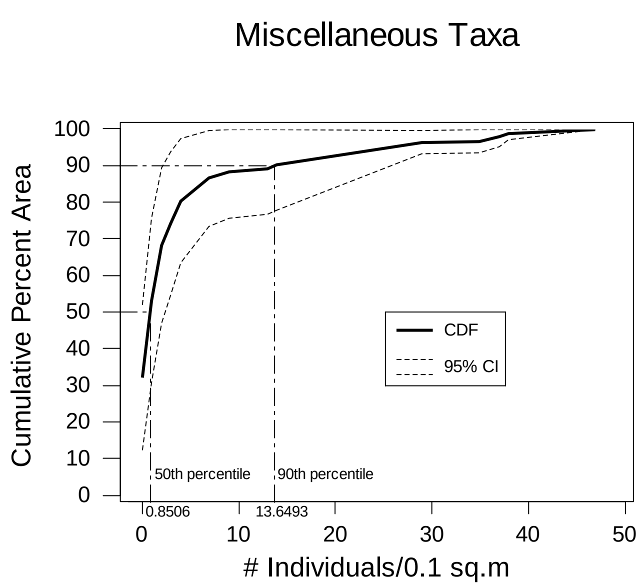

Arthropod Abundance
Estuaries grouped geographically
Individuals/0.1 m2
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca

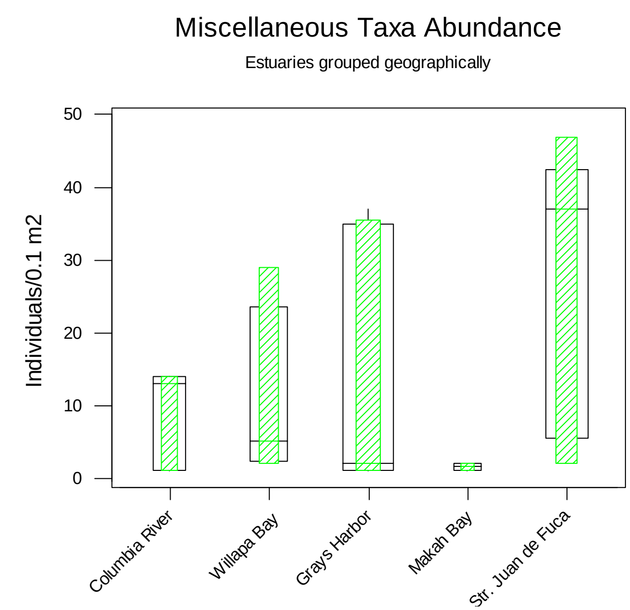

Echinodermata
Cumulative Percent Area
Individuals/0.1 sq.m
CDF
95% CI
50th percentile
90th percentile
1.81992


Echinoderm Abundance
Estuaries grouped geographically
Individuals/0.1 m2
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca


Mollusca
Cumulative Percent Area
Individuals/0.1 sq.m
CDF
95% CI
50th percentile
90th percentile
8.6128
57.8463


Mollusc Abundance
Estuaries grouped geographically
Individuals/0.1 m2
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca


Miscellaneous Taxa
Cumulative Percent Area
Individuals/0.1 sq.m
CDF
95% CI
50th percentile
90th percentile
0.8506
13.6493


Miscellaneous Taxa Abundance
Estuaries grouped geographically
Individuals/0.1 m2
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca

