Condition of Coastal Waters of Washington State, 2000-2003

A Statistical Summary

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Cover photos: NOAA *R/V Harold W. Streeter* in Puget Sound, 2000; Intertidal sampling by Ecology staff, 2002; Columbia River plume as seen from NOAA *R/V McArthur II*, 2003

Condition of Coastal Waters of Washington State, 2000-2003

A Statistical Summary

by
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Waterbody Numbers:

WA-01-0010	WA-09-0010	WA-15-0060	WA-22-0020	WA-PS-0100
WA-01-0020	WA-09-1010	WA-15-0070	WA-22-0030	WA-PS-0130
WA-01-0050	WA-10-0010	WA-15-0080	WA-24-0020	WA-PS-0200
WA-01-0070	WA-10-0020	WA-15-0100	WA-24-2010	WA-PS-0210
WA-02-0020	WA-13-0020	WA-15-0110	WA-24-3010	WA-PS-0220
WA-02-0030	WA-13-0030	WA-15-0130	WA-PS-0010	WA-PS-0230
WA-02-0040	WA-14-0010	WA-17-0010	WA-PS-0020	WA-PS-0240
WA-03-0020	WA-14-0110	WA-17-0020	WA-PS-0030	WA-PS-0250
WA-06-0010	WA-14-0130	WA-20-0010	WA-PS-0040	WA-PS-0260
WA-06-0020	WA-15-0010	WA-21-0010	WA-PS-0070	WA-PS-0290
WA-07-0010	WA-15-0030	WA-22-0010	WA-PS-0090	WA-PS-0300

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Glossary, Acronyms, Abbreviations, and Units of Measure

Following are definitions of terms, acronyms, abbreviations, and units of measure used frequently in this report.

Glossary

Benthic	Relating to the bottom of a waterbody
Benthos	Organisms living at the bottom of, or in the sediments of, a waterbody
Bioassay	A test to measure the toxicity of a contaminant using living cells or test organisms
Bioindex	Single number characterizing a biological community
Colonial species	An invertebrate species of interconnected individuals which function as a single organism
Continental shelf	Gradually sloping seabed from the shore of a continent to a sharp slope or 200-m depth
Demersal	Dwelling at or near the bottom of a waterbody
Epibenthic	Animals that live on the bottom sediments of a waterbody
Epifauna	Animals that live on another structure (generally on the bottom sediments)
Exotic species	Non-indigenous or non-native species
H4IIE test	A bioassay to measure the toxicity of certain contaminants in fish tissue extracts using the H4IIE cultured line of rat hepatoma cells
Hydrographic profile	Description of the physical characteristics of a water column
Hypoxic	Having a low dissolved oxygen concentration
Index	Single number derived from measurements of multiple characteristics
Indices	Plural of index
Infauna	Animals that live burrowing or buried in the bottom
Intertidal zone	Area between low tide and high tide
Macrofauna	Invertebrates retained on a 1-mm mesh sieve
Offshore	Submerged area over the continental shelf
Pielou's Evenness (J')	A measure of how equitably distributed the taxa are
Quadrat	Sample plot of defined size
Shannon-Wiener Diversity (H')	A function of taxa richness and abundance used to characterize community composition
Swartz' Dominance Index	Minimum number of taxa accounting for 75% of the total abundance
Taxa	Plural of taxon
Taxa richness	Number of different taxa
Taxon	Lowest level of identification for each organism, usually species

Acronyms and Abbreviations

CDF	Cumulative distribution function
CHN	Carbon-hydrogen-nitrogen analysis
CI	Confidence interval
CSL	Washington State sediment Cleanup Screening Level
CTD	Conductivity-temperature-depth probe
DO	Dissolved oxygen
Ecology	Washington State Department of Ecology
EMAP	Environmental Monitoring and Assessment Program (U.S. EPA)
EMAP-West	West Coast EMAP
ERL	NOAA Effects Range-Low sediment quality guideline
ERM	NOAA Effects Range-Median sediment quality guideline
GFF	Glass fiber filter
HPAH	High molecular weight PAH
LPAH	Low molecular weight PAH
MDS	Non-metric multidimensional scaling
N:P ratio	Nitrogen-to-phosphorus ratio
NCA	National Coastal Assessment (U.S. EPA)
NMFS	National Marine Fisheries Service (NOAA)
NMS	National Marine Sanctuary (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NOS	National Oceans Service (NOAA)
OCNMS	Olympic Coast National Marine Sanctuary
ORD	U.S. EPA's Office of Research and Development
PAH	Polycyclic aromatic hydrocarbon
PAR	Photosynthetically active radiation
PCB	Polychlorinated biphenyl
pH	Measure of acidity or alkalinity
PSAMP	Puget Sound Assessment and Monitoring Program (Puget Sound Partnership); formerly the Puget Sound Ambient Monitoring Program
PSEP	Puget Sound Estuary Program (U.S. EPA)
QA/QC	Quality assurance/quality control
QAPP	Quality assurance project plan
SCCWRP	Southern California Coastal Water Resources Project
SDI	Swartz' Dominance Index
SQS	Washington State Sediment Quality Standard
STORET	EPA's STOrage and RETrieval database of environmental data
SubPAR	Submerged PAR (PAR measured underwater)

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

Units of Measure

°C	degrees Celsius
cm	centimeter
F_0	level of fluorescence of the suspended pigments
F_a	post-acidification fluorescence measured
g	gram
kg	kilogram
km	kilometer
L	liter
m	meter
mg	milligram
mm	millimeter
ng	nanogram
nm	nanometer
nmi	nautical mile
psu	practical salinity unit
$\Delta\sigma_t$ 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	micromole
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/m^3 units

Abstract

The U.S. Environmental Protection Agency developed the Coastal Environmental Monitoring and Assessment Program (EMAP) to measure the condition of the nation's coastal waters. Numerous water, sediment, and biological measurements provide information on the physical environment, resident invertebrates and fish, and exposure of those animals to pollutants.

Coastal EMAP was the first large-scale assessment of all of Washington State's coastal areas and provides a baseline for future coastal assessments. The Washington State Department of Ecology and the National Marine Fisheries Service sampled the following areas:

- 1999 - Small outer-coast estuaries.
- 2000 - Puget Sound including the Strait of Georgia and the Strait of Juan de Fuca.
- 2002 - Intertidal reaches of Puget Sound, Grays Harbor, and Willapa Bay.
- 2003 - The continental shelf (offshore coastal waters).

This report summarizes 2000-2003 results. A previous report documented 1999 results.

During 2000-2003, 184 randomly-selected sites were sampled from 14,000 square kilometers (5400 square miles) of marine and estuarine areas. Overall, sample results suggest that the condition of Washington's coastal areas was generally good, but habitats were degraded in some urban bays in Puget Sound.

No surface waters had low dissolved oxygen (DO), but bottom waters had moderately low DO (2-5 mg/L) in 35% of Puget Sound and 83% of the offshore area. Bottom waters had very low DO (< 2 mg/L) in Lynch Cove (Hood Canal).

Metals were found in sediments everywhere. Organic contaminants (PAHs, PCBs, DDT, pesticides) were low or not detected in most areas, except urban areas of Puget Sound (e.g., Elliott Bay, Everett Harbor) which had relatively high levels of contaminants. Metals, PCBs, and DDT were found in most fish tissues, including offshore.

Nine percent of intertidal invertebrate species were non-native, but constituted 36% of the organisms. In Puget Sound and offshore areas, 1-2% of species, 0.2%-3% of organisms, were non-native. *Spartina alterniflora*, an invasive, non-native saltmarsh plant, was present in much of Willapa and Skagit Bays.

Less than 2% of Puget Sound fish had external abnormalities, almost all being naturally-occurring parasites. No offshore fish had abnormalities.

Preface

This document is a statistical summary of the data from the 2000-2003 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 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 and the Canadian government, 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 every year, providing equipment, supplies, and weeks of boat time and personnel on the *R/V Harold W. Streeter*, as well as performing the histopathological analyses. In 2003 NOAA National Oceans Service (NOS) provided four weeks of ship time and personnel on the *R/V McArthur II* for EMAP sample collection on the entire west coast.

The Southern California Coastal Water Resources Project (SCCWRP) and ORD designed, developed, and maintain the west coast databases.

All of the EMAP partners provided technical assistance and support to one another.

Many staff with the Washington State Department of Ecology participated in the project over the years, directly or indirectly, performing administrative/fiscal/managerial tasks, equipment manufacture, transportation, planning and preparation, field and lab work, taxonomic standardization and coordination, data entry and QA, database management, data analysis and reporting, and other support. The primary contributors are listed in chronological order for each heading:

- Administration, Management – Ken Dzinbal, Maggie Dutch, Brian Grantham, Carol Maloy
- Administrative Support – Michelle Ideker, Ann Armstrong, Cindy Cook
- Chemistry Lab Analyses – Chemists at Manchester Environmental Laboratory
- Data Analysis and Reporting – Sarah Wilson, Valerie Partridge
- Data, Quality Assurance, Database Management – Chrissy Ricci, Sandra Aasen, Karin Feddersen, Valerie Partridge
- Equipment Manufacture, Transportation, Other Support – Bernie Strong
- Fiscal – Gary Koshi
- Planning, Preparation – Casey Clishe, Chrissy Ricci, Dustin Bilhimer, Sarah Wilson, Angelita Rodriquez, Julia Bos
- Project Management – Casey Clishe, Allan Fukuyama, Sarah Wilson, Valerie Partridge

- Sample Processing, Data Entry, Quality Assurance – Casey Clishe, Chrissy Ricci, Dustin Bilhimer, Sandra Aasen, Sarah Wilson, Angelita Rodriquez, Kathy Welch, Julia Bos, Valerie Partridge
- Sampling – Casey Clishe, Chrissy Ricci, Dustin Bilhimer, Sandra Aasen, Ken Dzinbal, Kara Nakata, Sarah Wilson, Angelita Rodriquez, Kathy Welch, Maggie Dutch, Julia Bos, Valerie Partridge, Noel Larson
- Taxonomy Coordination and Standardization – Kathy Welch

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Executive Summary

The National Coastal Assessment (NCA) is a multi-year, comprehensive survey of the condition of the nation's coastal resources (estuaries and offshore waters) based on the Environmental Monitoring and Assessment Program (EMAP). EMAP is a nationwide program to (1) assess how well pollution-control programs and policies protect ecological resources, and (2) assist EPA's regional offices and the states in meeting reporting requirements of the federal Clean Water Act. EMAP was developed by the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD).

The NCA is accomplished in partnership with the 24 coastal states. Each state conducts the NCA survey and assesses the condition of its coastal resources independently using a compatible, probabilistic design and a common set of survey indicators. Because of the compatible design, these estimates can be aggregated to assess conditions at the EPA regional, biogeographical, and national levels. These aggregated results are used in the National Coastal Condition Reports (U.S. EPA, 2001c, 2005).

The Coastal Component of EMAP-West began as a partnership between EPA, 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 coastal areas of these three states during 1999-2003.

- In 1999 and 2000, estuaries were sampled.
- In 2002, intertidal zones in all three states, from mean low water to mean high water, were the survey focus. Because the landward boundary of the 1999-2000 estuary surveys extended to the limit of saltwater influence, some intertidal areas were included. However, any intertidal sites in 1999-2000 were sampled submerged, whereas the intertidal sites in 2002 were all sampled when exposed to air.
- In 2003, the West Coast survey targeted offshore areas, specifically the continental shelf between 30-120 meters depth, 7-40 kilometers (4-25 miles) offshore, along the Pacific coast from the Canadian border to the Mexican border.

This report provides a statistical summary of the data collected in Washington State by the Washington State Department of Ecology and the NOAA National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center in 2000, 2002, and 2003. The 2000 survey focused on Puget Sound, including the San Juan Islands, southern Strait of Georgia, and eastern Strait of Juan de Fuca. Intertidal reaches in Puget Sound, Willapa Bay, and Grays Harbor were sampled in 2002. In 2003, sampling was conducted on the continental shelf from the Strait of Juan de Fuca to the Oregon border. A previous report summarized the data from the 1999 survey of Washington's small outer-coast estuaries (Wilson and Partridge, 2007).

The combined 1999-2003 EMAP survey results provide the first comprehensive look at all of Washington's coastal resources. The results serve as a baseline for comparison of subsequent monitoring surveys, such as gauging the impacts of increasing population on relatively undeveloped areas and the effects of cleaning up known contaminated areas on the health of the whole of Puget Sound.

EMAP sample sites were selected using probability-based sampling designs. A total of 71 randomly-selected sites were sampled in Puget Sound (2000), 61 sites were sampled in intertidal areas (2002), and 50 sites were sampled offshore (2003).

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 characteristics (grain size and organic content), water quality indicators (chlorophyll-a, nutrients, total suspended solids), vegetation (intertidal).
- Abiotic/Pollutant Exposure Condition Indicators: sediment and fish-tissue contaminants, sediment toxicity, marine debris.
- Biotic Condition Indicators: diversity and abundance of benthic infauna (invertebrates living in the sediment) and demersal (bottom-dwelling) fish species, fish pathological anomalies, epibenthic invertebrates (those living on the sediment surface).

The Coastal EMAP surveys are designed to provide broad assessments of condition for large areas based on one-time samples. This report summarizes state-wide information which will become part of region-wide and nation-wide coastal assessments. In-depth and long-term assessments of the conditions of Washington's marine and estuarine areas are provided by other monitoring programs which have been designed to study specific elements in detail, such as the marine waters, sediments, fish, and nearshore components of the Puget Sound Assessment and Monitoring Program (www.psp.wa.gov/our_work/science/psamp.htm).

General Habitat Condition Indicators

Water Characteristics

Puget Sound and offshore waters were largely stratified, or layered. Density stratification indices showed that just over 10% of the greater Puget Sound area (including the southern Strait of Georgia and eastern Strait of Juan de Fuca) had well-mixed waters, and only 3% of the area 7-40 km off the Pacific coast shore had well-mixed waters. About 79% of the offshore area waters were strongly stratified, as were 59% of the Puget Sound area waters. The remainder were intermediate.

No surface waters were hypoxic, but bottom waters were moderately hypoxic (dissolved oxygen 2-5 mg/L) in 35% of Puget Sound and 83% of the offshore area. Bottom waters were severely hypoxic (dissolved oxygen < 2 mg/L) in Lynch Cove (Hood Canal).

Water clarity was high everywhere, with the exception of one station in the Puyallup River plume (Commencement Bay).

About 10% of the Puget Sound waters had surface nitrogen-to-phosphorus (N:P) ratios < 5, which may be limiting to marine algal growth, whereas 67% of the offshore area had N:P ratios < 5. A number of the offshore areas also had low phosphorus levels in the surface waters.

Sediment Characteristics

The physical characteristics of the sediment varied considerably by study area. The proportion of area with sandy sediments (< 20% silt-clay) was around 10% in the Puget Sound area (subtidal), but 62% in the intertidal region and 64% offshore. Muddy sediment (> 80% silt-clay) characterized 43% of Puget Sound, less than 4% of the intertidal area, and none of the offshore area.

Total organic carbon (TOC) ranged widely in Puget Sound proper and in Willapa Bay. TOC was very low in the open waters of the Straits of Georgia and Juan de Fuca and on the continental shelf (offshore area).

Vegetation (2002 only)

Eelgrass (*Zostera* spp.) was present in approximately 50% of the intertidal area. Eelgrass beds are important for many species, including salmon. About 15% of the intertidal area was bare. Several species of green algae were common; red and brown algae were found rarely. *Spartina alterniflora*, an invasive, non-native saltmarsh grass, occurred throughout Willapa Bay and Skagit Bay. *Spartina* displaces native saltmarsh vegetation and causes changes in the physical characteristics of the intertidal areas.

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 study was not designed to draw conclusions about fish for human consumption.*

Because sample sites were selected randomly from the entire greater Puget Sound area, few sites happened to be in urban or industrial locations. However, the results from these 1999-2003 Coastal EMAP studies are consistent with those of other studies, such as the Puget Sound Assessment and Monitoring Program for marine sediments, with respect to the occurrence of environmental contamination.

Although PCBs and DDT were discontinued or banned more than 30 years ago, those chemicals are still appearing in the most recently-deposited sediments and in fish tissues.

Metals

Aluminum, antimony, arsenic, chromium, copper, iron, lead, manganese, nickel, and zinc were found in sediments in all study areas, though in Puget Sound antimony was detected in only about half of the area. Selenium was rarely found in intertidal and offshore sediments, and in only about half of Puget Sound sediments. Tin was not found in any offshore sediment.

None of the areas sampled had metals contaminant levels higher than the Washington State Sediment Quality Standard (SQS) or Cleanup Screening Level (CSL) regulatory standards for sediment contamination or the NOAA Effects Range-Median (ERM) sediment quality guidelines for metals. However, about one-third of the Puget Sound subtidal sites and a few intertidal sites exceeded the NOAA Effects Range-Low (ERL) guidelines for one or more metals. Many of those locations were in or near urban or industrialized areas.

Aluminum, arsenic, iron, selenium, tin, and zinc were found in all, or all but one, of the fish-tissue samples. Mercury was found in all of the offshore fish-tissue samples and all but a few Puget Sound samples. While cadmium, chromium, and copper were found in all offshore fish, they were found in only a few fish in Puget Sound. Lead was found in the majority of fish-tissue samples from Puget Sound and in about half of those from the offshore. The remaining metals, nickel and silver, were found in only a few fish in each study area.

Polynuclear Aromatic Hydrocarbons (PAHs)

No Washington State regulatory sediment quality standards for Total PAH were exceeded in the areas sampled, and no NOAA ERL or ERM sediment quality guidelines were exceeded in the intertidal and offshore areas. However, ERL and ERM guidelines for PAH totals were exceeded in several urban bays of Puget Sound (Port Gamble, Everett Harbor, Elliott Bay and Duwamish River, Port of Olympia, Commencement Bay and Hylebos Waterway, Port of Shelton, Bellingham Bay, Port Ludlow, Gig Harbor). In the intertidal areas, the highest PAH concentrations were found in Drayton Harbor and Oyster Bay, at the northern and southern extremes of Puget Sound.

Because they are metabolized quickly in living organisms, PAHs are generally not target analytes in fish tissues. (That does not mean that there are no sub-lethal effects on the fish.) In the offshore fish, the only tissue samples analyzed for PAHs, no PAHs were detected.

Polychlorinated Biphenyls (PCBs)

No PCBs were detected in any of the intertidal and offshore sediments or in two-thirds of the Puget Sound samples, the latter representing almost 60% of the total Puget Sound study area. However, PCBs were measured in 20 of the Puget Sound subtidal locations, representing more than 40% of the area of Puget Sound. In the Duwamish River, Total PCB levels exceeded the NOAA ERM guideline and the Washington State SQS sediment quality standard and were one or more orders of magnitude higher than elsewhere. A few urban bays (Elliott Bay, Hylebos Waterway of Commencement Bay, Port of Olympia, Everett Harbor) exceeded the ERL guideline for Total PCB.

In contrast, PCBs were found in all Puget Sound fish-tissue samples. Total PCB concentrations in fish tissue were several times higher in Elliott Bay, the Duwamish River, and the Hylebos Waterway of Commencement Bay than elsewhere. The fish caught at the locations with the highest PCB concentrations were usually English sole. Although two PCB congeners (138 and 153) were detected in a few fish tissues from the offshore areas, the single Dover sole tissue sample from the offshore contained multiple PCBs.

DDT

No DDT isomers were detected in any of the intertidal sediments. Only 4,4'-DDD and 4,4'-DDE were measurable in offshore sediments at 14 of the 50 locations sampled. Those same two DDT isomers plus 2,4'-DDD were found in Puget Sound. Most of the DDT in Puget Sound was found in urban waters, representing 16.9% of the study area. The offshore locations with DDT occurred closer to shore near the Columbia River and got deeper and farther from shore going northward. No DDT was detected in the 30-120 meter depth band in the northern half of the Olympic Coast National Marine Sanctuary (NMS).

Again in contrast to infrequent measurable DDT occurrence in sediments, DDT was found in all Puget Sound and all but three offshore fish-tissue samples. As with PCBs, the fish-tissue DDT concentrations were several times higher in Elliott and Commencement Bays and their associated waterways than elsewhere.

Other Chlorinated Pesticides

No other chlorinated pesticides were found in any of the intertidal and offshore sediments. In the Puget Sound study area, only a few pesticides were detected, at only a few locations.

Hexachlorobenzene was found in the majority of the fish-tissue samples. Otherwise, only a few pesticides were detected in only a few of the Puget Sound fish-tissue samples. No pesticides were detected in any of the offshore fish-tissue samples.

Sediment Toxicity Tests (2000, 2002 only)

The sea urchin fertilization toxicity tests performed in the Puget Sound and intertidal studies indicated that approximately 9% of the sediments in both areas was toxic. The sea urchin morphological development tests and the amphipod mortality tests (Puget Sound study only) indicated toxicity in approximately 28% and 22% of the area, respectively, with some overlap between the results of the two types of tests.

Some of the areas with toxic sediments in the Puget Sound subtidal survey were in or near urban or industrial areas (Port of Olympia, Dabob Bay, Fidalgo Bay, Duwamish River, Elliott Bay, Port Gamble), while the rest were among the San Juan Islands and Gulf Islands (Canada) in the Strait of Georgia. The intertidal sites with toxic sediments were located in Drayton Harbor (Puget Sound), Willapa Bay, and Grays Harbor.

Biotic Condition Indicators

Benthic Infauna

The characteristics of the infaunal communities (bottom-dwelling invertebrates) varied considerably by study area. The average number of *taxa* (generally species) in the intertidal areas was about half that in Puget Sound or the offshore area. However, the average number of *organisms* (the mean abundance of infauna) was greater in the intertidal zone than in Puget Sound and far greater than on the continental shelf. In the intertidal areas, the *mean* infaunal abundance was more than twice the *median* abundance. One subtidal station in Budd Inlet (Puget Sound) had no benthic macrofauna in the sediment.

Within the intertidal areas, the infaunal community composition in Willapa Bay was quite different from communities in Puget Sound or Grays Harbor. In the offshore areas, there was no difference between the infaunal communities within or outside the Olympic Coast NMS. In the Puget Sound study area, the infaunal communities in the open waters of the Straits of Georgia and Juan de Fuca were different from those in Puget Sound proper, the San Juan Islands, and the embayments off the two straits.

While the top ten taxa accounted for approximately the same proportion of total abundance in all three study areas (48-55%), the contribution of introduced species was remarkably different: less than one-quarter of 1% in the offshore, about 3% in Puget Sound, and 36% in the intertidal areas. Five of the ten most abundant infaunal organisms in the intertidal areas were introduced (non-native) species, accounting for 23% of the benthic infauna. Overall, 9% of intertidal benthic infaunal species were introduced species, whereas about 1.5% of subtidal species were introduced species.

Benthic infaunal diversity and evenness (degree of equal abundance) were relatively high in Puget Sound and relatively low in the intertidal areas. In the offshore areas, diversity was relatively high, but evenness was relatively low.

Demersal (Bottom-dwelling) Fish

Pacific sanddab (*Citharichthys sordidus*) were caught at all of the 21 stations fished offshore, but only occasionally in the Puget Sound area (about one-third of the stations). The most frequently caught species in Puget Sound was English sole (*Parophrys vetulus*), which was not caught offshore. In the Puget Sound study area, the fish caught in greatest numbers were the spotted ratfish (*Hydrolagus colliei*).

Fish with visible pathological anomalies (tumors, parasites, deformities, lesions) were caught at more than half of the Puget Sound stations trawled, representing about 63% of the area, but they constituted less than 2% of the total catch over all stations. Almost all of the anomalies were naturally-occurring parasites, fully 67% of the cases being infestations of the nematode (roundworm) *Philometra*. English sole represented about 10-20% of the fish caught but more than 60% of the fish with gross external pathologies and almost 85% of the *Philometra* cases. No external anomalies were found on the offshore fish.

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) developed by the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD). The NCA is accomplished in partnership with the 24 coastal states in an integrated, comprehensive monitoring program based on the ORD's Environmental Monitoring and Assessment Program (EMAP).

Each state conducts the NCA 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 Washington State Department of Ecology (Ecology).

Estuaries were sampled during the summers of 1999 and 2000, small estuaries in 1999 and large estuaries (such as Puget Sound) in 2000. Nelson et al. (2004), Wilson and Partridge (2007), and Hayslip et al. (2006) are reports on the 1999 surveys of the three states combined, on the 1999 results in Washington only, and on the 1999-2000 results for EPA Region 10 (Washington and Oregon), respectively.

In subsequent years, sampling was designed to fulfill the objectives of the 5-year Coastal EMAP Western Pilot project. Intensive studies were performed in California and Oregon in 2001, but no sampling was performed in Washington that year. Intertidal zones in all three states, from mean low water to mean high water, were the focus in 2002. Nelson et al. (2007) reports those 2002 results. In 2003, the West Coast survey targeted offshore areas, specifically the continental shelf between 30 and 120 meters depth, from the Canadian border to the Mexican border.

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 coastal waters. This report presents a statistical summary of data from the 2000, 2002, and 2003 studies conducted by Ecology with the NOAA National Marine Fisheries Service (NMFS) and EPA.

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).

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. The total marine and estuarine area surveyed under Coastal EMAP covers about 14,000 square kilometers (5400 square miles):

- Small outer-coast estuaries along the eastern Strait of Juan de Fuca, Pacific Ocean, and lower Columbia River, including Willapa Bay and Grays Harbor (760 km^2)
- Puget Sound, including the southern Strait of Georgia, San Juan Islands, and eastern Strait of Juan de Fuca (7200 km^2)
- Intertidal reaches (730 km^2, partially overlapping the Puget Sound and outer-coast estuaries)
- Inner continental shelf along the Pacific coast (5700 km^2)

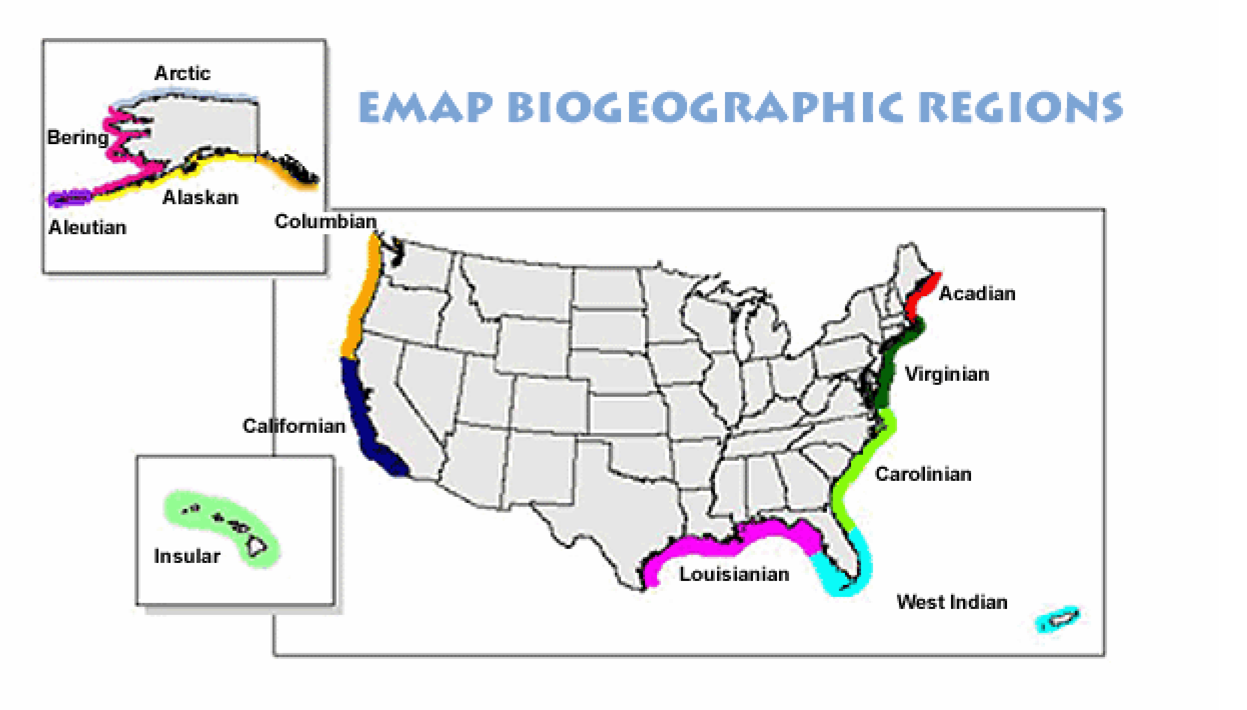


Figure 1. North American coastal biogeographic provinces.

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).

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 concentration, total suspended solids, and pH in the water, as well as grain size and total organic carbon in the sediment. The intertidal study surveyed vegetation and burrowing shrimp, in addition to sediment characteristics.

2. *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.

3. *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, several supplemental indicators were measured by either Western Coastal EMAP participants or external collaborators, including characterization of vegetation and shrimp burrows (intertidal survey only), additional chemical parameters, two sediment porewater toxicity tests, and a fish-tissue bioassay (Table 2). Descriptions of the EMAP indicators, their applicability, and their importance are given in Appendix A.

Table 2. Supplemental environmental indicators measured or under development for the Washington State component of the EMAP Western Coastal 2000-2003 surveys.

Indicators	EMAP Partner(s)
Habitat	
Vegetation types, percent cover, biomass (2002 only)	Coastal EMAP-West
Shrimp burrows (2002 only)	Coastal EMAP-West
Benthic	
West Coast benthic infaunal index (under development)	Coastal EMAP-West
Exposure	
Additional sediment chemistry analytes (Appendix Tables A-1, A-2)	Washington State Department of Ecology
Sediment porewater toxicity (PSAMP/NOAA stations only) sea urchin *Strongylocentrotus purpuratus* fertilization	USGS/BEST (USGS, 1997, 1998, 1999)
Sediment porewater toxicity (2000, 2002) sea urchin *Arbacia punctulata* fertilization	USGS/BEST (USGS, 2001, 2003a)
Sediment porewater toxicity (2000 only) sea urchin *Arbacia punctulata* embryo development	USGS/BEST (USGS, 2001)
H4IIE Test for exposure of fish to planar halogenated hydrocarbons (2000 only)	USGS/BEST (USGS, 2003b)

Methods

Sample Design

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/ .

Site selection

EPA uses a random tessellation stratified (RTS) design method for EMAP surveys. An RTS design for an areal survey involves placing a regular grid, beginning in a random location, over the area to be sampled (the population), 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 the condition of the total population are weighted based on the areas of the subpopulations (Stevens and Olsen, 1999, 2003).

The sampling frames, or design study areas, for the EMAP Western Coastal Program were 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 Geographic Information System (GIS) data layer in ARC/INFO (Nelson et al., 2004).

For the 1999-2000 survey, sites were selected by USGS using ArcView programs and scripts written by Bourgeois et al. (1998), according to parameters specified by the EPA Gulf Ecology Division. The RTS-design programs overlaid a sampling grid of hexagons on the sample frame, in which the size (area) of the hexagons within each stratum (sampling region or subpopulation) was determined iteratively by the number of sample stations to be generated for that stratum. Then hexagons were randomly selected, and within each hexagon a single sampling point was randomly located. The random-sample generator program determined whether a sampling point fell in water or on land, and excluded sites on land (Nelson et al., 2004).

From 2002 on, the EPA Western Ecology Division (WED) generated the sample draws using a generalized random tessellation stratified (GRTS) survey design for areal sampling with reverse hierarchical randomization (Stevens and Olsen, 1999, 2003; U.S. EPA, 2001d), a mathematical technique, rather than hexagons. Separate multidensity categories were used to generate samples for subpopulations. Sites were selected by WED using ArcView and SAS programs (U.S. EPA, 2001d).

Washington Sampling Designs

2000: Puget Sound

The sampling of Puget Sound for EMAP 2000 capitalized on the recently concluded, three-year joint Ecology-NOAA sampling effort as part of the Washington State Puget Sound Ambient Monitoring Program (PSAMP, now called the Puget Sound Assessment and Monitoring Program) and the NOAA National Status and Trends (NS&T) program. Thirty randomly-chosen EMAP stations were augmented by 41 PSAMP/NOAA stations which had been sampled for sediment chemistry, sediment toxicity, and infauna in 1997-1999. The EMAP stations were sampled for all parameters in 2000, and the PSAMP/NOAA stations were revisited in 2000 to sample fish and water parameters.

The EMAP 2000 sample frame encompassed all of the greater Puget Sound area, both U.S. and Canadian waters, including the embayments and open waters of the eastern Strait of Juan de Fuca and southern Strait of Georgia, the San Juan Islands, and the Gulf Islands (Canada). The PSAMP/NOAA sample frame included only Puget Sound proper plus the embayments of the eastern Strait of Juan de Fuca and southern Strait of Georgia (U.S. waters only). The landward boundary of the EMAP sample frame extended to the limit of saltwater influence (Nelson et al., 2004), while the PSAMP/NOAA boundary was defined by the 2-meter depth contour (below mean lower low water), the depth limit of the sampling vessel. Areas known to have rocky bottoms, such as the Tacoma Narrows, were excluded from the PSAMP/NOAA sample frame (Long et al., 2003).

The number of sampling points was determined by considering (1) the maximum number of stations logistically viable for collection of all of the NCA indicators within one field season, (2) the minimum number of sampling points needed for statistical validity, and (3) the minimum number of sites needed within each stratum (sample areas described next) to account for its areal contribution to the total samplable area (Harwell, 2005). Approximately 60% of the sampling effort was targeted for the PSAMP/NOAA area. To ensure adequate representation of the waters of the San Juan Islands, 10% of the sample sites were targeted within the San Juan archipelago. The remaining 30% were targeted from the Gulf Islands and the open waters of the straits, Admiralty Inlet, and the central basin of Puget Sound (Harwell, 2005).

Sample sites were selected randomly from each of the three strata, using a different hexagon size for each stratum. For selection of sites within the PSAMP/NOAA sampling area, a hexagonal grid was placed over the area and EMAP sites were chosen at random. If a PSAMP/NOAA station was within a hexagon where a randomly chosen EMAP site had been selected, then the PSAMP/NOAA site was used in lieu of the EMAP site (Nelson et al., 2004). In all, 71 sites were selected: 41 PSAMP/NOAA stations, 10 stations in the San Juan Islands, and 20 stations in the remaining areas (Figure 2, Appendix Table B-1). No alternate sites were selected to replace unsamplable sites.

The sampling design of the PSAMP/NOAA survey is described in Long et al. (2003). A stratified random design was used, similar to those used for the NOAA National Status and Trends program (NS&T) and compatible with EMAP designs. The PSAMP/NOAA study area was divided into 97 irregularly-shaped strata based on boundaries of waterbodies and on relatively homogeneous oceanographic and geologic conditions (Long et al., 2003). In areas far removed from point sources of contaminants, and where sediment contaminant levels were known or expected to be low, fewer and larger strata were defined. In urban bays and industrial harbors, where sediment contamination was known or expected to be high, and where heterogeneous conditions or gradients were expected, more and smaller strata were defined (Long et al., 2003). In the PSAMP/NOAA survey, 300 stations were sampled over the 97 strata. In most strata, three randomly-chosen sites were sampled; in a few strata, four samples were taken (Long et al., 2003).

The target and actual sampling locations for EMAP 2000 are shown in Figure 2. Details of the selected targets are given in Appendix Table B-1.

2002: Intertidal

In 2002, the Washington Coastal EMAP program concentrated on intertidal areas throughout the state of Washington, along all coasts except the Columbia River. The sampling frame was defined as between mean low tide and mean high tide. The design called for 30 stations to be sampled in Willapa Bay, 25 in Puget Sound, and 13 in the remainder of the state (U.S. EPA, *undated*). Sixty-eight target sites and nine times that many alternate sites were chosen at random from the three sample areas. Most of the potential sample sites in the third area ("remainder of Washington") fell in Grays Harbor, due to its disproportionate size.

The target and actual sampling locations are shown in Figure 3. Details of the selected targets are given in Appendix Table B-2.

2003: Offshore

Washington Coastal EMAP sampling in 2003 focused on offshore areas, mostly the continental shelf from the Canadian border to the Oregon border, bounded by 30-m and 120-m depth contours. The U.S. side of the Strait of Juan de Fuca was included in the sample frame. The sample frame was divided into two sample areas, the area inside the Olympic Coast NMS and the rest of the Washington coastline (U.S. EPA, 2002b). Fifty stations were selected at random, 30 within the sanctuary and 20 in the "remainder of Washington". A few stations in the latter fell in the Strait of Juan de Fuca (Figure 4). Another 50 sites – same balance – were randomly selected to serve as alternates in case target sites proved to be unsamplable.

The target and actual sampling locations are shown in Figure 4. Details of the selected targets are given in Appendix Table B-3.

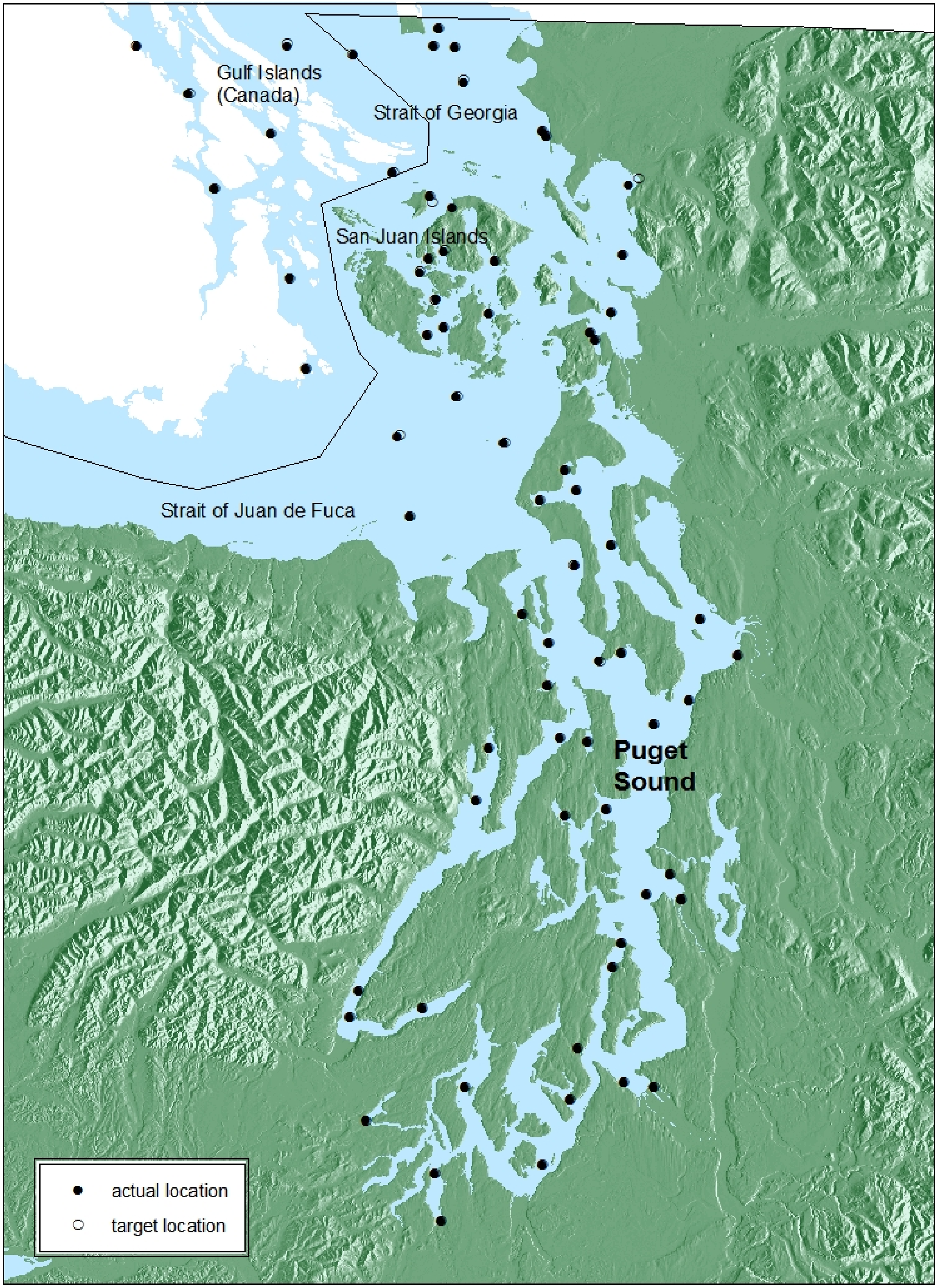


Figure 2. Washington Coastal EMAP 2000 target (open circle) and actual (solid circle) survey sites. Location details are given in Appendix Table B-1.

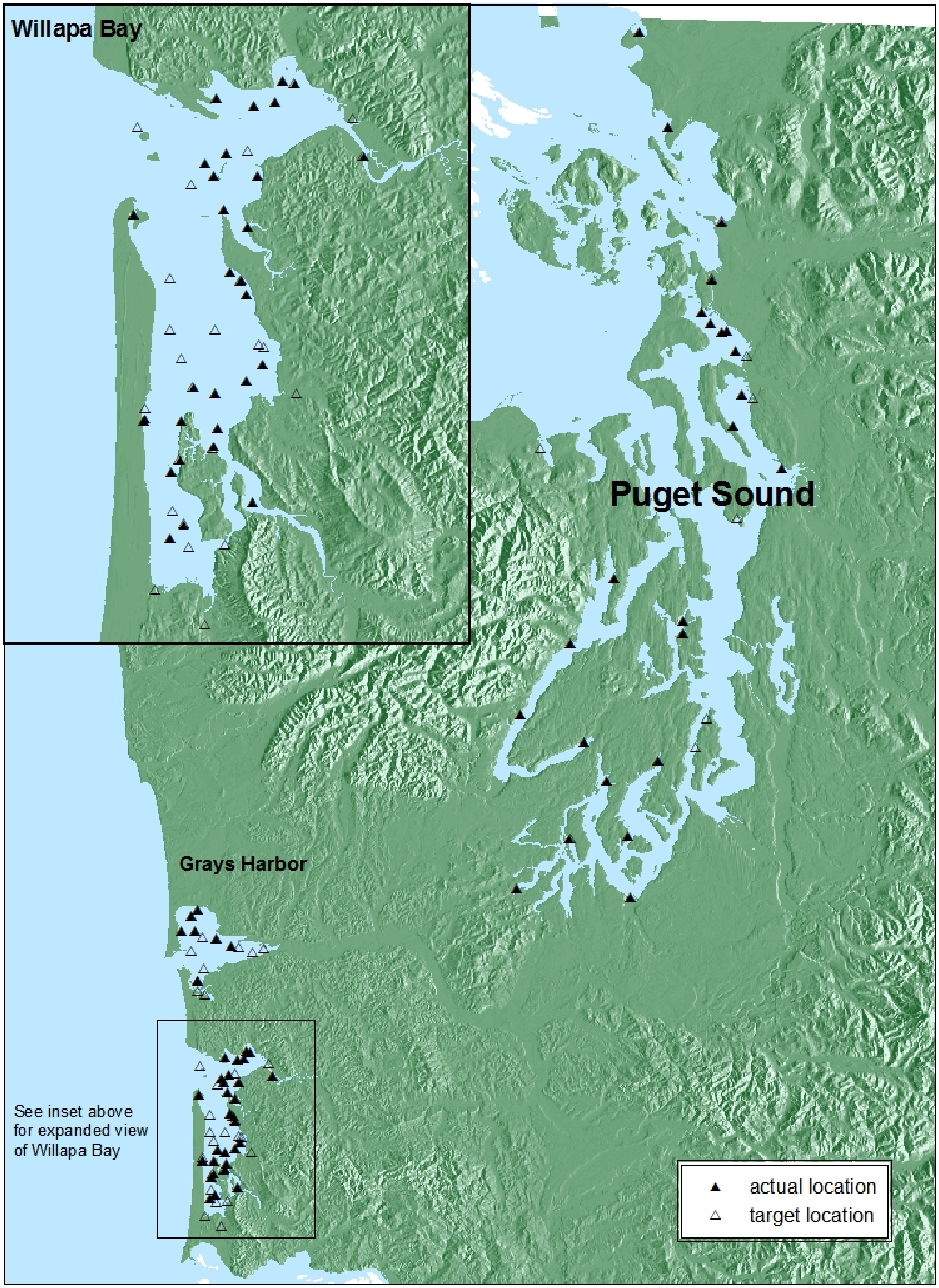


Figure 3. Washington Coastal EMAP 2002 target (open triangle) and actual (solid triangle) survey sites. Location details are given in Appendix Table B-2.

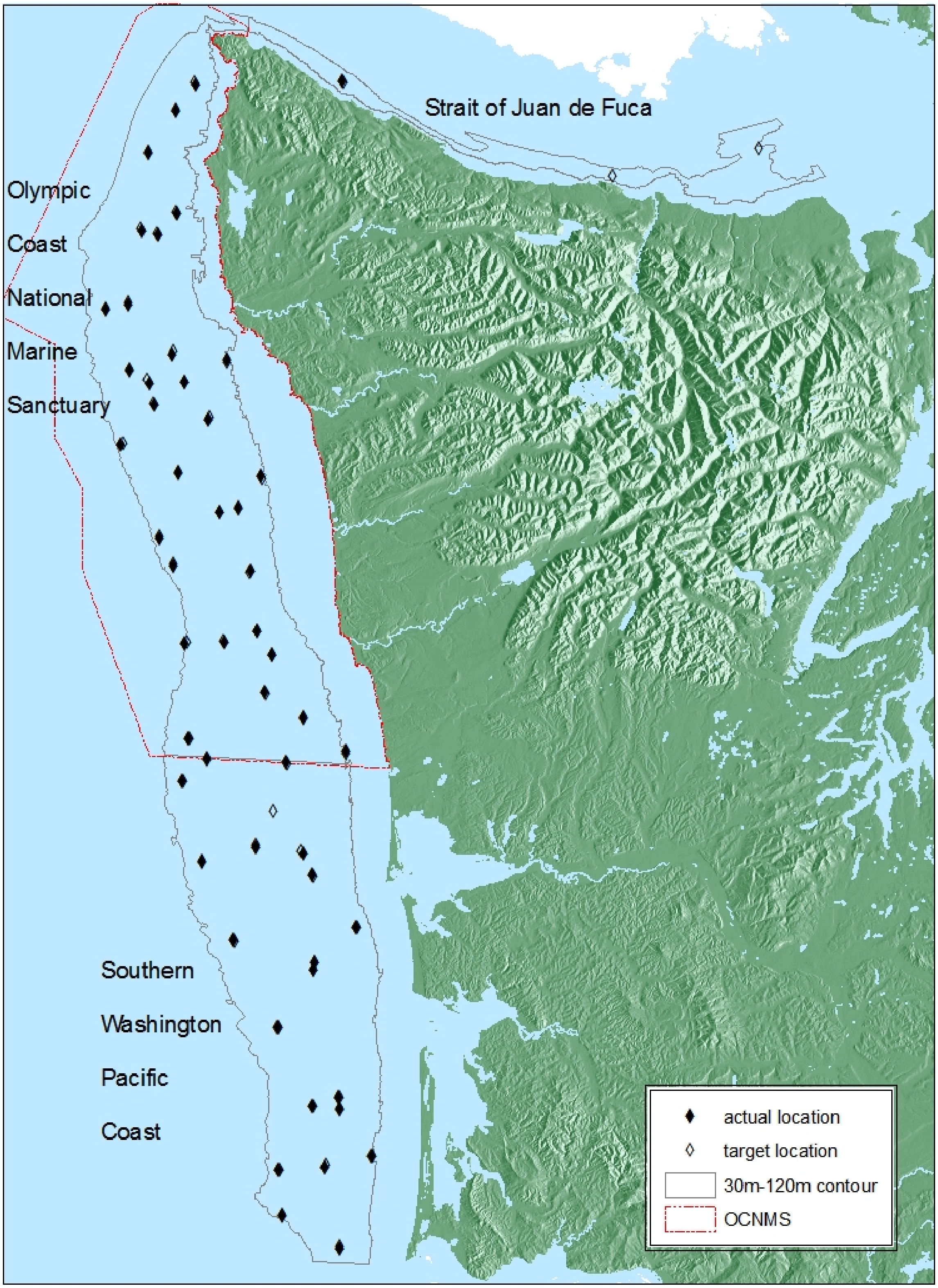


Figure 4. Washington Coastal EMAP 2003 target (open diamond) and actual (solid diamond) survey sites. Location details are given in Appendix Table B-3.