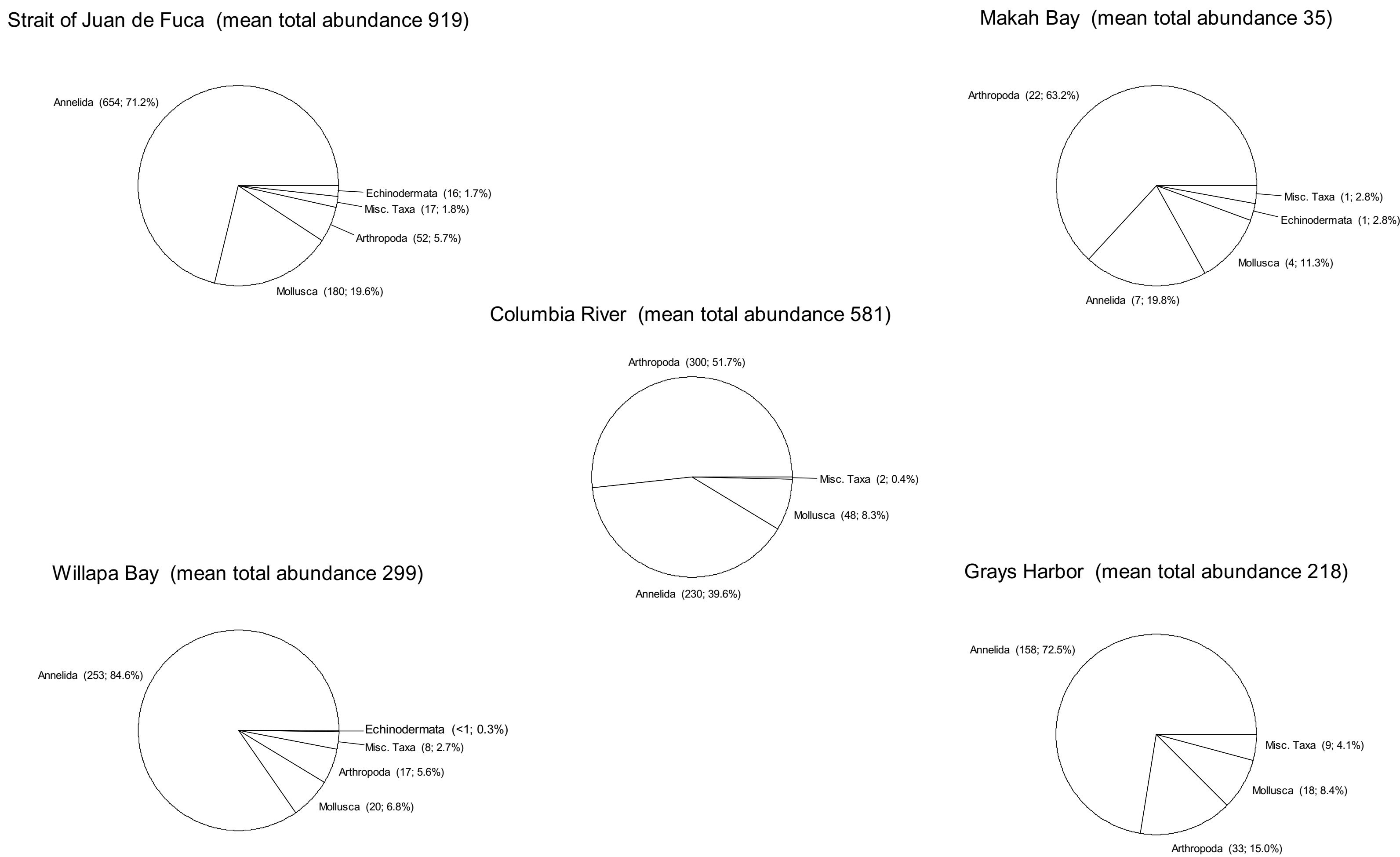


Figure E-2. Mean abundance and percent of major taxonomic groups by geographic area

Figure E-3. Percent abundance by major taxonomic group at each station sampled. The numbers in the diagram are the station IDs.

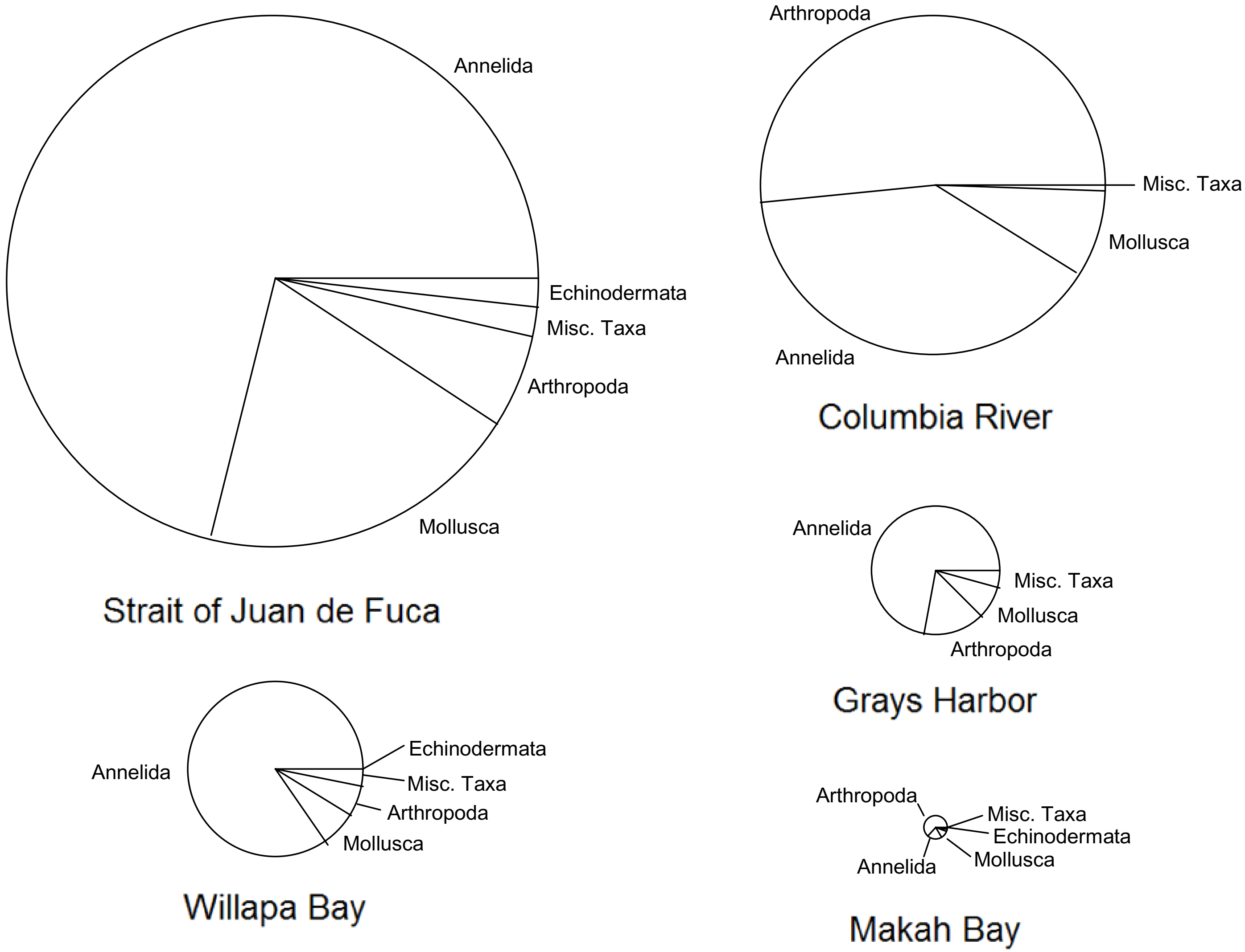
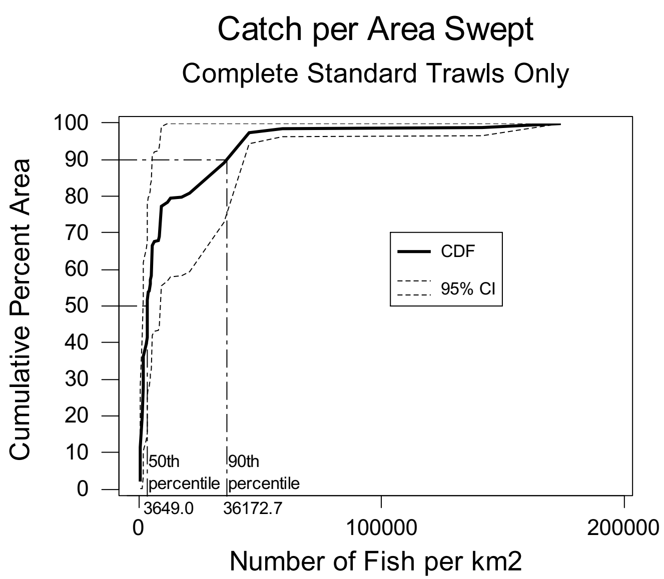
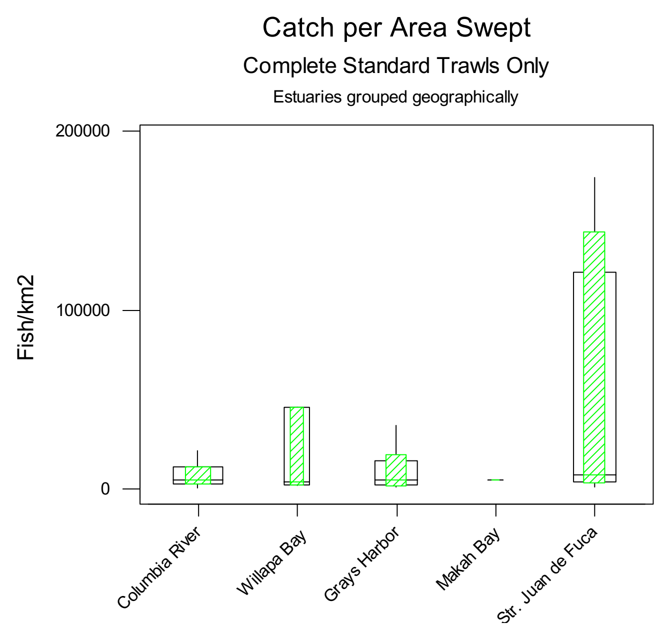
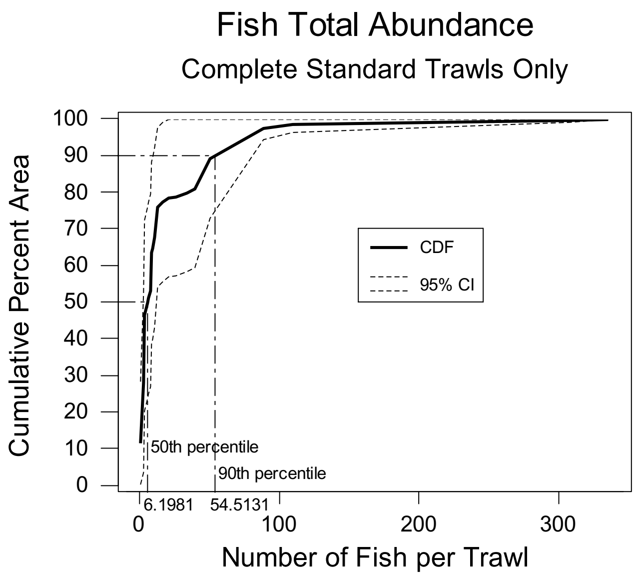