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 2000 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.

Similarly, the QAPP for the PSAMP/NOAA survey (Dutch et al., 1998) specified that program's data quality and measurement quality objectives, agencies' responsibilities, and procedures for all field and laboratory measurements. (The document was in draft for the 1997 sampling event.)

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 NCA QAPP (U.S. EPA, 2001a) for details. In a general assessment of data collection and analyses by EPA, Ecology's Environmental Monitoring and Trends Section and Ecology's 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

Site Visits

2000: Puget Sound

Sampling in 2000 was divided into two cruises, a "deep station" cruise and a "shallow station" cruise. The deep station cruise, targeting 18 stations greater than 90 meters deep, was conducted June 15-27 on board the *F/V Chasina*, chartered by interagency agreement with the Washington Department of Fish and Wildlife. The remaining 53 shallow stations (i.e., less than 90 meters deep) were sampled from the NOAA National Marine Fisheries Service (NMFS) *R/V Harold W. Streeter* between July 18 and August 22. Water quality, fish, and sediment sampling were conducted by personnel from Ecology, EPA, and NMFS.

The 1997-1999 PSAMP/NOAA sediment sampling was conducted by Ecology and NOAA National Oceans Service (NOS) personnel aboard the *R/V Kittiwake*, a chartered vessel. Details are provided in Long et al. (1999, 2000, 2002).

During the 2000 sampling events, water quality samples were collected at all 71 stations, fish were captured at 64 of the 71 stations, and sediment/benthic infauna samples were taken at 19 of the 30 EMAP-only stations (Appendix Table B-1, Figure B-1). (Sediment/infauna samples had been taken and processed at all of the PSAMP/NOAA stations during 1997-1999.) The most common reason why fish or sediment samples were not successfully collected in 2000 was irregular bathymetry and/or rocky substrate (Appendix Table B-1).

2002: Intertidal

Washington's 2002 intertidal field season began July 1 and was completed September 26. Ecology used a chartered hovercraft to access all sample stations. This craft proved a fundamental component of the sampling operations, allowing transfer of personnel, equipment, and samples across otherwise inaccessible substrates. The EPA *R/V Monitor* was used as a support vessel for three weeks during July, and was a significant help with sample preparation and personnel safety. Ecology's 20-foot whaler was used as a support vessel for four days during the latter part of Willapa Bay operations.

Fourteen sites were pre-abandoned, mostly due to lack of permission from landowners. Two of the 14 sites were pre-abandoned because all available information suggested they fell in the upper marsh. Fifteen sites were abandoned in the field, mostly due to being submerged at low tide. Of these 15, one site was rejected because it fell in the upper marsh and two because they fell > 300 meters (m) into *Spartina* meadows. Stations in Drayton Harbor and Skagit Bay were found to be submerged when initially visited, but were resampled successfully at lower tides. Six extra sites were added in Willapa Bay at the end of the field season, in order to meet the requirements for 30 stations in the intensive survey area. Due to the time constraints involved with obtaining private landowner permissions, all six sites were acquired on state-owned lands.

The sampling protocol allowed a sample station to be moved within a 100-m radius of the planned position. It was necessary to employ this rule on numerous occasions to move stations from submerged to subaerial ground. All stations were acquired within this allowable 100-m radius, except for one station which fell in a particularly inaccessible Spartina meadow in Willapa Bay. Following discussions with EPA personnel, that station was sampled 240 m NNE of the planned location.

A total of 61 stations were sampled successfully: 30 in Willapa Bay, 24 in Puget Sound, and 7 in Grays Harbor (Figure 3). Details of all sample sites are given in Appendix Table B-2.

2003: Offshore

Sampling took place June 1-5, 2003 on NOAA's *R/V McArthur II*. Ecology, EPA, NOAA NMFS, NOAA NOS, NOAA NMS, and other state agencies' personnel performed the sampling.

Three stations in the Strait of Juan de Fuca and two on the continental shelf proved unsamplable under EMAP protocols and were abandoned due to insufficient soft sediment for analysis (Figure 4, Appendix Table B-3). The rejected shelf stations were replaced with the nearest alternate sites, and the rejected Strait of Juan de Fuca stations were replaced with three alternate stations north and northwest of the Columbia River outfall. Fifty stations were successfully sampled for sediment: 30 in the Olympic Coast NMS, and 20 off the southern Washington Pacific coast.

Field Sampling Procedures

Field procedures are specified in the following documents:

- NCA Field Operations Manual (U.S. EPA, 2001b, in draft for the 2000 sampling effort).
- Ecology protocols for Coastal EMAP West for each year (stored as metadata in the NCA databases).
- Quality Assurance Project Plan for the PSAMP/NOAA survey (Dutch et al., 1998, in draft for the 1997 sampling effort).
- Puget Sound Estuary Program protocols (PSEP, 1986, 1987, 1996a).

Brief descriptions of field procedures, including QA/QC, are given below.

Because the areas to be sampled in 2002 were intertidal, new protocols were needed for field sampling. Some parameters measured in the other coastal EMAP surveys could not be measured at all in 2002 (namely, water and fish), or could not be sampled in the same way (specifically, the use of a boat-deployed van Veen grab); therefore, other parameters were added (shrimp burrows, vegetation). The EPA Western Ecology Division developed the protocols, which are described in an addendum to the NCA QAPP (U.S. EPA, 2002a).

Special Sampling Procedures for 2002

Upon arrival at the GPS-located site, a 0.25-m^2 quadrat was placed randomly on the sediment at the site. The 0.25-m^2 quadrat was turned over three times in sequence to define a 1-m square sampling site. Each of the quadrats thus delineated was sampled for separate parameters in turn. One quadrat was used to characterize the habitat by presence and abundance of burrowing shrimp, one quadrat to characterize plant cover and biomass, one quadrat for collection of sediment samples for toxicity and chemical analysis, and one quadrat for collection of benthic infauna, in that order. In addition, a 5-m transect was used for further characterization of plant cover.

Burrowing shrimp quadrat: Shrimp burrows > 3 mm in diameter, in bare sediment only, were counted independently by two field personnel and recorded. If the plant cover in the burrowing shrimp quadrat was > 50%, plants were gently lifted so that estimates (only) of the numbers of shrimp burrows could be made. If possible to identify, the species of shrimp was recorded.

Plant quadrat: The percent cover of the sediment surface by plants was estimated quantitatively by species and by bare substrate. Seagrasses and other rooted plants were identified to species level when possible; algae were identified to division (green, red, brown algae). Reference specimens of unknown species were collected for later identification. Rooted plant species were harvested for biomass measurements.

Plant species cover was the percentage of the sampling plot overlain by the canopy of that species occurring in the plot. Upper layers were lifted gently to see what was underneath, to determine how much of the plot was actually occupied by each type of plant being estimated. If some plant species overlay other plant species within the plot, the summed percent cover could be greater than 100%. Cover for bare substrate was the percentage of the sampling plot not overlain by any plant.

For rooted species, the plant height (height above the soil or sediment surface for upright or creeping forms) or blade length of the longest blades (recumbent forms such as *Zostera* spp.) were recorded. All vegetation was cut at the sediment surface, sorted by species, and placed in plastic zipper-type bags for later determination of dry weight (grams dry weight) of biomass in the lab.

Sediment chemistry quadrat: See “Sediment samples for laboratory analyses” section below.

Infauna quadrat: See “Benthic infauna” section below. Prior to the taking of the infauna sample, the percent plant cover by species in the infauna quadrat was estimated.

Plant transect: A meter tape was placed on the sediment, parallel to shore and centered on the center of the 1-m^2 quadrat, to delineate a 5-m plant transect. At each of 25 random points along the tape, the plant species and cover (or bare) were recorded. The 25 random points were generated prior to the beginning of the field season, independently for each station, using the random sample selection routine in Minitab version 13.

Hydrographic Profile (2000, 2003)

Continuous water column profiles of salinity, temperature, dissolved oxygen (DO), transmissivity (2003 only), and photosynthetically active radiation (2000 only) were acquired at each site with a Sea Bird Electronics conductivity-temperature-depth (CTD) profiler and attached sensors (Table 3). In 2000, the CTD was an SBE-25 Seacat. Data were stored in the unit and downloaded after sampling. The CTD in 2003 was an SBE 9Plus with an 11Plus deck unit to provide real-time data.

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 0.25 meters per second (m/s). The CTD was held near the seabed for 1 minute, then recovered at approximately 0.25 m/s. (In 2003, the downcast and upcast velocities were 0.8 m/s.) To prevent the equipment from hitting the seabed due to wave motion, the maximum depth to which the CTD was lowered was generally 1-3 m above the bottom in 2000 (bottom depth determined by the vessel's depth-sounder) and about 3-8 m above the bottom in 2003.

During processing of the CTD data, data were averaged for every 0.5 m. Although continuous profiles were captured, only near-surface and bottom results are presented in this report. Due to wave motion and instrument configuration making it difficult to measure some parameters close to the surface of the water, the shallowest depths for which the CTD data are usable are in the range of 0.5-3.5 m in 2000 and 1.5-8.5 m in 2003. Because all but one station in 2000 had CTD measurements at 1 m depth, the 1-m results will be used for consistency. All but three stations in 2003 had CTD measurements at 5 m depth, so the 5-m results will be presented.

Table 3. Hydrographic profile measurements, 2000 and 2003.

Parameter	Measurement	Source
Salinity	S,B*	Derived from conductivity (CTD)
Temperature	S,B*	CTD
Density	S,B	Derived from temperature and salinity
Density stratification	--	Derived from surface and bottom densities
Dissolved oxygen	S,B*	Beckman sensor (2000); Sea Bird Electronics SBE-43 sensor (2003)
Chlorophyll-*a* fluorescence	S,B*	Wet Labs WetStar fluorometer
Submerged PAR (2000 only)	S,M,B	Li-Cor PAR LI-93SA sensor
Terrestrial PAR (2000 only)	with SubPAR	Li-Cor PAR LI-190SA sensor
Percent of Terrestrial PAR (2000 only)	S	Derived from PAR measurements
Mean light-extinction coefficient (2000 only)	mean	Derived from PAR measurements
Secchi depth (2000 only)	S	Secchi disk
Transmissivity (2003 only)	S,B*	Wet Labs C-Star transmissometer

* = continuous depth profiles, 0.5-m bins; only near-surface (1 m for 2000, 5 m for 2003) and bottom presented. S = near-surface, M = mid-water, B = bottom.

Light Attenuation – PAR (2000 only)

Two sensors 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 the CTD.

The terrestrial PAR (TerPAR) data were collected with a Li-Cor LI-1400 datalogger set in instantaneous mode. Readings were transcribed by hand from the datalogger's display to the field logs when the CTD was at the bottom and at mid and surface depths as the CTD ascended through the water column. (The continuous TerPAR recordings were not kept.) The submerged PAR (SubPAR) data were recorded in the CTD datalogger and retrieved during the processing of the CTD data.

The light-extinction coefficient was calculated from the bottom PAR measurements, using the Beer-Lambert equation: $K_d = \ln(I_0/I_z) / z$, where z is the depth, I_z is the submerged PAR measurement at that depth, and I_0 is the coincident terrestrial PAR measurement.

Secchi Depth (2000 only)

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 the Secchi depth.

Some researchers use Secchi depth to estimate the light-extinction coefficient, dividing an empirically-derived constant by the Secchi depth. For Puget Sound, the constant used is 1.6 (Newton et al., 2002): k (1/m) $\approx$ 1.6/Secchi depth. In this study, there was modest agreement between this empirical estimate and the light-extinction coefficient derived by the Beer-Lambert equation, excluding the outlier which was a Secchi depth of 0.5 m obtained in the Puyallup River plume (Deming regression $k_{Secchi} = 0.08 + 0.73\ k_{bottom\ PAR}$, constant and slope P-values both = 0.10). The empirical method provides a means of estimating the light-extinction coefficient when the bottom PAR measurement (I_z) is zero.

Water Samples for Laboratory Analyses (2000, 2003)

Samples for analyses of dissolved nutrients (ammonium, nitrite, nitrate, orthophosphate, and silicic acid), chlorophyll-*a* concentration, pH (2003 only), total suspended solids, and dissolved oxygen were taken at each site with 1.5-L Niskin bottles mounted to a rosette attached to the CTD and triggered by an automatic firing mechanism (AFM). Samples were taken in separate Niskin bottles when the CTD was stopped near the bottom and, during the CTD's ascent, mid-way through the water column, and near the surface (nominally 1.0 m depth). Due to wave motion on the ship in 2003, "surface" samples were taken from 1.5 to 9 m deep. The AFM was programmed to take "bottom" samples at the deepest depth to which the CTD was lowered.

Dissolved Oxygen (DO)

As a check on the accuracy of the Beckman DO sensor deployed on the CTD, Winkler titrations were performed on water samples taken each day at randomly-chosen stations. In 2000, a single bottom sample was analyzed each day. In 2003, Winkler titrations were performed for either surface/mid-water/bottom or just bottom, for every few stations, at a minimum of two sets of titrations per day.

Samples for DO determination were collected first, as soon as the CTD rosette was placed back on the deck. A piece of ¼ inch (inside diameter) Tygon tubing was attached to the stopcock valve on the Niskin bottle. (Tygon tubing was kept saturated in de-ionized (DI) water between uses.) The end of the Tygon tubing was inserted into an inverted 300-ml biological oxygen demand (BOD) bottle, and the BOD bottle was rinsed thoroughly. With the BOD sample bottle upright and the free end of the Tygon tubing placed into the bottom corner, water from the Niskin bottle was allowed to overflow three times the volume of the sample container, flushing out any residual air bubbles. First a 1-ml powder pillow of alkali-iodide-azide, then a 1-ml powder pillow of manganous sulfate were added to the BOD bottle.

The glass stopper was placed carefully in the top of the bottle to keep from getting air bubbles in the sample and then twisted gently but firmly to seal the bottle. The sample bottle was inverted to homogenize the reagents throughout the sample. Finally, deionized water was squirted around the top of the stopper as a seal.

The sample bottles were wrapped immediately in aluminum foil and kept in dark and cool conditions until transported to the laboratory for analysis. In 2003, samples were analyzed in the shipboard lab.

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. In 2000, the tubes were placed on ice until they could be stored in a freezer at the end of the day. In 2003, the tubes were placed in the freezer immediately on board the ship. The frozen samples were stored in the dark until delivery to the laboratory (as soon as possible after acquisition).

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. The filtrate was collected in pre-cleaned, 60-ml polyethylene sample bottles. In 2000, the samples were placed on ice, then frozen until delivery to the laboratory. In 2003, the samples were frozen immediately on board the ship.

Total Suspended Solids (TSS)

One sample for TSS analysis was taken from the Niskin bottle for each sampled depth. TSS samples were collected in pre-cleaned polyethylene bottles (1-L in 2000, two 500-ml in 2003). The samples were then chilled at 4°C until delivery to the laboratory (within seven days of acquisition).

pH (2003 only)

One sample for measurement of pH was taken from the Niskin bottle for each tested depth (surface/mid-water/bottom). Samples were collected in pre-cleaned polyethylene bottles. The samples were taken immediately to the shipboard laboratory for analysis.

Sediment Samples for Laboratory Analyses

Sediment samples were taken for grain size characterization, TOC and chemical analyses, and toxicity testing. Field replicates were taken at approximately 10% of the sample stations.

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. In PSAMP/NOAA, the decontamination procedure included an additional acetone rinse after the Liquinox scrub and seawater rinse.

Sediment was collected with a double stainless steel van Veen sampler (0.1-m^2 surface area in each half) in 2000 and 2003. In 2002, sediment was collected directly from the quadrat surface.

Upon recovery of each grab (2000, 2003), 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 or a polyethylene scoop (using a new scoop for each sample station).

Sediment from multiple grabs was composited to collect about six liters of sediment. The number of grabs required depended on the sediment characteristics and seabed density. Once adequate sediment was collected, it was homogenized in the bucket by thorough stirring. Certified pre-cleaned sample containers for toxicity and chemical analyses were filled, then held at 4°C until delivery to the labs.

Benthic Infauna

Single sediment samples for analysis of benthic infauna were collected at each station. In 2000 and 2003, the sediment was collected in one side of a double stainless steel van Veen sampler, 0.1-m^2 surface area. The sampling equipment and procedures in 2002 were designed to approximate the surface area and volume of sediment collected with a van Veen grab. Sediment was collected by four grabs 10 cm deep with an aluminum sampler resembling a post-hole digger, which had a surface area of 0.0225 m^2, for a total area of 0.09 m^2. When the sediment was too sandy to use the post-hole sampler, the sampler was used to mark the surface of the sediment, which was then dug with a shovel to the same depth as a sampler grab (10 cm). The total surface area for a sample taken in that manner was 0.1184 m^2 (larger because it was based on the external, instead of internal, dimensions of the sampler). Infauna sample abundances were normalized to 0.1 m^2.

The contents of the grab or sampler were sieved through nested 1.0-mm and 0.5-mm mesh sieves (no 0.5-mm mesh sieves were used in 2003) using *in-situ* seawater. In 2002, a 2000 gallon-per-hour bilge pump attached to a marine float was used to provide water for sieving. The material retained on each sieve was placed into zipper-type plastic 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 two weeks of field collection. The 1.0-mm-sieve samples were shipped for sorting and taxonomic identification. The 0.5-mm-sieve samples (taken in only 2000 and 2002) were archived for future reference; results are not reported for those samples.

Fish (2000, 2003)

Fish were sampled by trawl in 2000 and by hook-and-line in 2003. In 2000, trawling was attempted at 67 of the 71 sample sites and completed successfully at 65 stations. Equipment problems hindered trawling at two stations. Three other stations were too deep to attempt trawling, and the presence of kelp prevented trawling at the remaining station (Appendix Table B-1). In 2003, fish samples were collected by hook-and-line. Fishing was successful at 21 stations, unsuccessful ("fish not biting") at 15 stations, and hindered at 14 stations (11 stations too deep to fish by hook-and-line, current too strong at 2 stations, sea too rough at 1 station) (Appendix Table B-3).

Fish trawls (2000) were conducted by NOAA NMFS personnel. The trawl used on the deep-station cruise (*F/V Chasina*) was an Eastern 400 (39-m footrope, 21-m headrope, 5-in mesh, 1-in mesh liner). On the shallow-station cruise (*R/V Harold W. Streeter*), a high-rise SCCWRP trawl was used (36-ft footrope, 34-ft headrope, 64-in open height, 1.5-in mesh, 1.25-in cod end mesh). Trawling was conducted at approximately 2 knots along a straight line centered on the site location. Trawl duration was usually 10 minutes per tow, but ranged from 3 to 18 minutes, depending on seabed conditions. Trawl speed was generally slightly faster, and trawl duration generally shorter, on the *Chasina* than on the *Streeter*.

All fish were sorted by species and measured (fork length or total length, as appropriate) and visually inspected for abnormalities. Fish not kept for histological analyses or tissue chemistry analyses were returned to the water as quickly as possible, to minimize mortality.

Several species of demersal fish which are ubiquitous on the West Coast were targeted for analysis of chemical contaminants in whole-body tissue, the primary species being English sole (*Parophrys vetulus*). In the absence of English sole, other common flatfish or bottom-dwelling fish were kept for analyses. 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 five fish to incorporate some statistical variability.

Up to four trawls were conducted at each station (2000) in order to acquire adequate specimens for fish-tissue contaminant analyses, though most stations needed only a single trawl. In 2000, no fish were caught at one of the 65 stations trawled, no target fish species were caught at two stations, and five other stations had insufficient fish of target species for chemical analysis. At all stations fished successfully in 2003, Pacific sanddab (*Citharichthys sordidus*) were caught. At most stations the EMAP-suggested number of five fish of a species for tissue composites was caught.

The fish kept for tissue analyses 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. In 2000, 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. In 2003, the fish were frozen immediately on board the ship.

Fish Species and Abundance (2000 only)

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 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 Northwest Fisheries Science Center) for analysis. A separate fish pathology report is to be prepared by NOAA.

No pathologies were found on any of the fish caught by hook-and-line in 2003.

Epibenthic Invertebrates (2000 only)

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

Laboratory Analysis Procedures

The laboratory analytical methods are specified in the NCA QAPP (U.S. EPA, 2001a), the PSAMP/NOAA QAPP (Dutch et al., 1998), PSEP protocols (PSEP, 1986, 1987, 1995, 1996b, 1996c), and in the individual laboratories' Standard Operating Procedures, which are stored as metadata in the NCA databases. Brief descriptions of laboratory procedures, including QA/QC, are given below.

Hydrographic Profile

CTD files were processed with Seasoft software versions 4.015 (2000 data) and 5.28f (2003 data) provided by Sea Bird Electronics, the CTD manufacturer, following methods prescribed by Sea Bird (Sea-Bird Electronics, Inc., 2002, 2003).

Laboratory Analyses of Water Samples

Total Suspended Solids (TSS)

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

In the laboratory, 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

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 then run with each batch.

pH (2003 only)

In the shipboard laboratory, water was decanted from the polyethylene bottle into a beaker. A Denver Instrument AP5 pH meter probe was placed in the water to measure the pH.

Dissolved Oxygen (DO)

In the field laboratory, DO concentrations were determined by Winkler titration (APHA et al., 1989; Hach, 1989).

Sediment Characteristics

Grain Size

The sieve-pipette method specified in the PSEP protocol (PSEP, 1986) was used to determine particle size distribution. The analyses were performed by Columbia Analytical Systems in 1997 (PSAMP/NOAA), Hart Crowser in 1998 (PSAMP/NOAA), and the Rosa Environmental and Geotechnical Laboratory from 1999 on (PSAMP/NOAA and EMAP). 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 NCA QAPP (U.S. EPA, 2001a), 10% of EMAP samples were analyzed in triplicate, with a limit of no more than 10% deviation amongst the replicates. In addition, Rosa Laboratory internal quality control checks required a limit of no more than 5% deviation from 100% in summed grain size percentages.

Total Organic Content (TOC)

Sediment TOC analyses were performed by the Manchester Environmental Laboratory. The PSAMP/NOAA and EMAP 2000 samples were analyzed according to the PSEP protocol (PSEP, 1986). A modification of the PSEP protocol for EMAP (PSEP-TOCM), in which samples are dried at 104°C instead of 70°C, was used for EMAP 1999-2003 samples and 1999 PSAMP/ NOAA samples. In addition, in 2002 total carbon was reported from the CHN analyses performed by the Marine Science Institute (MSI) at the University of California - Santa Barbara (see “Sediment nutrients” section below).

Samples for TOC analyses were frozen upon receipt by the Manchester Laboratory, and all analyses were performed within the holding times specified by the NCA QAPP (U.S. EPA, 2001a), PSAMP/NOAA QAPP (Dutch et al., 1998), or PSEP protocol (PSEP, 1986).

The Manchester Laboratory performed QA/QC checks as specified by the NCA QAPP (U.S. EPA, 2001a), PSEP protocol, or PSAMP/NOAA QAPP (Dutch et al., 1998). The QA/QC included 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.

Sediment Nutrients (2002 only)

Sediment samples were analyzed for nutrients by two analyses. The Marine Science Institute at the University of California - Santa Barbara performed CHN analyses (Dumas method), yielding percentages of total carbon, total nitrogen, and total hydrogen, and a carbon:nitrogen ratio. Total phosphorus was determined by inductively coupled plasma-atomic emission spectrophotometry (ICPAES) analysis by the Department of Natural Resources lab at the University of California – Davis.

Sediment Chemistry

Sediment chemistry analyses for EMAP and PSAMP/NOAA were performed by the Manchester Environmental Laboratory. Only the results for the EMAP-required analytes are presented in this report. Table 4 lists EMAP target analytes and the analytical methods used. The analytical methods, holding times, and QA/QC for EMAP and PSAMP/NOAA samples were those specified in the NCA QAPP (U.S. EPA, 2001a), PSAMP/NOAA QAPP (Dutch et al., 1998), and PSEP protocols (PSEP, 1996b, 1996c, 1997).

Samples for organics analyses were frozen upon receipt by the lab, and all analyses were performed within the required holding times. All mercury analyses were performed on non-frozen sediment within the 28-day holding time specified by PSEP (1996b) (*vs.* 1 year frozen, as specified 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 or PSEP protocols.

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 Table A-1. The methods are the same for all compounds within a class.

Parameter	Analytical Methods			
	Sediment		Fish Tissue	
	Manchester Lab, 1997-2000	Manchester Lab, 2002, 2003	Manchester Lab, 2000	GPL Labs, 2003
Metals*				
Aluminum**; Iron; Manganese (sed. only)	EPA200.7/SW6010	SW6010 (ICPAES)	EPA200.7 (ICPAES)	SW6010B (ICPMS)
Antimony (sediment only)	EPA204.2 (97,98,00); EPA200.8 (98,99)	EPA200.8 (ICPMS)	--	--
Arsenic	EPA206.2 (GFAA)	EPA206.2 (GFAA)	SW7060 (GFAA)	SW6010B (ICPMS)
Cadmium	EPA200.7/SW6010 (97,98); EPA200.8 (98,99); EPA213.2 (00)	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)	SW6010B (ICPMS)
Chromium, Zinc	EPA200.7/SW6010	SW6010 (ICPAES)	EPA200.8 (ICPMS)	SW6010B (ICPMS)
Copper	EPA200.7/SW6010 (97-00); EPA200.8 (99)	SW6010 (ICPAES)	EPA200.8 (ICPMS)	SW6010B (ICPMS)
Lead	EPA239.2 (97,00); EPA200.8 (98,99); EPA200.7/SW6010 (98)	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)	SW6010B (ICPMS)
Mercury	EPA245.5 (CVAA)	EPA245.5 (CVAA)	EPA245.5 (CVAA)	EPA245.5 (CVAA)
Nickel	EPA200.7/SW6010 (97,98,00); EPA200.8 (99)	SW6010 (ICPAES)	EPA200.8 (ICPMS)	SW6010B (ICPMS)
Selenium	EPA270.2 (GFAA)	EPA270.2 (GFAA)	SW7740 (GFAA)	SW6010B (ICPMS)
Silver	EPA200.7/SW6010 (97,98); EPA200.8 (99); EPA272.2 (00)	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)	SW6010B (ICPMS)
Tin	EPA282.2 (97,98,00); EPA200.8 (98,99)	EPA200.8 (ICPMS)	EPA200.8 (ICPMS)	SW6010B (ICPMS)
Chlorinated Pesticides, including DDT (20)	SW8081 (GCECD)	SW8081 (GCECD)	SW8081/8082 (GCECD)	SW8081A (GCECD)
PCB Congeners (21)	SW8081 (GCECD)	SW8081 (GCECD)	SW8081/8082 (GCECD)	SW8082A (GCECD)
PAHs (22) – sediment only except in 2003	SW8270 (GCMS)	SW8270 (GCMS)	--	SW8270C (GCMS)

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

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

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

The laboratory QA/QC included 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 databases.

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.

Sediment Toxicity (2000, 2002)

Amphipod Survival Test (2000 only)

The Marine Pollution Studies Laboratory of the University of California - Davis conducted amphipod survival tests using *Ampelisca abdita* on sediment samples from the 2000 EMAP-only stations, following procedures detailed in U.S. EPA (1994) and U.S. EPA (1995). Science Applications International Corporation conducted amphipod survival tests (*Ampelisca abdita*) on PSAMP/NOAA sediment samples, following ASTM (1993) protocol (SAIC, 1997, 1998, 2000).

Sediment samples were stored at 4°C and then shipped on ice within 7 days to the laboratories by overnight courier. Upon arrival, each sample was inspected to ensure that it was within acceptable temperature limits and then stored at 4°C until testing was initiated. Testing was begun within 14 days of the sample collection date.

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 urchins *Strongylocentrotus purpuratus* (PSAMP/NOAA, EMAP 2002) or *Arbacia punctulata* (EMAP 2000), following the methods of Carr and Chapman (1995), Carr et al. (1996a,b), Carr (1998), and USGS SOPs F10.6 and F10.7 (USGS, 2001). The methods and results of the urchin fertilization and embryo-development tests are described in separate reports (USGS, 2001, 2003a).

Sediment samples were stored at 4°C and then shipped on ice within 7 days to the laboratory by overnight courier. Upon arrival at the laboratory, 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).

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 Analyses (2000, 2003)

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. In 2000, 3 to 55 fish were combined into a composite sample. In 2003, 1 to 5 fish were composited in each sample.

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, the implements were rinsed with pesticide-grade acetone, dried in a fume hood, rinsed with hexane, and dried again.

In 2000, tissue samples from 57 stations were sent to the Manchester Environmental Laboratory for analysis of organic and metal contaminant concentrations. Fifty-four samples from 49 (2000) stations were sent to the USGS Columbia Environmental Research Center for H4IIE analysis. Both tissue chemistry and H4IIE analyses were conducted on samples from 48 stations (Appendix Table D-1). The majority of the 2000 tissue samples were from English sole.

In 2003, Pacific sanddab samples from all 21 sites fished, plus the additional fish species samples taken at three of those stations, were sent to GPL Labs for analysis of organic and metal contaminant concentrations.

Tissue Chemistry

Manchester Laboratory determined wet/dry weight ratio (% moisture), lipid content, and contaminant concentrations for each of the composited EMAP 2000 samples. The target analytes and analytical methods are listed in Table 4. Aluminum values were qualified as estimated because fish were wrapped and frozen in aluminum foil prior to processing. Except in 2003, PAHs were not measured in fish tissues due to their rapid metabolism in vertebrates.

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.

The analytical methods used by GPL Labs on the fish-tissue samples from 2003 are listed in Table 4.

H4IIE Bioassay (2000 only)

The USGS Columbia Environmental Research Center conducted H4IIE bioassays on ground whole-body tissues of 62 samples from 49 stations. 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, 2003b).

Samples were shipped overnight to the laboratory, at which time the samples were refrozen at -80°C until processed for extraction. The methods and results of the H4IIE test are described in a separate report (USGS, 2003b) and are not included in this report.

Benthic Infauna

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.

Because a few of the 1.0-mm-sieve infauna samples in 2002 were so voluminous as to be impractical to sort, those samples were subsampled using a procedure modified from Harrington and Born (1999; see Lazorchak et al., 1999). All of the sieved material in a sample to be subsampled was placed in a large, flat photographic tray marked into four equal-sized quadrats. The sample was gently agitated until equally distributed across the tray. Most of the alcohol was then drawn off the sample by suctioning with a turkey baster from the center of the tray, until the sample was immobile within the tray. Animals that were drawn up with the alcohol were caught on a screen guard and returned to the center of the tray. A flat plastic blade was used to draw the sample in from the sides of a randomly selected quadrat until the sample was concentrated into the corner of the selected quadrat, away from the other three quadrats. This isolated portion of the entire sample was the one-quarter quantitative subsample.

The subsample was then sorted by standard sorting procedure. After thorough sorting of the one-quarter fraction was completed, the three-quarters faction was redistributed in the tray and inspected with a magnifying glass. Any taxa that were not represented in the one-quarter fraction were removed for a qualitative subsample of the remaining three-quarter sample. The remaining residues were archived.

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 Coastal EMAP-West.

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 were used to compute total numbers of individuals (abundance) and total number of species (species richness) per grab. 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.

Plant Biomass (2002 only)

Plant material collected at the sites was dried to constant weight in a Cenco 95379 drying oven at 80 °C and then weighed.

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. Results from field replicates were averaged. The concentrations of individual PAH, PCB, and DDT compounds were summed to obtain the Total PAH, PCB, and DDT concentrations. Benthic infauna abundances were normalized to 0.1 m^2 prior to analyses.

Cumulative Distribution Function Analyses

Cumulative distribution functions (CDFs) with 95% confidence limits are presented for each indicator. Fiftieth and 90^{th} 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 5. 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.

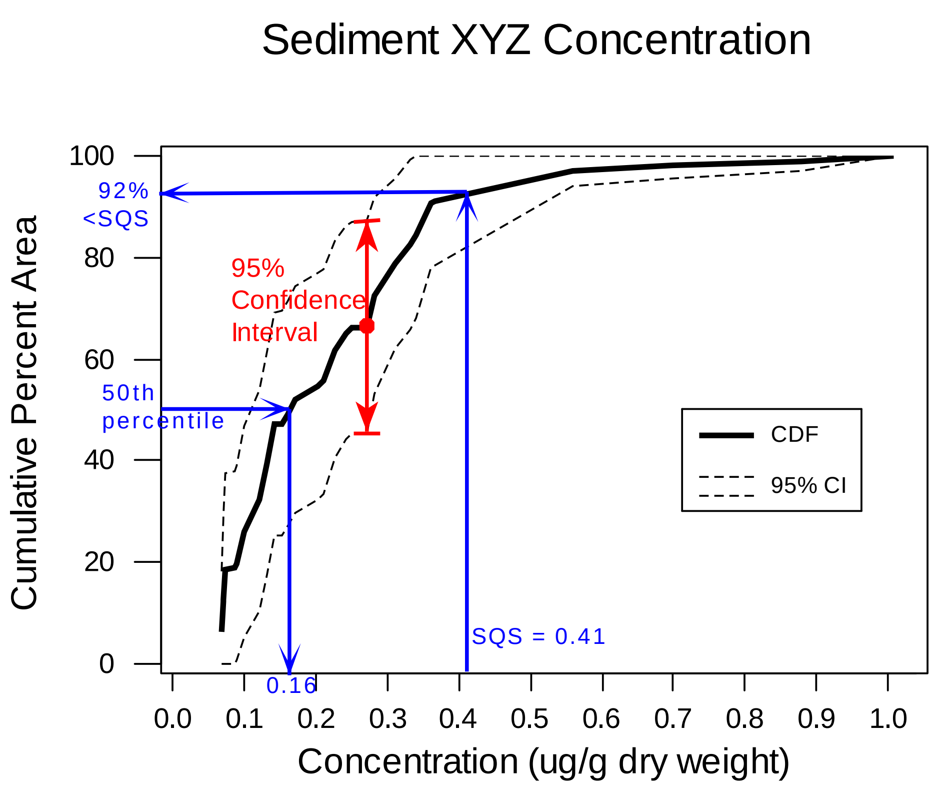


Figure 5. Sample cumulative distribution function (CDF) graph. The CDF indicates the percent area with a given indicator value or less. Dashed lines indicate the 95% confidence band (confidence interval, or CI) for the cumulative distribution function.

For the example in Figure 5, 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 that 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 the example in Figure 5, 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 slightly 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 10th and 50th 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 Coastal Water Research Project (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 (U.S. EPA, 2001a):

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 (2005, 2007a, 2007b) contains the QA review of the chemistry data for 2000, 2002, and 2003, respectively.

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 for storage in the national EMAP database and for data-transfers to other EPA databases, such as STORET. The national EMAP IM Coordinator, located at the Atlantic Ecology Division of EPA at Narragansett, Rhode Island, is the point of contact for data requests.

Results – 2000 (Puget Sound)

The results reported herein were analyzed in 2005-2006 with data extracted from the West Coast EMAP 2000 database version 4.05.10, with corrections approved by the Washington EMAP Information Management Coordinator. The corrections were incorporated into subsequent versions of the West Coast EMAP database.

Because sample sites for this study were selected randomly from the entire greater Puget Sound area, few sites happened to fall in urban or industrial locations. Therefore, even though some of the EMAP 2000 sediment sample data were from the 1997-1999 PSAMP/NOAA survey, the overall EMAP results may not be consistent with those from the published PSAMP/NOAA reports (Long et al., 1999, 2000, 2002, 2003) because the PSAMP/NOAA study had a much higher sampling density in urban areas.

The Coastal EMAP survey of Puget Sound was designed to provide a broad assessment of condition based on one-time samples. In-depth and long-term assessments of the environmental conditions in Puget Sound are provided by targeted monitoring programs, in particular the Marine Water Quality Monitoring, Marine Sediment Monitoring, and WDFW Fish Program components of the Puget Sound Assessment and Monitoring Program (PSAMP, www.psp.wa.gov/our_work/science/psamp.htm).

Site Visits

During the 2000 sampling events, water quality samples were collected at all 71 stations, fish were captured at 64 of the 71 stations, and sediment/benthic infauna samples were taken at 19 of the 30 EMAP-only stations (Appendix Table B-1, Figure B-1). Sediment/infauna samples had been collected and processed from all of the 41 PSAMP/NOAA stations during 1997-1999. All parameters (water, sediment, fish) were sampled successfully at 57 stations. The following sections describe the results categorized as indicators of general habitat condition, abiotic/pollution exposure condition, and biotic condition.

Data Quality Objectives

Assessments of the sediment and tissue chemistry data for adherence to EPA's Data Quality Objectives (DQO; see U.S. EPA, 2001a) found the metals analyses (sediment and tissue) to have met the DQOs (Ozretich, 2005). The analyses of organic compounds, however, had difficulties meeting the DQOs for precision and therefore must be interpreted with caution (Ozretich, 2005).

General Habitat Condition Indicators

Water Characteristics

Hydrographic Profile

Because the minimum depths at which CTD data could be resolved were inconsistent, surface results are given for both the shallowest depths (mostly 0.5 m or 1 m) and 1-m depth. Bottom results represent measurements taken at the deepest depth to which the CTD was lowered, 0.5-5.0 m above the seafloor. Surface, 1 meter, and bottom results are summarized here for continuously-measured parameters (salinity, temperature, dissolved oxygen, and chlorophyll-*a* fluorescence) profiled by the CTD.

Density and Water Column Stratification

Water density is a function of salinity and temperature, and the difference between minimum and maximum densities indicates the degree of water-column stratification. The *Stratification Index* is calculated as the difference between the maximum and minimum densities. (Maximum density usually occurs at the bottom, minimum usually at the surface.) A stratification index less than 0.5 σ_t indicates well-mixed waters, whereas strongly stratified waters are indicated by a stratification index greater than 2 σ_t (Newton et al., 2002). Between 0.5 σ_t and 2 σ_t is intermediate.

Only 10.5% of the study area had stratification index values less than 0.5 σ_t , indicating well-mixed waters (Figure 6). About 59% of the area had stratification indices greater than 2 σ_t , indicating strongly stratified waters. The remaining 30.5% had intermediate stratification.

Dissolved Oxygen (DO)

No surface waters measured were hypoxic, defined for Coastal EMAP as DO < 5 mg/L (Table 6, Figure 7). The bottom waters were moderately hypoxic (DO 2-5 mg/L) in 35% of the study area and severely hypoxic (DO < 2 mg/L) in only 1.5% of the study area. A single site, Station 29 in Lynch Cove (Hood Canal), had bottom DO of 0.21 mg/L.

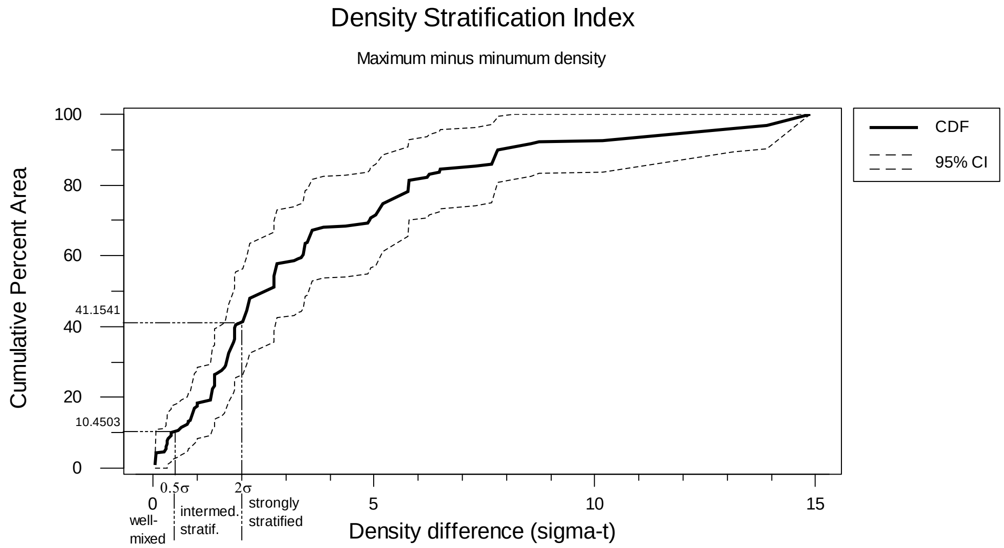


Figure 6. Cumulative percent area by water column density stratification index, indicating well-mixed and strongly stratified water.

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
Salinity (psu)	Surface	71	12.67	30.98	27.28	29.91
	1 meter	70	12.69	30.99	27.29	29.91
	Bottom	71	25.67	33.02	29.95	31.45
Water Temperature (°C)	Surface	71	10.73	19.97	14.16	18.35
	1 meter	70	10.69	19.69	13.84	18.28
	Bottom	71	8.08	17.89	10.24	12.45
Density (σ_t)	Surface	71	8.92	23.57	20.35	22.70
	1 meter	70	8.93	23.60	20.37	22.71
	Bottom	71	19.10	25.71	22.96	24.33
Density Stratification ($\Delta\sigma_t$)	Bottom-Surface	71	0.04	14.86	2.51	7.79
	Bottom-1 meter	70	0.045	14.84	2.56	7.67
	Maximum -Minimum	71	0.05	14.86	2.54	7.80
Dissolved Oxygen (mg/L)	Surface	71	5.54	11.20	7.60	9.20
	1 meter	70	5.53	11.12	7.39	9.33
	Bottom	71	0.21	8.55	5.31	7.49
Chlorophyll-*a* (measured by CTD fluorometer) (µg/L)	Surface	71	0.70	27.04	3.95	9.26
	1 meter	70	0.77	27.04	3.86	8.23
	Bottom	70	0.41	23.47	1.55	6.77

Bottom Dissolved Oxygen

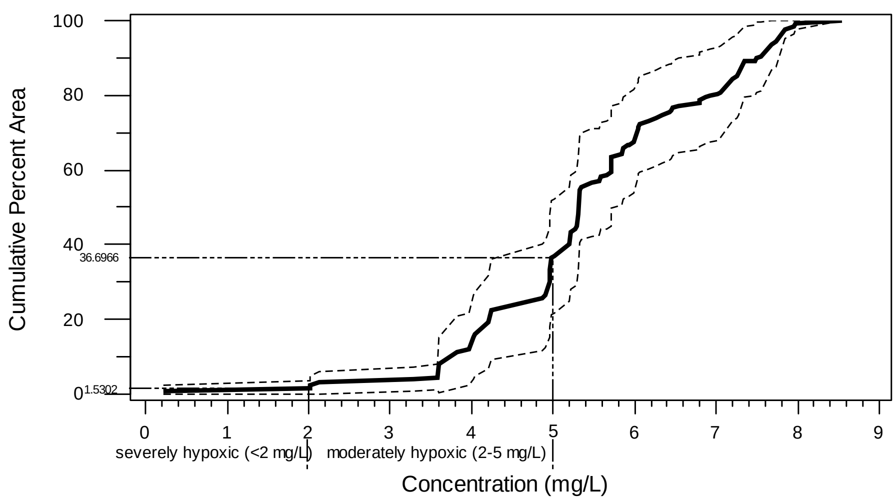


Figure 7. Cumulative percent area by dissolved oxygen concentration at the bottom.

Photosynthetically Active Radiation (PAR) and Water Clarity

Percent of TerPAR — The surface SubPAR/TerPAR ratio ranged from 0% to 235%. At 13 stations the ratio was over 100% (i.e., the terrestrial PAR reading was lower than the submerged PAR measurement). This suggests that the underwater and terrestrial PAR readings may not have been coincident or that something may have shadowed the in-air PAR sensor.

Secchi Depth — Secchi depths ranged from 0.5 m to 12.5 m (Table 7). The value of 0.5 m was from Station WA00-0040, in the Puyallup River plume. Fifty percent of the study area had Secchi depths of 5.1 m or less; 90% of the area had Secchi depths of 9 m or less. Station WA00-0040 represented approximately 1% of the area.

Light-Extinction Coefficient — All of the study area, including the station in the Puyallup River plume, had bottom light-extinction coefficients (calculated by Beer-Lambert) less than 1.387 m^{-1}, indicative of high water clarity (Newton et al., 2002) (Table 7, Figure 8). However, the light-extinction coefficient estimated from the Secchi depth at that station (1.6/0.5 m = 3.2 m^{-1}) would be indicative of low water clarity ($k > 2.303$ m^{-1}; Newton et al., 2002).

Table 7. Summary statistics for water-clarity parameters.

Parameter (units)	Calculation	Number of Stations	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Light-Extinction	$k = \ln(I_0/I_z) / z$	50	0.0166	0.8812	0.235	0.401
Coefficient K_d (m^{-1})	$k \approx 1.6$/Secchi depth	67	0.128	3.2*	0.30	0.544
Secchi Depth (m)		67	0.5*	12.5	5.13	9.02

* Outlier at Station WA00-0040, in the Puyallup River plume, where Secchi depth was 0.5 m. Without the outlier, the smallest Secchi depth was 2.3 m, and the highest estimated k was 0.696 m^{-1}.