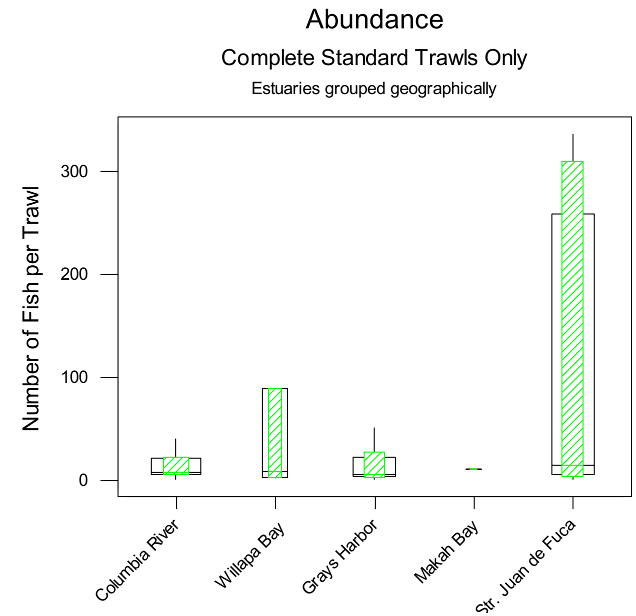
Figure E-4. Relative mean abundance of major taxonomic groups by geographic area. The diameters are proportional to the abundances.