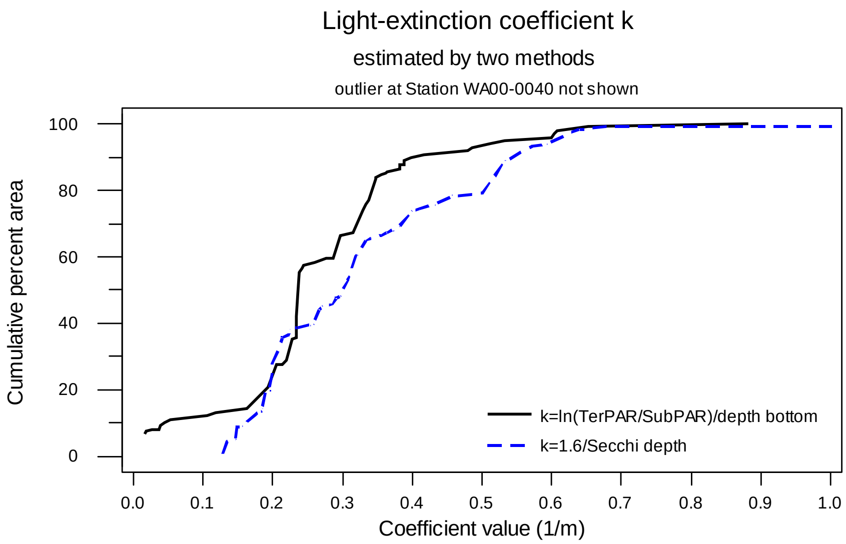


Figure 8. Cumulative percent area by water-column mean light-extinction coefficient k calculated from Beer-Lambert equation and estimated from Secchi depth. The scale has been truncated for visibility, and the outlier at Station WA00-0040 in the Puyallup River plume (3.2 m^{-1}) is not shown.

Laboratory Analyses of Water

Surface, mid-water, bottom, and mean results are presented for discrete water parameters (TSS, photosynthetic pigments, and dissolved nutrients) for all stations sampled. The surface and bottom depths are the same as for the CTD measurements.

Summary statistics for the results of water laboratory analyses are given in Table 8. The measured values and graphical summaries of the data are given in Appendix G in a separate volume.

Dissolved Nutrients

Ammonium (NH_4)

Although surface ammonium concentrations were all below 70 µg/L, the criterion for high levels of ammonium suggested by Newton et al. (2002), several mid-water and bottom ammonium concentrations were above 70 µg/L, with one concentration in the “very high” range of > 140 µg/L (Figure 9).

Bottom Dissolved Ammonium (NH4)

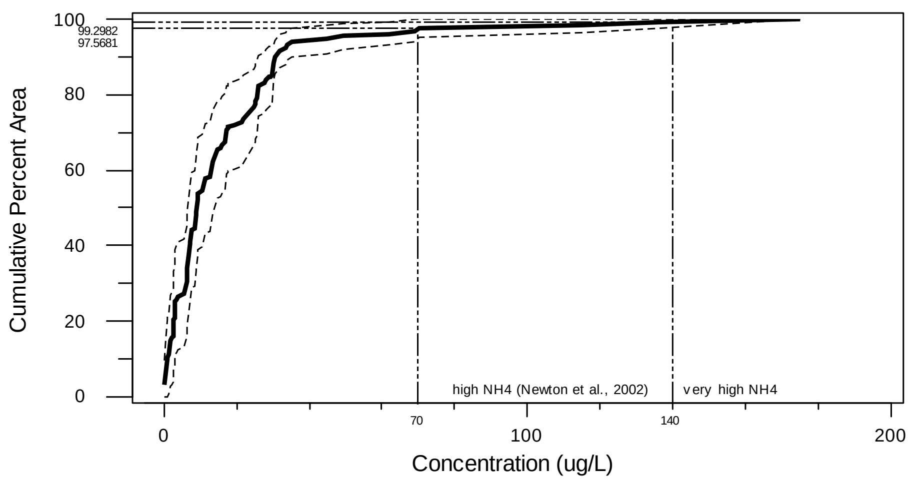


Figure 9. Cumulative percent area by dissolved ammonium (NH4) concentrations at the bottom.

Total Nitrogen, Total Phosphorus, Nitrogen:Phosphorus (N:P) Ratio

Surface total dissolved inorganic nitrogen (Total N = NH_4 + NO_2 + NO_3) was sufficient for marine algal growth in approximately 88% of the area (Figure 10). Approximately 12% of the area was potentially nitrogen-limited at the surface (< 1 µM; Newton et al., 2002). Mean Total N concentrations (average of surface, mid-water, and bottom) were above 1 µM at all but one station which represented about 3% of the area.

The only component of total dissolved inorganic phosphorus (Total P) was dissolved phosphate. The Total P concentrations were all above the minimum for algal growth (0.07 – 0.2 µM) used in Newton et al. (2002), with the exception of one non-detect in bottom Total P at one station.

Slightly over 75% of the area had a sufficient N:P ratio at the surface for algal growth (Newton et al., 2002). The surface N:P ratio was low in about 22% of the area (Figure 11). Averaged over the surface, mid-water, and bottom, the mean N:P ratio was sufficient in 91% of the area and low in about 9% of the area.

Surface Total N

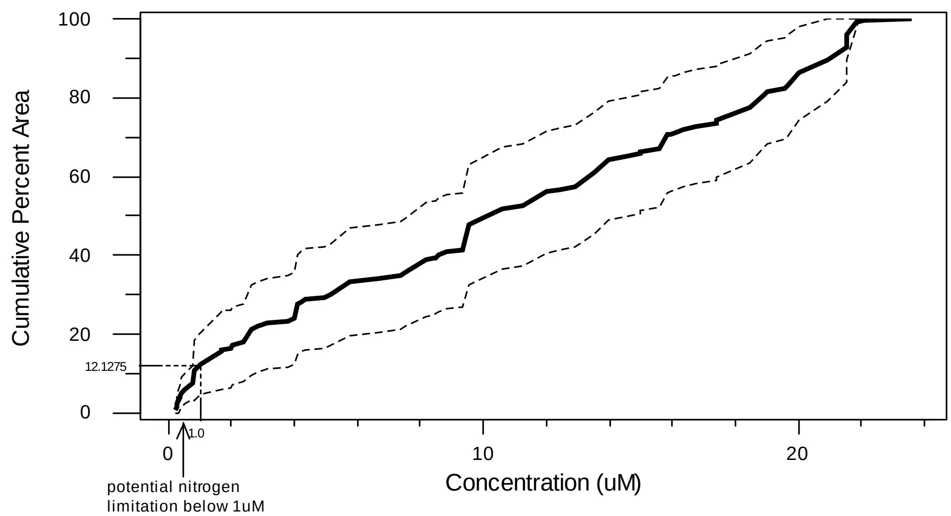


Figure 10. Cumulative percent area by total dissolved inorganic nitrogen at the surface.

Surface N:P Ratio

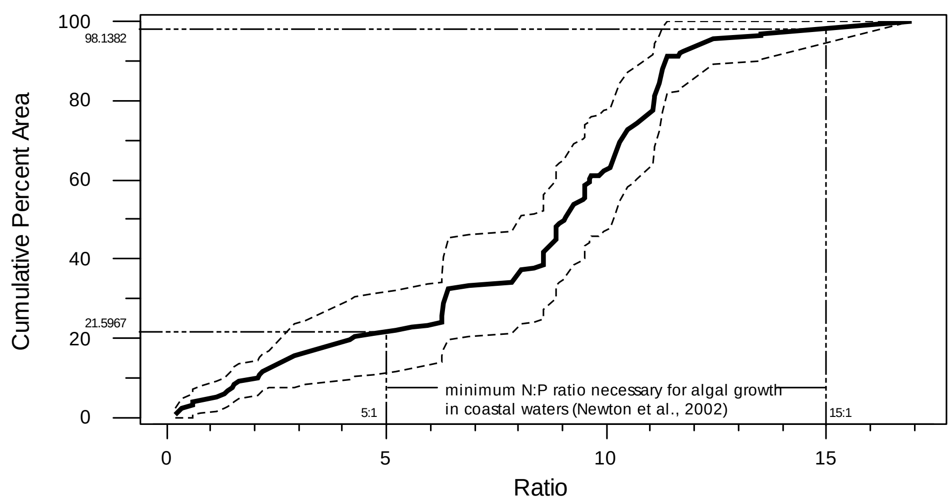


Figure 11. Cumulative percent area by molar nitrogen-to-phosphorus (N:P) ratio at the surface, indicating minimum N:P ratio range for algal growth in coastal areas (Newton et al., 2002).

Table 8. Summary statistics for TSS, photosynthetic pigments, and dissolved nutrients. The proportions of area 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
Total Suspended Solids (mg/L)	Surface	71	2.00	9.50	3.78	5.76
	Mid-water	70	2.00	9.00	3.75	5.56
	Bottom	71	2.00	11.50	4.55	7.72
	Mean	***71***	***2.33***	***8.67***	***4.55***	***5.92***
Chlorophyll-*a* (µg/L)	Surface	71	0.62	15.68	3.92	9.87
	Mid-water	70	0.06	19.32	1.63	5.78
	Bottom	71	0.04	16.92	1.24	6.34
	Mean	***71***	***0.29***	***15.11***	***2.85***	***6.73***
Phaeopigment (µg/L)	Surface	71	0.00	4.97	0.93	1.65
	Mid-water	70	0.06	4.67	1.06	1.89
	Bottom	71	0.00	4.42	1.40	2.62
	Mean	***71***	***0.31***	***4.01***	***1.18***	***1.91***
Dissolved Ammonium (µg/L)	Surface	71	0.00	56.74	6.64	18.18
	Mid-water	70	0.00	83.50	8.03	27.16
	Bottom	71	0.00	174.98	9.15	30.54
	Mean	***71***	***0.35***	***84.66***	***9.01***	***20.69***
Dissolved Nitrite (µg/L)	Surface	71	0.14	8.41	3.42	5.16
	Mid-water	70	0.00	12.33	3.98	5.04
	Bottom	71	0.00	14.15	4.10	5.46
	Mean	***71***	***0.23***	***10.79***	***3.80***	***5.39***
Dissolved Nitrate (µg/L)	Surface	71	2.66	315.79	136.84	281.17
	Mid-water	70	0.70	464.15	253.61	338.88
	Bottom	71	0.00	456.10	290.00	386.99
	Mean	***71***	***6.16***	***373.83***	***223.14***	***310.25***
Total Inorganic Nitrogen (µM)	Surface	71	0.22	23.59	10.09	20.97
	Mid-water	70	0.20	33.22	20.17	25.25
	Bottom	71	0.00	32.76	22.83	28.96
	Mean	***71***	***0.62***	***27.31***	***17.20***	***23.05***
Dissolved Inorganic Phosphate (µg/L)	Surface	71	5.26	104.37	41.94	62.75
	Mid-water	70	10.22	136.58	59.58	69.84
	Bottom	71	0.00	161.66	64.49	79.37
	Mean	***71***	***9.29***	***106.54***	***55.41***	***67.03***
Total Inorganic Phosphorus (µM)	Surface	71	0.17	3.37	1.35	2.02
	Mid-water	70	0.33	4.41	1.92	2.25
	Bottom	71	0.00	5.21	2.08	2.56
	Mean	***71***	***0.30***	***3.44***	***1.79***	***2.16***
Nitrogen: Phosphorus Ratio	Surface	71	0.20	16.94	9.04	11.36
	Mid-water	70	0.61	13.61	10.22	11.89
	Bottom	70	0.69	13.63	10.84	12.24
	Mean	***71***	***1.13***	***13.56***	***10.11***	***11.79***
Dissolved Silicic Acid (µg/L)	Surface	71	251.97	2996.36	1030.24	1295.11
	Mid-water	70	251.97	2644.95	1157.02	1364.84
	Bottom	71	116.29	3405.35	1273.71	1598.72
	Mean	***71***	***251.41***	***2169.58***	***1170.32***	***1365.19***

Sediment Characteristics

Sediment samples were collected at 60 stations, the 41 PSAMP/NOAA stations (in 1997-1999) and 19 of the 30 EMAP-only stations. The sections below present the results of analyses of the sediment grain size and organic carbon content; sediment chemistry and toxicity results are described in the following section on abiotic/pollution exposure condition indicators.

Silt-Clay Content (Grain Size Analysis)

Approximately 10% of the area has sandy sediment (< 20% silt-clay), approximately 46% of the area is composed of muds (> 80% silt-clay), and the remainder is intermediate (Table 9, Figure 12, Figure 13). On average, the predominant grain sizes are sand (47.9%) and silt (37%). Less than 2% of the sediments are gravel; the remainder is clay. The sands are almost all fine and very fine, according to the Wentworth classification (Figure 14).

Table 9. Summary statistics for sediment characteristics. Results are given for TOC analyzed by two methods: PSEP (1986), in which sediments are dried at 70 °C (all samples), and PSEP-TOCM, a modification for EMAP in which sediments are dried at 104 °C (1999-2000 samples only).

Statistic	Percent Fines (% silt-clay)	TOC (%) PSEP (1986)	TOC (%) PSEP-TOCM
Number of samples	60	60	38
Minimum	1.6	0.70	0.70
Maximum	94.3	4.48	4.50
CDF 50th Percentile	44.7	0.89	0.90
CDF 90th Percentile	85.4	2.14	2.33

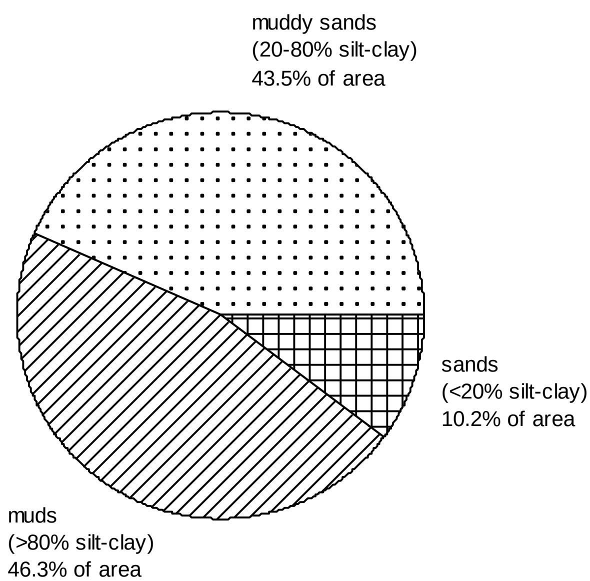


Figure 12. Distribution of sediment types in Puget Sound, weighted by area

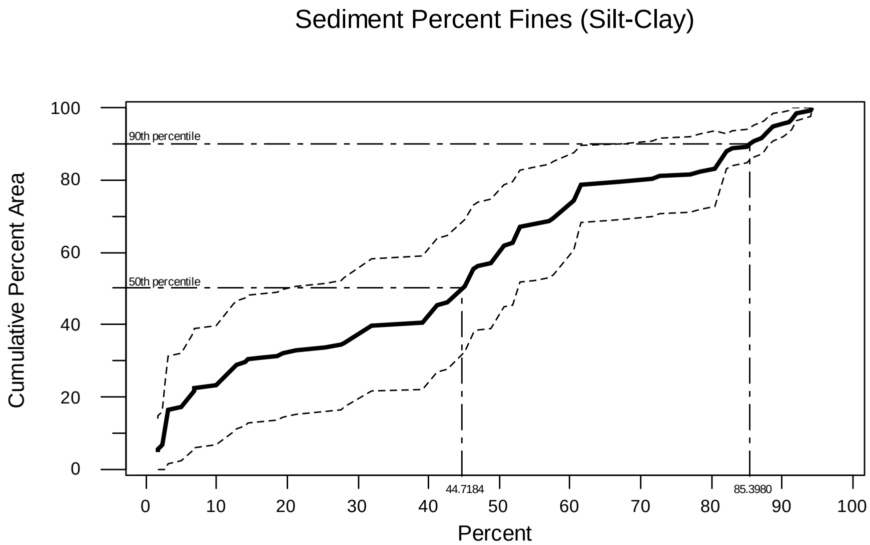


Figure 13. Cumulative percent area by silt-clay content of sediments.

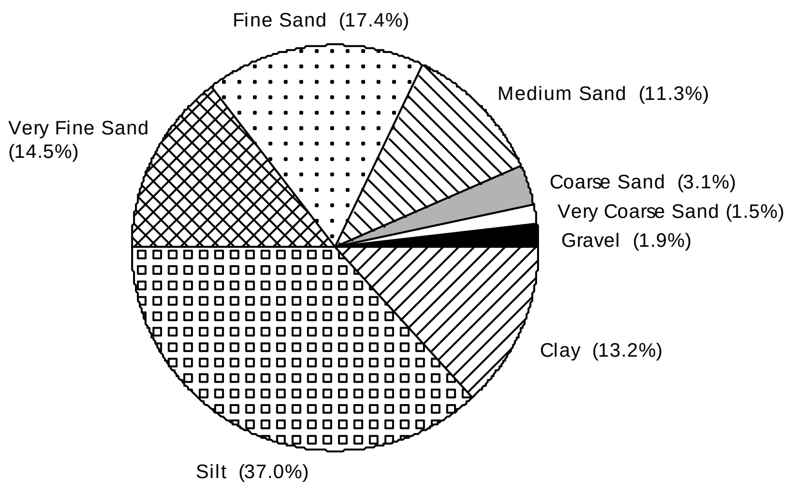


Figure 14. Average grain size (not weighted for differing inclusion probabilities) in Puget Sound, according to the Wentworth scale.

The PSAMP/NOAA stations had more silt and less sand than the sites sampled in the rest of the Puget Sound area (Figure 15; chi-quare test, 4 *df*, P-value < 0.0001). Sediment sampling was unsuccessful at 5 of the 10 San Juan Islands stations and 16 of the 30 other EMAP-only stations, indicating even larger grain sizes (cobble) and less soft sediments at those locations. (Sediment samples were collected at all PSAMP/NOAA stations, a few of which were alternates for unsamplable target stations at the time.)

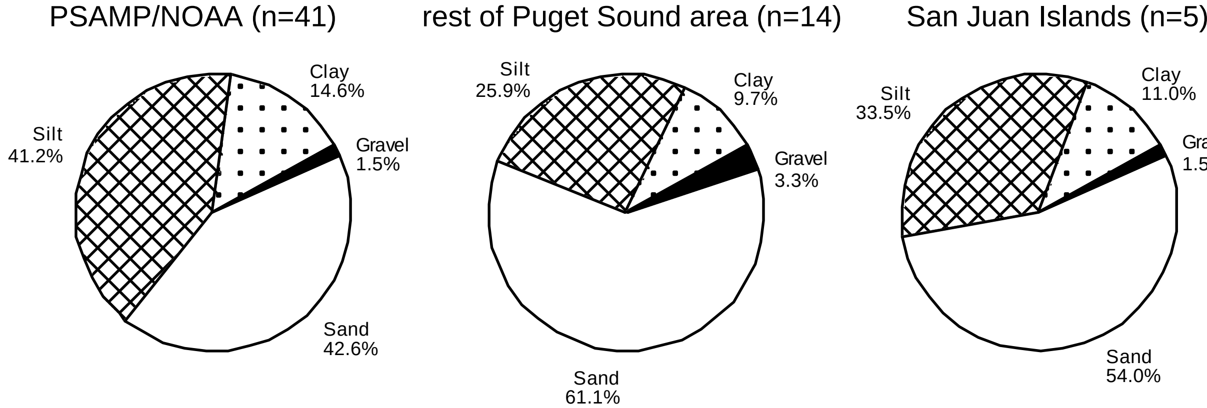


Figure 15. Grain size distribution by stratum.

Total Organic Carbon (TOC) Content

TOC content was under 5% everywhere, and 86% of the area had TOC content 2% or less (Table 9, Figure 16). Approximately 26% of the area had TOC content less than 0.5%, and less than 17% of the area had TOC content less than 0.2%.

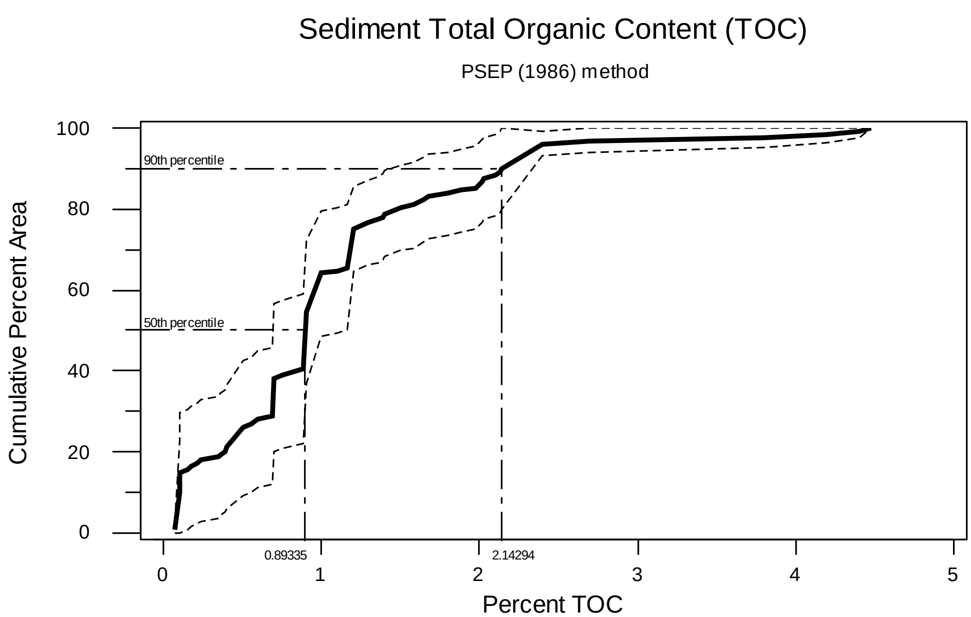


Figure 16. Cumulative percent area by sediment TOC.

The TOC content was lower in the "rest of Puget Sound" areas than in the PSAMP/NOAA areas, as indicated by non-overlapping confidence intervals for the medians in Figure 17. This result is consistent with the grain size results.

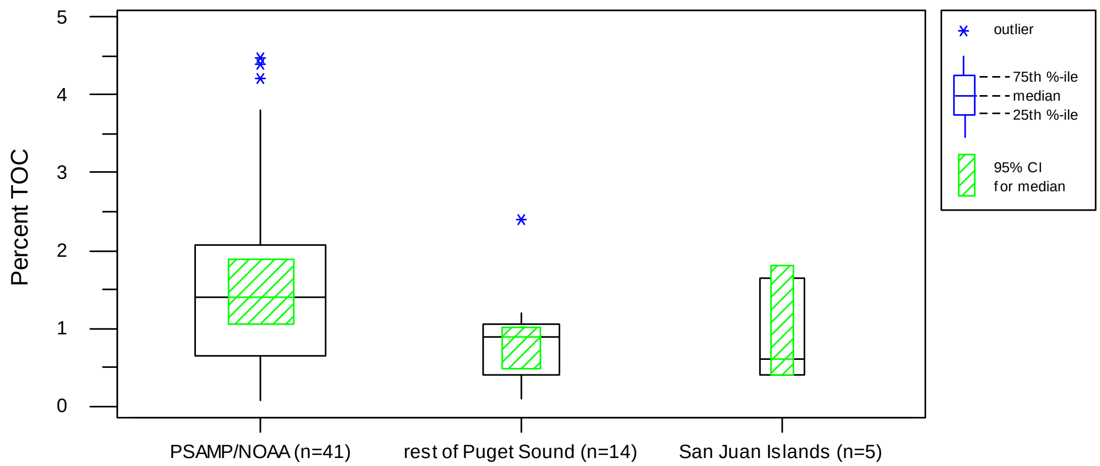


Figure 17. TOC by stratum. The widths of the boxplots are proportional to sample size.

Abiotic/Pollutant Exposure Condition Indicators

Sediment Contaminants

Metals

Nine metals were detected in all 60 sediment samples: aluminum, arsenic, chromium, copper, iron, lead, manganese, nickel, and zinc (Table 10). Tin was detected at all but one station, while mercury was detected all but two. Cadmium was detected at 42 stations. The other metals were detected at fewer than half of the stations.

Table 10. 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=60 stations)	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Aluminum	60	32800	95900	78084.3	93123.3
Antimony	29	0 (non-detect)	5.66	0.26	0.97
Arsenic	60	1.9	18.2	6.35	10.83
Cadmium	42	0 (non-detect)	2.09	0.059	0.364
Chromium	60	30	227	75.07	92.73
Copper	60	3.74	219	17.3	41.99
Iron	60	14900	126000	35835.8	39483.6
Lead	60	5.22	51.3	11.94	23.34
Manganese	60	296	3330	442.6	811.1
Mercury	58	0 (non-detect)	0.316	0.04066	0.1266
Nickel	60	9.8	100	24.09	40.97
Selenium	26	0 (non-detect)	1.75	0 (non-detect)	0.55
Silver	29	0 (non-detect)	2.1	0.03	0.31
Tin	59	0 (non-detect)	8.32	1.35	2.91
Zinc	60	25	225	73.3	102.2

Comparisons to Sediment Quality Standards and Guidelines for Metal Contaminants

None of the stations in this study had metals contaminant levels higher than the Washington State sediment quality standards (SQS and CSL) or the NOAA Effects Range-Median (ERM) sediment quality guideline. But 36 of the 60 stations sampled for sediment did exceed the NOAA Effects Range-Low (ERL) sediment quality guideline for one or more metals. One station (Station 33, Port of Olympia) exceeded the ERLs for 6 of 8 metals, and several other stations exceeded the ERLs for 5 of 8 metals. The ERL was frequently exceeded for arsenic, chromium, and copper, but rarely exceeded for lead (Table 11). Many of the stations exceeding the ERLs are in or near urban or industrialized areas.

Table 11. Comparisons of sediment metals concentrations to Washington State sediment quality standards (SQS, CSL) and NOAA sediment quality guidelines (ERL, ERM).

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	21.0	70	0	57	0	93	0
Cadmium	1.2	3.5	9.6	0	5.1	0	6.7	0
Chromium	81	36.4	370	0	260	0	270	0
Copper	34	20.1	270	0	390	0	390	0
Lead	46.7	0.4	218	0	450	0	530	0
Mercury	0.15	8.1	0.71	0	0.41	0	0.59	0
Silver	1	2.3	3.7	0	6.1	0	6.1	0
Zinc	150	1.2	410	0	410	0	960	0

Polynuclear Aromatic Hydrocarbons (PAHs)

Individual PAHs

PAHs were detected at all 60 stations analyzed, though not all PAH compounds were measured at all stations (Table 12).

Table 12. Summary of sediment individual and Total PAH concentrations (ng/g dry weight).

PAH Compound	Number of Detects (N=60 stations)	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
LPAHs					
1-Methylnaphthalene	56	0 (non-detect)	151	21.95	39.73
1-Methylphenanthrene	60	0.08	75	12.82	25.61
2,3,5-Trimethylnaphthalene	60	0.45	66	13.19	24.09
2,6-Dimethylnaphthalene	60	0.09	131	27.35	68.15
2-Methylnaphthalene	57	0 (non-detect)	250.5	28.27	51.89
Acenaphthene	55	0 (non-detect)	295	2.22	7.20
Acenaphthylene	59	0 (non-detect)	1190	1.70	15.48
Anthracene	59	0 (non-detect)	550.5	4.42	31.67
Biphenyl	56	0 (non-detect)	1780	5.65	13.50
Dibenzothiophene	55	0 (non-detect)	54.5	2.79	9.50
Fluorene	58	0 (non-detect)	405	9.37	20.34
Naphthalene	56	0 (non-detect)	3980	21.93	60.67
Phenanthrene	60	1.4	2030	46.58	123.67
Total LPAH	60	4.62	10666	129.41	951.30
HPAHs					
Benz(a)anthracene	60	0.26	666.5	8.02	68.48
Benzo(a)pyrene	59	0 (non-detect)	534	8.70	86.63
Benzo(b)fluoranthene	60	1.3	759	12.73	105.85
Benzo(g,h,i)perylene	54	0 (non-detect)	522	9.76	78.75
Benzo(k)fluoranthene	57	0 (non-detect)	448	8.78	57.99
Chrysene	58	0 (non-detect)	764	18.38	102.79
Dibenz(a,h)anthracene	56	0 (non-detect)	74	1.91	15.02
Fluoranthene	60	0.95	2210	25.77	179.78
Indeno(1,2,3-c,d)pyrene	59	0 (non-detect)	338	10.55	74.20
Pyrene	59	0 (non-detect)	2635	23.62	194.56
Total HPAH	60	6.11	7650	205.64	479.80
All					
Total PAH	60	17.505	18178	358.85	1503.21

Total PAHs

The largest Total LPAH, Total HPAH, and Total PAH concentrations occurred consistently in the same 11-12 urban bays and harbors, representing about 8-13% of the study area (Table 13).

Table 13. Locations with largest Total PAH concentrations, sorted in decreasing concentration order. The locations listed in the columns represent the stated proportions of the study area.

Total LPAH (8.4% of study area)	Total HPAH (13.1% of study area)	Total PAH (13.1% of study area)
Port Gamble Bay	Everett Harbor, middle	Port Gamble Bay
Everett Harbor, middle	Port Gamble Bay	Everett Harbor, middle
Port of Olympia	Duwamish River - East W'way	Duwamish River - East W'way
Duwamish River - East W'way	Port of Olympia	Port of Olympia
Bellingham Bay	Elliott Bay, northeast	Elliott Bay, northeast
S.E. Commencement Bay	Hylebos Waterway	Hylebos Waterway
Port of Shelton	Port of Shelton	Port of Shelton
Elliott Bay, northeast	Gig Harbor	Bellingham Bay
Hylebos Waterway	Bellingham Bay	S.E. Commencement Bay
Port Ludlow	S.E. Commencement Bay	Port Ludlow
Outside Elliott Bay	Gig Harbor	Gig Harbor
	Outside Elliott Bay	Outside Elliott Bay

Comparisons with Sediment Quality Standards and Guidelines

No stations exceeded the Washington State sediment quality standards (SQS or CSL) for PAH totals (Table 14). For Total LPAH, ten stations exceeded the NOAA ERL sediment quality guideline and two exceeded the ERM. Six stations exceeded the ERL for Total HPAH, and four exceeded the ERL for Total PAH. No stations exceeded the ERMs for either Total HPAH or Total PAH. All of the stations at which the sediment quality guidelines for PAH totals were exceeded are in urban bays.

Table 14. Comparisons of sediment Total PAH concentrations to Washington State sediment quality standards and NOAA sediment quality guidelines. Constituent compounds and treatment of non-detects for ERL/ERM and SQS/CSL Total PAH are specified in Appendix Table A-3.

PAH Total	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	7.4	3160	1.0	370	0	780	0
Total HPAH	1700	4.1	9600	0	960	0	5300	0
Total PAH	4022	2.6	44792	0	--	--	--	--

ERL = NOAA Effects Range-Low
ERM = NOAA Effects Range-Median
SQS = Washington State Sediment Quality Standard
CSL = Washington State Cleanup Screening Level

Polychlorinated Biphenyls (PCBs)

PCBs were detected at 20 of the 60 stations, representing 43% of the total study area (Table 15). Individual congeners were found at as few as one station (PCB110, PCB126) or as many as 19 stations (PCB153). Of the 21 PCB congeners, 18 were measured at one station, Station 71 in the central basin just outside Elliott Bay. Five stations had 14-15 congeners, and the remainder of stations at which PCBs were found had 1-8 congeners. The Total PCB concentration at Station 22 (Duwamish River – East Waterway) was one to three orders of magnitude greater than at any other station at which PCBs were detected.

Half of the locations where PCBs were detected are urban or industrial, but half are not.

Table 15. Summary statistics for sediment PCB concentrations (ng/g dry weight). Non-detects were set to zero and included in the statistical analyses.

PCB Congener	Number of Detects (N=60 stations)	CDF 90th Percentile (CDF 50th Percentile is non-detect)	Maximum (Minimum is non-detect)
PCB8	3	0.007	0.29
PCB18	3	0.005	0.61
PCB28	9	0.126	5.4
PCB44	7	0.103	11
PCB52	9	0.153	19
PCB66	9	0.241	4.4
PCB77	2	0 (non-detect)	0.7
PCB101	13	0.603	76
PCB105	8	0 (non-detect)	35
PCB110	1	0 (non-detect)	0.11
PCB118	13	0.374	5.3
PCB126	1	0 (non-detect)	1.3
PCB128	5	0 (non-detect)	14
PCB138	15	0.706	140
PCB153	19	0.770	210
PCB170	6	0 (non-detect)	110
PCB180	8	0.0294	190
PCB187	6	0 (non-detect)	100
PCB195	3	0 (non-detect)	18
PCB206	4	0 (non-detect)	14
PCB209	5	0 (non-detect)	23
Total PCB	20	2.831	934.7

Total DDT

Only 2,4'-DDD, 4,4'-DDD, and 4,4'-DDE were measurable (Table 16). One or more DDT isomers (most often 4,4'-DDE) were found at 12 stations, representing 16.9% of the study area. Almost all of the stations are in urban waters.

Other Chlorinated Pesticides

Of the pesticides tested, only four were detected, and at only one or two locations each: Alpha-Chlordane, Hexachlorobenzene, Lindane, and Trans-Nonachlor (Table 16). Hexachlorobenzene was analyzed by two methods, EPA SW8081 (GCMS) and EPA SW8270 (GCECD). The compound was not measurable by GCECD.

Table 16. Summary statistics for sediment pesticide concentrations (ng/g dry weight). Non-detects were set to zero and included in the statistical analyses.

Pesticide	Number of Detects (N=60 stations)	CDF 90th Percentile (CDF 50th Percentile is non-detect)	Maximum (Minimum is non-detect)
2,4'-DDD	1	0 (non-detect)	2.1
2,4'-DDE	0	0 (non-detect)	0 (non-detect)
2,4'-DDT	0	0 (non-detect)	0 (non-detect)
4,4'-DDD	5	0 (non-detect)	5.3
4,4'-DDE	10	0.377	6.7
4,4'-DDT	0	0 (non-detect)	0 (non-detect)
Total DDT	12	0.621	12
Aldrin	0	0 (non-detect)	0 (non-detect)
Alpha-Chlordane	2	0 (non-detect)	1.4
Dieldrin	0	0 (non-detect)	0 (non-detect)
Endosulfan I	0	0 (non-detect)	0 (non-detect)
Endosulfan II	0	0 (non-detect)	0 (non-detect)
Endosulfan Sulfate	0	0 (non-detect)	0 (non-detect)
Endrin	0	0 (non-detect)	0 (non-detect)
Heptachlor	0	0 (non-detect)	0 (non-detect)
Heptachlor Epoxide	0	0 (non-detect)	0 (non-detect)
Hexachlorobenzene	2	0 (non-detect)	20
Lindane (gamma-BHC)	1	0 (non-detect)	2.1
Mirex	0	0 (non-detect)	0 (non-detect)
Toxaphene	0	0 (non-detect)	0 (non-detect)
Trans-Nonachlor	1	0 (non-detect)	0.74

Comparisons with Sediment Quality Standards and Guidelines

One station, Station 22 in the Duwamish River, exceeded both the SQS and the ERM for Total PCB (Table 17). The total PCB concentration at that station was an order of magnitude higher than at any other station. Five stations (including Station 22), representing 4% of the study area, exceeded the NOAA ERL sediment quality guideline for Total PCB. The numbers of stations exceeding the ERLs for Total DDT and for 4,4'-DDE were 6 and 2, respectively, accounting for 4.6% and 1.5% of the study area. No stations exceeded the respective DDT ERMs. All of the stations at which the sediment quality guidelines or standards were exceeded are in urban bays.

Table 17. Comparisons of sediment DDT and PCB total concentrations to Washington State sediment quality standards and NOAA sediment quality guidelines.

Analyte	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 PCB	22.7	3.8	180	1.2	12	1.2	65	0
Total DDT	1.58	4.6	46.1	0	--	--	--	--
4,4'-DDE	2.2	1.5	27	0	--	--	--	--

Fish-Tissue Contaminants

Chemical analyses were performed on ground *whole* fish to gauge ecological exposure only. *The study was not designed to be extrapolated to fish for human consumption.*

Forty-three of the 57 samples analyzed for organic and metal contaminants were from English sole (Figure 18), so results are presented here for all fish tissue and for just English sole.

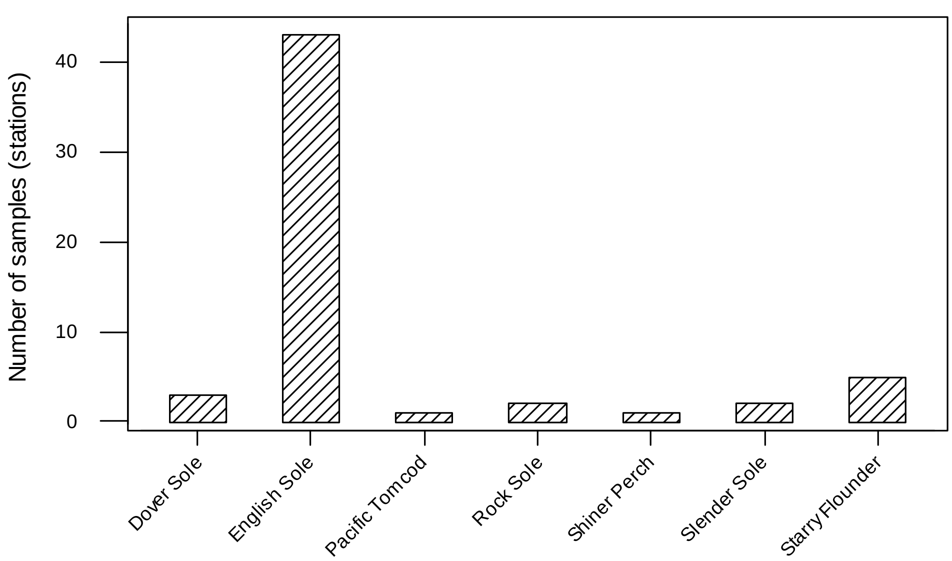


Figure 18. Species composition of fish-tissue chemistry samples.

Metal Residues

Aluminum and zinc were found in all 57 composited fish-tissue samples, whereas cadmium was measurable in only one sample (Table 18, Figure 19). Iron and tin were found in all but one sample, and selenium was measured in all but two samples. Mercury was found in 51 of the 57 samples. Arsenic and lead were measured in 46 samples. Chromium, copper, nickel, and silver were found in fewer than 10 samples.

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	Species	Number of Detects	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Aluminum	all	57 of 57	10	381	116.35	206.67
	English sole	43 of 43	17	381	126.24	217.57
Arsenic	all	46 of 57	0 (non-detect)	20.2	2.76	4.92
	English sole	39 of 43	0 (non-detect)	20.2	2.9	4.74
Cadmium	all	1 of 57	0 (non-detect)	0.11	0 (non-detect)	0 (non-detect)
	English sole	1 of 43	0 (non-detect)	0.11	0 (non-detect)	0 (non-detect)
Chromium	all	8 of 57	0 (non-detect)	4.6	0 (non-detect)	1.41
	English sole	6 of 43	0 (non-detect)	4.6	0 (non-detect)	1.12
Copper	all	3 of 57	0 (non-detect)	4.1	0 (non-detect)	0 (non-detect)
	English sole	3 of 43	0 (non-detect)	4.1	0 (non-detect)	0 (non-detect)
Iron	all	56 of 57	0 (non-detect)	1090	85.8	173.3
	English sole	42 of 43	0 (non-detect)	1090	102.4	175.0
Lead	all	46 of 57	0 (non-detect)	0.63	0.10	0.24
	English sole	37 of 43	0 (non-detect)	0.628	0.118	0.253
Mercury	all	51 of 57	0 (non-detect)	0.05	0.03	0.04
	English sole	37 of 43	0 (non-detect)	0.0496	0.0245	0.0414
Nickel	all	3 of 57	0 (non-detect)	1.98	0 (non-detect)	0 (non-detect)
	English sole	3 of 43	0 (non-detect)	1.98	0 (non-detect)	0 (non-detect)
Selenium	all	55 of 57	0 (non-detect)	2.39	0.50	1.13
	English sole	42 of 43	0 (non-detect)	2.39	0.51	1.36
Silver	all	9 of 57	0 (non-detect)	0.18	0 (non-detect)	0.01
	English sole	6 of 43	0 (non-detect)	0.024	0 (non-detect)	0.007
Tin	all	56 of 57	0 (non-detect)	56.5	5.93	9.87
	English sole	42 of 43	0 (non-detect)	56.5	5.93941	9.41065
Zinc	all	57 of 57	7.59	18.3	12.49	15.78
	English sole	43 of 43	9.75	16.9	12.4675	13.8732

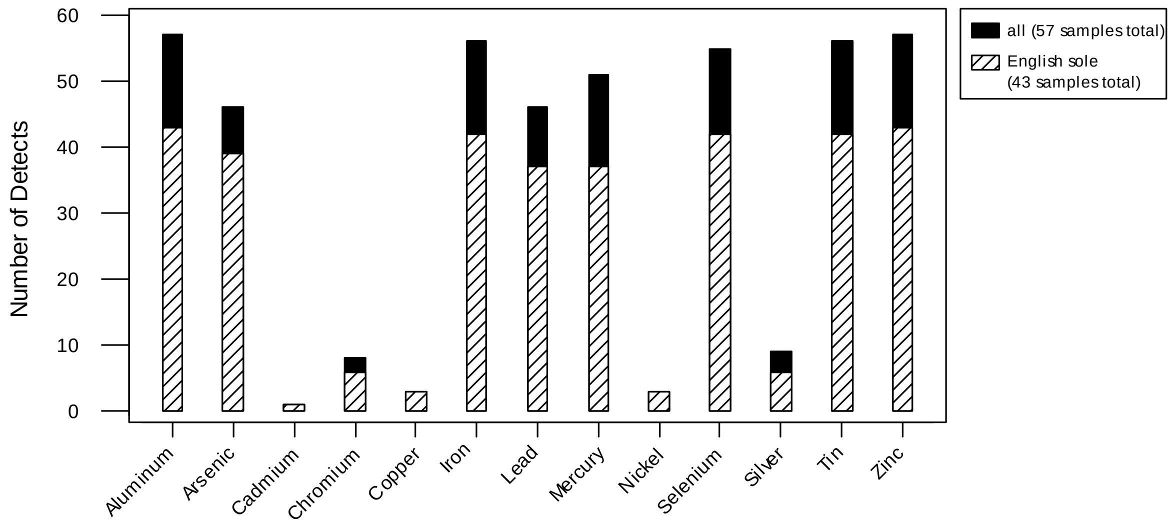


Figure 19. Detection rates of metals in whole-fish tissue, all species, and just English sole.

Organics Residues — PCBs, DDT, and other Pesticides

PCBs and DDT were measured in all 57 fish-tissue samples (Table 19). Hexachlorobenzene was found in 43 samples. Of the other chlorinated pesticides tested, only Alpha-Chlordane, Dieldrin, and Trans-Nonachlor were measured, and only at fewer than 10 stations. The detection rate for PCBs ranged from 0% for PCB 126 to 100% for PCBs 138 and 153 (Figure 20).

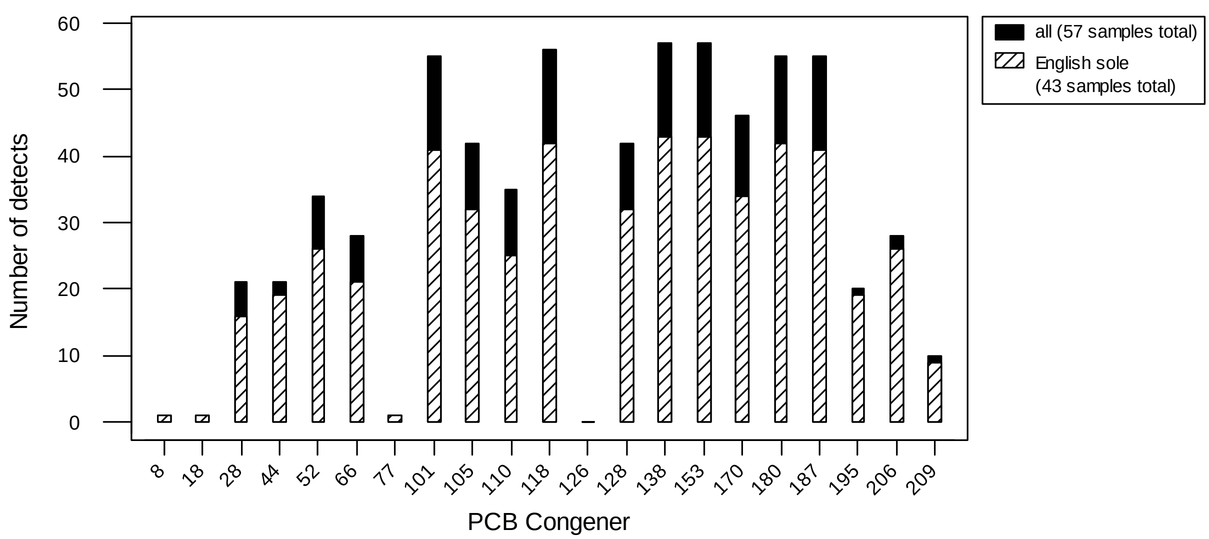


Figure 20. Detection rates of PCB congeners in whole-fish tissue, all species, and just English sole.

Table 19. Summary of fish-tissue PCB, DDT, and other pesticide residues (ng/g wet weight) for all tissue samples and for English sole samples only. 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.

Analyte	Species	Number of Detects	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Total PCB	all	**57 of 57**	**1.32**	**770.17**	**9.01**	**43.46**
	English sole	43 of 43	1.3	770.2	9.04	63.86
Total DDT	all	**57 of 57**	**0.695**	**93.7**	**4.49**	**8.75**
	English sole	43 of 43	0.7	93.7	4.49	12.28
2,4'-DDD	all	3 of 57	0 (non-detect)	2.7	0 (non-detect)	0 (non-detect)
	English sole	3 of 43	0 (non-detect)	2.7	0 (non-detect)	0 (non-detect)
4,4'-DDD	all	34 of 57	0 (non-detect)	17	0.23	0.65
	English sole	31 of 43	0 (non-detect)	17	0.34	1.24
4,4'-DDE	all	57 of 57	0.695	31	3.58	6.64
	English sole	43 of 43	0.695	31	3.59	8.50
4,4'-DDT	all	31 of 57	0 (non-detect)	51	0 (non-detect)	2.04
	English sole	27 of 43	0 (non-detect)	51	0.54	3.12
Alpha-Chlordane	all	6 of 57	0 (non-detect)	1.7	0 (non-detect)	0 (non-detect)
	English sole	5 of 43	0 (non-detect)	1.7	0 (non-detect)	0.04
Dieldrin	all	3 of 57	0 (non-detect)	2	0 (non-detect)	0 (non-detect)
	English sole	3 of 43	0 (non-detect)	2	0 (non-detect)	0 (non-detect)
Hexachloro-benzene	all	43 of 57	0 (non-detect)	32	0.14	0.34
	English sole	35 of 43	0 (non-detect)	32	0.22	0.35
Trans-Nonachlor	all	9 of 57	0 (non-detect)	4	0 (non-detect)	0.68
	English sole	6 of 43	0 (non-detect)	4	0 (non-detect)	0.73

Since 43 of the 57 samples were from English sole, the results for all samples largely resemble the results for only English sole, except for the CDF 90th percentiles for Total PCB and Total DDT (Figure 21, Figure 22, Table 19). That the 90th percentiles are higher for the English sole than for all species together reflects that the fish caught at the stations with the largest PCB and pesticide concentrations were usually English sole.

The tissue Total PCB and Total DDT concentrations were 3-8 times higher in fish caught at three urban bays (Duwamish River - East Waterway, Hylebos Waterway, and northeast Elliott Bay, in order of decreasing concentrations) than at the next highest locations, and at least two orders of magnitude higher than at some of the rural locations.

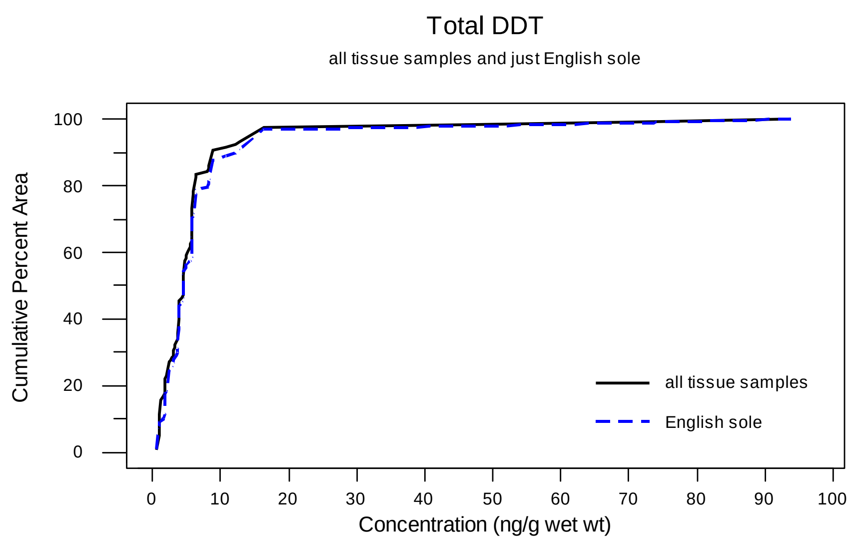


Figure 21. Cumulative percent area by whole-fish tissue Total DDT concentrations, all tissue samples, and just English sole samples.

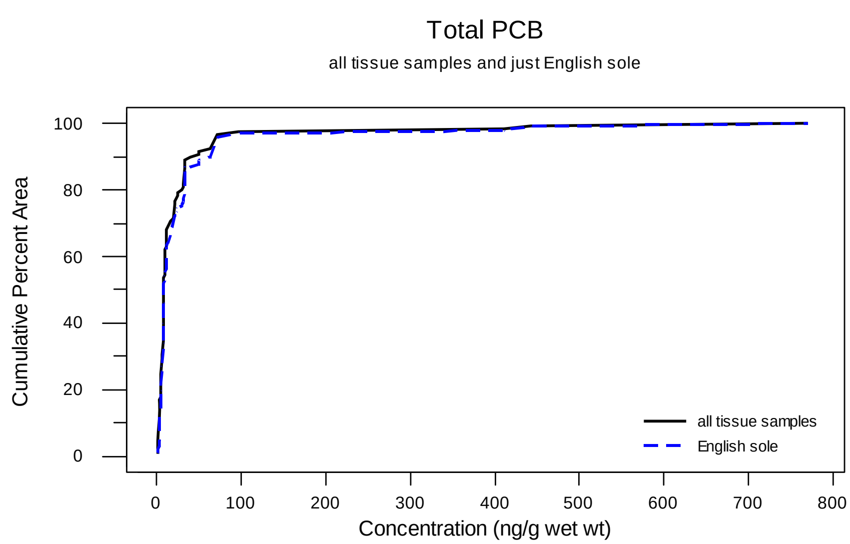


Figure 22. Cumulative percent area by whole-fish tissue Total PCB concentrations, all tissue samples, and just English sole samples.

Sediment Toxicity

Control conditions for a scientifically acceptable toxicity test in EMAP require the negative controls to have a mean endpoint success rate of at least 90% in the control replicates, with no replicate's success less than 85% (U.S. EPA, 2001a). For the amphipod survival tests, these requirements were not met in the batches containing five of the EMAP samples and 14 of the PSAMP/NOAA samples (Table 20); accordingly, those results were excluded from the analyses. All batches met the control conditions for the sea urchin fertilization and embryological development tests.

Table 20. Summary of control-corrected sediment toxicity test results.

Test	Amphipod Survival (%)		Sea Urchin Fertilization (%)		Sea Urchin Normal Morphological Development (%)
Species	*Ampelisca abdita*		*Strongylocentrotus purpuratus*	*Arbacia punctulata*	*Arbacia punctulata*
Number of Samples	PSAMP/NOAA	EMAP	PSAMP/NOAA	EMAP	EMAP
Meeting Control Conditions	27 of 41	14 of 19	40 of 40	19 of 19	19 of 19
< 80% of Control	0	3	5	1	5
80-100% of Control	17	9	8	3	9
> 100% of Control	10	2	27	15	5

The toxicity indications of the amphipod and urchin tests overlapped partially (Table 21).

Table 21. Locations for which sediment toxicity test results were less than 80% of control, indicating toxic conditions.

EMAP Station ID	Location	Amphipod Survival	Sea Urchin Fertilization	Sea Urchin Development
WA00-0008	Fidalgo Bay, inner		X	
WA00-0022	Duwamish River - East Waterway		X	
WA00-0025	Port Gamble Bay		X	
WA00-0027	Dabob Bay		X	
WA00-0033	Port of Olympia		X	
WA00-0042	Stuart Channel (north)		X	X
WA00-0045	Strait of Georgia	X		
WA00-0054	Cordova Channel			X
WA00-0056	Deer Harbor			X
WA00-0063	Baynes Channel	X		X
WA00-0071	Puget Sound, near Elliott Bay	X		X

Amphipod Survival Test

Three stations, representing 22% of the study area, had control-corrected percent survival of *Ampelisca abdita* < 80%, indicating toxic conditions (Figure 23). The lowest amphipod survival rate was 65% of control. Approximately 65% of the study area had 80-100% survival relative to controls; the remaining 13% of area had > 100% survival, indicating better survival of amphipods in test sediments than in controls.

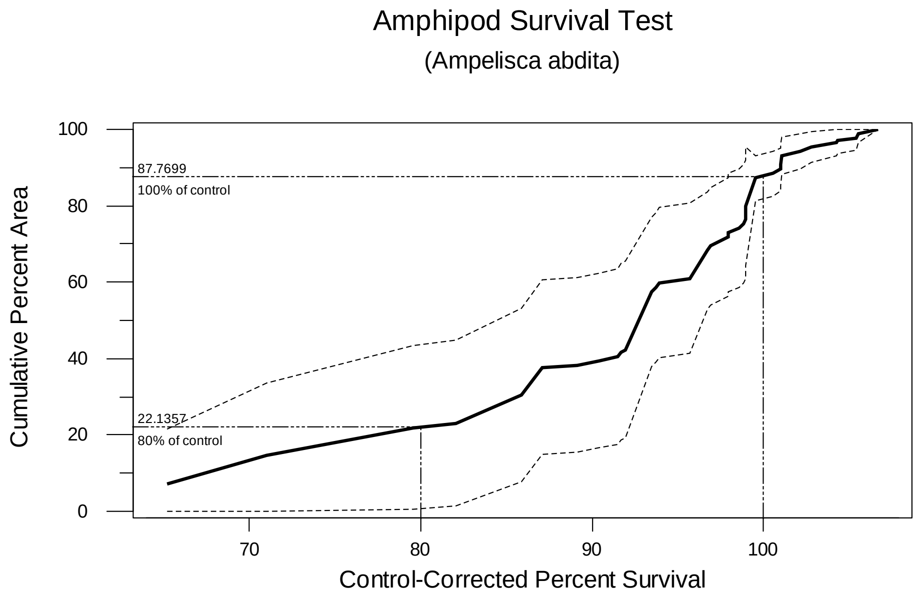


Figure 23. Cumulative percent area by control-corrected survival of *Ampelisca abdita*, indicating comparison to control. All results are included.

Sea Urchin Fertilization and Embryo Development Tests

Of the two urchin tests, the embryo-development test is generally the more sensitive (USGS, 2001).

Sea Urchin Fertilization Test

The control-corrected fertilization rate of *Arbacia punctulata* eggs in porewater toxicity tests was 53% in a single test sample; all other samples had fertilization rates above 99%. Percent control-corrected fertilization of *Strongylocentrotus purpuratus* eggs in porewater toxicity tests ranged from 0% to 143%, with five samples below 80% of control. With the test results combined, six samples, representing approximately 9% of the study area, had control-corrected sea urchin fertilization rates of <80%, indicating toxic conditions (Figure 24). One sample had 0% fertilization (Station 33, Port of Olympia); the other five had fertilization rates 45-71% of the controls. Forty-two of the 59 stations in the combined results had control-corrected fertilization > 100%, indicating better fertilization of sea urchin eggs in test sediments than in controls.

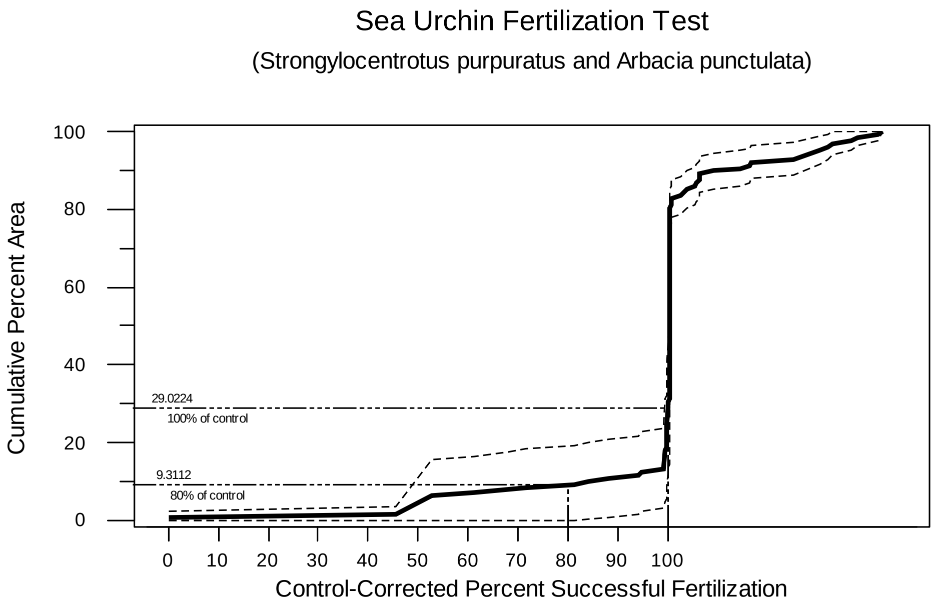


Figure 24. Cumulative percent area by control-corrected sea urchin fertilization success (both *Arbacia punctulata* and *Strongylocentrotus purpuratus*) at 100% salinity-adjusted porewater, indicating comparison to control.

Archived frozen porewater extracted from 40 of the 41 PSAMP/NOAA stations was tested with *Arbacia punctulata* as a comparison to the original 1997-1999 urchin fertility tests conducted with *Strongylocentrotus purpuratus*. The results were largely the same (USGS, 2001).

Sea Urchin Embryo Development Test

Of the five stations for which control-corrected normal morphological development < 80% (Table 20), three stations had 0% normal development and one station had 8% normal development. Those four stations were in the Strait of Georgia, among the San Juan and Gulf Islands (Table 21) and represented approximately 21% of the study area. The fifth station, with 74% control-corrected normal development, was just outside Elliott Bay and represented 7% of the study area. Because small samples tend to have unreliable estimates of variance for calculation of confidence intervals for CDFs (U.S. EPA, 2001d; Olsen, 2003; Nelson, 2003), no CDF is presented here for the 19 embryo development tests.

Approximately 50% of the study area had normal development rates of 80-100% of the controls. Samples from the remainder had > 100% normal development, indicating higher rates of normal development of sea urchin embryos in test sediments than in controls.

Biotic Condition Indicators

Infaunal Species Richness and Diversity

Although samples for benthic macroinvertebrate analysis were collected at 60 stations (all 41 of the PSAMP/NOAA stations and 19 of the EMAP-only stations), macroinvertebrates were found at only 59 stations; the sample taken at Station WA00-0033 (PSAMP/NOAA station 243) in Budd Inlet had no benthic macroinvertebrates. In all, 750 benthic taxa were found. The taxa included 48 colonial species, one of which was exotic, and 13 exotic species, one of which was colonial (Appendix Table C-1).

Taxa richness, the total number of taxa identified (lowest level) in a 0.1-m^2 sample, ranged from 0 (at Station 33) to 198 taxa per .0.1 m^2 (Table 22).

The *Shannon-Wiener Diversity Index (H')* is a commonly-used measure of the distribution of individual organisms amongst the taxa in the sample, whereas *Pielou's Evenness Index (J')* is the Shannon-Wiener Diversity Index as a proportion of the maximum possible diversity. The more taxa there are and the more evenly the individuals are distributed among the taxa, the higher the diversity index will be. *Evenness* is a measure of equitability of distribution of individuals among species, and so will be minimized when one taxon dominates the abundance and maximized when there are equal numbers of individuals in all taxa.

Swartz' Dominance Index (SDI), the number of taxa making up at least 75% of the total abundance, ranged from 2 taxa to 48 taxa (Station 33 excluded), or from about 3% to over 60% of total infaunal abundance (Table 22).

Table 22. Summary statistics for benthic macrofauna bioindices of community richness and diversity. Station 33, which had no macrofauna in the sample, was excluded from the calculations of diversity, evenness, and dominance.

Statistic	Taxa Richness (Number of Taxa)	Shannon-Wiener Diversity H'	Pielou's Evenness J'	Swartz' Dominance (Number of Taxa)	Dominance Standardized by Taxa Richness (%)
Number of Samples	60	59	59	59	59
Minimum	0	1.96	0.36	2	3.23%
Maximum	198	6.36	0.95	48	62.50%
CDF 50^{th} Percentile	59	4.26	0.73	10.9	19.66%
CDF 90^{th} Percentile	95	5.72	0.86	27.5	31.18%
Mean (unweighted)	56.6	4.3	0.1	13.3	23.6%
Median (unweighted)	52.0	4.4	0.1	12.0	23.0%

Infaunal Abundance and Taxonomic Composition

Infaunal abundance ranged from 0 individuals per 0.1 m^2 in Budd Inlet to 5783 individuals per 0.1 m^2 in Bellingham Bay, with a median of 488 individuals per 0.1 m^2 (Table 23, Figure 25). Colonial species were included with an abundance of 1.

The ten numerically-dominant taxa made up 48.3% of the total benthic macrofauna (Appendix Table C-1). Exotic species (13, including one colonial species) accounted for approximately 3% of the total benthic infauna collected. The abundance and proportion of all of the taxa found, including the 10 most abundant, are given in Appendix Table C-1. Exotic and colonial species are indicated. Table 24 below lists the number of taxa by phylum.

The bivalve *Axinopsida serricata* was by far the most common species, found at 48 stations; 282 species were found at a single station each.

Table 23. Summary statistics for total benthic macrofauna abundance (# individuals/0.1 m^2).

Statistic	All Taxa	Annelida	Arthropoda	Echinodermata	Mollusca	Misc. Taxa
Minimum	0	0	0	0	0	0
Maximum	5783	4129	2062	564	2581	96
CDF 50th Percentile	432.5	146.6	60.7	10.2	4.9	130.6
CDF 90th Percentile	1290.8	478.4	242.6	41.8	38.1	846.9
Mean (unweighted)	347.3	181.2	64.7	8.7	84.7	8
Median (unweighted)	333	133	30.5	5	80	5

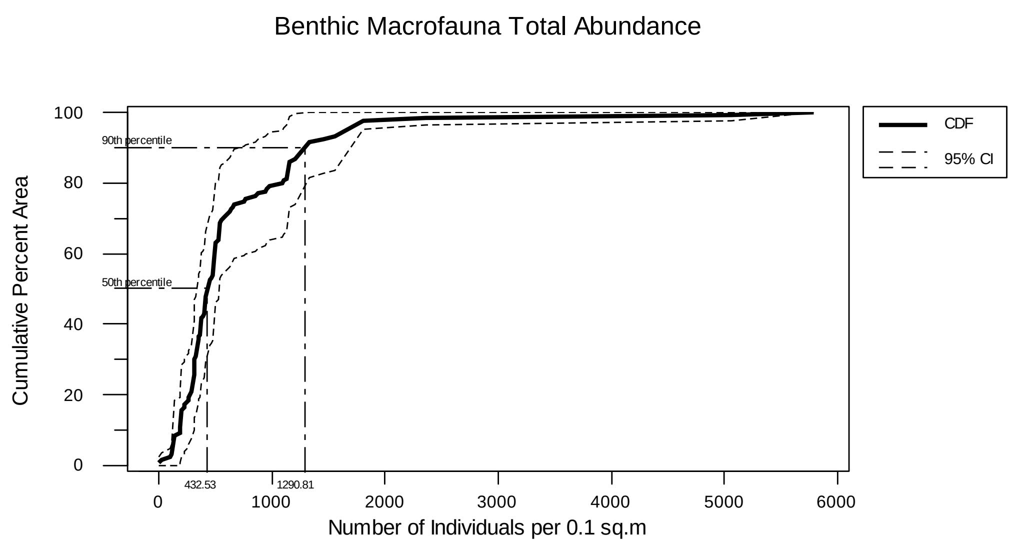


Figure 25. Cumulative percent area by benthic macrofauna total abundance (number of individuals per sampled 0.1-m^2 area). Colonial species were included with an abundance of 1.

At the level of the major taxonomic groups, the infaunal communities are quite different in the PSAMP/NOAA stations compared to the EMAP-only stations (chi-square test, $df = 8$, P-value << 0.0001). The PSAMP/NOAA stations overall had more annelids and arthropods, and fewer molluscs, than the other stations (Figure 26).

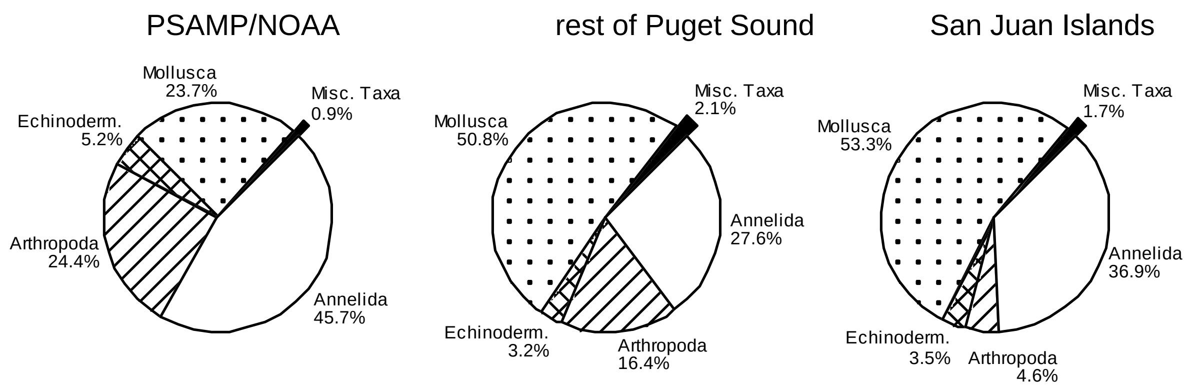


Figure 26. Relative abundance of major taxonomic groups by geographic area (unweighted).

Table 24. Taxonomic composition of benthic macrofauna.

Major Taxonomic Group	Phylum	Number of taxa	Total taxa
Annelida	Annelida	294	294
Arthropoda	Arthropoda	187	187
Echinodermata	Echinodermata	28	28
Mollusca	Mollusca	125	125
Miscellaneous Taxa			116
	Brachiopoda	2	
	Chaetognatha	3	
	Chordata	13	
	Cnidaria	33	
	Echiura	2	
	Ectoprocta	25	
	Entoprocta	2	
	Nematoda	1	
	Nemertea	20	
	Phorona	4	
	Platyhelminthes	3	
	Porifera	3	
	Sipuncula	5	

Demersal Fish Species Richness and Abundance

Seventy-one fish species were found over the 65 stations which were trawled successfully. The number of fish species per station ranged from 0 at Station 29 in Lynch Cove (Hood Canal) to 20 at Station 39 in Colvos Passage, on the northwest side of Vashon Island (Appendix Table D-2). The median number of species per trawl was 9, and the median number of individual fish caught per trawl was 65. Twenty-one fish species were caught at a single station each.

The fish caught most often were English sole (*Parophrys vetulus*), but the fish caught in greatest abundance were the spotted ratfish (*Hydrolagus colliei*). English sole were found at 52 of 65 stations but represented only 7.7% of the combined total catch, whereas spotted ratfish were caught at 28 stations but made up 33.6% of all fish (Figure 27). Most of the spotted ratfish were found at deep stations sampled with the large vessel (*F/V Chasina*) and large trawl (Eastern 400).

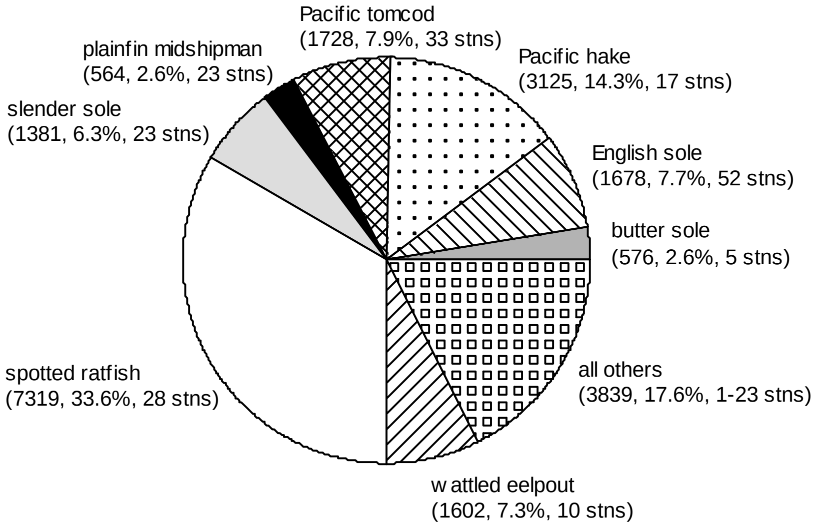


Figure 27. Most common fish species caught in trawls (abundance, percent, number of stations).

Table 25. Fish abundance by type of fish and sampling area.

Group	PSAMP/ NOAA	Rest of Puget Sound	San Juan Islands	Total
Ratfish	5242	1795	282	7319
Flatfish	3999	870	91	4960
Hake	3028	97	0	3125
Eelpout	1804	36	0	1840
Cod	1674	40	33	1747
Herring	391	7	3	401
Sculpin	303	35	3	341
Perch	276	3	33	312
Dogfish	187	84	14	285
Rockfish	73	18	0	91
Skate	53	17	2	72
Other	1021	268	30	1319

Catch per Area Swept

The number of fish caught in each trawl ranged from none at Station 29 in Lynch Cove to 2407 at Station 38 in Colvos Passage, at the north end of Vashon Island. The latter was equivalent to a catch per area swept of over 166,000 fish per km^2 (Table 26, Appendix Table D-3). Average catch per area swept was approximately 22,500 fish per km^2, though the median was less than 8700 fish per km^2.

Table 26. Summary statistics for fish taxa richness, abundance, and catch per area swept, complete standard trawls (1st trawl only).

Statistic	Taxa Richness (# of taxa/trawl)	Abundance (# individuals/trawl)	Catch per Area Swept (# fish / km^2)
Minimum	0	0	0
Maximum	20	2407	166386
CDF 50th Percentile	8.4	72	7516
CDF 90th Percentile	13.3	759	38825

Demersal Fish Species Gross Pathology

Fish with gross pathological anomalies (tumors, parasites, deformities, lesions) were caught at 40 stations. Fully 67% of the cases were naturally-occurring infestations of the nematode *Philometra*. Parasitic copepods or sea lice accounted for another 13.6% of cases. "White spots on gills" were 7% of the anomalies and were observed only on Pacific hake (*Merluccius productus*). Other anomalies were 2.7% or fewer each of the pathologies (Appendix Table D-4).

Overall, the number of fish with anomalies was 1.8% of the total catch over all stations. English sole represented just 7.7% of fish caught, but more than 60% of the fish with gross external pathologies, and almost 85% of the *Philometra* cases.

Epibenthic Invertebrates Caught in Trawl

The most common epibenthic invertebrates caught in the trawls were Dungeness crabs (*Cancer magister*) at 29 stations and Crangonid shrimp (*Crangon* sp.) at 28 stations (Appendix Table F-1). The number of invertebrate taxa found ranged from 0 at two stations to 15 at one station, averaging 5 species (both mean and median). The most abundant epibenthic invertebrates caught in trawls were Pandalid shrimp.

Results – 2002 (Intertidal)

The results reported herein were analyzed in 2007 with data taken from the West Coast EMAP 2002 database version 2.06.10, with corrections approved by the Washington EMAP Information Management Coordinator. The infauna data used were from version 2.07.02 of the database. The corrections were incorporated into subsequent versions of the West Coast EMAP database.

The Coastal EMAP survey of Washington State's intertidal areas was designed to provide a broad assessment of condition based on one-time samples. In-depth and long-term assessments of the environmental conditions in nearshore areas are provided by targeted monitoring programs, such as the Nearshore Habitat Program of the Washington State Department of Natural Resources (www.dnr.wa.gov/htdocs/aqr/nshr/index.html).

Site Visits

Sampling was attempted at 76 stations and successful at 61. All but three of the 15 stations abandoned in the field were submerged at low tide: two of the three were found to be in the upper marsh, and conditions were unsafe for sampling at the remaining station. In addition, 15 stations were rejected prior to sampling: eight due to lack of landowner permission, and the remaining seven because all available information indicated that the sites were in the upper marsh, on a rocky foreshore, or on land. Details are given in Appendix Table B-2.

Data Quality Objectives

Assessments of the sediment chemistry data for adherence to EPA's Data Quality Objectives (DQO; see U.S. EPA, 2001a) found the metals analyses to have met the DQOs (Ozretich, 2007a). The analyses of organic compounds, however, had difficulties meeting the DQOs for precision and therefore must be viewed with caution (Ozretich, 2007a).

General Habitat Condition Indicators

Vegetation

Eelgrass was the vegetation found most commonly, followed in frequency by several species of green algae (Table 27, Figure 28). Red algae were found at only one station in Willapa Bay, and brown algae were found at one station in each Willapa Bay and Drayton Passage (Puget Sound). Ten stations, seven in Puget Sound and three in Willapa Bay, were devoid of vegetation in the sampling plots, though vegetation was nearby in some cases (Appendix Figure B-2).

Spartina alterniflora was present in the sampling plots at three stations in Willapa Bay and in the vicinity of ten other Willapa Bay stations. The inaccessibility of *Spartina* meadows forced the relocation seaward of one station and the abandonment of another, both in Willapa Bay. *Spartina* was seen extensively in Skagit Bay (Puget Sound), though not in or near the sample plots.

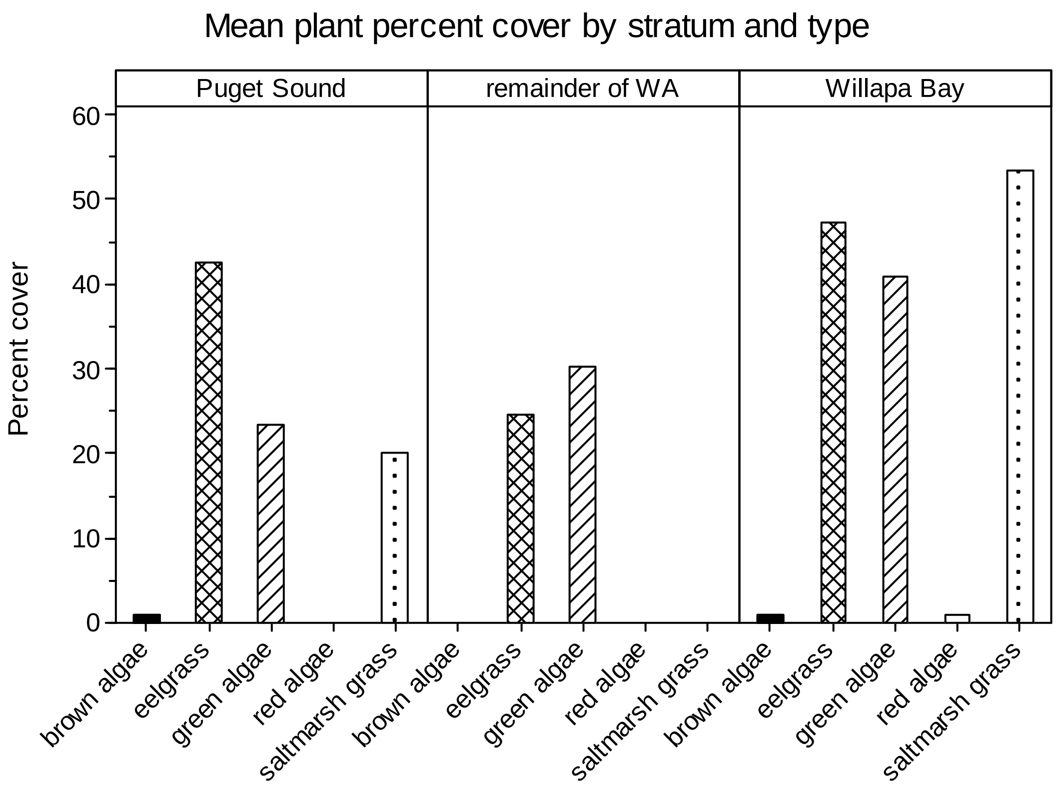


Figure 28. Mean percent cover by plant type (plant quadrat).

Table 27. Occurrence of plant species by sampling stratum (number of stations).

Species	Puget Sound	Remainder of WA (Grays Harbor)	Willapa Bay	Total stations
Eelgrass	8	3	18	29
Nanozostera americana	0	0	2	2
Zostera japonica	5	1	14	20
Zostera marina	4	2	8	14
Green algae	12	7	10	29
Cladophora sp.	0	2	4	6
Enteromorpha linza	3	5	0	8
Enteromorpha prolifera	3	4	2	9
Enteromorpha sp.	3	2	4	9
Ulva sp.	4	1	0	5
Ulvoid sp.	3	4	0	7
Saltmarsh grass	1	0	3	4
Juncus gerardii	1	0	0	1
Spartina alterniflora	0	0	3	3
Brown algae	1	0	1	2
Fucus gardneri	0	0	1	1
unspecified species	1	0	0	1
Red algae	0	0	1	1
Gracilaria sp.	0	0	1	1
None	7	0	3	10

The vegetation percent cover estimated from the plant quadrat and the plant transect were similar, but the benthos quadrat percent cover was considerably lower. The difference stems from the larger proportion of benthos quadrats which were bare (Table 28, Figure 29).

Table 28. Summary statistics for intertidal vegetation. Note that percent cover may exceed 100% where plants overlie each other.

Variable	Number of stations	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Percent cover in plant quadrat	61	0 (15 stations)	100.5	32.2	98.0
Percent cover along plant transect	61	0 (13 stations)	152	30.8	95.6
Percent cover in benthos quadrat	61	0 (22 stations)	125	1.6	93.4
Variable	Number of samples	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Maximum plant length in plant quadrat (cm)	27	2	188	39.8	92.7
Maximum plant length along transect (cm)	11	1	200	58.2	142.4
Biomass in plant quadrat ($g/0.25\ m^2$)	61	0 (19 stations)	540	9.4	60.1

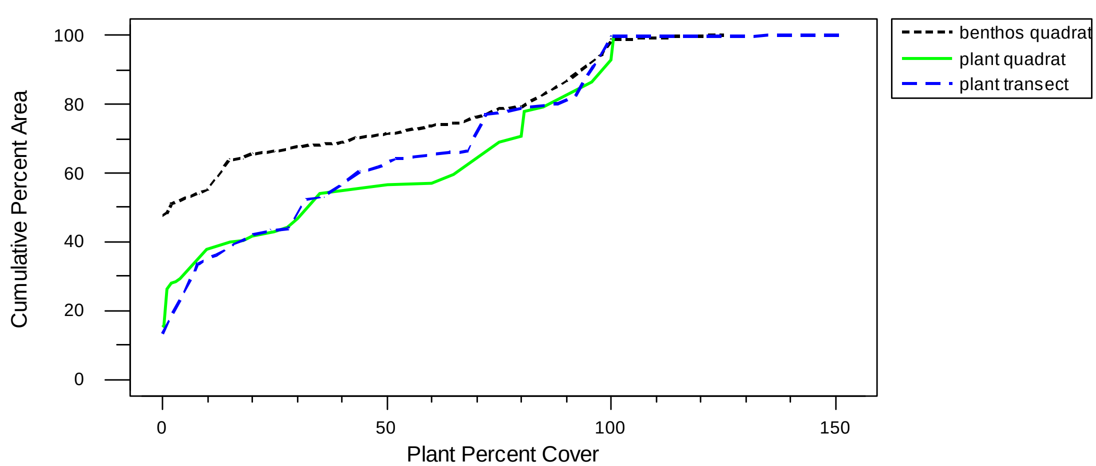


Figure 29. Cumulative percent area by plant percent cover.

Burrowing Shrimp

Shrimp burrows were evident in the burrowing-shrimp quadrat at 36 of the 61 stations. When present, burrows ranged in number from 1 to 57 burrows per 0.25 m^{-2} (Appendix Table E-5). Approximately 90% of the study area had 12 or fewer burrows per 0.25 m^{-2}; slightly under 50% of the area had 3 or fewer burrows per 0.25 m^{-2} (Figure 30). The burrow count was generally similar for *Neotrypaea* sp. and *Upogebia pugettensis* (Figure 31).

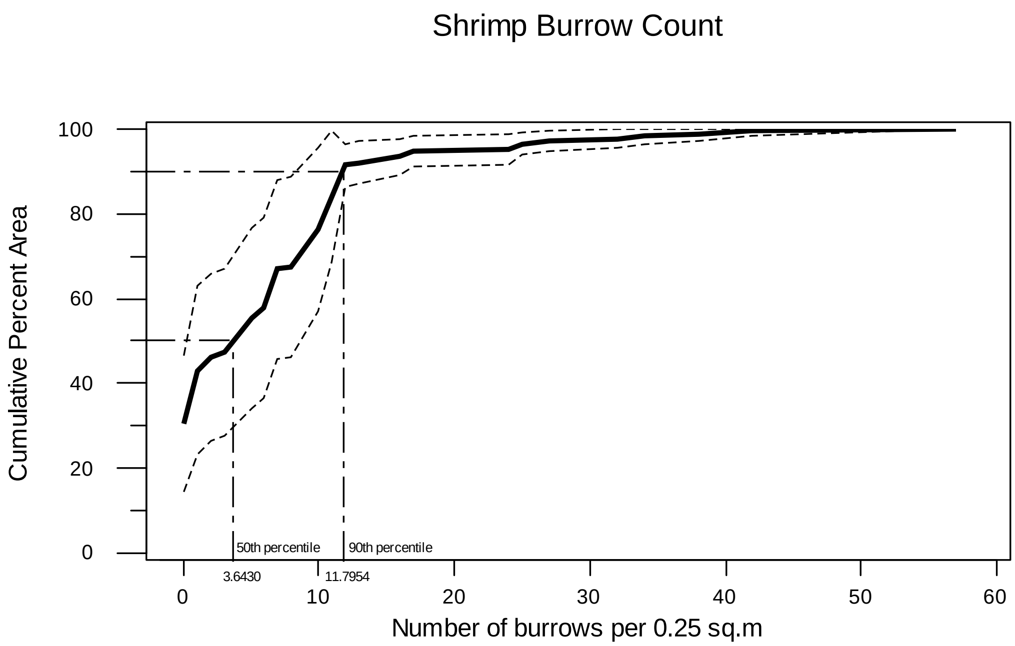


Figure 30. Cumulative percent area by number of shrimp burrows.

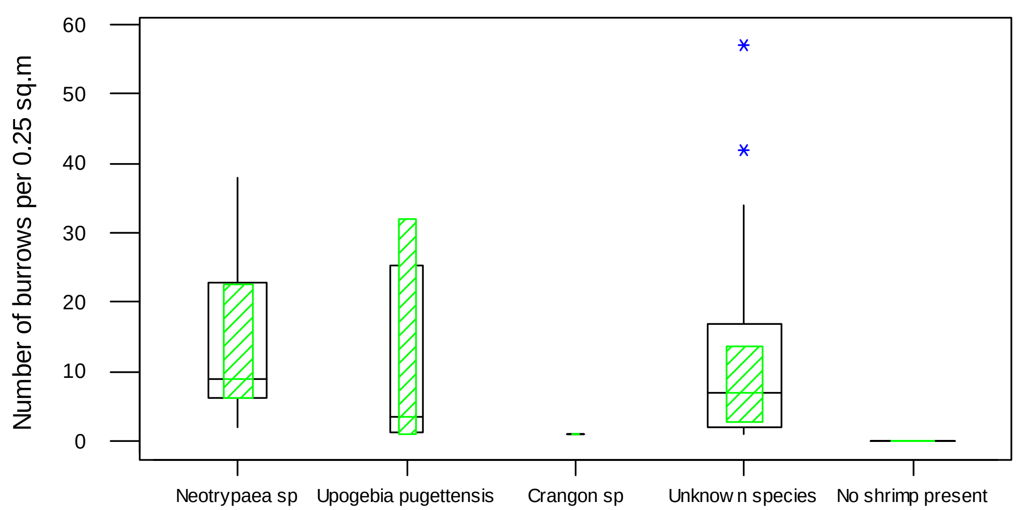


Figure 31. Species present in burrow-count quadrat.

At 19 of the 36 stations, the shrimp species could not be identified. *Neotrypaea* sp. was identified at 12 stations, *Upogebia pugettensis* at 4 stations, and *Crangon* sp. at one station (Table 29, Figure 32). *Upogebia* was not found in Puget Sound. The single *Crangon* was found in Puget Sound.

Table 29. Number of stations with shrimp burrows present.

Species	Puget Sound	Remainder of WA (Grays Harbor)	Willapa Bay
Neotrypaea sp.	3	3	6
Upogebia pugettensis	0	2	2
Crangon sp.	1	0	0
Unknown species	7	1	11
No shrimp present	13	1	11

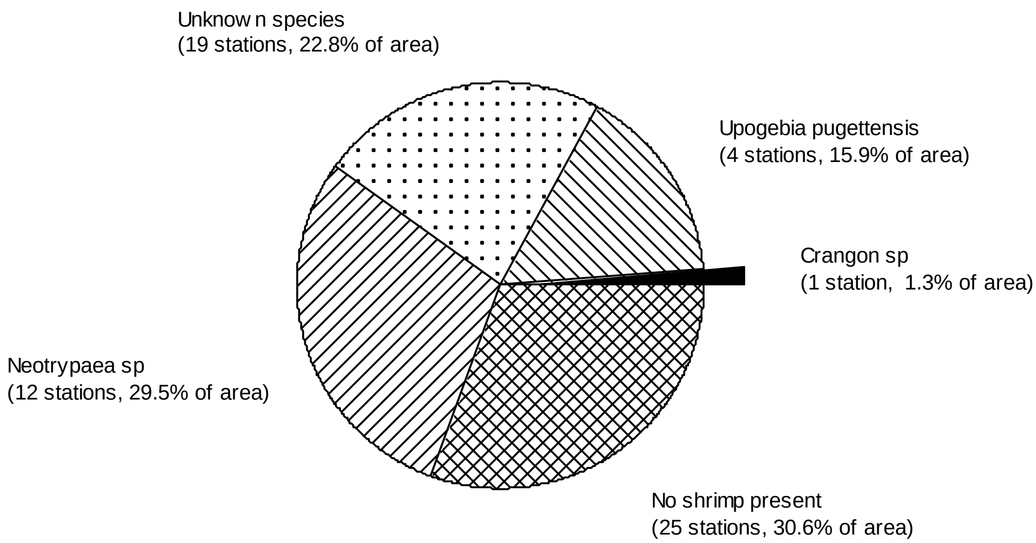


Figure 32. Presence of shrimp species in burrow-count quadrat.

Total Organic Carbon (TOC) content

Total organic carbon was measured by two methods, the PSEP method (PSEP, 1986) and the simultaneous carbon-hydrogen-nitrogen (CHN) analysis (Dumas combustion method).

TOC content was under 3% almost everywhere. Ninety percent of the area had a TOC content of 1.4% or less, and 50% of the area had a TOC content of less than 0.4% (Table 30, Figure 33). With the exception of one station in Oyster Bay in Puget Sound, the TOC content of Puget Sound and Grays Harbor sediments was less than 1.5% (Figure 34).

Table 30. Summary statistics for sediment characteristics.

Analyte	Number of Detects (N=61 stations)	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Percent Fines (% silt-clay)	61	0.6	95.2	9.8	70.0
TOC (%) analyzed by PSEP method	54	0 (non-detect)	3.11	0.35	1.40
TOC (%) analyzed by CHN method	61	0.07	3.16	0.32	1.36
TOC (%) averaged over both methods	61	0.04	3.14	0.34	1.39
Total Nitrogen (CHN)	61	0.01	0.28	0.04	0.13
Carbon:Nitrogen Ratio (CHN)	61	4.97	14.54	8.74	10.92
Total Phosphorus (CHN)	61	0.02	0.11	0.03	0.06
Total Hydrogen (CHN)	61	0.21	1.05	0.36	0.67

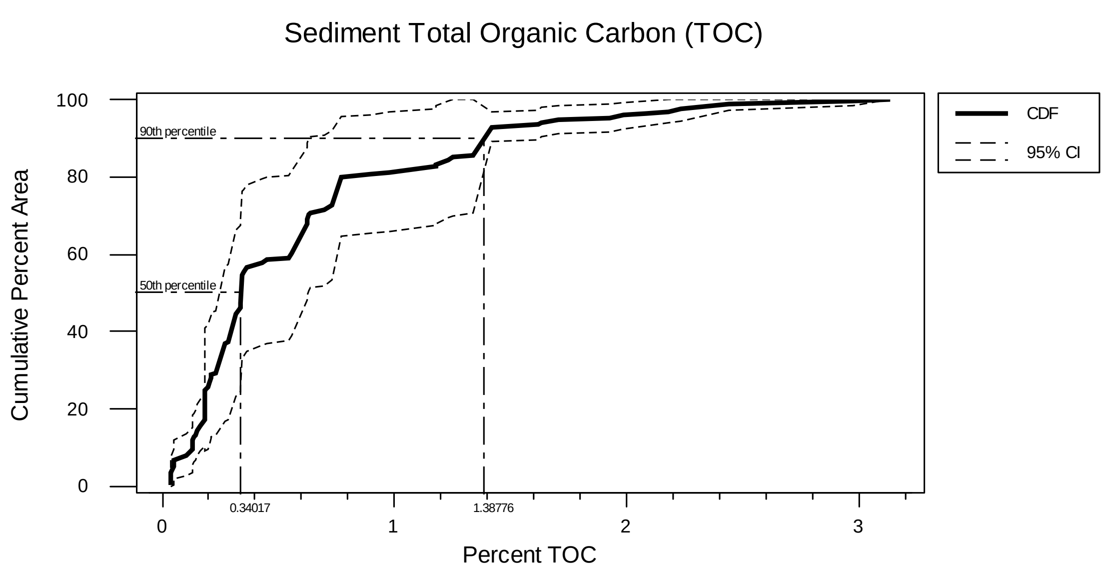


Figure 33. Cumulative percent area by sediment TOC.

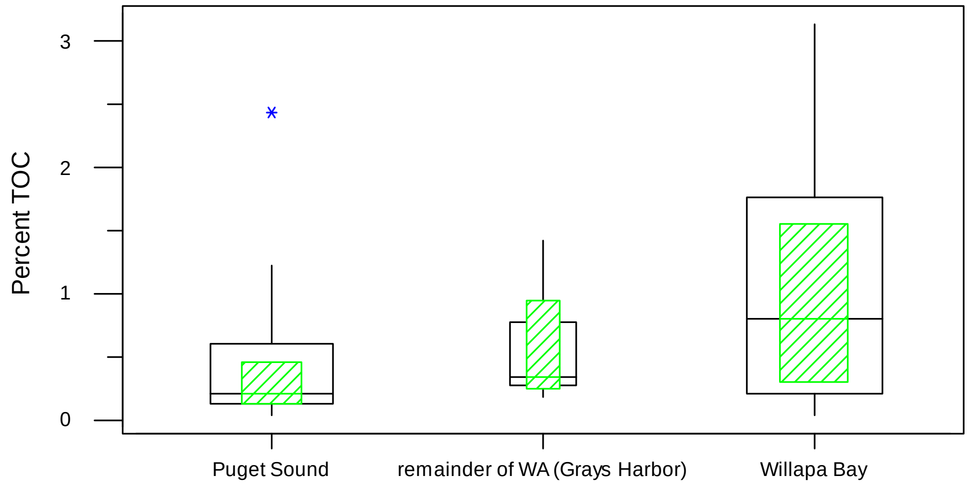


Figure 34. Sediment TOC by stratum.

Silt-Clay Content (Grain Size Analysis)

Approximately 62% of the area has sandy sediment (< 20% silt-clay), less than 4% of the area is composed of muds (> 80% silt-clay), and the remainder is intermediate (Figure 35). Fifty percent of the area has less than 10% fines (silt-clay), and 90% of the area has less than 70% fines (Figure 36).

The predominant grain size (Wentworth classification) is fine sand (Figure 37). Grays Harbor sediments are mostly fine sand, whereas Willapa Bay sediments are siltier and Puget Sound sediments are more mixed. In Grays Harbor the average fine sand fraction is 64%, compared to 44% in Willapa Bay and 31% in Puget Sound. The mean silt fraction in Willapa Bay is 28%, approximately double the silt fraction in Grays Harbor and in Puget Sound.

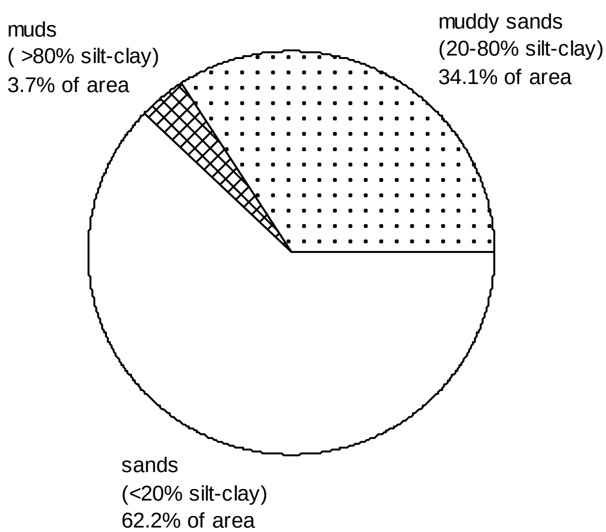


Figure 35. Distribution of sediment types.