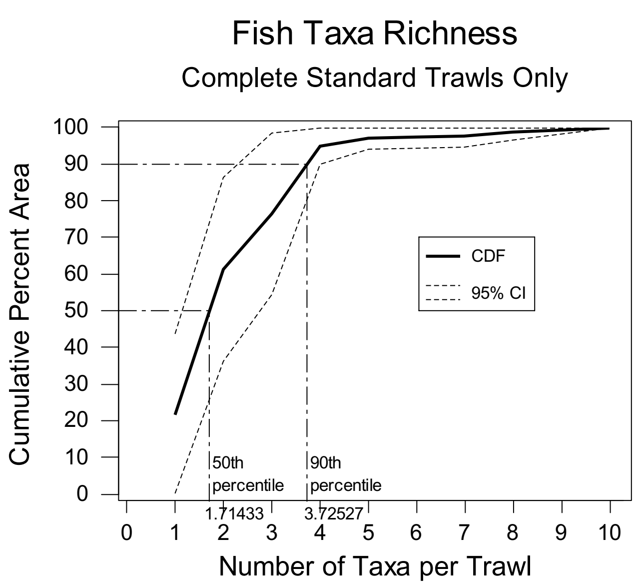
Figure E-5. Demersal fish CDFs and boxplots

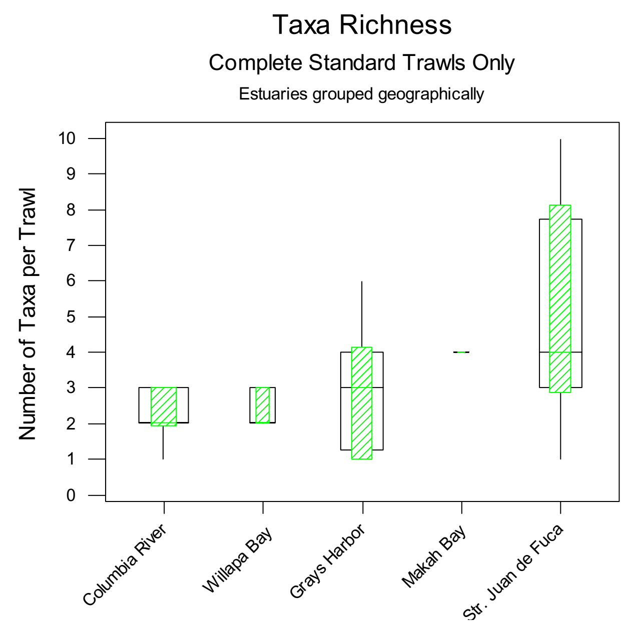





Fish Total Abundance
Complete Standard Trawls Only
Cumulative Percent Area
Number of Fish per Trawl
CDF
95% CI
50th percentile
90th percentile
6.1981
54.5131
0
100
200
300
0
10
20
30
40
50
60
70
80
90
100


Abundance
Complete Standard Trawls Only
Estuaries grouped geographically
Number of Fish per Trawl
0
100
200
300
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca


Fish Taxa Richness
Complete Standard Trawls Only
Cumulative Percent Area
Number of Taxa per Trawl
CDF
95% CI
50th
percentile
90th
percentile
1.71433
3.72527
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
80
90
100


Taxa Richness
Complete Standard Trawls Only
Estuaries grouped geographically
Number of Taxa per Trawl
0
1
2
3
4
5
6
7
8
9
10
Columbia River
Willapa Bay
Grays Harbor
Makah Bay
Str. Juan de Fuca