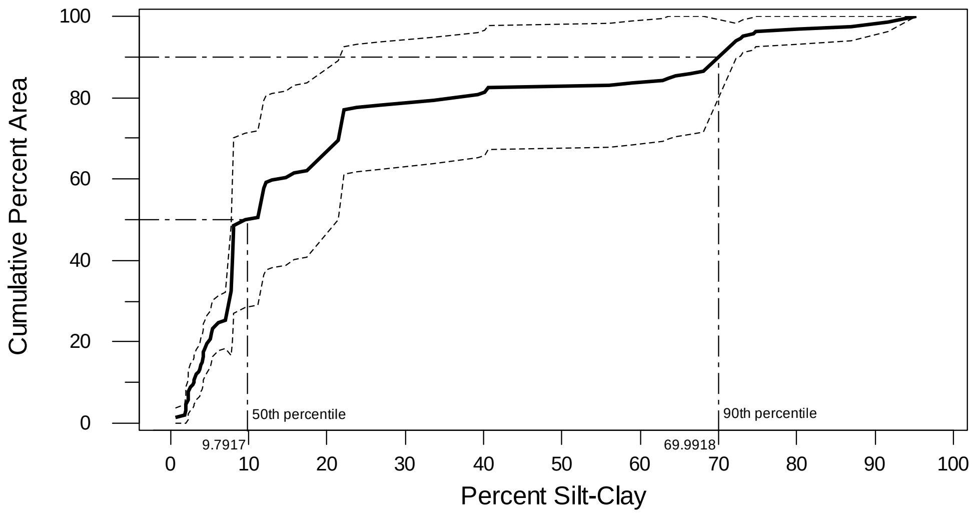


Figure 36. Cumulative percent area by sediment percent fines (silt-clay).

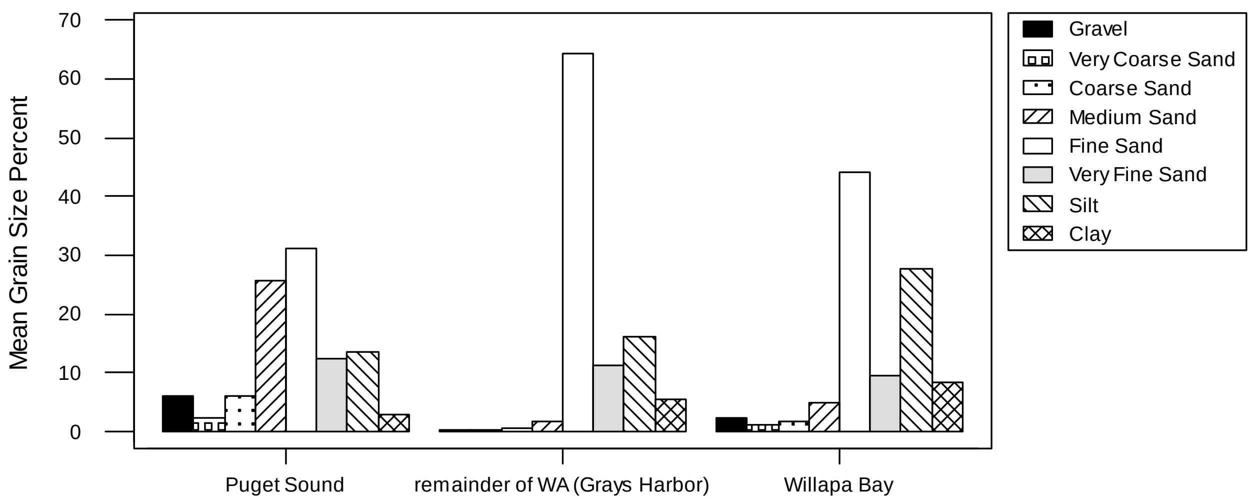


Figure 37. Grain size distribution by stratum.

Abiotic/Pollutant Exposure Condition Indicators

Sediment Contaminants

Metals

Selenium was detected at only one station, representing 2% of the study area. Cadmium was detected at 41 stations, silver at 51 stations, and mercury at 54 stations. All other metals were detected at all 61 of the stations (Table 31).

Aluminum

Aluminum concentrations were widely variable but not significantly different among the three areas.

Antimony

Antimony concentrations were generally lower in Grays Harbor than in Puget Sound. The antimony concentrations in Elliott Bay and Everett Harbor were approximately twice as high as everywhere else.

Table 31. 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=61 stations)	Minimum	Maximum	CDF 50^{th} Percentile	CDF 90^{th} Percentile
Aluminum	61	4160	74600	48108.0	70639.5
Antimony	61	0.21	0.77	0.33	0.47
Arsenic	61	2.04	11.80	4.95	7.92
Cadmium	41	0 (non-detect)	0.94	0.11	0.20
Chromium	61	30.1	166.0	48.9	112.1
Copper	61	5.9	61.4	14.2	54.3
Iron	61	431	58800	31584.1	49393.3
Lead	61	3.13	14.80	8.28	10.92
Manganese	61	239.0	907.0	404.7	731.6
Mercury	54	0 (non-detect)	0.162	0.012	0.055
Nickel	61	12.6	81.8	19.9	41.6
Selenium	1	0 (non-detect)	0.5	--	--
Silver	51	0 (non-detect)	0.40	0.14	0.32
Tin	61	0.16	1.14	0.33	0.84
Zinc	61	32.0	98.0	49.2	85.4

Arsenic

Arsenic concentrations in Puget Sound were lower than in Willapa Bay and Grays Harbor, with the exception of high concentrations in Elliott Bay and Oyster Bay.

Cadmium

Cadmium was not detected at 20 stations, representing 42.3% of the area. Five of those stations were in Puget Sound, 11 were in Willapa Bay, and 4 were in Grays Harbor. Cadmium concentrations were more than twice as high at the head of Carr Inlet and more than 5 times as high in Drayton Harbor and Oyster Bay (all in Puget Sound) than at any other station in the study.

Chromium

The chromium concentration was exceptionally high at one station in Port Susan (Puget Sound).

Copper

The highest copper concentrations were found at two stations in northern and eastern Grays Harbor. Oyster Bay and two stations in Hood Canal (all in Puget Sound) had the next-highest sediment copper concentrations. The remainder of the study area had lower, and similar, copper levels.

Iron

The iron concentration at one station in northern Grays Harbor was two orders of magnitude lower than at most other stations in the entire study area. At another station in eastern Grays Harbor, however, the iron concentration was the highest in the study and was about twice as high as in the rest of Grays Harbor.

Lead

Lead concentrations in Willapa Bay were higher than in Grays Harbor and Puget Sound.

Manganese

With the exception of one station in the Naselle River in southeastern Willapa Bay, manganese concentrations in Willapa Bay were lower than in Grays Harbor and Puget Sound.

Mercury

The mercury concentration at one station in Willapa Bay (Palix River) was more than twice as high as the next highest concentrations, and 3-36 times as high as at most stations in the study area. Fifteen of the 18 highest mercury concentrations were in Willapa Bay, the other 3 being in Oyster Bay and Drayton Harbor (both in Puget Sound) and northern Grays Harbor.

Mercury was not detected at 7 stations, representing 8.4% of the area. One of those stations was in Willapa Bay; all of the others were in Puget Sound.

Nickel

With the exception of one station, the nickel concentrations in Willapa Bay were generally lower than in Puget Sound. The nickel concentration at one station in Port Susan (in Puget Sound) was about 2-4 times as high as the nickel concentrations in most of the rest of the study area.

Selenium

The sole station at which selenium was detected was at Oyster Bay in Puget Sound.

Silver

Silver was not detected at 10 stations, representing 11.5% of the area. Eight of those 10 stations were in Puget Sound; the other 2 were in Willapa Bay.

Tin

With the exceptions of 3 unusually high values, in Drayton Harbor in the north and Oyster Bay and Peale Passage in the south, the tin concentrations in Puget Sound were lower than in Willapa Bay and Grays Harbor.

Zinc

The distribution of zinc concentrations was basically the same everywhere.

Comparisons to Sediment Quality Standards and Guidelines for Metal Contaminants

The ERL was exceeded for a few metals at a few stations (Table 32). No areas exceeded the Washington State sediment quality standards or NOAA ERM sediment quality guidelines for metals. However, the ERL was exceeded for a few metals, notably chromium (Table 32).

Ten stations, representing more than 20% of the study area, had chromium levels in excess of the ERL, eight in Puget Sound and two in Grays Harbor. By contrast, six of the seven stations exceeding the ERL for arsenic were in southern Willapa Bay; the other was in Puget Sound (Port Gardner). The ERL for copper was exceeded at 5 stations, three in Puget Sound (one in Oyster Bay and two in Hood Canal) and two in Grays Harbor. Only a single station in Willapa Bay (Palix River) had sediment mercury concentration higher than the ERL.

All of the sites exceeding the copper ERL also exceeded the chromium ERL. There was no other overlap amongst occurrences of metals concentrations exceeding ERLs.

Table 32. Comparisons of sediment metals concentrations to NOAA Effects Range Low (ERL) sediment quality guidelines.

Analyte	ERL (µg/g)	Number of stations > ERL	% of area > ERL
Arsenic	8.2	7	4.7
Cadmium	1.2	0	0
Chromium	81	10	25.1
Copper	34	5	18.6
Lead	46.7	0	0
Mercury	0.15	1	0.6
Silver	1.0	0	0
Zinc	150	0	0

Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs were detected at all 61 stations, though not all PAH compounds were measured at all stations (Table 33). Fluoranthene was detected at all stations. All other PAH compounds were non-detect at one or more stations, but no PAHs were non-detect everywhere, and at least one PAH was detected at each station. Phenanthrene was detected at all but one station, and Pyrene was detected at all but two stations. Dibenz(a,h)anthracene, the least frequently detected PAH, was found at only 29 stations.

The highest Total LPAH, Total HPAH, and Total PAH concentrations were at Station 60, in Drayton Harbor off the Strait of Georgia. Station 60 had the highest or second-highest concentrations of all ten HPAH compounds and five of the 13 LPAH compounds among all stations.

The lowest PAH totals were also found in Puget Sound: Total LPAH at Lilliwaup Creek in Hood Canal, Total HPAH at Drayton Passage in southern Puget Sound, and Total PAH at Case Inlet, also in southern Puget Sound. Non-detected or lowest measured concentrations of pyrene and phenanthrene among the stations were the determiners of the lowest PAH totals.

With the exception of high concentrations at Puget Sound Stations 60 (Drayton Harbor) and 10 (Oyster Bay), Total LPAH concentrations in Puget Sound were generally lower than those in Grays Harbor. Total LPAH concentrations at Stations 60 and 10 were more than 3 and 2.5 times, respectively, the next-highest concentrations at other Puget Sound stations. Total HPAH and Total PAH concentrations at Stations 60 and 10 were approximately 6 and 5 times, respectively, the next-highest concentrations at other Puget Sound stations. Similar patterns occurred for almost all of the individual PAH compounds.

Several stations commonly had the highest individual and Total PAH concentrations: Puget Sound Stations 60 (Drayton Harbor) and 10 (Oyster Bay), which dominated the HPAHs; Station 37 at the northern edge of Grays Harbor; and Willapa Bay Stations 3 (Nahcotta/Ocean Park), 66 (Willapa River), and 70 (Nemah River Channel).

Table 33. Summary of sediment individual and Total PAH concentrations (ng/g dry weight).

PAH Compound	Number of Detects (N=61 stations)	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
LPAHs					
1-Methylnaphthalene	42	0 (non-detect)	12.0	2.4	8.2
1-Methylphenanthrene	42	0 (non-detect)	8.7	2.8	4.7
2,3,5-Trimethylnaphthalene	40	0 (non-detect)	10.0	1.4	9.0
2,6-Dimethylnaphthalene	53	0 (non-detect)	26.0	3.2	9.6
2-Methylnaphthalene	38	0 (non-detect)	20.0	3.7	14.8
Acenaphthene	42	0 (non-detect)	3.1	0.4	1.4
Acenaphthylene	49	0 (non-detect)	18.0	0.9	2.9
Anthracene	38	0 (non-detect)	14.0	1.0	3.0
Biphenyl	31	0 (non-detect)	7.4	1.7	4.6
Dibenzothiophene	41	0 (non-detect)	3.7	0.6	2.2
Fluorene	44	0 (non-detect)	8.7	1.4	4.7
Naphthalene	37	0 (non-detect)	47.0	4.8	16.5
Phenanthrene	60	0 (non-detect)	55.5	6.7	30.1
Total LPAH	61	0.18	162.7	30.4	124.4
HPAHs					
Benz(a)anthracene	37	0 (non-detect)	30.5	1.7	6.1
Benzo(a)pyrene	49	0 (non-detect)	56.5	2.5	12.1
Benzo(b)fluoranthene	38	0 (non-detect)	36.0	2.9	9.7
Benzo(g,h,i)perylene	52	0 (non-detect)	32.0	2.4	9.7
Benzo(k)fluoranthene	37	0 (non-detect)	36.5	1.8	6.7
Chrysene	49	0 (non-detect)	43.0	4.3	17.6
Dibenz(a,h)anthracene	29	0 (non-detect)	5.9	0.0	2.0
Fluoranthene	61	0.56	88.0	7.2	17.7
Indeno(1,2,3-c,d)pyrene	45	0 (non-detect)	27.0	1.3	5.9
Pyrene	59	0 (non-detect)	90.0	5.5	18.1
Total HPAH	61	0.60	425.4	28.9	102.4
All					
Total PAH	61	2.20	588	58.7	226.7

Comparisons with Sediment Quality Standards and Guidelines

No stations exceeded any of the Washington State sediment quality standards or NOAA sediment quality guidelines for any individual or Total PAHs.

Chlorinated Pesticides and PCBs

No chlorinated pesticides (including DDT) or PCBs were detected at any station.

Sea Urchin Fertilization Test

Percent control-corrected fertilization of *Arbacia punctulata* eggs in porewater toxicity tests ranged from 37.9% to 106.7% at 100% salinity-adjusted porewater (Table 34).

The sediment from 37 of the 61 stations, representing 53.2% of the study area, had control-corrected fertilization ≥ 100% (Table 34, Figure 38), indicating as good or better fertilization of sea urchin eggs in test sediments than in controls. Only three stations, accounting for approximately 9.2% of the study area, had sediments in which control-corrected fertilization was < 80%. (The percentiles indicated in the graph in Figure 38 result from linear interpolation of a continuous curve, rather than the step function inherent in a set of sample results.)

Table 34. Summary of control-corrected sea urchin fertilization sediment toxicity test results.

Benchmark	Number of Samples (N=61 Stations)	Percent of Study Area	Test Results	Percent Fertilization
Meeting Control Conditions*	61	--	Minimum	37.9
< 80% of Control	3	9.2%	Maximum	106.7
< 100% of Control	24	46.8%	CDF 50th Percentile	100.2
			CDF 90th Percentile	104.3

*Mean fertilization in controls ≥ 90% in each batch, with no individual control replicate fertilization < 85%.

Each stratum had one of the three stations with urchin fertilization rates less than 80% of the controls. Puget Sound Station 60 (Drayton Harbor) had the lowest fertilization success in the study: 37.9%. Willapa Bay Station 35, at the mouth of the Palix River, had a fertilization rate of 58.2%; and Grays Harbor Station 5 had a fertilization rate of 60.9%.

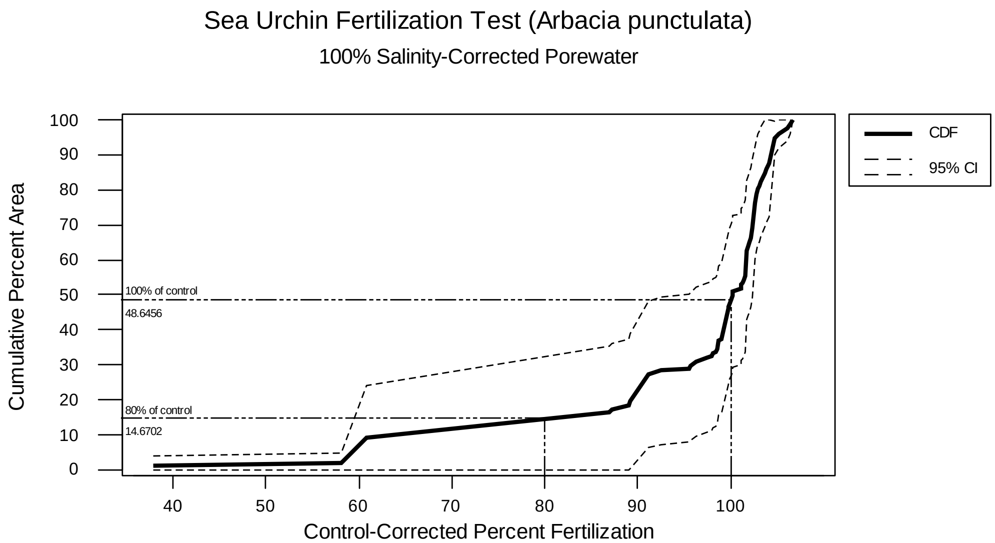


Figure 38. Cumulative percent area by control-corrected fertilization success of *Arbacia punctulata* at 100% salinity-adjusted porewater, indicating comparison to control.

Biotic Condition Indicators

Infaunal Species Richness and Diversity

Benthic invertebrate samples were collected at all 61 stations. The 232 taxa found in the 0.1-mm sieve fractions included 1 colonial species and 21 exotic species (Appendix Table C-2).

Taxa richness ranged from 7 to 64 taxa per sample (Table 35), averaging 26.8 taxa.

Table 35. Summary statistics for benthic macrofauna bioindices of community richness and diversity.

Statistic	Taxa Richness (Number of Taxa)	Shannon-Wiener Diversity H'	Pielou's Evenness J'	Swartz' Dominance (Number of Taxa)	Dominance Standardized by Taxa Richness (%)
Minimum	7	0.47	0.03	1	3.1
Maximum	64	4.69	0.28	14	50
CDF 50th Percentile	22.3	3.26	0.13	5.0	24.2
CDF 90th Percentile	39.6	4.19	0.17	9.9	28.7
Mean (unweighted)	26.8	3.02	0.13	5.3	20.4
Median (unweighted)	25.0	3.24	0.12	5.0	19.1

The *Shannon-Wiener Diversity Index (H')* ranged from 0.47 to 4.69, averaging 3.02.

The *Pielou's Evenness Index (J')* ranged from 0.03 to 0.28, averaging 0.13.

The *Swartz' Dominance Index (SDI)*, the number of taxa accounting for at least 75% of the total abundance, ranged from 1 to 14, averaging 5.3 taxa.

When standardized by taxa richness (the total number of taxa in the sample), the *standardized Swartz' Dominance Index (SDISTD)* ranged from 3.1% to 50%, averaging 20.4%.

Infaunal Abundance and Taxonomic Composition

Infaunal abundance ranged from 35 individuals per 0.1 m^2 to 8528 individuals per 0.1 m^2, averaging 1112 individuals per 0.1 m^2 (Table 36, Figure 39). Total infaunal abundance exceeded 1800 individuals per 0.1 m^2 in ten percent of the study area (Table 36, Figure 39).

Table 36. Summary statistics for total benthic macrofauna abundance (# individuals/0.1 m^2).

Statistic	All Taxa	Annelida	Arthropoda	Echino-dermata	Mollusca	Misc. Taxa
Minimum	35	2	0	0	2	0
Maximum	8528	6357	1568	40	462	545
CDF 50th Percentile	363.5	147.8	36.7	0	74.0	4.2
CDF 90th Percentile	1799.6	773.7	703.8	0	175.1	38.3
Mean (unweighted)	1112	723	253.4	0.9	111.2	22.6
Median (unweighted)	510	267	106.4	0	68.4	4.2

The ten numerically-dominant taxa (9 annelids, 1 arthropod) made up 55% of the total benthic macrofauna (Appendix Table C-2). Of those, half the species were exotic, accounting for 23% of the total benthic macrofauna. Twenty-one exotic species accounted for 36% of the total benthic infauna collected. The abundance and proportion of all of the taxa found, including the 10 most abundant, are given in Appendix Table C-2. Exotic and colonial species are indicated.

Only a single colonial species was found, *Campanularia gelatinosa*, a hydrozoan, at a single station; that species was included with an abundance of 1.

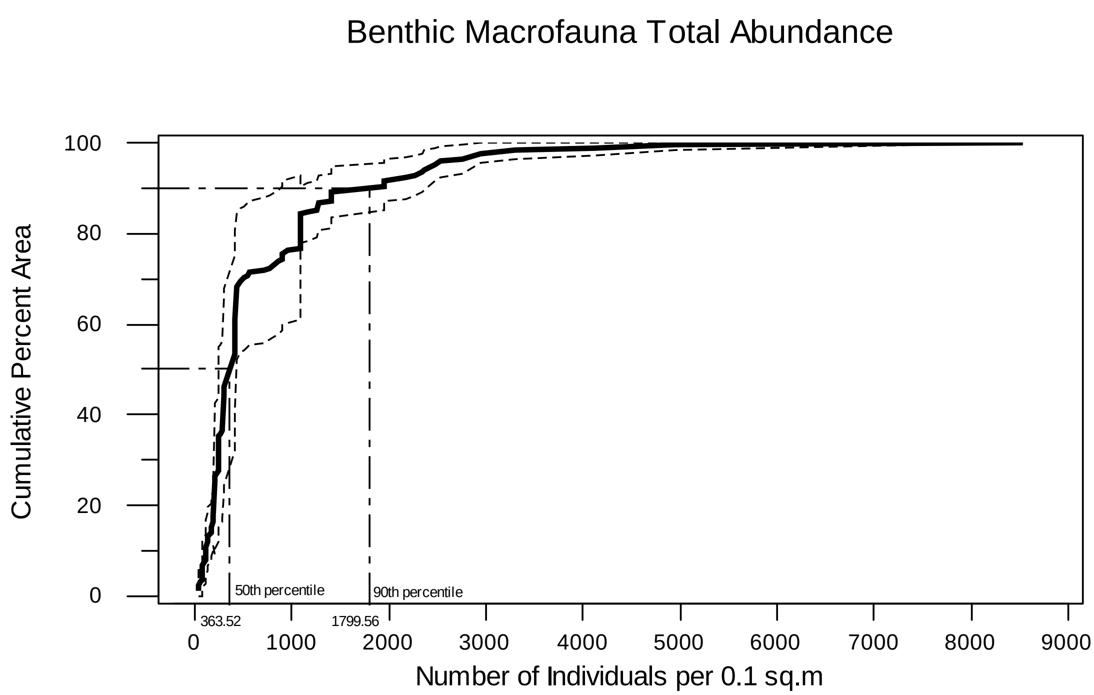


Figure 39. Cumulative percent area by benthic macrofauna total abundance (number of individuals per sampled 0.1-m^2 area). Colonial species were included with an abundance of 1.

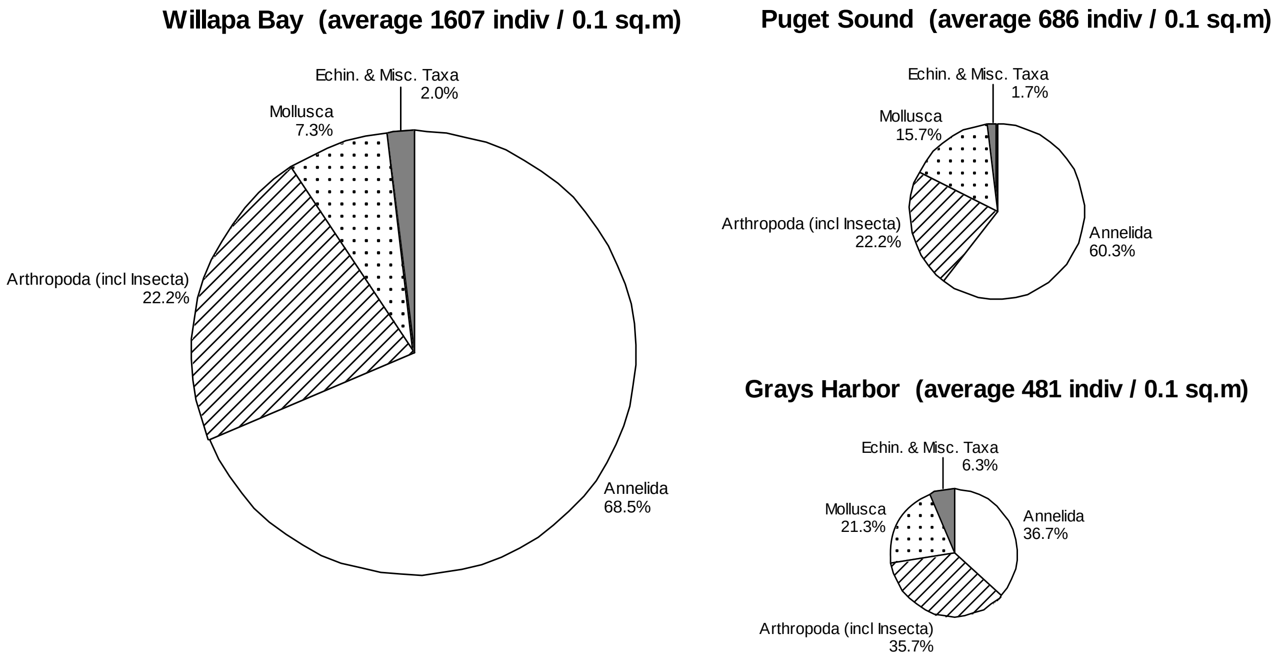
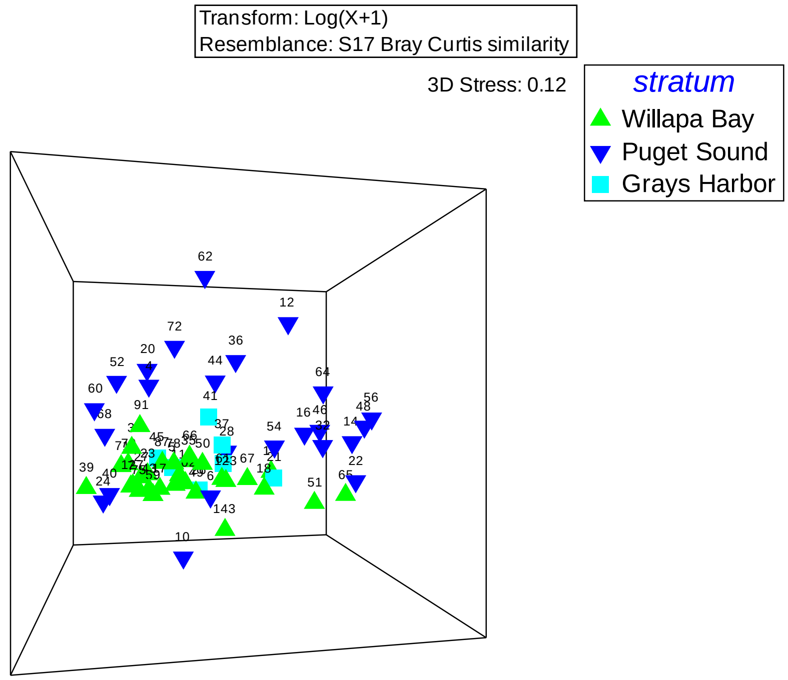


Figure 40. Mean abundance of major taxonomic groups by geographic area. The sizes of the pies are proportional to the mean total infaunal abundance in each stratum.

Total abundance in Willapa Bay was more than twice as high as in Puget Sound, and more than three times as high as in Grays Harbor (Figure 40).

The results of the Analysis of Similarities (ANOSIM) test comparing the infaunal communities of the three strata, based on Bray-Curtis similarities of log-transformed species abundances, indicates significant differences among the strata (P-value = 0.001). Pairwise comparisons indicate significant differences between Willapa Bay and the other two strata (P-values = 0.001 and 0.024), but not between Puget Sound and Grays Harbor (P-value = 0.936).

The differences in Willapa Bay and Puget Sound infaunal communities can be seen in the multidimensional scaling (MDS) diagrams in Figure 41, in which the Willapa Bay stations are essentially co-planar, while the Puget Sound stations are mapped in a cloud around the outside. The relatively large distances between the Puget Sound stations in the MDS diagram also indicate widely varying infaunal communities within Puget Sound. The Willapa Bay stations are fairly tightly clustered, indicating that the infaunal communities are relatively similar.



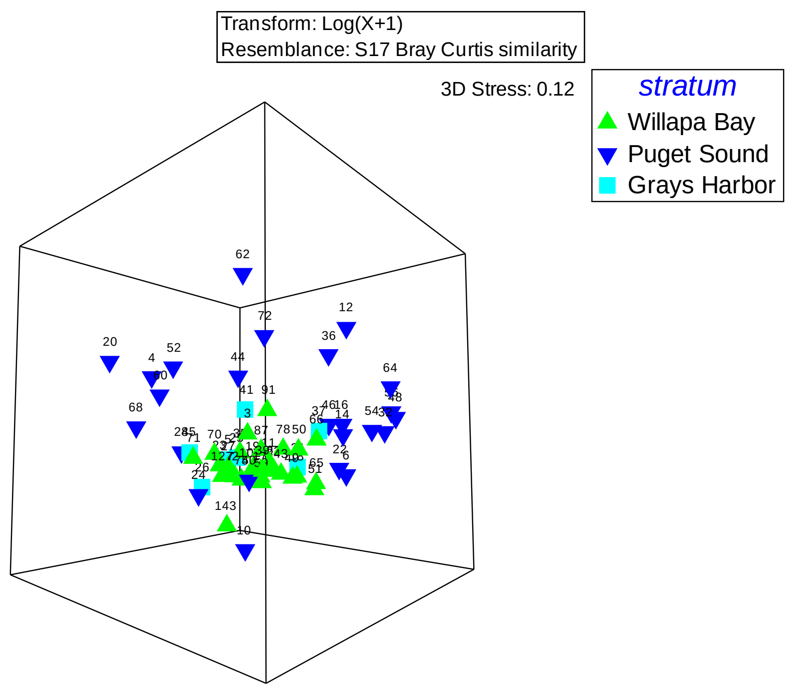


Figure 41. Two rotated views of a multidimensional scaling (MDS) graph of benthic macrofaunal community similarity (taxa and abundance), based on Bray-Curtis similarity of log-transformed abundance data (stress = 0.12).

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.

Results – 2003 (Offshore)

The results reported herein were analyzed in 2007 with data taken from the West Coast EMAP 2000 database 1.07.01, with corrections approved by the Washington EMAP Information Management Coordinator. The corrections were incorporated into subsequent versions of the West Coast EMAP database.

The Coastal EMAP survey of Washington State's offshore areas was designed to provide a broad assessment of condition based on one-time samples. In-depth and long-term assessments of the environmental conditions in the Olympic Coast NMS are provided by NOAA National Marine Sanctuary Program (http://olympiccoast.noaa.gov/research/ongoing/welcome.html).

Site Visits

Sampling was attempted at 55 stations and successful for sediment sampling at 50: 30 in the Olympic Coast NMS and 20 along the Washington coast south of the sanctuary (details in Appendix Table B-3, Figure B-3). Water sampling was successful at all 50 stations. Fishing was attempted at 36 stations and successful at 21 stations.

The first three stations attempted were in the Strait of Juan de Fuca, which was in the "remainder of Washington" stratum. Although an infauna sample was collected from one side of the first grab at one of those stations, further grabs were unsuccessful in obtaining enough sediment for sediment chemistry analyses, and so the station was abandoned. The Strait of Juan de Fuca was removed from the sample frame because (1) the strait is oceanographically quite different from the continental shelf on the Pacific coast, and (2) sediment sampling was unsuccessful at all three stations in the strait. Station weights in the "remainder of Washington" stratum were adjusted accordingly.

In addition, water sampling was performed at two target stations, one in the Strait of Juan de Fuca, prior to the stations' being abandoned for lack of soft sediment. Because the stations were rejected, the results are not included in the analyses.

Data Quality Objectives

Assessments of the sediment, tissue, and water chemistry data for adherence to EPA's Data Quality Objectives (DQO; see U.S. EPA, 2001a) found the water analyses and metals analyses (sediment and tissue) to have met the DQOs (Ozretich, 2007b). The analyses of organic compounds, however, had difficulties meeting the DQOs for precision and therefore must be interpreted with caution (Ozretich, 2007b).

General Habitat Condition Indicators

Water Characteristics

Hydrographic Profile

Surface (shallowest depth measured, in this study ranging 1.5-9.0 m) and bottom results (approximately 5-10 m above seafloor) are summarized here for continuously-measured parameters profiled by the CTD. These parameters are salinity, temperature, dissolved oxygen, transmissivity, and chlorophyll-*a* fluorescence (Table 37).

In addition, because all but three stations had CTD measurements at 5-m depth, results for that depth are presented for a view of a consistent near-surface depth.

Table 37. Summary statistics for water vertical-profile physical parameters.

Parameter (units)	Water Level	Number of Stations	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Depth of bottom measurements (m)	Bottom	50	14	113	59.5	104.5
Salinity (psu)	Surface	50	21.2	32.1	31.4	31.7
	5 Meters	47	28.2	32.3	31.5	31.8
	Bottom	49	31.6	34.0	33.7	33.9
Water Temperature (°C)	Surface	50	10.5	14.4	12.1	13.3
	5 Meters	47	9.4	14.4	11.8	13.2
	Bottom	49	5.8	9.8	7.3	8.1
Density (σ_t)	Surface	50	15.7	24.6	23.7	24.1
	5 Meters	47	21.3	24.9	23.8	24.2
	Bottom	49	24.3	26.8	26.3	26.6
Density Stratification ($\Delta\sigma_t$) [$Density_{Max} - Density_{Min}$]	--	50	0.24	10.64	2.63	2.97
Dissolved Oxygen (mg/L)	Surface	50	7.8	12.6	11.0	11.9
	5 Meters	47	7.7	13.6	10.9	12.2
	Bottom	49	2.3	8.3	3.3	6.2
Chlorophyll-*a* (measured by CTD fluorometer) (ug/L)	Surface	50	1.6	50.2	16.5	37.5
	5 Meters	47	1.7	53.0	22.9	42.6
	Bottom	49	0.0	9.1	0.6	1.3
Transmissivity (%)	Surface	50	13.7	86.3	68.7	83.2
	5 Meters	47	13.8	86.1	68.9	84.6
	Bottom	50	5.0	95.2	85.6	93.1

Salinity

Salinity in the upper 5 meters was virtually all the same, with the exception of Station WA03-0010 in the Columbia River plume, representing 2.26% of the study area (Figure 42). The surface salinity at that station was 21.2 psu, in contrast to 31-32 psu everywhere else. At Station WA03-0010 the bottom salinity was 33.7 psu, 12.5 psu higher than at the surface. Everywhere else, bottom salinities were ≤ 3 psu higher than at the surface. (At Station WA00-0039, where the bottom reading was taken at 14 m deep, the difference was only 0.02 psu).

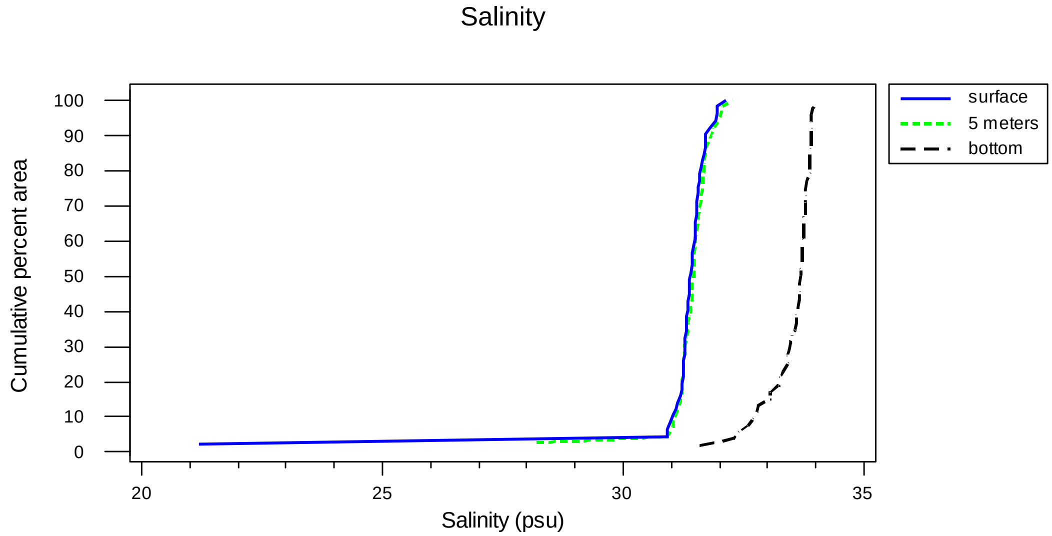


Figure 42. Cumulative percent area by salinity at surface (shallowest depth in CTD record), 5 meters depth, and bottom.

Temperature

The temperatures at the 5-m depth were lower, overall, than those at the "surface," or minimum depth of CTD data (paired sign test, P-value = 0.0001). The depths of the surface measurements varied from 1.5 to 8.5 m, with most from 2-2.5 m. The differences in surface and 5-m temperatures were < 1 °C in all but a few cases, and more than half were less than 0.1 °C. In one case (Station WA03-0047), the surface temperature at the surface (1.5 m) was 1.75 °C higher than at 5 meters deep.

The "bottom" temperatures (taken at 14 to 113 m deep, averaging 60 +/- 3 m) were all lower than the surface temperatures, by 1.4 to 8.6 °C, averaging 4.9 °C (Figure 43).

Density and Water Column Stratification

Water density is a function of salinity and temperature. The *Stratification Index*, calculated as the maximum density minus the minimum density (Newton et al., 2002), indicates the degree of water-column stratification. A stratification index less than 0.5 σ_t indicates well-mixed waters, whereas strongly stratified waters are indicated by a stratification index greater than 2 σ_t (Newton et al., 2002). Between 0.5 σ_t and 2 σ_t is intermediate stratification.

Approximately 3% of the study area had stratification index values less than 0.5 σ_t , indicating well-mixed waters (Figure 44). Seventy-nine percent of the area was strongly stratified, as indicated by a stratification index greater than 2 σ_t . The remaining 18% had intermediate stratification.

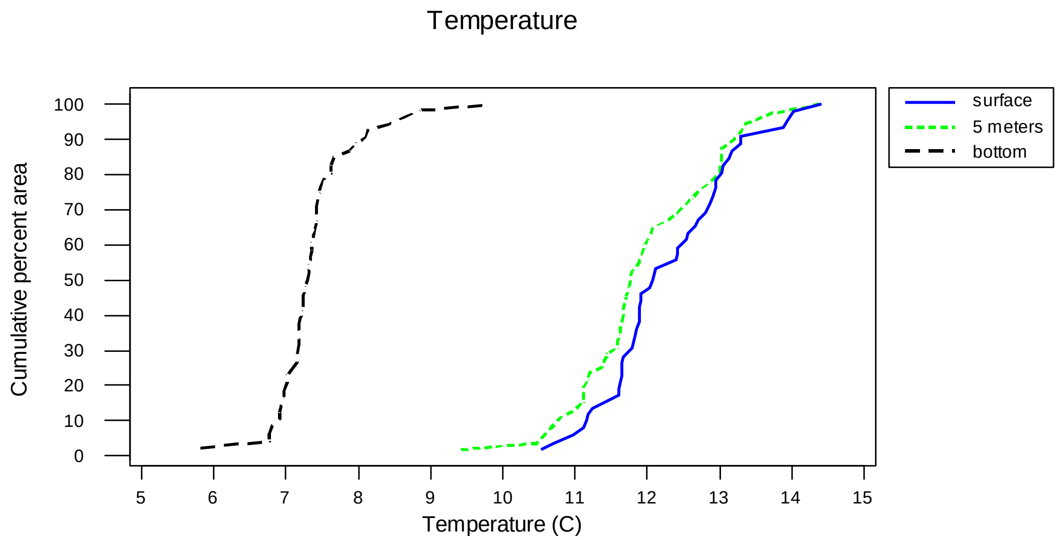


Figure 43. Cumulative percent area by water temperature at surface (shallowest depth in CTD record), 5 meters depth, and bottom.

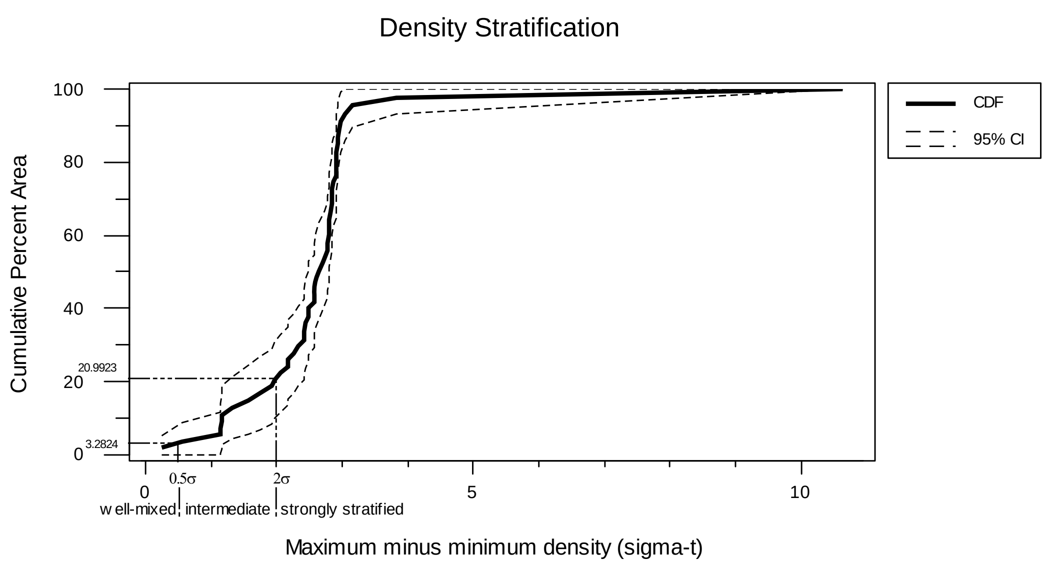


Figure 44. Cumulative percent area by water column density stratification index, indicating well-mixed and strongly stratified water.

Dissolved Oxygen (DO)

None of the study area was severely hypoxic (DO < 2 mg/L), and none of the study area had moderately hypoxic (DO < 5 mg/L) surface waters. However, 83% of the study area was moderately hypoxic (DO < 5 mg/L) at the bottom (Figure 45).

Bottom DO was less than 8 mg/L at all but one station; surface and 5-meter DO levels were greater than 8 mg/L for all but one and two stations, respectively (Figure 46).

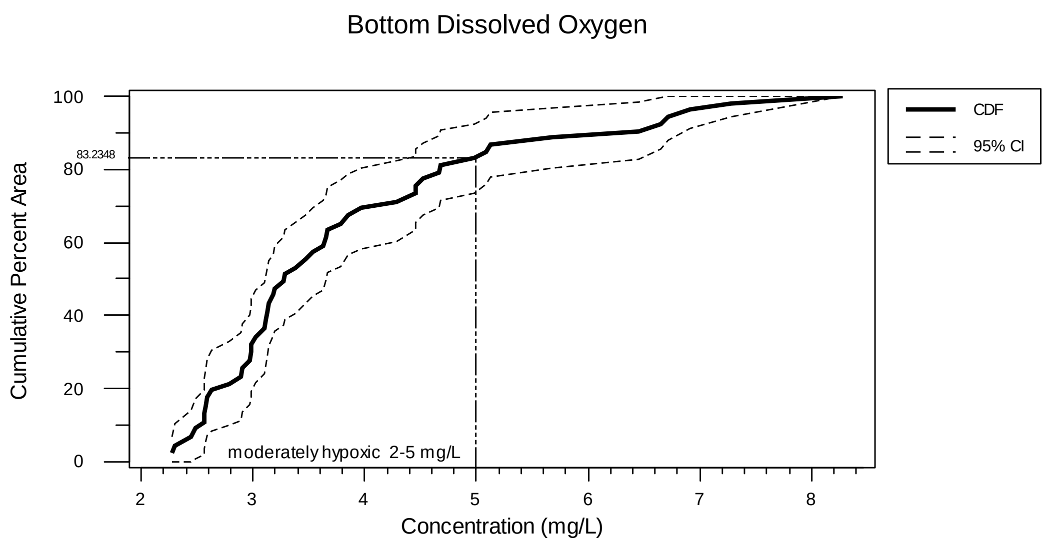


Figure 45. Cumulative percent area by bottom DO, indicating amount of area moderately hypoxic.

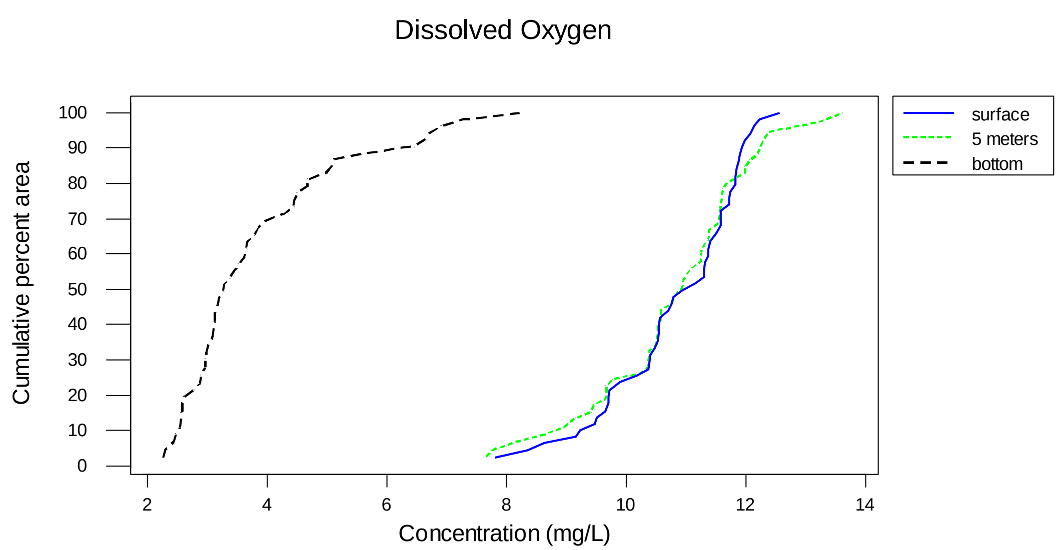


Figure 46. Cumulative percent area by DO concentration at surface (shallowest depth in CTD record), 5 meters depth, and bottom.

Transmissivity

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, measured with 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%.