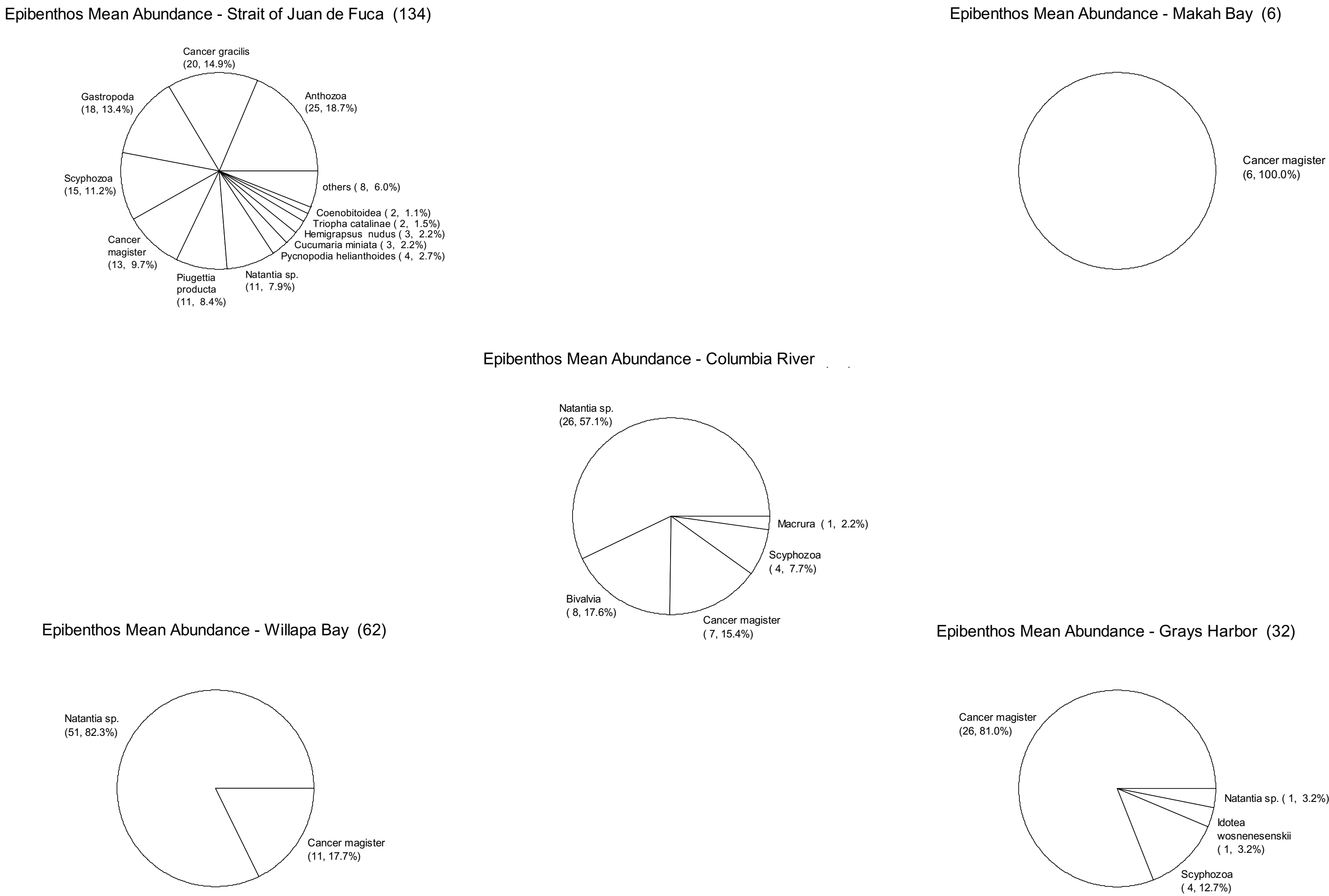


Figure E-6. Mean epibenthic invertebrates occurrence in trawls

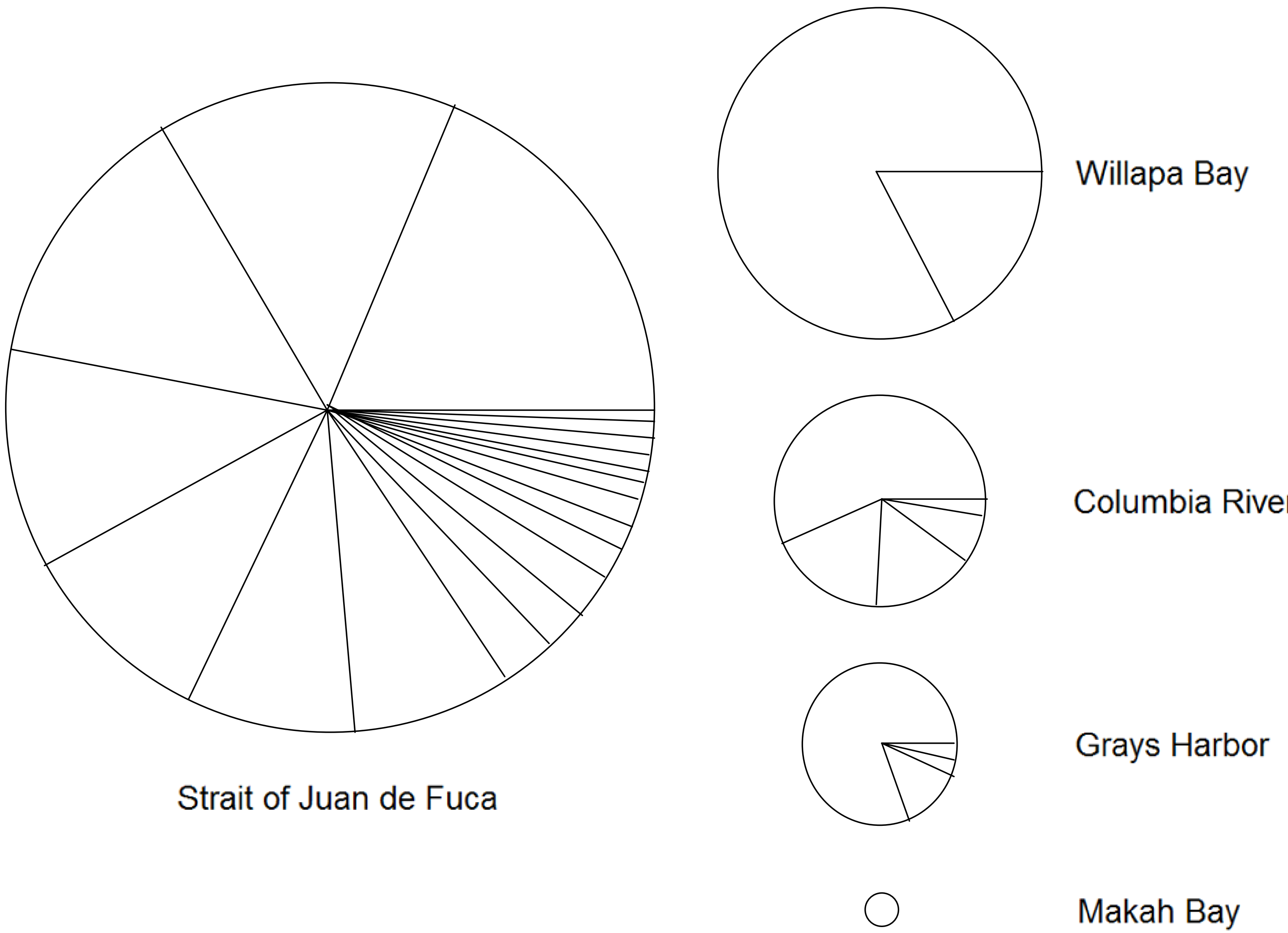


Figure E-7. Relative number of taxa and mean abundance of epibenthic invertebrates caught in trawls. The diameters are proportional to the abundances. Species are identified in Figure E-6.