Only two stations, WA03-0023 and WA03-0034, together representing under 5% of the study area, had transmissivities below 55%. In both cases, near-surface (including 5 meters depth) transmissivity was around 14%, and bottom transmissivity was 5-8%. In general, however, bottom transmissivity was greater than transmissivity near the surface (Figure 47, Friedman test, P-value < 0.0005).

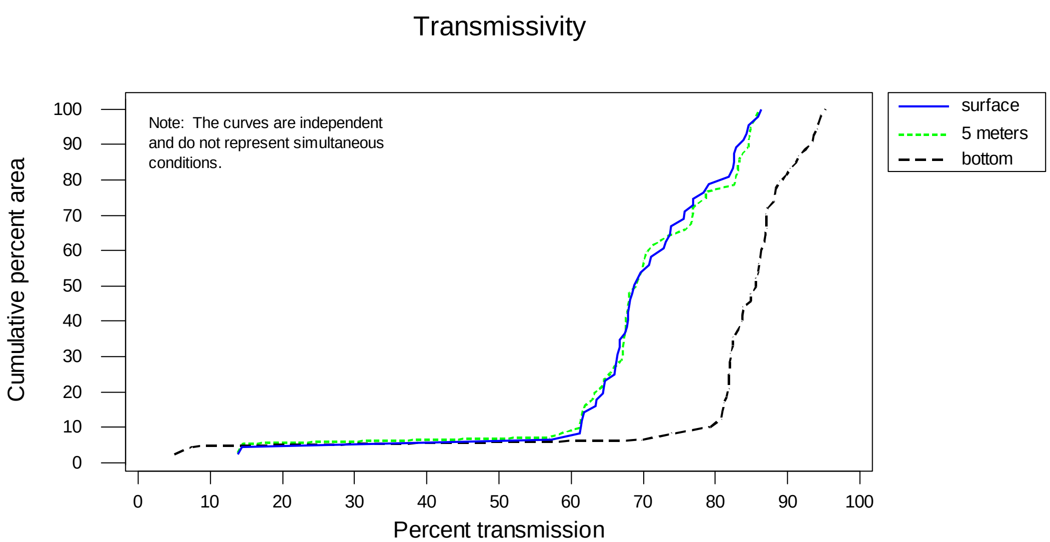


Figure 47. Cumulative percent area by transmissivity at surface (shallowest depth in CTD record), 5 meters depth, and bottom.

Chlorophyll-a

Although the CDFs for the surface and 5-meter depth are almost identical for other parameters, there is a distinct difference for fluorescence-measured chlorophyll-*a* (Figure 48). The chlorophyll levels at 5 meters are higher, overall, than at the "surface" depths, most of which are 2-2.5 meters (paired sign test, P-value = 0.0001). The bottom chlorophyll levels were less than 2.1 µg/L at all but one station, Station WA03-0039 in the Olympic Coast NMS (9.1 µg/L), the "bottom" measurement for which was at 14 meters depth.

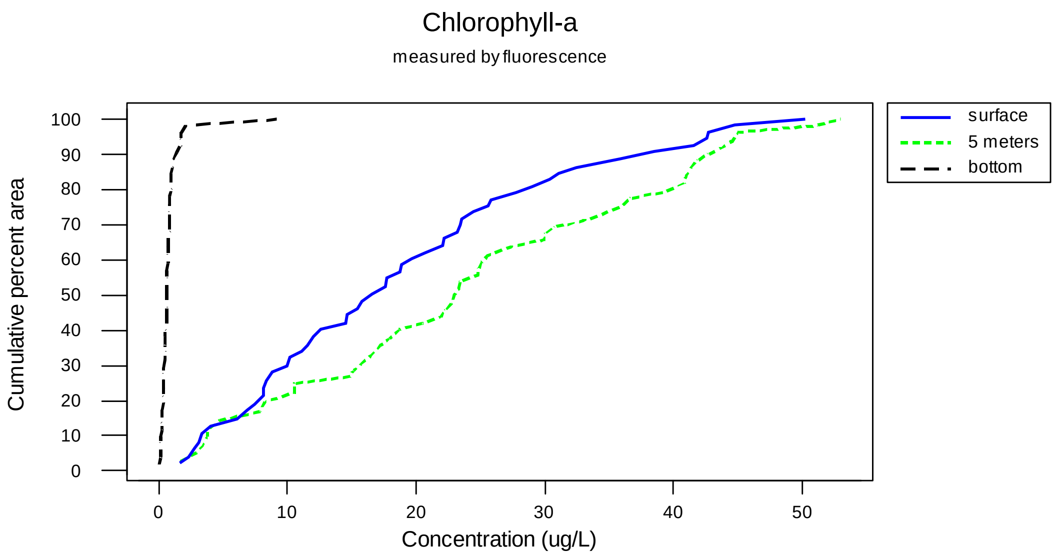


Figure 48. Cumulative percent area by chlorophyll fluorescence at surface (shallowest depth in CTD record), 5 meters depth, and bottom.

Laboratory Analyses of Water

Surface, mid-water, bottom, and mean results are presented for discrete water parameters (TSS, photosynthetic pigments, and dissolved nutrients) for all stations sampled. The surface and bottom depths are the same as for the CTD measurements.

Summary statistics for the results of water laboratory analyses are given in Table 38 and Table 39.

Table 38. Summary statistics for water chemical parameters. Only the water-column mean represents simultaneous conditions at surface, mid-water, and bottom. Because conditions vary by station, the proportions of area (50th and 90th percentiles) may not represent the same stations at different water levels and thus may vary by water level.

Parameter (units)	Water Level	Number of Stations	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
TSS (mg/L)	Surface	50	3.5	10	4.6	5.9
	Mid-water	50	0	5	1.9	3.7
	Bottom	49	0	8	2.6	4.0
	Mean	***50***	***2.2***	***7.0***	***3.3***	***4.0***
Chlorophyll-*a* (µg/L)	Surface	50	0.99	21.55	7.5	16.5
	Mid-water	48	0.14	11.78	0.5	3.0
	Bottom	49	0.03	1.15	0.3	0.7
	Mean	***50***	***0.58***	***8.16***	***3.1***	***6.2***
Phaeopigment (µg/L)	Surface	50	0.49	6.00	1.8	3.3
	Mid-water	48	0.17	3.26	0.9	1.6
	Bottom	49	0.12	4.15	1.0	2.0
	Mean	***50***	***0.50***	***2.41***	***1.3***	***2.1***
pH	Surface	48	7.98	8.41	8.3	8.4
	Mid-water	49	7.71	8.11	7.9	8.1
	Bottom	48	7.60	7.93	7.7	7.8
	Mean	***49***	***7.80***	***8.11***	***8.0***	***8.0***

Dissolved Nutrients

Total Nitrogen, Total Phosphorus, Nitrogen:Phosphorus (N:P) Ratio

Thirty stations, representing 62% of the study area, had surface Total N concentrations of < 1 µM. The same 30 stations and three others besides, or about 67% of the area, had surface N:P ratios under 5. Both of those conditions may be nitrogen-limiting (Newton et al., 2002). Surface Total P concentrations at seven stations were below 0.07 µM, possibly phosphorus-limiting conditions (Newton et al., 2002). At those seven stations, Total N and N:P were also low, possibly nitrogen-limiting conditions. Surface Total P concentrations were below 0.2 µM at 30 stations, or 62% of the area; 28 of those stations also had Total N < 1 µM.

Table 39. Summary statistics for dissolved nutrients. Only the water-column mean represents simultaneous conditions at surface, mid-water, and bottom. Because conditions vary by station, the proportions of area (50th and 90th percentiles) may not represent the same stations at different water levels and thus may vary by water level.

Parameter (units)	Water Level	Number of Stations	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Dissolved Ammonium (µg/L)	Surface	50	0	11.47	1.7	4.4
	Mid-water	50	0	32.06	5.5	19.7
	Bottom	50	0	33.09	2.9	8.7
	Mean	*50*	*0*	*17.30*	*3.9*	*9.1*
Dissolved Nitrite (µg/L)	Surface	50	0.05	3.74	0.3	2.6
	Mid-water	50	0.06	5.25	3.3	4.3
	Bottom	50	0.33	5.56	2.8	4.6
	Mean	*50*	*0.40*	*3.45*	*2.4*	*3.1*
Dissolved Nitrate (µg/L)	Surface	50	0	476.3	2.0	128.9
	Mid-water	50	0.9	381.3	269.9	330.5
	Bottom	50	0	539.1	406.7	457.1
	Mean	*50*	*85.2*	*358.8*	*232.2*	*263.2*
Total Inorganic Nitrogen (µM)	Surface	50	0.03	34.59	0.3	9.6
	Mid-water	50	0.16	27.48	20.5	24.6
	Bottom	50	0.07	38.70	29.8	33.1
	Mean	*50*	*6.15*	*25.96*	*16.9*	*19.5*
Dissolved Inorganic Phosphate (µg/L)	Surface	50	1.32	80.07	4.8	21.6
	Mid-water	50	1.38	67.43	53.8	62.5
	Bottom	50	3.75	90.32	73.1	82.2
	Mean	*50*	*19.04*	*55.66*	*43.6*	*50.3*
Total Inorganic Phosphorus (µM)	Surface	50	0.04	2.58	0.2	0.7
	Mid-water	50	0.04	2.18	1.7	2.0
	Bottom	50	0.12	2.91	2.4	2.7
	Mean	*50*	*0.61*	*1.80*	*1.4*	*1.6*
Nitrogen: Phosphorus Ratio	Surface	50	0.19	143.52	3.6	11.3
	Mid-water	50	3.56	12.63	11.6	12.4
	Bottom	50	0.56	13.51	12.4	13.3
	Mean	*50*	*7.88*	*16.70*	*11.9*	*12.3*
Dissolved Silicic Acid (µg/L)	Surface	50	61.5	2040.5	137.9	622.0
	Mid-water	50	70.1	1407.5	886.5	1136.6
	Bottom	50	109.9	2070.7	1352.0	1557.1
	Mean	*50*	*303.2*	*1486.1*	*799.1*	*970.0*

Sediment Characteristics

Total Organic Carbon (TOC) content

TOC content was under 1.5% everywhere. Ninety percent of the area had TOC content 1.13% or less, and 50% of the area had TOC content less than 0.24% (Table 40, Figure 49). No TOC was detected at 9 of the 50 stations.

Table 40. Summary statistics for sediment characteristics.

Parameter	Number of Detects (N=50 stations)	Minimum	Maximum	CDF 50th Percentile	CDF 90th Percentile
Percent Fines (% silt-clay)	50	0.5	65.25	12.23	55.56
TOC (%)	41	0 (non-detect)	1.4	0.24	1.13

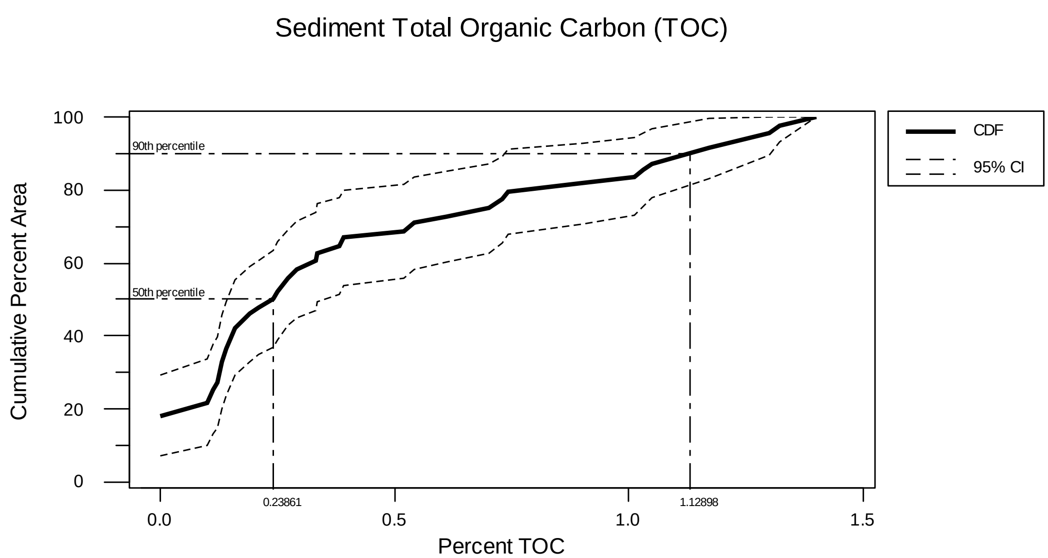


Figure 49. Cumulative percent area by sediment TOC.

Sediment TOC was not different in the Olympic Coast NMS versus the rest of the coast at significance level 0.05 (Mann-Whitney test P-value= 0.0552).

Silt-Clay Content (Grain Size Analysis)

The predominant sediment type was sand, which was almost 80%, on average. Very fine sand and fine sand averaged 35.9% and 31.6% of the sediment particles, respectively (Figure 50). The mean silt content was 16.5%. Clay constituted only 3.2% of the sediment particles, on average.

Approximately 50% of the area had less than 12% fines (silt-clay), and approximately 90% of the area had less than 56% fines (Figure 51).

The percent fines was generally lower in the Olympic Coast NMS than along the rest of the Washington Pacific coast at significance level 0.05 (Figure 52).

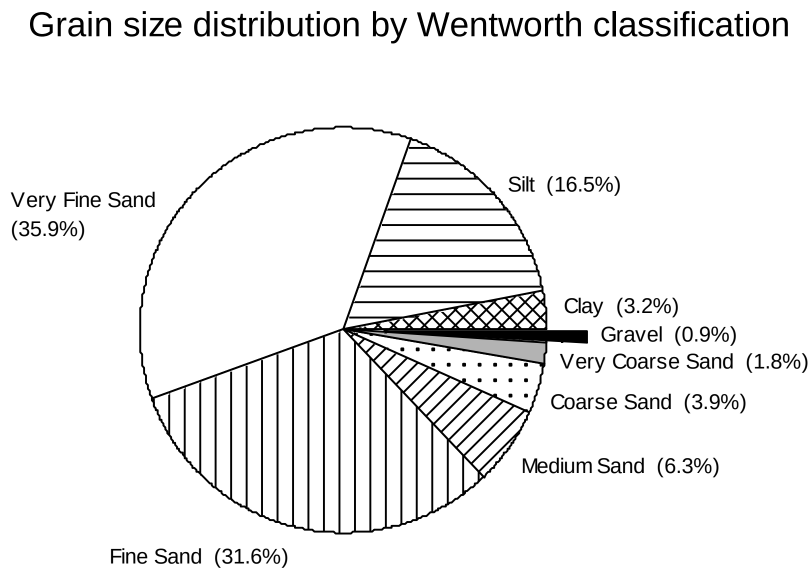


Figure 50. Mean grain size distribution, according to the Wentworth scale.

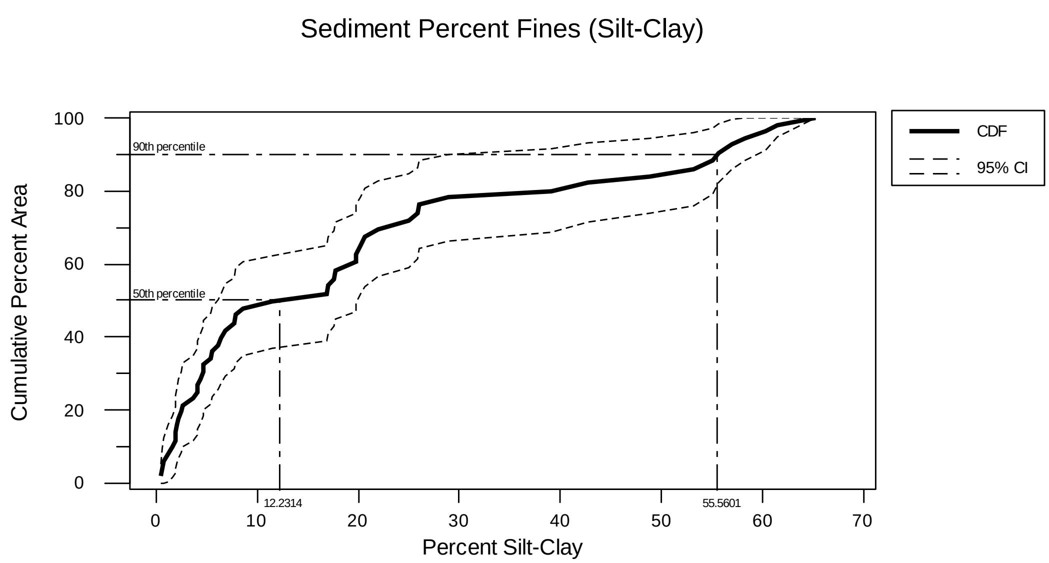


Figure 51. Cumulative percent area by sediment percent fines (silt-clay).

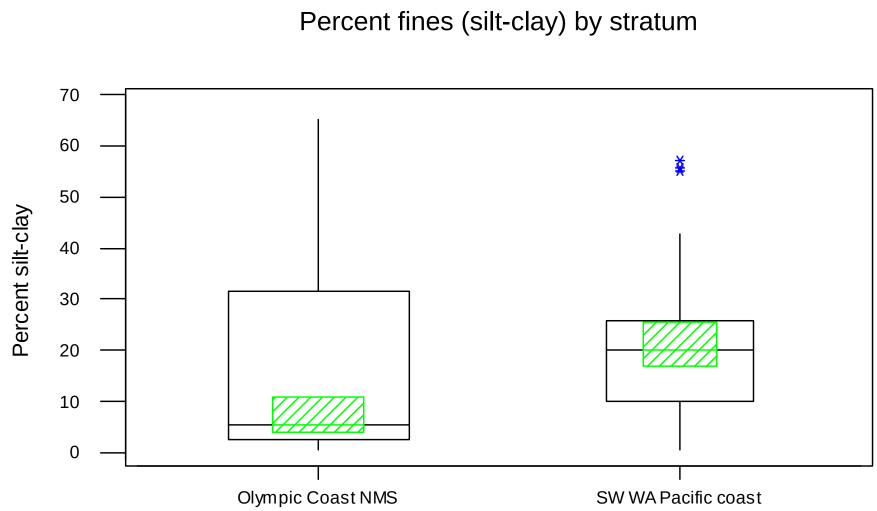


Figure 52. Sediment percent fines by sampling stratum. The non-overlapping 95% confidence intervals for the medians indicates that the medians are significantly different at alpha = 0.05.

Abiotic/Pollutant Exposure Condition Indicators

Sediment Contaminants

Metals

Ten metals were detected in all 50 sediment samples: aluminum, antimony, arsenic, chromium, copper, iron, lead, manganese, nickel, and zinc (Table 41). Silver was found at all but two stations, and mercury was found at all but four stations. Tin was not detected at any station, and selenium was detected at only 5 stations. Cadmium was found at 33 stations.

Comparisons to Sediment Quality Standards and Guidelines for Metal Contaminants

The NOAA Effects Range-Low (ERL) sediment quality guideline was exceeded for only three metals (arsenic, chromium, and silver), at a few stations (Table 42). None of the other NOAA and Washington State sediment quality guidelines or standards were exceeded at any station. Five stations, four in the Olympic Coast NMS, had chromium concentrations higher than the corresponding ERL. The sediment arsenic concentrations at two stations, both in the southern Washington Pacific coast stratum, exceeded the arsenic ERL. One station in each stratum had sediment silver concentrations higher than the silver ERL.

Table 41. Summary statistics for sediment metal concentrations (µg/g dry weight). Non-detects were set to zero and included in the statistical analyses, except when the analyte was not detected in any sample.

Analyte	Number of Detects (N=50 stations)	Minimum (µg/g dry wt)	Maximum (µg/g dry wt)	CDF 50th Percentile	CDF 90th Percentile
Aluminum	50	1930	78200	53139	68424
Antimony	50	0.26	0.75	0.39	0.55
Arsenic	50	3.17	10.50	5.08	6.79
Cadmium	33	0 (non-detect)	0.53	0.12	0.33
Chromium	50	25.6	124	61.9	79.2
Copper	50	5.57	21	11.6	17.4
Iron	50	3050	70000	42376	50759
Lead	50	2.87	16.7	9.5	14.6
Manganese	50	324	1090	458.6	745
Mercury	46	0 (non-detect)	0.0935	0.0169	0.0602
Nickel	50	14	26.8	21.2	24.6
Selenium	5	0 (non-detect)	0.99	0 (non-detect)	0.16
Silver	48	0 (non-detect)	2.03	0.2	0.28
Tin	0				
Zinc	50	38	88.4	60.8	72.2

Table 42. 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	4.5	70	0	57	0	93	0
Cadmium	1.2	0	9.6	0	5.1	0	6.7	0
Chromium	81	9.6	370	0	260	0	270	0
Copper	34	0	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	4.1	3.7	0	6.1	0	6.1	0
Zinc	150	0	410	0	410	0	960	0

ERL = NOAA Effects Range-Low
ERM = NOAA Effects Range-Median
SQS = Washington State Sediment Quality Standard
CSL = Washington State Cleanup Screening Level

Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs were detected at 48 of the 50 stations analyzed, with the number of stations at which the individual PAH compounds were detected ranging from 21 to 47 (Table 43). Phenanthrene was found most frequently, and acenaphthene was found least frequently. No PAHs were detected at two stations, WA03-0042 and WA03-0070, both in the southern Pacific coast stratum. In addition, no LPAHs were found at station WA03-0007 (southern Pacific coast), and no HPAHs were found at station WA03-0027 (Olympic Coast NMS).

Table 43. Summary of sediment individual and Total PAH concentrations (ng/g dry weight)

PAH Compound	Number of Detects (N=50 stations)	Minimum (ng/g dry wt)	Maximum (ng/g dry wt)	CDF 50th Percentile	CDF 90th Percentile
LPAHs					
1-Methylnaphthalene	40	0 (non-detect)	25	2.8	7.3
1-Methylphenanthrene	36	0 (non-detect)	32	2.9	5.8
2,3,5-Trimethylnaphthalene	41	0 (non-detect)	25	2.1	4.8
2,6-Dimethylnaphthalene	47	0 (non-detect)	29	6.7	18.6
2-Methylnaphthalene	38	0 (non-detect)	25	3.7	10.8
Acenaphthene	21	0 (non-detect)	2.1	0 (non-detect)	1.6
Acenaphthylene	26	0 (non-detect)	6.1	0.4	4.4
Anthracene	27	0 (non-detect)	8	0.6	5.4
Biphenyl	32	0 (non-detect)	6.7	1.9	5.0
Dibenzothiophene	34	0 (non-detect)	3.6	0.8	2.4
Fluorene	34	0 (non-detect)	5.9	1.2	4.4
Naphthalene	34	0 (non-detect)	26	3.8	19.4
Phenanthrene	45	0 (non-detect)	46	7.2	26.5
Total LPAH	47	0 (non-detect)	203.5	35.1	120
HPAHs					
Benz(a)anthracene	25	0 (non-detect)	18	0.3	12.5
Benzo(a)pyrene	35	0 (non-detect)	25	2.5	17.1
Benzo(b)fluoranthene	31	0 (non-detect)	22	1.8	13.5
Benzo(g,h,i)perylene	37	0 (non-detect)	23	2.6	17.8
Benzo(k)fluoranthene	30	0 (non-detect)	17	1.8	13.9
Chrysene	32	0 (non-detect)	12	1.8	9.6
Dibenz(a,h)anthracene	23	0 (non-detect)	4	0 (non-detect)	3.3
Fluoranthene	43	0 (non-detect)	40	5.1	31.5
Indeno(1,2,3-c,d)pyrene	30	0 (non-detect)	15	1.2	11.8
Pyrene	44	0 (non-detect)	54	6.5	33.6
Total HPAH	47	0 (non-detect)	226.8	19.6	171.7
All					
Total PAH	48	0 (non-detect)	350.2	64.4	283.3

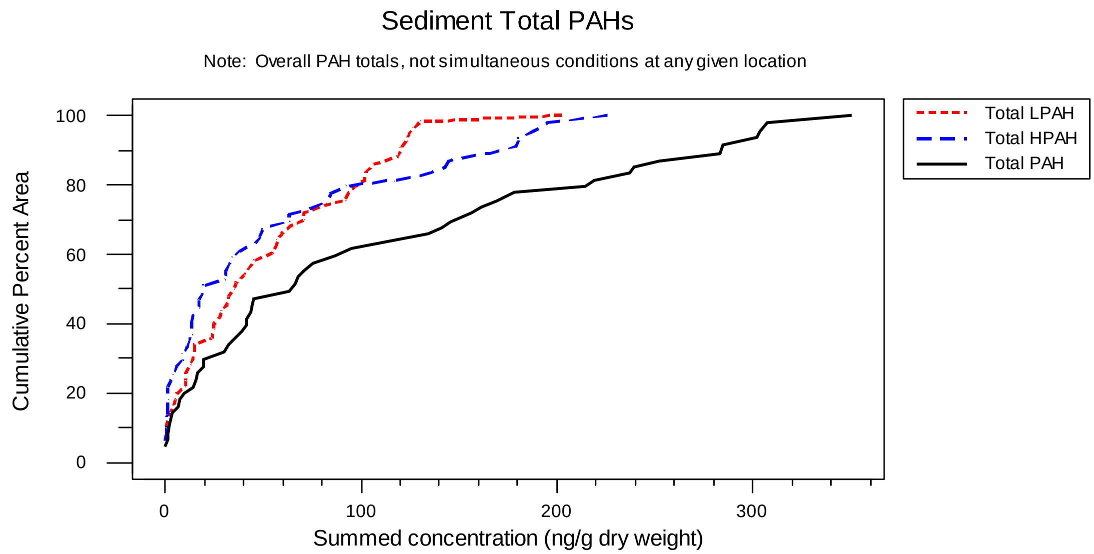


Figure 53. Cumulative percent area by sediment PAH totals. The CDFs are independent and do not represent simultaneous conditions.

Comparisons with Sediment Quality Standards and Guidelines

No stations exceeded any sediment quality standards or guidelines for individual PAH compounds nor PAH totals (Table 44).

Table 44. Comparisons of sediment Total PAH concentrations to Washington State sediment quality standards and NOAA sediment quality guidelines. Constituent compounds and treatment of non-detects for ERL/ERM and SQS/CSL Total PAH are specified in Appendix Table A-3.

PAH Total	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	3160	0	370	0	780	0
Total HPAH	1700	0	9600	0	960	0	5300	0
Total PAH	4022	0	44792	0	--	n.a.	--	n.a.

ERL = NOAA Effects Range-Low
ERM = NOAA Effects Range-Median
SQS = Washington State Sediment Quality Standard
CSL = Washington State Cleanup Screening Level

Polychlorinated Biphenyls (PCBs)

No PCB congeners were detected at any station.

DDT and Chlorinated Pesticides

Only 4,4'-DDD and 4,4'-DDE were detected at any stations (Table 45). Overall, DDT and its breakdown products were found at five stations in the Olympic Coast National Marine Sanctuary and at nine stations along the southern Washington Pacific coast.

Table 45. Summary statistics for sediment pesticide concentrations (ng/g dry weight). Non-detects were set to zero and included in the statistical analyses.

Pesticide	Number of Detects (N=50 stations)	Minimum (ng/g dry wt)	Maximum (ng/g dry wt)
Total DDT	14	0 (non-detect)	0.8
4,4'-DDD	11	0 (non-detect)	0.38
4,4'-DDE	10	0 (non-detect)	0.4

Fish-Tissue Contaminants

Chemical analyses were performed on ground *whole* fish to gauge ecological exposure only. *The study was not designed to draw conclusions about fish for human consumption.*

Where samples were analyzed in replicate in the laboratory, the results of the lab replicates were averaged before statistical analyses were performed.

Small samples tend to have unreliable estimates of variance for calculation of confidence intervals for CDFs (U.S. EPA, 2001d; Olsen, 2003; Nelson, 2003). Since there were only 21 stations with fish samples, no CDFs will be presented.

At all 21 stations with fish samples, Pacific sanddab (*Citharichthys sordidus*) tissue was composited for analysis. Three of those stations had additional tissue samples, two with butter sole (*Isopsetta isolepis*) and one with Dover sole (*Microstomus pacificus*). Results for the other species were averaged with the Pacific sanddab results at those stations. Results are given here with and without the butter sole and Dover sole samples.

Metal Residues

Eight metals were found at all 21 stations in all fish-species samples: arsenic, chromium, copper, iron, mercury, selenium, tin, and zinc (Table 46). Cadmium was found in all samples but one (butter sole). Aluminum was found in all samples but one (Pacific sanddab). Nickel was found in only the butter sole and Dover sole samples, not in Pacific sanddab samples. Silver was measured in one of the butter sole and seven of the Pacific sanddab samples. Lead was measured in the Dover and butter sole samples and eight of the Pacific sanddab samples.

Table 46. Summary of fish-tissue metal concentrations (µg/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.

Analyte	All Fish Species			Pacific Sanddab Only		
	Number of Detects (N=21 stations)	Minimum	Maximum	Number of Detects (N=21 samples)	Minimum	Maximum
Aluminum	20	0 (non-detect)	80.3	20	0 (non-detect)	80.3
Arsenic	21	1.35	4.2	21	1.4	3.6
Cadmium	21	0.049	0.25	21	0.049	0.25
Chromium	21	0.21	0.8	21	0.21	0.8
Copper	21	0.82	5	21	0.82	5
Iron	21	11.9	80.5	21	11.2	80.5
Lead	10	0 (non-detect)	0.45	8	0 (non-detect)	0.45
Mercury	21	0.035	0.095	21	0.035	0.095
Nickel	3	0 (non-detect)	0.1	0		
Selenium	21	0.43	0.56	21	0.43	0.56
Silver	8	0 (non-detect)	0.047	7	0 (non-detect)	0.047
Tin	21	1.5	1.9	21	1.5	1.9
Zinc	21	10.65	15.9	21	10.9	15.9

Organics Residues: PAHs, PCBs, DDT, and other Pesticides

No PAH compounds were detected in any tissue samples. Nine PCB congeners were found in the Dover sole sample, and two PCBs were found in each of six Pacific sanddab samples (Table 47). Of the DDT isomers, only 4,4'-DDE was found, in 18 Pacific sanddab, one butter sole, and the Dover sole samples. No other chlorinated pesticides were detected in any samples.

Table 47. Summary of fish-tissue DDT and PCB 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.

Analyte	All Fish Species			Pacific Sanddab Only		
	Number of Detects (N=21 stations)	Minimum	Maximum	Number of Detects (N=21 samples)	Minimum	Maximum
Total DDT	**18**	0 (non-detect)	**3.3**	**18**	0 (non-detect)	**3.3**
4,4'-DDE	18	0 (non-detect)	3.3	18	0 (non-detect)	3.3
Total PCB	**7**	0 (non-detect)	**18.105**	**6**	0 (non-detect)	**2.5**
PCB8	1	0 (non-detect)	10.5	0		
PCB110	1	0 (non-detect)	1.35	0		
PCB118	1	0 (non-detect)	0.455	0		
PCB128	1	0 (non-detect)	1.65	0		
PCB138	6	0 (non-detect)	1.1	6	0 (non-detect)	1.1
PCB153	6	0 (non-detect)	1.4	6	0 (non-detect)	1.4
PCB180	1	0 (non-detect)	0.55	0		
PCB187	1	0 (non-detect)	0.8	0		
PCB195	1	0 (non-detect)	1.3	0		
PCB206	1	0 (non-detect)	0.9	0		
PCB209	1	0 (non-detect)	0.6	0		

Biotic Condition Indicators

Infaunal Species Richness and Diversity

Benthic invertebrate samples were collected at 50 stations in the Olympic Coast NMS and southern Washington Pacific coast. In all, 416 benthic taxa, 6 of which are exotic, were identified (Appendix Table C-3). One species, the bivalve *Axinopsida serricata*, was found at 46 of the 50 stations. By contrast, exactly one-quarter of the taxa (104 of 416) were found at a single station each.

Taxa richness (the total number of taxa in the sample) ranged from 23 to 102 taxa per sample (Table 48), averaging 57 taxa.

Table 48. Summary statistics for benthic macrofauna bioindices of community richness and diversity.

Statistic	Taxa Richness (number of taxa)	Shannon-Wiener Diversity H'	Pielou's Evenness J'	Swartz' Dominance (number of taxa)	Dominance Standardized by Taxa Richness (%)
Minimum	23	2.1	0.0	2	4.9
Maximum	102	5.4	0.2	29	38.8
CDF 50th Percentile	51.7	4.39	0.077	11.8	23
CDF 90th Percentile	85.7	5	0.115	21.4	33.1
Mean (unweighted)	60.12	4.008	0.692	12.1	0.20
Median (unweighted)	54	4.018	0.678	10	0.18

The *Shannon-Wiener Diversity Index (H')* ranged from 2.1 to 5.4, averaging 4.3.

The Pielou's Evenness Index (J') ranged from 0 to 0.2, averaging 0.1.

The Swartz' Dominance Index (SDI), the number of taxa accounting for at least 75% of the total abundance, ranged from 2 to 29, averaging 13 taxa.

When standardized by taxa richness, the *standardized Swartz' Dominance Index (SDISTD)* ranged from less than 5% to almost 39%, averaging 23.6%.

Infaunal Abundance and Taxonomic Composition

Infaunal abundance ranged from 77 to 1606 individuals per 0.1 m^2, averaging 347 individuals per 0.1 m^2 (Table 49, Figure 54). Colonial species were included with an abundance of 1.

The ten numerically-dominant taxa made up 49.9% of the total benthic macrofauna (Appendix Table C-3). Exotic species accounted for 0.22% of the total benthic infauna collected. The abundance and proportion of all of the taxa found, including the 10 most abundant, are given in Appendix Table C-3. Exotic and colonial species are indicated.

Table 49. Summary statistics for total benthic macrofauna abundance (# individuals/0.1 m^2).

Statistic	All Taxa	Annelida	Arthropoda	Echinodermata	Mollusca	Misc. Taxa
Minimum	77	28	2	0	19	0
Maximum	1606	889	607	59	231	50
CDF 50th Percentile	332.4	129.8	30.2	4.6	79.5	4.9
CDF 90th Percentile	501	363	153.1	20.4	135.7	17.6
Mean (unweighted)	762	318.4	164.3	36	234.1	9.2
Median (unweighted)	488	179	58.5	3.5	119	4.5

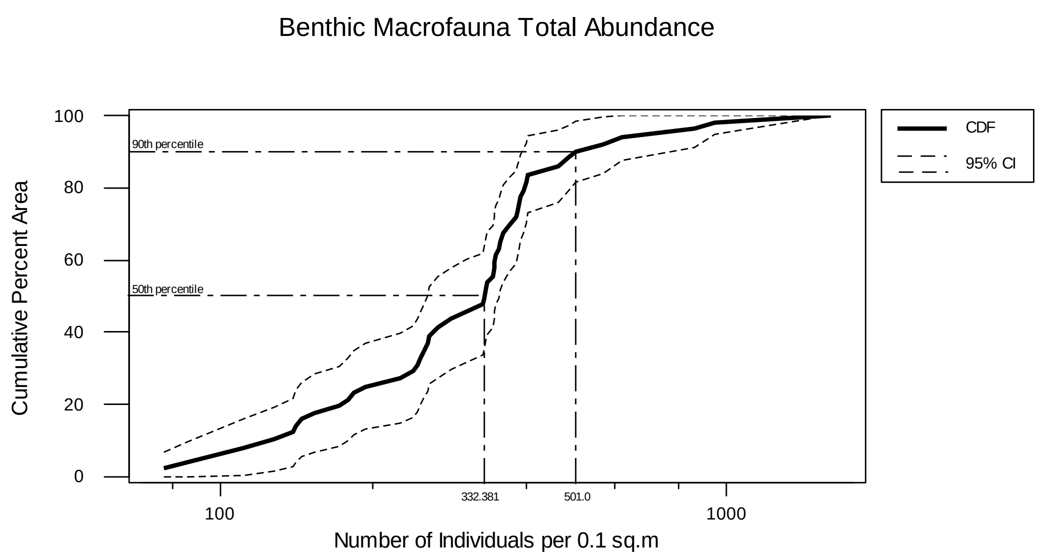


Figure 54. Cumulative percent area by benthic macrofauna total abundance (number of individuals per sampled 0.1-m^2 area). Colonial species were included with an abundance of 1.

Annelids were the most abundant taxa, followed by molluscs and arthropods (Figure 55, Figure 56).

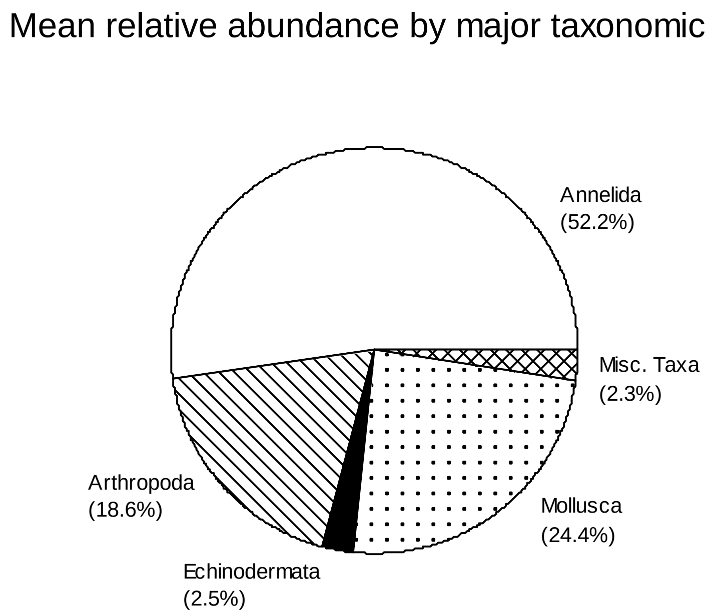


Figure 55. Mean relative abundance by major taxonomic group.

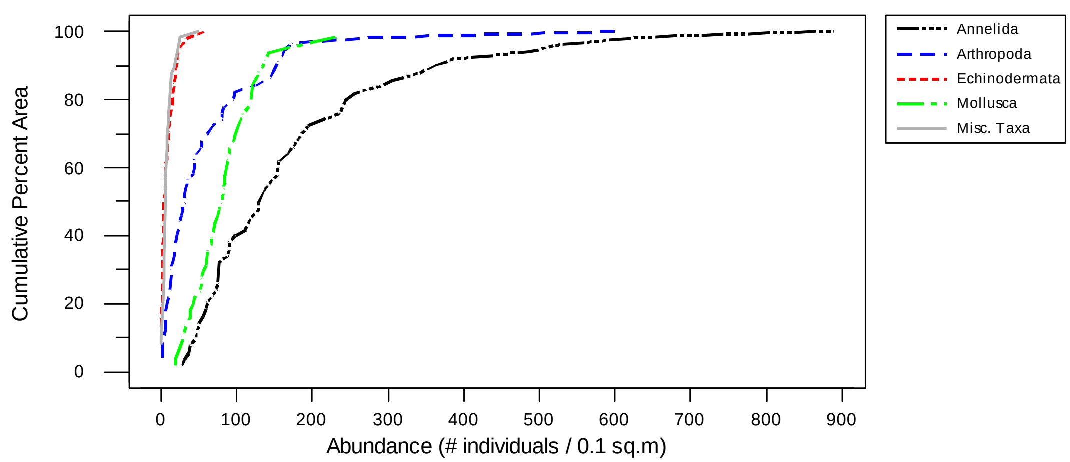


Figure 56. Cumulative percent area by major taxonomic group. The CDFs are independent and do not represent simultaneous conditions.

The infaunal communities do not differ significantly between the Olympic Coast NMS and the rest of the Washington coast (Figure 57; Bray-Curtis similarity calculated on 4^{th}-root-transformed data; ANOSIM P-value = 0.198, based on 999 permutations).

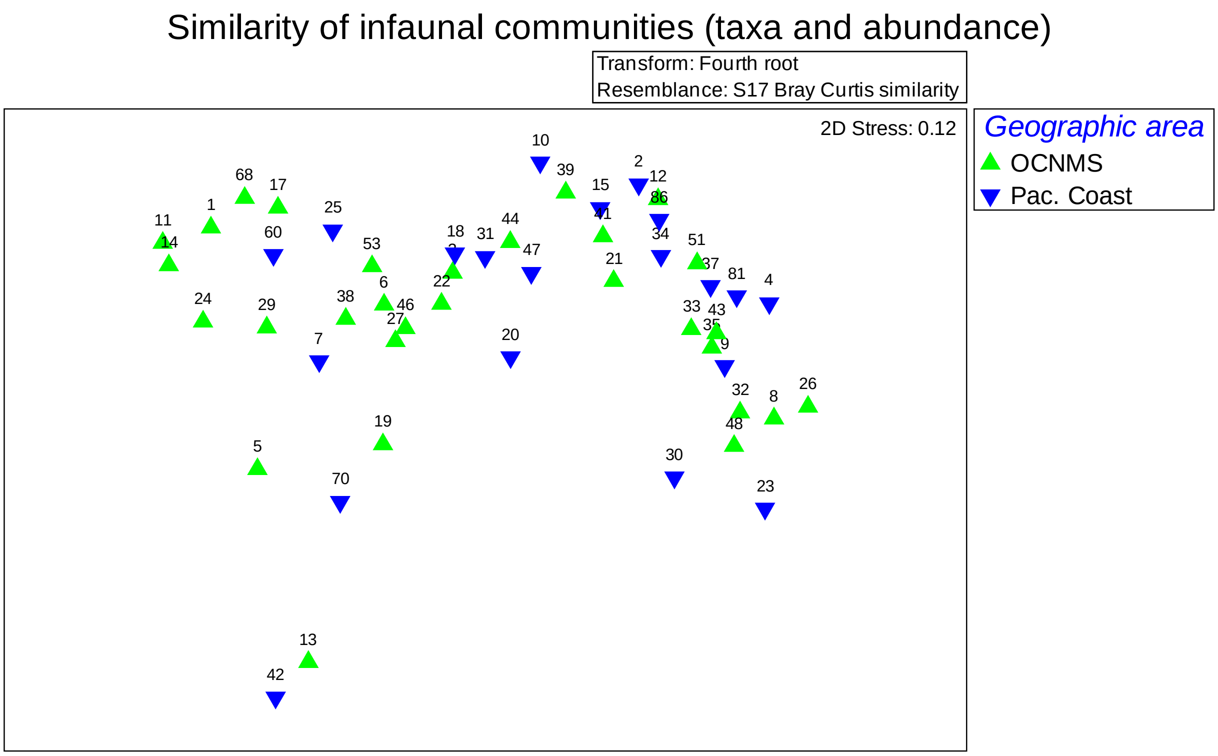


Figure 57. Multidimensional scaling (MDS) map of benthic macrofaunal community similarity (taxa and abundance), based on Bray-Curtis similarity of 4^{th}-root-transformed abundance data (2-D stress = 0.12, 3-D stress = 0.09).

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

Four fish species were found over the 21 stations at which fish were acquired by hook-and-line fishing (Appendix Table D-5). Pacific sanddab (*Citharichthys sordidus*) were caught at all stations. In addition, butter sole (*Isopsetta isolepis*) were caught at two stations, Pacific hake (*Merluccius productus*) at two other stations, and Dover sole (*Microstomus pacificus*) at one station with Pacific hake.

The mean size class of the Pacific sanddab was 25.5 cm overall, 26.0 cm weighted by station (Table 50).

Table 50. Summary of fish caught.

Species	Overall			Where caught only	
	Number of stations	Number of fish	Mean size class (cm)	Average number of fish	Average size class (cm)
Citharichthys sordidus	21	107	25.5	5.2	26
Isopsetta isolepis	2	6	22.7	3	21.2
Merluccius productus	2	3	27	1.5	26
Microstomus pacificus	1	1	22	1	22

Demersal Fish Species Gross Pathology

No grossly visible anomalies were observed on any fish caught.

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References

APHA-AWWA-WPCF (American Public Health Association-American Water Works Association-Water Pollution Control Federation), 1989. Standard Methods for the Examination of Water and Wastewater, 17th Edition.

ASTM (American Society for Testing Materials), 1993. Standard guide for conducting solid phase, 10-day, static sediment toxicity tests with marine and estuarine infaunal amphipods. ASTM E 1367-92. . Philadelphia, PA.

Bourgeois, P.E., V.J. Sclafani, J.K. Summers, S.C. Robb, and B.A. Vairin, 1998. Think before you sample. GEOWorld 11(12).

Carr, R.S., and D.C. Chapman, 1995. Comparison of methods for conducting marine and estuarine sediment porewater toxicity tests – Extraction, storage, and handling techniques. Arch. Environ. Contam. Toxicol. 28:69-77.

Carr, R.S., D.C. Chapman, C.L. Howard, and J. Biedenbach, 1996a. Sediment Quality Triad assessment survey in the Galveston Bay Texas system. Ecotoxicology 5:341-361.

Carr, R.S., E.R. Long, D.C. Chapman, G. Thursby, J.M. Biedenbach, H. Windom, G. Sloane, and D.A. Wolfe, 1996b. Toxicity assessment studies of contaminated sediments in Tampa Bay, Florida. Environmental Toxicology and Chemistry 15:1218-1231.

Carr, R.S., 1998. Sediment porewater testing. In: Standard methods for the examination of water and wastewater, section 8080, 20th edition, Clesceri, L.S., A.E. Greenberg, and A.D. Eaton (eds.), American Public Health Association, Washington, DC.

Diaz-Ramos, S., D.L. Stevens, Jr., and A.R. Olsen, 1996. EMAP Statistics Methods Manual. EPA/620/R 96/002. U.S. EPA Office of Research and Development, National Health and Environmental Effects Research Laboratory, Corvallis, OR.

DiToro, D.M., C J. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas, and P.R. Paquin, 1991. Technical bases for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. Environmental Toxicology and Chemistry 10:1541-1583.

Dutch, M., E. Long, W. Kammin, and S. Redman, 1998. Puget Sound Ambient Monitoring Program Marine Sediment Monitoring Component – Final Quality Assurance Project and Implementation Plan. Measures of bioeffects associated with toxicants in Puget Sound: Survey of sediment contamination, toxicity, and benthic macroinfaunal community structure. Washington State Department of Ecology, Olympia, WA. 31 pp.

Hach Company, 1989. Water Analysis Handbook. Loveland, CO.

Harwell, Linda, 2005. Personal communication. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division.

Hayslip, G., L. Edmond, V. Partridge, W. Nelson, H. Lee, F. Cole, J. Lamberson, and L. Caton, 2006. Ecological Condition of the Estuaries of Oregon and Washington. EPA 910/R-06/001. U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA.

Hyland, J.L., T.J. Herrlinger, T.R. Snoots, A.H. Ring-wood, R.F. Van Dolah, C.T. Hackney, G.A. Nelson, J.S. Rosen, and S.A. Kokkinakis, 1996. Environmental Quality of Estuaries of the Carolinian Province: 1994. Annual Statistical Summary for the 1994 EMAP- Estuaries Demonstration Project in the Carolinian Province. NOAA Technical Memorandum NOS ORCA 97. NOAA/NOS Office of Ocean Resources Conservation and Assessment, Silver Spring, MD.

Hyland, J.L., L. Balthis, C.T. Hackney, G. McRae, A.H. Ringwood, T.R. Snoots, R.F. Van Dolah, and T.L. Wade, 1998. Environmental quality of estuaries of the Carolinian Province: 1995. Annual statistical summary for the 1995 EMAP- Estuaries Demonstration Project in the Carolinian Province. NOAA Technical Memorandum NOS ORCA 123. NOAA/NOS Office of Ocean Resources Conservation and Assessment, Silver Spring, MD.

Lazorchak, J., D. Klemm, D. Averill, and D. Peck (editors), 1999. Environmental monitoring and assessment program – surface waters: field operations and methods for measuring the ecological condition of non-wadeable streams. U.S. Environmental Protection Agency, Corvallis, OR.

Long, E.R., 2000a. Spatial extent of sediment toxicity in U.S. estuaries and marine bays. Environmental Monitoring and Assessment 64: 391-407.

Long, E.R., 2000b. Degraded sediment quality in U.S. estuaries: A review of magnitude and ecological implications. Ecological Applications 10(2): 338-349.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder, 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1):81-97.

Long, E.R., A. Robertson, D.A. Wolfe, J. Hameedi, and G.M. Sloane, 1996. Estimates of the spatial extent of sediment toxicity in major USA estuaries. Environmental Science and Technology 30:3585-3592.

Long, E.R., and D.D. MacDonald, 1998. Recommended uses of empirically-derived sediment quality guidelines for marine and estuarine ecosystems. Journal of Human and Ecological Risk Assessment 4(5): 1019-1039.

Long, E.R., and K.A. Dzinbal, 1999. Toxicity of sediments in Northern Puget Sound: A national perspective. Pg. 302-311. Proceedings, Puget Sound Research '98 Conference. Seattle, WA. Puget Sound Water Quality Action Team, Olympia, WA.

Long, E.R., M. Dutch, S. Aasen, K. Welch, J. Hameedi, S. Magoon, R.S. Carr, T. Johnson, J. Biedenbach, K.J. Scott, C. Mueller, and J.W. Anderson, 2002. Sediment quality in Puget Sound: Year 3 – southern Puget Sound. National Oceanic and Atmospheric Administration Technical Memo 153 / Washington State Department of Ecology Publication 02-03-033. www.ecy.wa.gov/biblio/0203033.html

Long, E.R., M. Dutch, S. Aasen, K. Welch, and J. Hameedi, 2003. Chemical contamination, acute toxicity in laboratory tests, and benthic impacts in sediments of Puget Sound: A summary of results of the joint 1997-1999 Ecology/NOAA survey. National Oceanic and Atmospheric Administration Technical Memo 163 / Washington State Department of Ecology Publication 03-03-049. www.ecy.wa.gov/biblio/0303049.html

Long, E.R., J. Hameedi, A. Robertson, M. Dutch, S. Aasen, C. Ricci, K. Welch, W. Kammin, R. S. Carr, T. Johnson, J. Biedenbach, K.J. Scott, C. Mueller, and J.W. Anderson, 1999. Sediment quality in Puget Sound: Year 1 – northern Puget Sound. National Oceanic and Atmospheric Administration Technical Memo 139 / Washington State Department of Ecology Publication 99-347. www.ecy.wa.gov/biblio/99347.html

Long, E.R., J. Hameedi, A. Robertson, M. Dutch, S. Aasen, K. Welch, S. Magoon, R.S. Carr, T. Johnson, J. Biedenbach, K.J. Scott, C. Mueller, and J.W. Anderson, 2000. Sediment quality in Puget Sound: Year 2 – central Puget Sound. National Oceanic and Atmospheric Administration Technical Memo 147 / Washington State Department of Ecology Publication 00-03-055. www.ecy.wa.gov/biblio/0003055.html

Lorenzen, C.J., 1966. A method for the continuous measurement of *in vivo* chlorophyll concentration. Deep-Sea Research 13:223-227.

Macauley, J.M., J.K. Summers, P.T. Heitmuller, V.D. Engle, G.T. Brooks, M. Babikow, and A.M. Adams, 1994. Annual Statistical Summary: EMAP - Estuaries Louisiana Province - 1992. EPA/620/R-94/002. U.S. EPA Office of Research and Development, Environmental Research Laboratory, Gulf Breeze, FL.

Macauley, J.M., J.K. Summers, V.D. Engle, P.T. Heitmuller, and A.M. Adams, 1995. Annual Statistical Summary: EMAP - Estuaries Louisiana Province -1993. EPA/620/R-96/003. U.S. EPA Office of Research and Development, Environmental Research Laboratory, Gulf Breeze, FL.

Macauley, J.M., National Coastal Assessment Quality Assurance Coordinator, 2003. Final Report: NCA review of Washington State Department of Ecology. Memorandum to Ken Dzinbal, Manager of Environmental Monitoring and Trends Section, Washington State Department of Ecology, Olympia, WA.

Manchester Environmental Laboratory, 1997. Standard Operating Procedure 730009: Determination of Percent Lipids in Tissue. Washington State Department of Ecology, Port Orchard, WA.

Manchester Environmental Laboratory, 2000. Case Narrative: Polynuclear Aromatic Hydrocarbons, EMAP 1999. Washington State Department of Ecology, Port Orchard, WA.

Nelson, Walter, 2003. Personal communication. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division.

Nelson, W.G., H. Lee II, J.O. Lamberson, V. Engle, L. Harwell, and L.M. Smith, 2004. Condition of Estuaries of Western United States for 1999: A Statistical Summary. EPA 620/R-04/200. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory.

Nelson, W.G., H. Lee II, J.O. Lamberson, F. Cole, C.L. Weilhoefer, and P. Clinton, 2007. The Condition of Tidal Wetlands of Washington, Oregon and California – 2002. EPA/620/R-07/002. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory.

Newton, J.A., S.L. Albertson, K. Van Voorhis, C. Maloy, and E. Siegel, 2002. Washington State Marine Water Quality, 1998 through 2000. Washington State Department of Ecology Publication 02-03-056. www.ecy.wa.gov/biblio/0203056.html

Olsen, Anthony, 2003. Personal communication. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division.

Ozretich, R.J., Quality Assurance Manager, Western Ecology Division, National Health and Environmental Effects Research Laboratory of EPA, 2005. Final Review of the QAPP Chemical Data Quality Objective attained by 2000 WEMAP. Letter to Walt Nelson, Branch Chief, Pacific Coastal Ecology Branch of EPA. Revised 2007.

Ozretich, R.J., Quality Assurance Manager, Western Ecology Division, National Health and Environmental Effects Research Laboratory of EPA, 2007a. Review of the QAPP Chemical Data Quality Objectives with respect to the data obtained for the 2002 Washington National Coastal Assessment. Letter to Walt Nelson, Branch Chief, Pacific Coastal Ecology Branch of EPA.

Ozretich, R.J., Quality Assurance Manager, Western Ecology Division, National Health and Environmental Effects Research Laboratory of EPA, 2007b. Review of the QAPP Chemical Data Quality Objectives with respect to the data obtained for the 2003 Washington National Coastal Assessment. Letter to Walt Nelson, Branch Chief, Pacific Coastal Ecology Branch of EPA.

Paul, J.F., K.J. Scott, A.F. Holland, S.B. Weisberg, J.K. Summers, and A. Robertson, 1992. The estuarine component of the U.S. EPA's environmental monitoring and assessment program. Chemistry and Ecology 7: 93-116.

PSEP (Puget Sound Estuary Program), 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Prepared by Tetra Tech, Inc. for U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA, and Puget Sound Water Quality Authority, Olympia, WA.

PSEP (Puget Sound Estuary Program), 1987. Recommended protocols for sampling and analyzing subtidal benthic macroinvertebrate assemblages in Puget Sound. Prepared by Tetra Tech, Inc., Bellevue, WA for U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA and Puget Sound Water Quality Authority, Olympia, WA.

PSEP (Puget Sound Estuary Program), 1995. Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Prepared by King County Environmental Laboratory for U.S. Environmental Protection Agency Region 10, Seattle, WA, and Puget Sound Water Quality Authority, Olympia, WA.

PSEP (Puget Sound Estuary Program), 1996a. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Prepared by King County Environmental Laboratory for U.S. Environmental Protection Agency Region 10, Seattle, WA, and Puget Sound Water Quality Authority, Olympia, WA.

PSEP (Puget Sound Estuary Program), 1996b. Recommended guidelines for measuring metals in Puget Sound marine water, sediment and tissue samples. Prepared by King County Environmental Laboratory for U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA, and Puget Sound Water Quality Authority, Olympia, WA.

PSEP (Puget Sound Estuary Program), 1996c. Recommended guidelines for measuring organic compounds in Puget Sound water, sediment and tissue samples. Prepared by King County Environmental Laboratory for U.S. Environmental Protection Agency Region 10, Seattle, WA, and Puget Sound Water Quality Authority, Olympia, WA.

PSEP (Puget Sound Estuary Program), 1997. Recommended quality assurance and quality control guidelines for the collection of environmental data in Puget Sound. Prepared by King County Environmental Laboratory for U.S. Environmental Protection Agency Region 10, Seattle, WA, and Puget Sound Water Quality Authority, Olympia, WA.

SAIC (Science Applications International Corporation), 1997. Survey of sediment toxicity in Puget Sound. Report submitted by the SAIC Environmental Testing Center to the NOAA Western Administrative Support Center. Contract No. 50ABNC700065.

SAIC (Science Applications International Corporation), 1998. Survey of sediment toxicity in central Puget Sound. Report submitted by the SAIC Environmental Testing Center to the NOAA Western Administrative Support Center. Contract No. 50ABNC700065.

SAIC (Science Applications International Corporation), 2000. Survey of sediment toxicity in southern Puget Sound. Report submitted to NOAA/ORCA. Contract No. 50ABNC700065.

Sea-Bird Electronics, Inc., 2002. User's Manual for Seasoft CTD Data Acquisition Software. Sea-Bird Electronics, Inc., Bellevue, WA.

Sea-Bird Electronics, Inc., 2003. User's Manual for Seasoft-Win32: SBE Data Processing-Win32. CTD Data Processing and Plotting Software for Windows 95/98/NT/2000/XP. Sea-Bird Electronics, Inc., Bellevue, WA.

Slawyk, G. and J.J. MacIsaac, 1972. Comparison of two automated ammonium methods in a region of coastal upwelling. Deep-Sea Research 19:521-524.

Stevens, D.L., Jr. and A.R. Olsen, 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological and Environmental Statistics 4:415-428.

Stevens, D.L., Jr., and A.R. Olsen, 2003. Variance estimation for spatially balanced samples of environmental resources. Environmetrics 14:593-610.

Strobel, C.J., S.J. Benyi, D.J. Keith, H.W. Buffum, and E.A. Petrocelli, 1994. Statistical Summary: EMAP - Estuaries Virginian Province - 1992. EPA/620/R-94/019. U.S. EPA Office of Research and Development, Environmental Research Laboratory, Narragansett, RI.

Strobel, C.J., H.W. Buffum, S.J. Benyi, E.A. Petrocelli, D.R. Reifsteck, and D.J. Keith, 1995. Statistical Summary: EMAP - Estuaries Virginian Province - 1990 to 1993. EPA/620/R-94/026. U.S. EPA National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, RI.

Summers, J.K. and J.M. Macauley, 1993. Statistical Summary: EMAP - Estuaries Louisianian Province - 1991. EPA/600/R-93-001. U.S. EPA Office of Research and Development, Washington, DC.

UNESCO (United Nations Educational, Scientific and Cultural Organization), 1994. Protocols for the Joint Global Ocean Flux Study (JGOFS) core measurements. IOC Manuals and Guides No. 29.

U.S. EPA (U.S. Environmental Protection Agency), 1994. Methods for Assessing the Toxicity of Sediment Associated Contaminants with Estuarine and Marine Amphipods. EPA 600 R 94 025. Office of Research and Development, Environmental Monitoring and Systems Laboratory, Cincinnati, OH.

U.S. EPA (U.S. Environmental Protection Agency), 1995. Laboratory Methods Manual - Volume 1: Biological and Physical Analyses, EMAP Estuaries. EPA/620/R-95/008. Office of Research and Development, Environmental Monitoring and Systems Laboratory, Cincinnati, OH.

U.S. EPA (U.S. Environmental Protection Agency), 2001a. Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan 2001-2004. EPA/620/R-01/002. Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL.

U.S. EPA (U.S. Environmental Protection Agency), 2001b. National Coastal Assessment: Field Operations Manual. EPA/620/R-01/003. Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL.

U.S. EPA (U.S. Environmental Protection Agency), 2001c. National Coastal Condition Report. EPA/620/R-01/005. Office of Research and Development and Office of Water, Washington, DC. www.epa.gov/owow/oceans/nccr/

U.S. EPA (U.S. Environmental Protection Agency), 2001d. Region 10 Monitoring Design and Analysis Workshop. December 2001. Office of Research and Development, National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, OR.

U.S. EPA (U.S. Environmental Protection Agency), 2002a. Environmental Monitoring and Assessment Program National Coastal Assessment Field Operations West Coast Field Sampling Methods Intertidal 2002 (includes Washington State Specific Protocols). Amendment to: Environmental Monitoring and Assessment Program National Coastal Assessment Quality Assurance Project Plan 2001-2004.

U.S. EPA (U.S. Environmental Protection Agency), 2002b. EMAP West Coastal Offshore 2003 Design.

U.S. EPA (U.S. Environmental Protection Agency), 2005. National Coastal Condition Report II. EPA/620/R-03/002. Office of Research and Development and Office of Water, Washington, DC. www.epa.gov/owow/oceans/nccr/

U.S. EPA (U.S. Environmental Protection Agency), Undated. EPA EMAP West Estuary Sample for Washington, Oregon, and California in 2002.

USGS (U.S. Geological Survey), 1997. Final report on toxicity testing of sediments from Puget Sound, Washington and surrounding areas. Report submitted by the USGS Columbia Environmental Research Center, Marine Ecotoxicology Research Station to the NOAA Coastal Monitoring and Biological Assessment Division Bioeffects Assessment Branch.

USGS (U.S. Geological Survey), 1998. Final report on toxicity testing of sediments from central Puget Sound, Washington and surrounding areas. Report submitted by the USGS Columbia Environmental Research Center, Marine Ecotoxicology Research Station to the NOAA Coastal Monitoring and Biological Assessment Division Bioeffects Assessment Branch.

USGS (U.S. Geological Survey), 1999. Final report on toxicity testing of sediments from southern Puget Sound, Washington and surrounding areas. Report submitted by the USGS Columbia Environmental Research Center, Marine Ecotoxicology Research Station to the NOAA Coastal Monitoring and Biological Assessment Division Bioeffects Assessment Branch.

USGS (U.S. Geological Survey), 2001. Final report on toxicity testing of sediments from the BEST/EMAP Western Estuary Group monitoring study, Year II. Report submitted by the USGS Columbia Environmental Research Center, Marine Ecotoxicology Research Station to the USGS Biomonitoring and Environmental Status and Trends Program.

USGS (U.S. Geological Survey), 2003a. Final report on toxicity testing of sediments from intertidal wetlands for the Washington Coastal EMAP 2002. Report submitted by the USGS Columbia Environmental Research Center, Marine Ecotoxicology Research Station to the Washington State Department of Ecology.

USGS (U.S. Geological Survey), 2003b. H4IIE bioassay-derived 2,3,7,8 - tetrachlorodibenzo-*p*-dioxin equivalents (TCDD-EQ) in fish collected in 2000 from large estuaries along the western coast of the United States. Report submitted by the USGS Columbia Environmental Research Center to the USGS Biomonitoring and Environmental Status and Trends Program.

Washington State Department of Ecology, 1995. Sediment Management Standards, Chapter 173-204 WAC. Washington State Department of Ecology Publication 96-252. Revised December 1995.

Wilson, S., and V. Partridge, 2007. Condition of Outer Coastal Estuaries of Washington State, 1999: A Statistical Summary. Washington State Department of Ecology, Olympia, WA. Publication 07-03-012. www.ecy.wa.gov/biblio/0703012.html

Appendices

Appendices as part of this document, available on the web and in printed form

Appendix A – Descriptions of Indicators
Appendix B – Sampling Success
Appendix C – Benthos
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Appendix G – Data tables and graphical summaries, 2000
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Appendix I – Data tables and graphical summaries, 2003

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Appendix A. Descriptions of Indicators

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. 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.

Water Temperature

Water temperature 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 maximum and minimum densities:

$$\text{Stratification Index} = D_{maximum} - D_{minimum}$$

Density is derived from temperature and salinity. The density maximum occurs usually, but not always, near the bottom, whereas the minimum density is usually close to the surface. A stratification index less than 0.5 σ_t indicates well-mixed waters, whereas strongly stratified waters are indicated by a stratification index greater than 2 σ_t (Newton et al., 2002). Between 0.5 σ_t and 2 σ_t is intermediate.

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 2-5 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 (N:P ratio) is used as an indicator of which nutrient might be controlling primary production in estuaries. N:P ratios between 5 and 15 provide sufficient nitrogen for marine algal growth (Newton et al., 2002), while ratios outside that range may be limiting.

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).

Nutrients (Nitrogen, Phosphorus)

The availability of plant nutrients is a factor in the presence and health of submerged aquatic vegetation (SAV) communities.

Vegetation

Plant types, percent cover, and biomass

Submerged aquatic vegetation (*Zostera* spp., or eelgrass) species are used as indicators of ecological health. Eelgrass beds provide habitat, food, and protective cover for many invertebrates, migrating salmon, and other types of marine or estuarine organisms. Roots of eelgrass plants stabilize sediments, and breakdown of eelgrass and other submerged aquatic vegetation supplies organic material to nearshore areas.

Invasive saltmarsh grass species, particularly *Spartina alterniflora*, not only displace native species, but their presence affects water flow and sedimentation, thereby altering the physical characteristics of intertidal areas.

Shrimp Burrows

Burrowing shrimp species and density of shrimp burrows

Many invertebrates construct burrows in marine and estuarine sediments. In the intertidal areas of Washington State, the burrowing activity and extensive burrows of certain species of shrimp (*Neotrypaea* spp. and *Upogebia* spp., both comonly called “ghost shrimp”) can interfere with oyster mariculture. Some oyster farmers use carbaryl or other pesticides to kill the burrowing shrimp.

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.

DDT 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. DDT 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, 2003b). 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/Disturbance

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.

Disturbance of the sediment can cause direct or indirect mortality of invertebrates, by physical injury, loss of habitat, or interference with feeding and respiration. Although subtidal disturbance such as dredging is generally not visible, disturbance in intertidal areas, such as from recreation activities or clam-harvesting, is visible.

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.

References

Bay, S.M., 1996. Sediment Toxicity on the Mainland Shelf of the Southern California Bight in 1994. Southern California Coastal Water Research Project Annual Report. 1994-1995.

Bernhard, T., and S. Petron, 2001. Analysis of PCB Congeners vs. Aroclors in ecological risk assessment. Navy Guidance for Conducting Ecological Risk Assessments Issue Paper. Naval Facilities Engineering Command (NAVFAC). http://web.ead.anl.gov/ecorisk/issue/

CCME (Canadian Council of Ministers of the Environment), 1992. Canadian Water Quality Guidelines, prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Ministers of the Environment, Eco-Health Branch, Ottawa, Ontario, Canada.

DiToro, D.M., C J. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas, and P.R. Paquin, 1991. Technical bases for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. Environmental Toxicology and Chemistry 10:1541-1583.

Feddersen, Karin, 2003. Personal communication. Washington State Department of Ecology, Manchester Environmental Laboratory.

Gray, J. S., 1974. Animal-sediment relationships. Oceanography and Marine Biology: an Annual Review 12:223-261.

Hyland, J.L., T.J. Herrlinger, T.R. Snoots, A.H. Ring-wood, R.F. Van Dolah, C.T. Hackney, G.A. Nelson, J.S. Rosen, and S.A. Kokkinakis 1996. Environmental Quality of Estuaries of the Carolinian Province: 1994. Annual Statistical Summary for the 1994 EMAP- Estuaries Demonstration Project in the Carolinian Province. NOAA Technical Memorandum NOS ORCA 97. NOAA/NOS Office of Ocean Resources Conservation and Assessment, Silver Spring, MD.

Hyland, J.L., L. Balthis, C.T. Hackney, G. McRae, A.H. Ringwood, T.R. Snoots, R.F. Van Dolah, and T.L. Wade, 1998. Environmental quality of estuaries of the Carolinian Province: 1995. Annual statistical summary for the 1995 EMAP- Estuaries Demonstration Project in the Carolinian Province. NOAA Technical Memorandum NOS ORCA 123. NOAA/NOS Office of Ocean Resources Conservation and Assessment, Silver Spring, MD.

Irwin R.J., M. Van Mouwerik, L. Stevens, M. Dubler Seese, and W. Basham, 1997. Environmental Contaminants Encyclopedia, PAHs Entry. National Park Service Water Resources Divisions, Water Operations Branch, Fort Collins, CO.

Lefkovitz, L. F., V.I. Cullinan, and E.A. Crecelius, 1997. Historical Trends in the Accumulation of Chemicals in Puget Sound. NOAA Technical Memorandum NOS ORCA 111.

Long, E.R., A. Robertson, D.A. Wolfe, J. Hameedi, and G.M. Sloane, 1996. Estimates of the spatial extent of sediment toxicity in major USA estuaries. Environmental Science and Technology 30:3585-3592.

Macauley, J.M., J.K. Summers, V.D. Engle, P.T. Heitmuller, and A.M. Adams, 1995. Annual Statistical Summary: EMAP - Estuaries Louisiana Province -1993. EPA/620/R-96/003. U.S. EPA Office of Research and Development, Environmental Research Laboratory, Gulf Breeze, FL.

Messer, J.J., 1990. EMAP indicator concepts. In: C.T. Hunsaker and D.E. Carpenter (Eds). Ecological Indicators for the Environmental Monitoring and Assessment Program. EPA 600/3-90/060. U.S. Environmental Protection Agency. Research Triangle Park, NC.

Michelson, T.C. and K. Bragdon-Cook, 1993. Organic carbon normalization of sediment data. Technical Information Memorandum. WA Department of Ecology. p 11.

Newton, J.A., S.L. Albertson, K. Van Voorhis, C. Maloy, and E. Siegel, 2002. Washington State Marine Water Quality, 1998 through 2000. Washington State Department of Ecology Publication 02-03-056. www.ecy.wa.gov/biblio/0203056.html

Rhoads, D.C., 1974. Organism-sediment relations on the muddy sea floor. Oceanography and Marine Biology: an Annual Review 12: 263-300.

Schimmel, S.C., Melzian, B.D., Campbell, D.E., Strobel, C.J., Benyi, S.J., Rosen, J.S., and Buffum H.W., 1994. Statistical Summary: EMAP - Estuaries Virginian Province - 1991. EPA 620/R-94/005. U.S. Environmental Protection Agency. Washington, DC.

Strobel, C.J., S.J. Benyi, D.J. Keith, H.W. Buffum, and E.A. Petrocelli, 1994. Statistical Summary: EMAP - Estuaries Virginian Province - 1992. EPA/620/R-94/019. U.S. EPA Office of Research and Development, Environmental Research Laboratory, Narragansett, RI.

Strobel, C.J., H.W. Buffum, S.J. Benyi, E.A. Petrocelli, D.R. Reifsteck, and D.J. Keith, 1995. Statistical Summary: EMAP - Estuaries Virginian Province - 1990 to 1993. EPA/620/R-94/026. U.S. EPA National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, RI.

Summers, J.K. and J.M. Macauley, 1993. Statistical Summary: EMAP - Estuaries Louisianian Province - 1991. EPA/600/R-93-001. U.S. EPA Office of Research and Development, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency), 2000. Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance. EPA/822/B-00/024. Office of Water, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency), 2002. Environmental Monitoring and Assessment Program National Coastal Assessment Field Operations West Coast Field Sampling Methods Intertidal 2002 (includes Washington State Specific Protocols). Amendment to: Environmental Monitoring and Assessment Program National Coastal Assessment Quality Assurance Project Plan 2001-2004.

USGS (U.S. Geological Survey), 2003b. H4IIE bioassay-derived 2,3,7,8 - tetrachlorodibenzo-*p*-dioxin equivalents (TCDD-EQ) in fish collected in 2000 from large estuaries along the western coast of the United States. Report submitted by the USGS Columbia Environmental Research Center to the USGS Biomonitoring and Environmental Status and Trends Program.

Washington State Department of Ecology, 1995. Sediment Management Standards, Chapter 173-204 WAC. Washington State Department of Ecology Publication 96-252. Revised December 1995.

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, 2003). 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 nondetects 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			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.

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Appendix B. Sampling Success

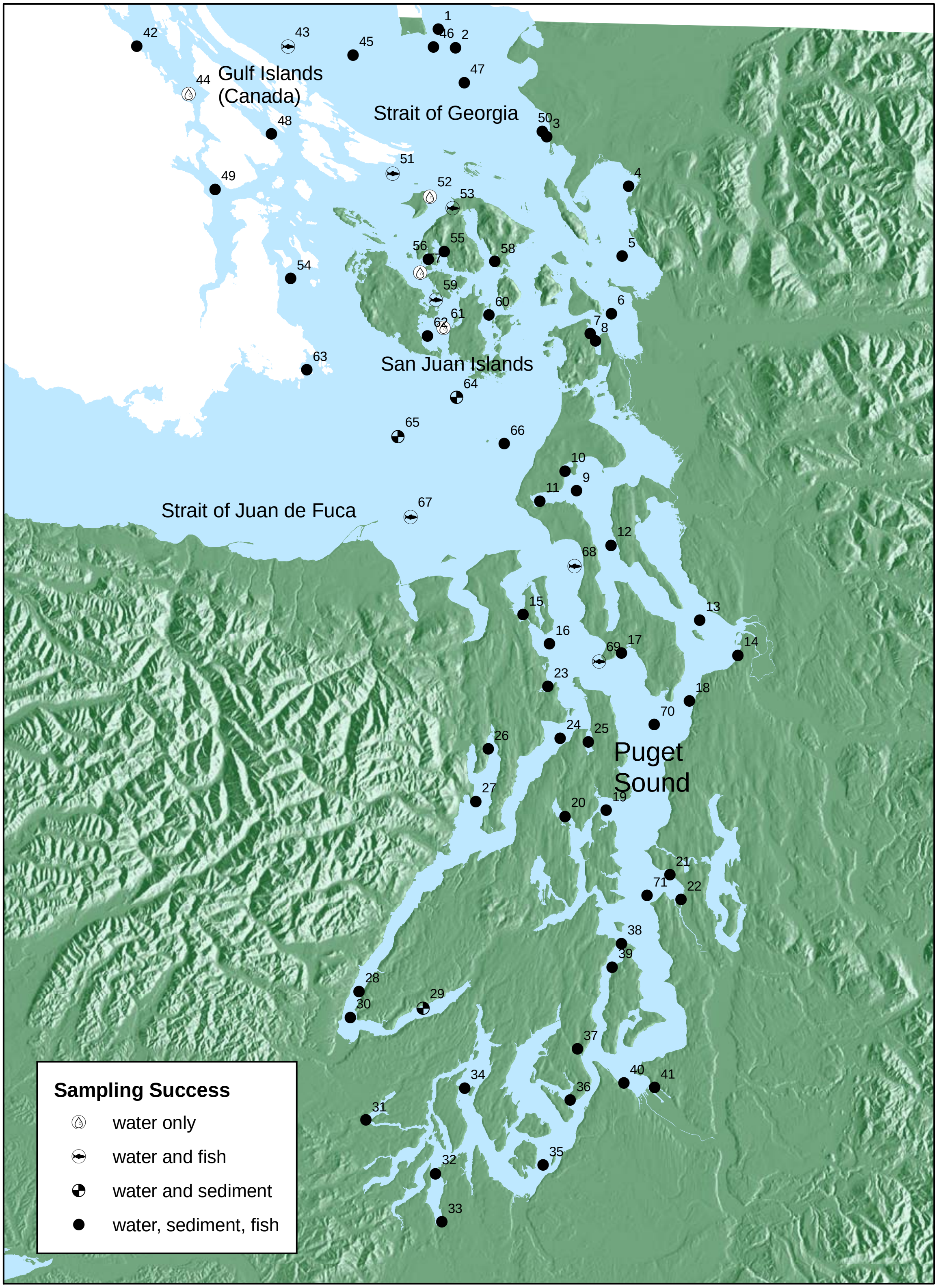

Figure B-1. Sampling success for Washington Coastal EMAP 2000

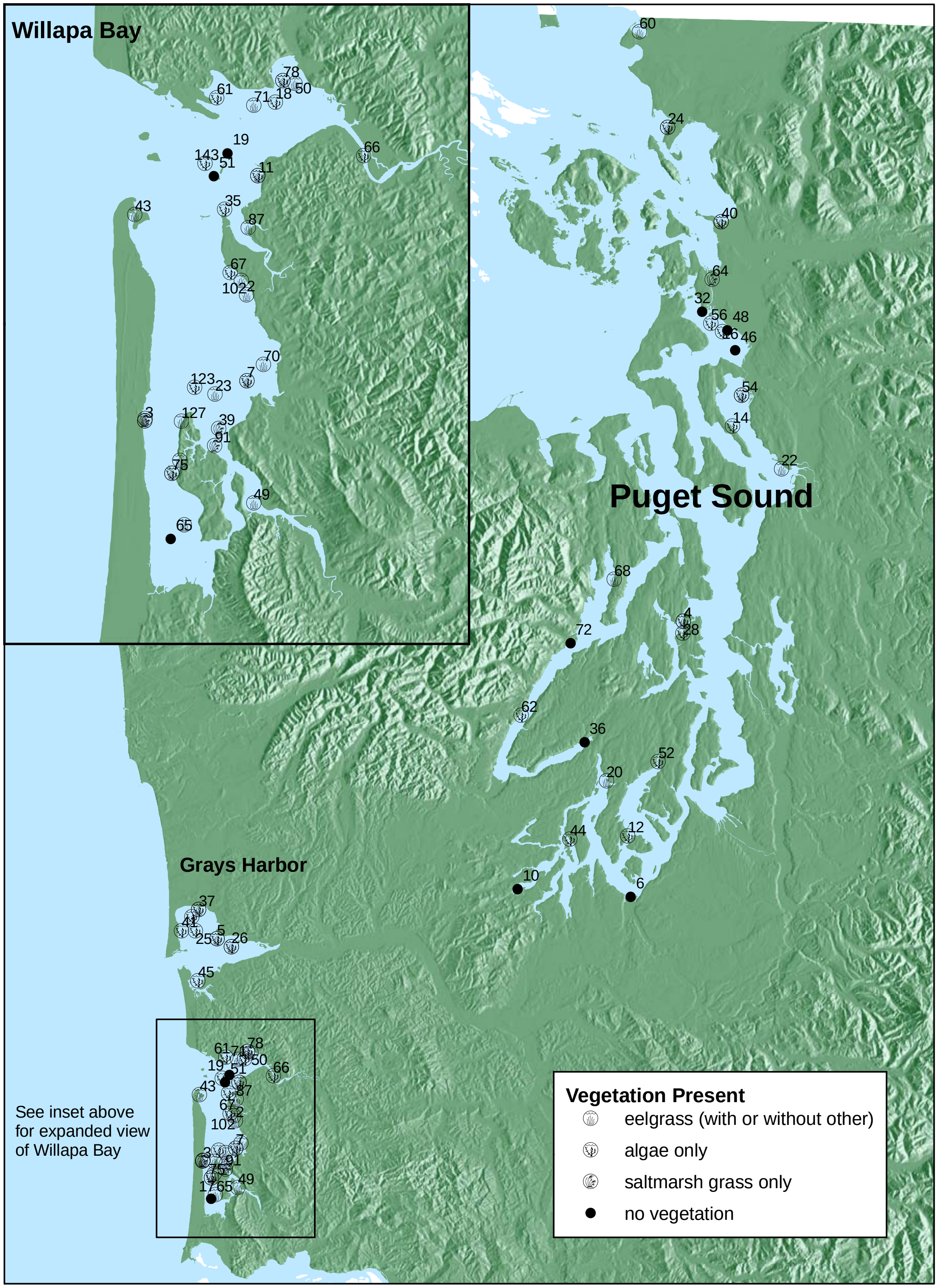

Figure B-2. Vegetation present at Washington Coastal EMAP 2002 sampling stations. All stations depicted were sampled successfully for all parameters.

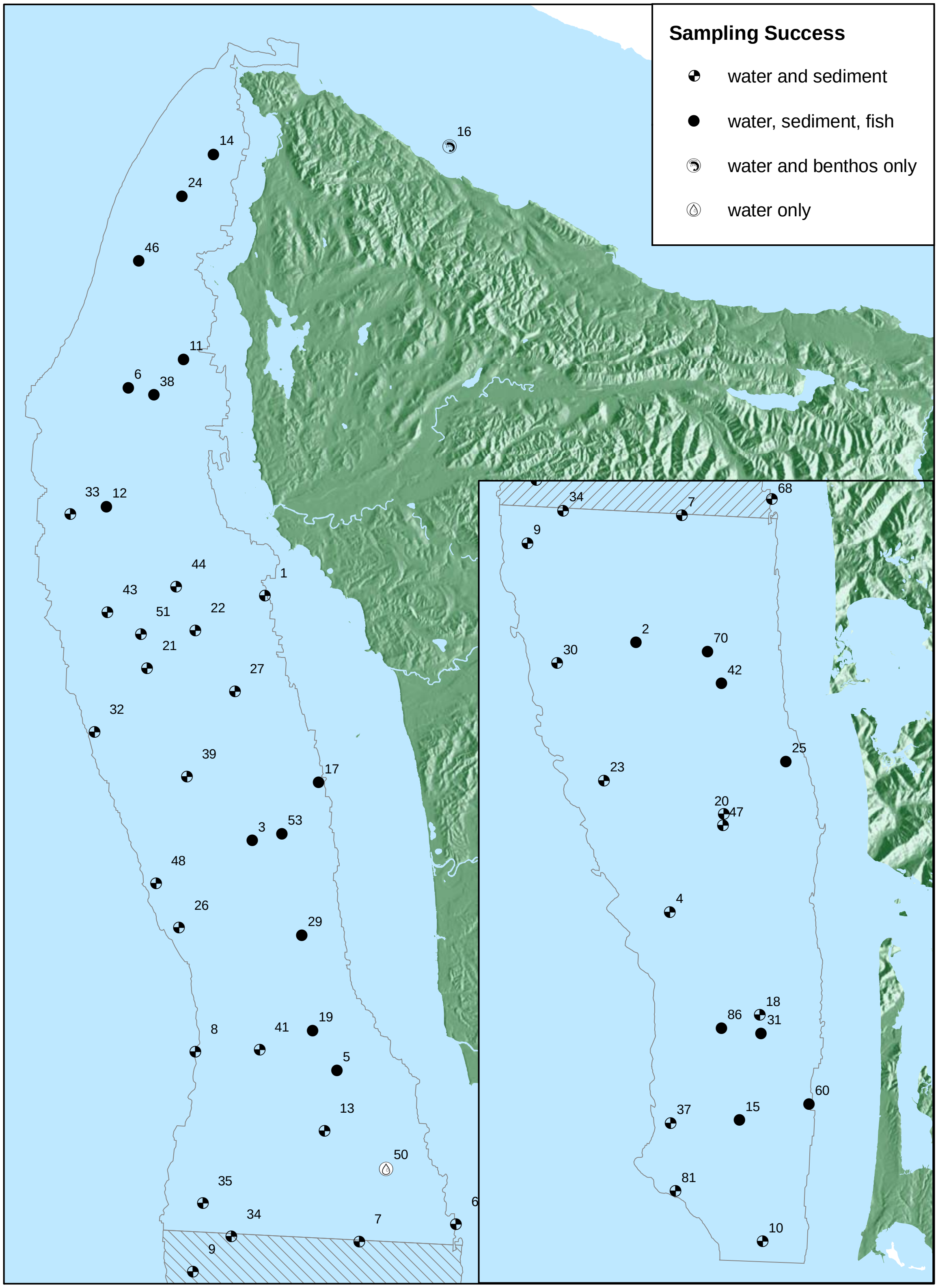

Figure B-3. Sampling success for Washington Coastal EMAP 2003

Table B-1. Sampling success by station, 2000
*Puget Sound Ambient Monitoring Program, now called the Puget Sound Assessment and Monitoring Program
**Coordinates of first successful sediment grab, if available; otherwise, coordinates of water sampling.
AA = *Ampelisca abdita* (amphipod mortality test)
AP = *Arbacia punctulata* (urchin fertilization and embryo development tests)
SP = *Strongylocentrotus purpuratus* (urchin fertilization test)

EMAP Station ID	Station	Target Latitude	Target Longitude	Estuary	Sampled Latitude**	Sampled Longitude**
WA00-0001*	007	48.984170	-122.993330	Boundary Bay, west	48.98415	-122.99332
WA00-0002*	012	48.954720	-122.949670	Boundary Bay, south	48.95468	-122.94975
WA00-0003*	017	48.815280	-122.718830	Cherry Point	48.81528	-122.71888
WA00-0004*	029	48.749720	-122.490170	Bellingham Bay	48.73862	-122.51528
WA00-0005*	038	48.625280	-122.525830	Samish Bay/ Bellingham	48.62530	-122.52582
WA00-0006*	042	48.531950	-122.548830	Padilla Bay, inner	48.53195	-122.54888
WA00-0007*	050	48.498330	-122.599670	Fidalgo Bay, inner	48.49830	-122.59968
WA00-0008*	051	48.486670	-122.586670	Fidalgo Bay, inner	48.48663	-122.58667
WA00-0009*	066	48.242780	-122.622170	Saratoga Passage, north	48.24283	-122.62218
WA00-0010*	069	48.274450	-122.651830	Oak Harbor	48.27445	-122.65198
WA00-0011*	071	48.224720	-122.710500	Penn Cove	48.22472	-122.71052
WA00-0012*	076	48.155830	-122.535170	Saratoga Passage, middle	48.15583	-122.53523
WA00-0013*	085	48.038620	-122.316330	Possession Sound	48.03865	-122.31643
WA00-0014*	090	47.982220	-122.222170	Everett Harbor, middle	47.98223	-122.22218
WA00-0015*	107	48.040180	-122.743480	Port Townsend Bay, inner	48.04017	-122.74352
WA00-0016*	112	47.993730	-122.678120	Oak Bay	47.99375	-122.67812
WA00-0017*	116	47.981530	-122.503380	Useless Bay	47.98152	-122.50338
WA00-0018*	118	47.906840	-122.336780	Possession Sound	47.90681	-122.33684
WA00-0019*	126	47.726020	-122.530480	Port Madison	47.72603	-122.53050
WA00-0020*	145	47.714700	-122.629300	Liberty Bay, outer	47.71468	-122.62932
WA00-0021*	179	47.623940	-122.374080	Elliott Bay, northeast	47.62394	-122.37410

Table B-1 (continued across). Sampling success by station, 2000

EMAP Station ID	CTD (Water)	Discrete Water Samples	Sediment Chemistry	Sediment Toxicity	Benthic Macro-fauna	Fish	Fish-Tissue Chemistry	Conditions Hindering Sampling
WA00-0001*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0002*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0003*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0004*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0005*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	eelgrass beds
WA00-0006*	Y	Y	Y	AA, SP	Y	Y	Y	
WA00-0007*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0008*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0009*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0010*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0011*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0012*	Y	Y	Y	AA, SP	Y	Y	Y	
WA00-0013*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0014*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0015*	Y	Y	Y	AA, SP	Y	Y	N	no target species caught
WA00-0016*	Y	Y	Y	AA, SP	Y	Y	N	insufficient target species caught
WA00-0017*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0018*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0019*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0020*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0021*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	

EMAP Station ID	Station	Target Latitude	Target Longitude	Estuary	Sampled Latitude**	Sampled Longitude**
WA00-0022*	200	47.584640	-122.345780	Duwamish River - East Waterway	47.58464	-122.34580
WA00-0023*	207	47.924470	-122.679500	Port Ludlow	47.92446	-122.67950
WA00-0024*	209	47.841030	-122.645930	Hood Canal (north)	47.84103	-122.64594
WA00-0025*	214	47.836290	-122.578500	Port Gamble Bay	47.83629	-122.57852
WA00-0026*	218	47.820590	-122.818380	Dabob Bay	47.82058	-122.81839
WA00-0027*	220	47.734650	-122.844070	Dabob Bay	47.73465	-122.84408
WA00-0028*	221	47.420630	-123.110320	Hood Canal (south)	47.42063	-123.11033
WA00-0029*	225	47.396540	-122.956000	Hood Canal, Lynch Cove	47.39654	-122.95602
WA00-0030*	226	47.377990	-123.129120	Hood Canal (south)	47.37798	-123.12913
WA00-0031*	229	47.209720	-123.082800	Port of Shelton	47.21236	-123.08392
WA00-0032*	237	47.129270	-122.913770	Budd Inlet	47.12927	-122.91378
WA00-0033*	243	47.051640	-122.895880	Port of Olympia	47.05164	-122.89588
WA00-0034*	252	47.269570	-122.851000	Case Inlet	47.26957	-122.85102
WA00-0035*	260	47.148370	-122.658830	East Anderson Island/North Cormorant Passage	47.14835	-122.65882
WA00-0036*	268	47.254630	-122.598100	Hale Passage	47.25460	-122.59808
WA00-0037*	269	47.337890	-122.584480	Gig Harbor	40.33789	-122.58449
WA00-0038*	273	47.510690	-122.485880	Colvos Passage	47.51068	-122.48590
WA00-0039*	274	47.472150	-122.506920	Colvos Passage	47.47214	-122.50693
WA00-0040*	286	47.284872	-122.472073	S.E. Commencement Bay	47.28487	-122.47207
WA00-0041*	304	47.278648	-122.398432	Hylebos Waterway	47.27865	-122.39842
WA00-0042	E01	48.937230	-123.735280	Stuart Channel (north)	48.93890	-123.73345
WA00-0043	E02	48.952400	-123.363430	Strait of Georgia	48.94755	-123.36203
WA00-0044	E03	48.865190	-123.599290	Stuart Channel (middle)	48.86513	-123.60103
WA00-0045	E04	48.937080	-123.201250	Strait of Georgia	48.93792	-123.20068
WA00-0046	E05	48.955550	-123.003900	Strait of Georgia	48.95550	-123.00450
WA00-0047	E06	48.901430	-122.925370	Strait of Georgia	48.89900	-122.92550
WA00-0048	E07	48.804980	-123.395030	Swanson Channel	48.80538	-123.39462

EMAP Station ID	CTD (Water)	Discrete Water Samples	Sediment Chemistry	Sediment Toxicity	Benthic Macro-fauna	Fish	Fish-Tissue Chemistry	Conditions Hindering Sampling
WA00-0022*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0023*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0024*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0025*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0026*	Y	Y	Y	AA, SP	Y	Y	Y	
WA00-0027*	Y	Y	Y	AA, SP	Y	Y	Y	
WA00-0028*	Y	Y	Y	AA, SP	Y	Y	Y	
WA00-0029*	Y	Y	Y	AA, SP	Y	N	N	no fish in trawls
WA00-0030*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0031*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0032*	Y	Y	Y	AA, SP	Y	Y	N, H4IIE	
WA00-0033*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0034*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0035*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0036*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0037*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0038*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0039*	Y	Y	Y	AA, SP	Y	Y	Y	
WA00-0040*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0041*	Y	Y	Y	AA, SP	Y	Y	Y, H4IIE	
WA00-0042	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	rocky bottom
WA00-0043	Y	Y	N	N	N	Y	Y	algal mats
WA00-0044	Y	Y	N	N	N	N	N	too deep to trawl; kelp bed; rocky bottom
WA00-0045	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0046	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0047	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0048	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	

EMAP Station ID	Station	Target Latitude	Target Longitude	Estuary	Sampled Latitude**	Sampled Longitude**
WA00-0049	E08	48.711880	-123.528260	Stuart Channel (south)	48.71200	-123.52800
WA00-0050	E09	48.823850	-122.730270	Cherry Point	48.82367	-122.73055
WA00-0051	E10	48.747820	-123.091970	Boundary Pass	48.74838	-123.09460
WA00-0052	E11	48.712910	-123.000200	President Channel	48.71268	-123.00070
WA00-0053	E12	48.701310	-122.994470	President Channel	48.69517	-122.94447
WA00-0054	E13	48.571570	-123.335410	Cordova Channel	48.57245	-123.33510
WA00-0055	E14	48.625480	-122.960520	West Sound	48.62467	-122.96133
WA00-0056	E15	48.611670	-123.000130	Deer Harbor	48.61133	-123.00000
WA00-0057	E16	48.589170	-123.019420	San Juan Channel	48.58878	-123.01845
WA00-0058	E17	48.610690	-122.837550	East Sound	48.61067	-122.83767
WA00-0059	E18	48.544530	-122.979770	San Juan Channel	48.54582	-122.97827
WA00-0060	E19	48.523610	-122.847190	Lopez Sound	48.52400	-122.84750
WA00-0061	E20	48.500410	-122.957240	San Juan Channel	48.50050	-122.95800
WA00-0062	E21	48.487970	-122.997020	Griffin Bay	48.48700	-122.99667
WA00-0063	E22	48.426200	-123.288090	Baynes Channel	48.42558	-123.28815
WA00-0064	E23	48.388860	-122.919660	Middle Channel	48.38820	-122.92077
WA00-0065	E24	48.323280	-123.055420	Strait of Juan de Fuca, east	48.32217	-123.06000
WA00-0066	E25	48.315900	-122.799920	Strait of Juan de Fuca, east	48.31617	-122.80100
WA00-0067	E26	48.192630	-123.023710	Strait of Juan de Fuca, east	48.19225	-123.02355
WA00-0068	E27	48.119940	-122.623340	Admiralty Bay	48.12040	-122.62203
WA00-0069	E28	47.965870	-122.554050	Mutiny Bay	47.96730	-122.55685
WA00-0070	E29	47.866020	-122.419460	Admiralty Inlet, south	47.86715	-122.42060
WA00-0071	E30	47.590160	-122.428350	Puget Sound	47.58965	-122.42770

EMAP Station ID	CTD (Water)	Discrete Water Samples	Sediment Chemistry	Sediment Toxicity	Benthic Macro-fauna	Fish	Fish-Tissue Chemistry	Conditions Hindering Sampling
WA00-0049	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0050	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0051	Y	Y	N	N	N	Y	Y	rocky bottom
WA00-0052	Y	Y	N	N	N	N	N	rocky bottom; torn net - no fish in catch
WA00-0053	Y	Y	N	N	N	Y	Y	rocky bottom
WA00-0054	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0055	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0056	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0057	Y	Y	N	N	N	N	N	kelp beds and reefs
WA00-0058	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	obstructions to trawling
WA00-0059	Y	Y	N	N	N	Y	Y, H4IIE	rocky bottom; fouled net
WA00-0060	Y	Y	Y	AA, AP	Y	Y	N	no target species caught
WA00-0061	Y	Y	N	N	N	N	N	rocky bottom; too deep to trawl
WA00-0062	Y	Y	Y	AA, AP	Y	Y	N	no target species caught
WA00-0063	Y	Y	Y	AA, AP	Y	Y	N	rocky bottom; no target species caught
WA00-0064	Y	Y	Y	AA, AP	Y	N	N	too deep to trawl
WA00-0065	Y	Y	Y	AA, AP	Y	N	N	net shredded, no fish caught
WA00-0066	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	
WA00-0067	Y	Y	N	N	N	Y	N	rocky bottom; no target species caught
WA00-0068	Y	Y	N	N	N	Y	Y, H4IIE	grab contents washed
WA00-0069	Y	Y	N	N	N	Y	Y, H4IIE	rocky bottom
WA00-0070	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	obstructions to trawling
WA00-0071	Y	Y	Y	AA, AP	Y	Y	Y, H4IIE	

Table B-2. Sampling success by station, 2002.
*Coordinates of sampled quadrat; NS = not sampled

EMAP Station ID	Target Latitude	Target Longitude	Estuary	Sampled Latitude*	Sampled Longitude*	Sediment Chemistry	Sediment Toxicity	Benthic Macrofauna	Plants	Shrimp Burrows
WA02-0001	46.403980	-123.978100	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0002	46.582350	-123.931170	Willapa Bay	46.58183	-123.93117	Y	Y	Y	Y	Y
WA02-0003	46.491170	-124.028600	Willapa Bay	46.49117	-124.02867	Y	Y	Y	Y	Y
WA02-0004	47.697000	-122.565250	Port Orchard	47.69700	-122.56400	Y	Y	Y	Y	Y
WA02-0005	46.973870	-124.014990	Grays Harbor	46.97383	-124.01500	Y	Y	Y	Y	Y
WA02-0006	47.096830	-122.708410	Case Inlet	47.09683	-122.70833	Y	Y	Y	Y	Y
WA02-0007	46.522070	-123.927310	Willapa Bay	46.52200	-123.92733	Y	Y	Y	Y	Y
WA02-0008	48.062530	-123.039790	Sequim Bay	NS	NS	N	N	N	N	N
WA02-0009	46.350920	-123.958340	Wallacut River	NS	NS	N	N	N	N	N
WA02-0010	47.106410	-123.068720	Oyster Bay	47.10617	-123.06883	Y	Y	Y	Y	Y
WA02-0011	46.665390	-123.925150	Willapa Bay	46.66533	-123.92517	Y	Y	Y	Y	Y
WA02-0012	47.229580	-122.722480	Drayton Passage	47.22917	-122.72267	Y	Y	Y	Y	Y
WA02-0013	46.907750	-124.049040	Grays Harbor	NS	NS	N	N	N	N	N
WA02-0014	48.122320	-122.421350	Port Susan	48.12233	-122.42133	Y	Y	Y	Y	Y
WA02-0015	46.556330	-123.961620	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0016	48.326200	-122.462310	Skagit Bay	48.32600	-122.46233	Y	Y	Y	Y	Y
WA02-0017	46.420210	-123.983970	Willapa Bay	46.42000	-123.98433	Y	Y	Y	Y	Y
WA02-0018	46.717200	-123.910660	Willapa Bay	46.71717	-123.91067	Y	Y	Y	Y	Y
WA02-0019	46.679940	-123.957150	Willapa Bay	46.68000	-123.95717	Y	Y	Y	Y	Y
WA02-0020	47.347340	-122.796750	Case Inlet	47.34733	-122.79633	Y	Y	Y	Y	Y
WA02-0021	47.019330	-124.097900	Grays Harbor	47.01933	-124.09783	Y	Y	Y	Y	Y
WA02-0022	48.032100	-122.260120	Port Gardner	48.03217	-122.26017	Y	Y	Y	Y	Y
WA02-0023	46.511930	-123.958920	Willapa Bay	46.51200	-123.95883	Y	Y	Y	Y	Y
WA02-0024	48.765420	-122.657570	Lummi Bay	48.76550	-122.65750	Y	Y	Y	Y	Y
WA02-0025	46.988950	-124.083880	Grays Harbor	46.98900	-124.08383	Y	Y	Y	Y	Y

Table B-2 (continued across). Sampling success by station, 2002.

EMAP Station ID	Conditions Hindering Sampling
WA02-0001	No response from landowner
WA02-0002	Moved 57.6m south; planned station submerged.
WA02-0003	
WA02-0004	Moved 90m east, as original station was submerged.
WA02-0005	
WA02-0006	
WA02-0007	
WA02-0008	On land
WA02-0009	Upper marsh
WA02-0010	Site moved 28m southwest of the planned position as actual site fell on eastern wall of a very steep sided channel inaccessible by hovercraft.
WA02-0011	
WA02-0012	Sample site moved south southwest by 49m to avoid operations on property whose owner denied entry permission. MHW restricted by bulkhead at upper beach. Paint cans filled with cement aid in sea defense.
WA02-0013	Submerged at low tide
WA02-0014	
WA02-0015	Submerged at low tide
WA02-0016	
WA02-0017	Station moved 36m southwest, as original site was submerged
WA02-0018	
WA02-0019	
WA02-0020	Site moved 32m east of planned position, as this was submerged even at a -2.9' tide.
WA02-0021	
WA02-0022	
WA02-0023	This area is sprayed with Rodeo (glyphosate) to control Spartina from June-October.
WA02-0024	100% cover of Zostera japonica. 3cm standing water over site.
WA02-0025	

EMAP Station ID	Target Latitude	Target Longitude	Estuary	Sampled Latitude*	Sampled Longitude*	Sediment Chemistry	Sediment Toxicity	Benthic Macrofauna	Plants	Shrimp Burrows
WA02-0026	46.958130	-123.968560	Grays Harbor	46.95817	-123.96850	Y	Y	Y	Y	Y
WA02-0027	46.499330	-124.028270	Willapa Bay	46.49283	-124.02833	Y	Y	Y	Y	Y
WA02-0028	47.671070	-122.564740	Port Orchard	47.67100	-122.56433	Y	Y	Y	Y	Y
WA02-0029	46.695270	-124.049210	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0030	48.275990	-122.380400	Stillaguamish River	NS	NS	N	N	N	N	N
WA02-0031	46.591180	-124.008520	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0032	48.368300	-122.529020	Skagit Bay	48.36833	-122.52900	Y	Y	Y	Y	Y
WA02-0033	46.373100	-124.010300	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0034	46.708430	-123.831050	Willapa River	NS	NS	N	N	N	N	N
WA02-0035	46.640880	-123.957260	Willapa Bay	46.64083	-123.95733	Y	Y	Y	Y	Y
WA02-0036	47.428450	-122.868630	Lynch Cove	47.42867	-122.87000	Y	Y	Y	Y	Y
WA02-0037	47.035250	-124.077720	Grays Harbor	47.03533	-124.07767	Y	Y	Y	Y	Y
WA02-0038	47.922160	-122.401540	Useless Bay	NS	NS	N	N	N	N	N
WA02-0039	46.488040	-123.953980	Willapa Bay	46.48800	-123.95383	Y	Y	Y	Y	Y
WA02-0040	48.564590	-122.474890	Samish Bay	48.56450	-122.47483	Y	Y	Y	Y	Y
WA02-0041	46.987680	-124.128470	Grays Harbor	46.98767	-124.12850	Y	Y	Y	Y	Y
WA02-0042	46.958430	-123.942560	Grays Harbor	NS	NS	N	N	N	N	N
WA02-0043	46.634480	-124.048120	Willapa Bay	46.63450	-124.04817	Y	Y	Y	Y	Y
WA02-0044	47.218150	-122.906910	Peale Passage	47.21817	-122.90700	Y	Y	Y	Y	Y
WA02-0045	46.881160	-124.070020	Grays Harbor	46.88150	-124.07000	Y	Y	Y	Y	Y
WA02-0046	48.285360	-122.418700	Skagit Bay	48.28583	-122.41900	Y	Y	Y	Y	Y
WA02-0047	46.554950	-124.007100	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0048	48.329310	-122.446510	Skagit Bay	48.32933	-122.44650	Y	Y	Y	Y	Y
WA02-0049	46.437210	-123.915130	Naselle River	46.43717	-123.91517	Y	Y	Y	Y	Y
WA02-0050	46.730600	-123.891680	Willapa Bay	46.73067	-123.89167	Y	Y	Y	Y	Y
WA02-0051	46.663730	-123.969800	Willapa Bay	46.66367	-123.96983	Y	Y	Y	Y	Y
WA02-0052	47.391980	-122.632990	Carr Inlet	47.39200	-122.63300	Y	Y	Y	Y	Y

EMAP Station ID	Conditions Hindering Sampling
WA02-0026	
WA02-0027	Moved 60m south to ensure fell on land w/ owner's permission.
WA02-0028	Sample moved 31m southeast as original position was submerged. Sea defense boulders at upper beach.
WA02-0029	Unsafe conditions
WA02-0030	Upper marsh/Spartina
WA02-0031	Submerged at low tide
WA02-0032	
WA02-0033	Upper marsh
WA02-0034	Upper marsh/Spartina
WA02-0035	
WA02-0036	Urban shoreline and Belfair State Park. Site moved 97m ENE in field. Original site under 75cm water at low tide.
WA02-0037	
WA02-0038	Permission denied
WA02-0039	Spartina alterniflora. This area is sprayed with Rodeo (glyphosate) from June to October to control Spartina.
WA02-0040	
WA02-0041	Shellfish bed
WA02-0042	Permission denied
WA02-0043	
WA02-0044	Sample fell on land owned by Squaxin Island Tribe's Hartstene Island Oyster Company.
WA02-0045	Station moved 38m north, as original site was submerged (fell in a channel). Area is sprayed with Carbaryl to control the Upogebia sp. Populations.
WA02-0046	Site moved 60m north northwest - planned site submerged.
WA02-0047	Submerged at low tide
WA02-0048	Original site under 10-15cm of water at low tide. Site moved 29m onto sub-aerial ground to the northwest.
WA02-0049	
WA02-0050	
WA02-0051	
WA02-0052	

EMAP Station ID	Target Latitude	Target Longitude	Estuary	Sampled Latitude*	Sampled Longitude*	Sediment Chemistry	Sediment Toxicity	Benthic Macrofauna	Plants	Shrimp Burrows
WA02-0053	46.859130	-124.068950	Grays Harbor	NS	NS	N	N	N	N	N
WA02-0054	48.189720	-122.394130	Port Susan	48.18967	-122.39417	Y	Y	Y	Y	Y
WA02-0055	46.535150	-123.994130	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0056	48.344060	-122.499640	Skagit Bay	48.34417	-122.50000	Y	Y	Y	Y	Y
WA02-0057	46.976250	-124.057480	Grays Harbor	NS	NS	N	N	N	N	N
WA02-0058	46.948910	-123.898700	Grays Harbor	NS	NS	N	N	N	N	N
WA02-0059	46.464640	-123.992430	Willapa Bay	46.46467	-123.99133	Y	Y	Y	Y	Y
WA02-0060	48.970480	-122.760060	Drayton Harbor	48.97050	-122.76000	Y	Y	Y	Y	Y
WA02-0061	46.718320	-123.970380	Willapa Bay	46.71833	-123.97033	Y	Y	Y	Y	Y
WA02-0062	47.483230	-123.075160	Lilliwaup Creek	47.48333	-123.07533	Y	Y	Y	Y	Y
WA02-0063	46.546030	-123.910840	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0064	48.439590	-122.500400	Swinomish Channel	48.43917	-122.50017	Y	Y	Y	Y	Y
WA02-0065	46.409950	-123.996830	Willapa Bay	46.40950	-123.99733	Y	Y	Y	Y	Y
WA02-0066	46.682260	-123.818890	Willapa River	46.68233	-123.81883	Y	Y	Y	Y	Y
WA02-0067	46.597080	-123.948970	Willapa Bay	46.59717	-123.94900	Y	Y	Y	Y	Y
WA02-0068	47.784270	-122.789910	Thorndike Bay	47.78433	-122.78967	Y	Y	Y	Y	Y
WA02-0069	46.514460	-123.876640	North Nemah River	NS	NS	N	N	N	N	N
WA02-0070	46.534060	-123.911200	Willapa Bay	46.53400	-123.91133	Y	Y	Y	Y	Y
WA02-0071	46.714180	-123.932390	Willapa Bay	46.71417	-123.93250	Y	Y	Y	Y	Y
WA02-0072	47.642780	-122.924410	Duckabush River	47.64283	-122.92433	Y	Y	Y	Y	Y
WA02-0073	46.945380	-124.091780	Grays Harbor	NS	NS	N	N	N	N	N
WA02-0074	46.956970	-123.864750	Grays Harbor	NS	NS	N	N	N	N	N
WA02-0075	46.455510	-123.998880	Willapa Bay	46.45550	-123.99883	Y	Y	Y	Y	Y
WA02-0076	47.486390	-122.481270	Colvos/Dalco Passage	NS	NS	N	N	N	N	N
WA02-0077	46.407340	-123.941830	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0078	46.732430	-123.903940	Willapa Bay	46.73250	-123.90400	Y	Y	Y	Y	Y
WA02-0079	46.682180	-123.936570	Willapa Bay	NS	NS	N	N	N	N	N

EMAP Station ID	Conditions Hindering Sampling
WA02-0053	Upper marsh
WA02-0054	Rodeo had been sprayed on the beach recently, as part of a Spartina eradication project.
WA02-0055	Submerged at low tide
WA02-0056	Sanctuary and undeveloped shoreline. Original site under 10-15cm of water at low tide. Site moved 29m onto sub-aerial ground to the northwest.
WA02-0057	Submerged at low tide
WA02-0058	Permission denied
WA02-0059	Station moved ~85m east of original site that was submerged.
WA02-0060	
WA02-0061	Carbaryl sprayed to control ghost shrimp - July 8th
WA02-0062	Site moved 17m in field, as overlain by water even at low tide.
WA02-0063	Submerged at low tide
WA02-0064	The site was moved 51m south, as original site fell in upland/marsh and was inaccessible. The channel is frequently dredged and sides are steep, and have suffered erosion (slumping).
WA02-0065	Site moved 64m, planned location submerged.
WA02-0066	
WA02-0067	
WA02-0068	Site moved 20m in field, as original position was submerged.
WA02-0069	Submerged at low tide
WA02-0070	Roots of Z. marina caused difficulty in obtaining sediment for chemistry analyses.
WA02-0071	
WA02-0072	Shellfish bed
WA02-0073	Submerged at low tide
WA02-0074	Permission denied
WA02-0075	Imported gravel for clam bed
WA02-0076	Rocky foreshore
WA02-0077	No response from landowner
WA02-0078	
WA02-0079	Permission denied

EMAP Station ID	Target Latitude	Target Longitude	Estuary	Sampled Latitude*	Sampled Longitude*	Sediment Chemistry	Sediment Toxicity	Benthic Macrofauna	Plants	Shrimp Burrows
WA02-0080	47.424060	-122.512900	Colvos/Dalco Passage	NS	NS	N	N	N	N	N
WA02-0081	46.850570	-124.044630	Beardslee Slough	NS	NS	N	N	N	N	N
WA02-0082	48.183910	-122.357340	Port Susan	NS	NS	N	N	N	N	N
WA02-0087	46.628850	-123.932940	Palix River	46.62888	-123.93268	Y	Y	Y	Y	Y
WA02-0091	46.473850	-123.958170	Willapa Bay	46.47587	-123.95702	Y	Y	Y	Y	Y
WA02-0102	46.591330	-123.937600	Willapa Bay	46.59197	-123.93710	Y	Y	Y	Y	Y
WA02-0111	46.657290	-123.991380	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0117	46.428560	-123.996140	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0123	46.515730	-123.980890	Willapa Bay	46.51608	-123.97987	Y	Y	Y	Y	Y
WA02-0127	46.491730	-123.991630	Willapa Bay	46.49180	-123.99165	Y	Y	Y	Y	Y
WA02-0134	46.547310	-123.916920	Willapa Bay	NS	NS	N	N	N	N	N
WA02-0143	46.672630	-123.979360	Willapa Bay	46.67247	-123.97932	Y	Y	Y	Y	Y

EMAP Station ID	Conditions Hindering Sampling
WA02-0080	Rocky foreshore
WA02-0081	Upper marsh
WA02-0082	Permission denied
WA02-0087	
WA02-0091	Site was taken 241m NNE of planned, inaccessible due to Spartina marsh.
WA02-0102	Moved 80m NE; planned location submerged.
WA02-0111	Submerged at low tide
WA02-0117	Submerged
WA02-0123	Site moved 88m as planned position was submerged.
WA02-0127	
WA02-0134	Submerged
WA02-0143	

Table B-3. Sampling success by station, 2003.
*Coordinates of first successful sediment grab, if available; otherwise, coordinates of water sampling. NS = not sampled.

EMAP Station ID	Station	Target Latitude	Target Longitude	Location	Sampled Latitude*	Sampled Longitude*
WA03-0001	3002	47.818267	-124.643973	Olympic Coast National Marine Sanctuary	47.82272	-124.64462
WA03-0002	3006	46.981284	-124.508145	SW WA Pacific coast shelf	46.97717	-124.50850
WA03-0003	3010	47.556611	-124.645791	Olympic Coast National Marine Sanctuary	47.55650	-124.64453
WA03-0004	3014	46.664219	-124.431448	SW WA Pacific coast shelf	46.66458	-124.42777
WA03-0005	3015	47.312937	-124.491338	Olympic Coast National Marine Sanctuary	47.31235	-124.49058
WA03-0006	3018	48.043630	-124.886457	Olympic Coast National Marine Sanctuary	48.03917	-124.88317
WA03-0007	3022	47.125615	-124.439118	SW WA Pacific coast shelf	47.12783	-124.44100
WA03-0008	3023	47.327732	-124.711330	Olympic Coast National Marine Sanctuary	47.32453	-124.71723
WA03-0009	3026	47.085254	-124.699983	SW WA Pacific coast shelf	47.08612	-124.70237
WA03-0010	3030	46.289195	-124.246230	SW WA Pacific coast shelf	46.28543	-124.24415
WA03-0011	3031	48.075192	-124.798558	Olympic Coast National Marine Sanctuary	48.07320	-124.79665
WA03-0012	3034	47.914127	-124.909202	Olympic Coast National Marine Sanctuary	47.90933	-124.90833
WA03-0013	3038	47.245251	-124.502828	Olympic Coast National Marine Sanctuary	47.24628	-124.50537
WA03-0014	3042	48.301223	-124.768879	Olympic Coast National Marine Sanctuary	48.29712	-124.76600
WA03-0015	3046	46.428976	-124.291791	SW WA Pacific coast shelf	46.42568	-124.29272
WA03-0016	3047	48.315183	-124.379687	Strait of Juan de Fuca	48.31883	-124.38333
WA03-0017	3050	47.619889	-124.539575	Olympic Coast National Marine Sanctuary	47.62320	-124.54317
WA03-0018	3054	46.549379	-124.264758	SW WA Pacific coast shelf	46.54938	-124.26653
WA03-0019	3055	47.352209	-124.531579	Olympic Coast National Marine Sanctuary	47.35410	-124.53283
WA03-0020	3058	46.780523	-124.344158	SW WA Pacific coast shelf	46.78168	-124.34447
WA03-0021	3063	47.739239	-124.829064	Olympic Coast National Marine Sanctuary	47.73667	-124.82800
WA03-0022	3066	47.778813	-124.752040	Olympic Coast National Marine Sanctuary	47.78033	-124.75343
WA03-0023	3070	46.812694	-124.549307	SW WA Pacific coast shelf	46.81417	-124.55100
WA03-0024	3074	48.252689	-124.813821	Olympic Coast National Marine Sanctuary	48.24972	-124.81373
WA03-0025	3078	46.845432	-124.240101	SW WA Pacific coast shelf	46.84685	-124.24320
WA03-0026	3079	47.462054	-124.755178	Olympic Coast National Marine Sanctuary	47.45777	-124.75408

Table B-3 (continued across). Sampling success by station, 2003.

EMAP Station ID	CTD (Water)	Discrete Water Samples	Sediment Chemistry	Benthic Macro-fauna	Fish	Fish-Tissue Chemistry	Conditions Hindering Sampling
WA03-0001	Y	Y	Y	Y	N	N	
WA03-0002	Y	Y	Y	Y	Y	Y	
WA03-0003	Y	Y	Y	Y	Y	Y	
WA03-0004	Y	Y	Y	Y	N	N	
WA03-0005	Y	Y	Y	Y	Y	Y	
WA03-0006	Y	Y	Y	Y	Y	Y	
WA03-0007	Y	Y	Y	Y	N	N	
WA03-0008	Y	Y	Y	Y	N	N	
WA03-0009	Y	Y	Y	Y	N	N	
WA03-0010	Y	Y	Y	Y	N	N	
WA03-0011	Y	Y	Y	Y	Y	Y	
WA03-0012	Y	Y	Y	Y	Y	Y	
WA03-0013	Y	Y	Y	Y	N	N	
WA03-0014	Y	Y	Y	Y	Y	Y	No discrete water sample for bottom depth
WA03-0015	Y	Y	Y	Y	Y	Y	
WA03-0016	Y	Y	N	Y	N	N	Station abandoned - hard bottom. Discrete water sample for bottom depth only
WA03-0017	Y	Y	Y	Y	Y	Y	
WA03-0018	Y	Y	Y	Y	N	N	
WA03-0019	Y	Y	Y	Y	Y	Y	
WA03-0020	Y	Y	Y	Y	N	N	
WA03-0021	Y	Y	Y	Y	N	N	
WA03-0022	Y	Y	Y	Y	N	N	
WA03-0023	Y	Y	Y	Y	N	N	
WA03-0024	Y	Y	Y	Y	Y	Y	
WA03-0025	Y	Y	Y	Y	Y	Y	
WA03-0026	Y	Y	Y	Y	N	N	

EMAP Station ID	Station	Target Latitude	Target Longitude	Location	Sampled Latitude*	Sampled Longitude*
WA03-0027	3082	47.721494	-124.682220	Olympic Coast National Marine Sanctuary	47.71683	-124.68517
WA03-0028	3086	47.042224	-124.466126	SW WA Pacific coast shelf	NS	NS
WA03-0029	3087	47.455371	-124.559719	Olympic Coast National Marine Sanctuary	47.45667	-124.55767
WA03-0030	3090	46.946824	-124.641856	SW WA Pacific coast shelf	46.94825	-124.64095
WA03-0031	3094	46.527625	-124.262354	SW WA Pacific coast shelf	46.52808	-124.26318
WA03-0032	3095	47.666653	-124.901915	Olympic Coast National Marine Sanctuary	47.66500	-124.90667
WA03-0033	3098	47.901079	-124.964785	Olympic Coast National Marine Sanctuary	47.89880	-124.96538
WA03-0034	3102	47.125027	-124.641700	SW WA Pacific coast shelf	47.12668	-124.64463
WA03-0035	3103	47.160642	-124.691686	Olympic Coast National Marine Sanctuary	47.16092	-124.69283
WA03-0036	3106	48.230471	-123.292424	Strait of Juan de Fuca	NS	NS
WA03-0037	3110	46.416678	-124.407388	SW WA Pacific coast shelf	46.41817	-124.40867
WA03-0038	3111	48.034647	-124.844826	Olympic Coast National Marine Sanctuary	48.03317	-124.84117
WA03-0039	3114	47.620117	-124.754914	Olympic Coast National Marine Sanctuary	47.62197	-124.75478
WA03-0041	3119	47.331796	-124.616268	Olympic Coast National Marine Sanctuary	47.33047	-124.61533
WA03-0042	3122	46.932378	-124.357325	SW WA Pacific coast shelf	46.93410	-124.35925
WA03-0043	3127	47.793501	-124.897264	Olympic Coast National Marine Sanctuary	47.79518	-124.89645
WA03-0044	3130	47.833364	-124.786493	Olympic Coast National Marine Sanctuary	47.82710	-124.78812
WA03-0046	3138	48.174961	-124.879267	Olympic Coast National Marine Sanctuary	48.17718	-124.87818
WA03-0047	3142	46.768866	-124.345054	SW WA Pacific coast shelf	46.76865	-124.34468
WA03-0048	3143	47.508574	-124.796183	Olympic Coast National Marine Sanctuary	47.50433	-124.79467
WA03-0049	3146	48.173687	-123.668208	Strait of Juan de Fuca	48.17365	-123.66882
WA03-0050	3150	47.205333	-124.403886	Olympic Coast National Marine Sanctuary	47.20820	-124.40410
WA03-0051	3152	47.780752	-124.850136	Olympic Coast National Marine Sanctuary	47.77348	-124.84087
WA03-0053	3160	47.566698	-124.597913	Olympic Coast National Marine Sanctuary	47.56543	-124.59808
WA03-0060	3180	46.448055	-124.176705	SW WA Pacific coast shelf	46.44823	-124.17625
WA03-0068	3204	47.147620	-124.289437	Olympic Coast National Marine Sanctuary	47.15242	-124.28867
WA03-0070	3208	46.973516	-124.392028	SW WA Pacific coast shelf	46.98865	-124.48768
WA03-0081	3244	46.336713	-124.392720	SW WA Pacific coast shelf	46.33923	-124.39470
WA03-0086	3260	46.531452	-124.329729	SW WA Pacific coast shelf	46.53217	-124.33078

EMAP Station ID	CTD (Water)	Discrete Water Samples	Sediment Chemistry	Benthic Macro-fauna	Fish	Fish-Tissue Chemistry	Conditions Hindering Sampling
WA03-0027	Y	Y	Y	Y	N	N	
WA03-0028	N	N	N	N	N	N	Station abandoned - hard bottom
WA03-0029	Y	Y	Y	Y	Y	Y	
WA03-0030	Y	Y	Y	Y	N	N	
WA03-0031	Y	Y	Y	Y	Y	Y	
WA03-0032	Y	Y	Y	Y	N	N	
WA03-0033	Y	Y	Y	Y	N	N	
WA03-0034	Y	Y	Y	Y	N	N	
WA03-0035	Y	Y	Y	Y	N	N	
WA03-0036	N	N	N	N	N	N	Station abandoned - hard bottom
WA03-0037	Y	Y	Y	Y	N	N	
WA03-0038	Y	Y	Y	Y	Y	Y	
WA03-0039	Y	Y	Y	Y	N	N	
WA03-0041	Y	Y	Y	Y	N	N	
WA03-0042	Y	Y	Y	Y	Y	Y	
WA03-0043	Y	Y	Y	Y	N	N	
WA03-0044	Y	Y	Y	Y	N	N	
WA03-0046	Y	Y	Y	Y	Y	Y	
WA03-0047	Y	Y	Y	Y	N	N	
WA03-0048	Y	Y	Y	Y	N	N	
WA03-0049	N	N	N	N	N	N	Station abandoned - hard bottom
WA03-0050	Y	Y	N	N	N	N	Station abandoned - hard bottom
WA03-0051	Y	Y	Y	Y	N	N	
WA03-0053	Y	Y	Y	Y	Y	Y	
WA03-0060	Y	Y	Y	Y	Y	Y	
WA03-0068	Y	Y	Y	Y	N	N	
WA03-0070	Y	Y	Y	Y	Y	Y	
WA03-0081	Y	Y	Y	Y	N	N	
WA03-0086	Y	Y	Y	Y	Y	Y	

Appendix C. Benthos

Table C-1. Infauna taxa in order of decreasing abundance, all stations combined (2000). The ten most abundant taxa are in bold type. C = colonial, X = exotic, XC = Exotic colonial.

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Owenia fusiformis	**14**	**4770**	**10.434%**
	Nutricola lordi	**27**	**4106**	**8.981%**
	Axinopsida serricata	**48**	**2709**	**5.926%**
	Aphelochaeta glandaria	**24**	**2616**	**5.722%**
	Rochefortia tumida	**39**	**2251**	**4.924%**
	Ampelisca agassizi	**2**	**1300**	**2.844%**
X	***Ericthonius brasiliensis***	**1**	**1198**	**2.620%**
	***Amphiodia* sp**	**26**	**1179**	**2.579%**
	Euphilomedes carcharodonta	**22**	**1022**	**2.235%**
	Acila castrensis	**23**	**945**	**2.067%**
	Eudorella pacifica	32	937	2.050%
	Euphilomedes producta	22	904	1.977%
	Levinsenia gracilis	34	721	1.577%
	Prionospio (Minuspio) lighti	40	633	1.385%
	Amphiodia periercta	4	482	1.054%
	Parvilucina tenuisculpta	34	463	1.013%
	Macoma carlottensis	29	462	1.011%
	Paraprionospio pinnata	33	451	0.987%
	Pinnixa schmitti	28	387	0.847%
	Prionospio (Prionospio) steenstrupi	37	365	0.798%
	Oligochaeta	21	356	0.779%
	Cheirimedeia zotea	1	327	0.715%
	Mediomastus sp	39	312	0.682%
	Pholoe sp Cmplx	32	312	0.682%
	Scoletoma luti	32	302	0.661%
	Galathowenia oculata	22	292	0.639%
	Scalibregma californicum	4	280	0.612%
	Protomedeia grandimana	10	276	0.604%
	Heteromastus filiformis	4	275	0.602%
	Odostomia sp	29	273	0.597%
	Sternaspis cf fossor	20	264	0.577%
	Protomedeia prudens	10	241	0.527%
	Aoroides intermedius	3	233	0.510%
	Leitoscoloplos pugettensis	29	229	0.501%
	Chaetozone nr setosa	15	227	0.497%
	Heterophoxus affinis	19	227	0.497%
	Rhepoxynius boreovariatus	4	227	0.497%
	Macoma sp	35	222	0.486%
	Capitella capitata Cmplx	18	220	0.481%
	Alvania compacta	27	214	0.468%
	Leptochelia dubia	15	214	0.468%
	Rhynchospio glutaea	2	196	0.429%
	Spiophanes berkeleyorum	24	193	0.422%
	Ennucula tenuis	21	191	0.418%
	Pulsellum salishorum	12	171	0.374%

Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Heteromastus filobranchus	16	170	0.372%
Microclymene caudata	7	168	0.367%
Tellina modesta	12	167	0.365%
Dipolydora socialis	24	166	0.363%
Sigambra bassi	12	163	0.357%
Amphiuridae	18	162	0.354%
Rhepoxynius daboius	2	151	0.330%
Lumbrineris californiensis	15	142	0.311%
Maldanidae	5	140	0.306%
Glycinde polygnatha	23	138	0.302%
Cossura pygodactylata	24	136	0.297%
Amphiodia urtica	10	134	0.293%
Nephtys cornuta	28	131	0.287%
Mediomastus californiensis	13	130	0.284%
Astyris gausapata	20	129	0.282%
Nuculana minuta	13	127	0.278%
Exogone lourei	10	124	0.271%
Aricidea (Acmira) lopezi	21	118	0.258%
Bittium sp	4	118	0.258%
Pinnotheridae	12	118	0.258%
Aphelochaeta tigrina	2	116	0.254%
Orchomene pinguis	3	111	0.243%
Spiochaetopterus costarum	19	106	0.232%
Aricidea (Allia) ramosa	8	103	0.225%
Pholoides asperus	9	101	0.221%
Pectinaria californiensis	10	97	0.212%
Nebalia pugettensis Cmplx	5	95	0.208%
Cyclocardia ventricosa	6	91	0.199%
Foxiphalus similis	5	90	0.197%
Glycera nana	30	89	0.195%
Tritella pilimana	8	87	0.190%
Caprella laeviuscula	1	85	0.186%
Cossura bansei	6	84	0.184%
Turbonilla sp	18	80	0.175%
Asabellides lineata	5	76	0.166%
Spiophanes bombyx	5	76	0.166%
Ampelisca careyi	14	75	0.164%
Nephtys ferruginea	29	74	0.162%
Lirobittium sp	5	73	0.160%
Balanus sp	1	71	0.155%
Polycirrus sp	13	69	0.151%
Aphelochaeta monilaris	13	68	0.149%
Armandia brevis	8	67	0.147%
Compsomyax subdiaphana	18	67	0.147%
Scoloplos acmeceps	4	67	0.147%
Euclymeninae	21	66	0.144%
Macoma elimata	19	64	0.140%
Amphipholis pugetana	3	62	0.136%

Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Lumbrineris cruzensis	13	62	0.136%
Macoma nasuta	10	59	0.129%
Prionospio (Minuspio) multibranchiata	8	59	0.129%
Ampharete finmarchica	13	58	0.127%
Ampharete acutifrons	9	55	0.120%
Calanoida	11	55	0.120%
Polycirrus californicus	8	55	0.120%
Photis brevipes	7	54	0.118%
Westwoodilla caecula	12	54	0.118%
Axiothella rubrocincta	5	53	0.116%
Phyllochaetopterus prolifica	8	53	0.116%
Euchone incolor	6	52	0.114%
Macoma golikovi	14	51	0.112%
Magelona longicornis	17	49	0.107%
Crepipatella dorsata	3	48	0.105%
Maldane sarsi	11	48	0.105%
Olivella baetica	5	48	0.105%
Circeis armoricana	2	47	0.103%
Platynereis bicanaliculata	9	46	0.101%
Yoldia sp	12	45	0.098%
Cyclostremella cf concordia	3	44	0.096%
Heterophoxus conlanae	9	44	0.096%
Micrura sp	19	44	0.096%
Protomedeia sp	11	44	0.096%
Tubulanus sp	13	44	0.096%
Terebellides sp	10	43	0.094%
Lumbrineridae	12	42	0.092%
Proceraea cornuta	11	42	0.092%
Photis sp	12	41	0.090%
Chaetozone acuta	7	39	0.085%
Lyonsia californica	14	39	0.085%
Lacuna sp	1	38	0.083%
Onuphis elegans	5	38	0.083%
Pinnixa sp	17	38	0.083%
Praxillella pacifica	11	37	0.081%
Sphaerodoropsis sphaerulifer	10	37	0.081%
Terebellides californica	10	37	0.081%
Ampelisca sp	11	36	0.079%
Amphiporus sp	4	36	0.079%
Chaetozone sp N2	3	36	0.079%
Cirratulus spectabilis	4	35	0.077%
Exogone dwisula	6	35	0.077%
Glycinde armigera	20	35	0.077%
Macoma inquinata	4	35	0.077%
Ophelina acuminata	12	35	0.077%
Eudorellopsis integra	3	34	0.074%
Mayerella banksia	2	34	0.074%
Notomastus hemipodus	11	34	0.074%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Pectinaria granulata	10	34	0.074%
	Dipolydora cardalia	9	33	0.072%
	Podarkeopsis glabrus	17	33	0.072%
	Tubulanus polymorphus	18	33	0.072%
	Ampelisca pugetica	6	32	0.070%
	Anonyx sp	1	32	0.070%
	Aoroides spinosa	4	31	0.068%
	Clinocardium nuttallii	12	31	0.068%
	Eudistylia sp	2	31	0.068%
	Cirratulidae	11	30	0.066%
	Scoloplos armiger armiger	2	30	0.066%
x	*Trochochaeta multisetosa*	11	30	0.066%
x	*Laonice cirrata*	16	29	0.063%
	Nephasoma diaphanes	2	29	0.063%
	Pseudochitinopoma occidentalis	2	29	0.063%
	Terebellides stroemi	6	29	0.063%
	Ampelisca brachycladus	1	28	0.061%
	Ampharete labrops	5	28	0.061%
	Desdimelita desdichada	6	28	0.061%
	Eobrolgus chumashi	3	28	0.061%
	Euclymene sp	3	28	0.061%
	Pinnixa occidentalis	5	28	0.061%
	Pista wui	7	28	0.061%
	Virgularia agassizi	2	28	0.061%
	Aoroides sp	6	27	0.059%
	Eteone sp	14	27	0.059%
	Euclymeninae sp A	6	27	0.059%
	Nereis procera	14	27	0.059%
	Prionospio sp	3	27	0.059%
	Harmothoe imbricata	6	26	0.057%
	Leptosynapta sp	6	26	0.057%
	Macoma yoldiformis	13	26	0.057%
	Terebellides horikoshii	3	26	0.057%
	Amphipholis squamata	6	25	0.055%
	Diopatra ornata	7	25	0.055%
	Dorvillea (Schistomeringos) annulata	5	25	0.055%
	Lumbrineris sp	7	25	0.055%
	Malmgreniella nigralba	4	25	0.055%
	Podocopida	1	25	0.055%
	Tharyx sp N1	3	25	0.055%
	Yoldia hyperborea	9	25	0.055%
	Amphissa columbiana	4	24	0.052%
x	*Lanassa venusta*	11	24	0.052%
	Pilargis maculata	9	24	0.052%
	Ampharete cf crassiseta	7	23	0.050%
	Chaetozone commonalis	2	23	0.050%
	Crangon alaskensis	13	23	0.050%
	Deutella californica	1	23	0.050%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Eulalia quadrioculata	2	23	0.050%
	Yoldia seminuda	9	23	0.050%
	Adontorhina cyclia	10	22	0.048%
	Araphura breviaria	2	22	0.048%
	Caulleriella pacifica	8	22	0.048%
	Cossura sp	5	22	0.048%
	Sphaerosyllis californiensis	6	22	0.048%
	Calyptraea fastigiata	4	21	0.046%
	Diastylis pellucida	6	21	0.046%
x	*Dipolydora caulleryi*	7	21	0.046%
	Ischnochiton trifidus	2	21	0.046%
	Lepidochitona dentiens	2	21	0.046%
	Odontosyllis phosphorea	5	21	0.046%
	Petaloproctus borealis	4	21	0.046%
	Americhelidium shoemakeri	5	20	0.044%
	Chaetoderma sp	9	20	0.044%
	Gammaropsis thompsoni	1	20	0.044%
	Gattyana cirrosa	3	20	0.044%
	Onuphis sp	4	20	0.044%
	Paleanotus bellis	8	20	0.044%
	Paraphoxus oculatus	3	20	0.044%
	Rhepoxynius barnardi	4	20	0.044%
	Terebratalia transversa	3	20	0.044%
	Lucinoma annulatum	12	19	0.042%
	Margarites pupillus	5	19	0.042%
	Praxillella gracilis	7	19	0.042%
	Proclea graffi	3	19	0.042%
	Cylichna attonsa	8	18	0.039%
	Lineidae	8	18	0.039%
	Monocorophium carlottensis	2	18	0.039%
	Prionospio (Prionospio) jubata	7	18	0.039%
	Amage anops	2	17	0.037%
	Ampelisca hancocki Cmplx	3	17	0.037%
	Chaetozone sp	10	17	0.037%
	Eusyllis habei	5	17	0.037%
	Lophopanopeus bellus	4	17	0.037%
	Mediomastus ambiseta	4	17	0.037%
	Micropodarke dubia	4	17	0.037%
	Onuphis iridescens	11	17	0.037%
	Aphelochaeta sp	9	16	0.035%
	Caprella mendax	3	16	0.035%
	Glycera americana	9	16	0.035%
	Monostylifera	1	16	0.035%
	Terebellidae	8	16	0.035%
	Thyasira flexuosa	10	16	0.035%
	Thysanocardia nigra	11	16	0.035%
	Drilonereis longa	9	15	0.033%
	Levinsenia oculata	5	15	0.033%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Pandora bilirata	7	15	0.033%
	Phyllodoce hartmanae	6	15	0.033%
	Spio cirrifera	6	15	0.033%
	Westwoodilla sp	4	15	0.033%
	Aoroides columbiae	1	14	0.031%
	Cancer oregonensis	3	14	0.031%
	Ischyrocerus sp	4	14	0.031%
	Nassarius mendicus	6	14	0.031%
	Protothaca staminea	9	14	0.031%
	Rochefortia compressa	1	14	0.031%
	Acteocina culcitella	9	13	0.028%
	Barantolla nr americana	5	13	0.028%
	Cancer sp	1	13	0.028%
	Distaplia occidentalis	2	13	0.028%
	Hiatella arctica	4	13	0.028%
	Leptasterias hexactis	1	13	0.028%
	Nemocardium centifilosum	5	13	0.028%
	Neosabellaria cementarium	3	13	0.028%
	Pododesmus macrochisma	2	13	0.028%
	Polycirrus sp V	1	13	0.028%
	Rutiderma lomae	4	13	0.028%
	Solen sicarius	4	13	0.028%
	Tellina nuculoides	3	13	0.028%
	Terebellides reishi	3	13	0.028%
	Chone minuta	1	12	0.026%
	Harmothoe extenuata	4	12	0.026%
x	*Mya arenaria*	5	12	0.026%
	Nephtys punctata	4	12	0.026%
	Onuphidae	4	12	0.026%
	Praxillella sp	4	12	0.026%
	Stenothoides sp	2	12	0.026%
	Tenonia priops	8	12	0.026%
	Terebratulida	1	12	0.026%
	Bathyleberis sp	6	11	0.024%
	Cardiomya pectinata	4	11	0.024%
	Carinoma mutabilis	7	11	0.024%
	Diastylis alaskensis	3	11	0.024%
	Laonome kroeyeri	3	11	0.024%
	Macoma calcarea	5	11	0.024%
	Myriochele heeri	4	11	0.024%
	Nicomache personata	2	11	0.024%
	Ophiodromus pugettensis	5	11	0.024%
	Pleurogonium rubicundum	1	11	0.024%
	Polycirrus sp I	6	11	0.024%
x	*Anobothrus gracilis*	5	10	0.022%
	Clymenura gracilis	1	10	0.022%
	Cucumaria piperata	1	10	0.022%
	Delectopecten vancouverensis	1	10	0.022%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Eudorellopsis longirostris	2	10	0.022%
	Harpiniopsis fulgens	4	10	0.022%
	Heterophoxus sp	4	10	0.022%
	Molpadia intermedia	3	10	0.022%
	Monticellina sp N1	2	10	0.022%
	Pentamera lissoplaca	4	10	0.022%
	Photis parvidons	5	10	0.022%
	Solamen columbianum	5	10	0.022%
	Byblis millsi	6	9	0.020%
	Chlamys hastata	2	9	0.020%
	Diaphana californica	5	9	0.020%
X	*Dipolydora bidentata*	3	9	0.020%
	Dyopedos sp	2	9	0.020%
	Eumida longicornuta	5	9	0.020%
	Eusyllis blomstrandi	2	9	0.020%
	Haliophasma geminatum	4	9	0.020%
	Hippolytidae	4	9	0.020%
	Leucon subnasica	6	9	0.020%
	Orchomene obtusa	2	9	0.020%
	Phyllodoce sp	5	9	0.020%
	Ptilosarcus gurneyi	4	9	0.020%
	Solariella sp	3	9	0.020%
	Streblosoma bairdi	2	9	0.020%
	Typosyllis cornuta	5	9	0.020%
	Typosyllis heterochaeta	7	9	0.020%
	Alia carinata	2	8	0.017%
	Ampharete sp	5	8	0.017%
	Bathymedon pumilus	2	8	0.017%
	Decamastus gracilis	4	8	0.017%
	Euphysa sp A	1	8	0.017%
	Flabellina sp	2	8	0.017%
	Foxiphalus xiximeus	1	8	0.017%
	Modiolus sp	4	8	0.017%
	Ophiurida	5	8	0.017%
	Oregonia gracilis	6	8	0.017%
	Phoronopsis harmeri	4	8	0.017%
	Tetrastemma sp	6	8	0.017%
	Typosyllis armillaris	1	8	0.017%
	Ampharetidae	3	7	0.015%
	Aoroides exilis	1	7	0.015%
	Apistobranchus ornatus	4	7	0.015%
	Aricidea (Acmira) catherinae	2	7	0.015%
	Clinocardium sp	3	7	0.015%
	Diastylis santamariensis	6	7	0.015%
	Exogone molesta	2	7	0.015%
	Lirularia lirulata	4	7	0.015%
	Macoma balthica	1	7	0.015%
	Malmgreniella bansei	5	7	0.015%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Orchomene pacificus	5	7	0.015%
	Pentamera sp	3	7	0.015%
	Phyllodoce mucosa	1	7	0.015%
	Phylo felix	5	7	0.015%
	Pista brevibranchiata	5	7	0.015%
	Protodorvillea gracilis	4	7	0.015%
	Rhodine bitorquata	6	7	0.015%
	Sabellidae	4	7	0.015%
	Saxidomus giganteus	4	7	0.015%
	Sphaerosyllis sp N1	3	7	0.015%
	Tetrastemmatidae	5	7	0.015%
C	*Abietinaria* sp	6	6	0.013%
	Acteocina harpa	2	6	0.013%
	Ampelisca brevisimulata	4	6	0.013%
	Anoplodactylus viridintestinalis	1	6	0.013%
	Boccardia pugettensis	4	6	0.013%
	Brada sachalina	4	6	0.013%
	Cancer gracilis	4	6	0.013%
	Caprella sp	2	6	0.013%
	Cryptomya californica	1	6	0.013%
	Demonax rugosus	3	6	0.013%
	Eranno bicirrata	5	6	0.013%
	Eusyllis magnifica	1	6	0.013%
	Gammaropsis ellisi	1	6	0.013%
	Gastropteron pacificum	5	6	0.013%
	Heteromastus sp	3	6	0.013%
	Hyperiidae	3	6	0.013%
	Lamprops quadriplicatus	2	6	0.013%
	Microjassa sp	1	6	0.013%
	Monticellina serratiseta	5	6	0.013%
	Monticellina sp	3	6	0.013%
	Musculus discors	2	6	0.013%
	Nutricola tantilla	1	6	0.013%
	Pagurus sp	4	6	0.013%
X	*Pontogeneia rostrata*	1	6	0.013%
	Pygospio elegans	4	6	0.013%
	Rhabdus rectius	2	6	0.013%
	Sphaerosyllis ranunculus	1	6	0.013%
	Travisia forbesii	2	6	0.013%
	Typosyllis caeca	5	6	0.013%
	Artacama coniferi	4	5	0.011%
	Chone duneri	3	5	0.011%
	Cyphocaris challengeri	3	5	0.011%
	Edwardsia sp G	4	5	0.011%
	Eochelidium sp	1	5	0.011%
	Euspira pallida	1	5	0.011%
	Hemilamprops californicus	1	5	0.011%
	Heterophoxus ellisi	4	5	0.011%

Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Homalopoma luridum	1	5	0.011%
Leptochiton rugatus	1	5	0.011%
Limnoria lignorum	2	5	0.011%
Lineus sp	3	5	0.011%
Magelona sacculata	1	5	0.011%
Megamoera dentata	1	5	0.011%
Metacaprella anomala	2	5	0.011%
Metaphoxus frequens	1	5	0.011%
Mopalia sinuata	3	5	0.011%
Mytilidae	1	5	0.011%
Notomastus latericeus	3	5	0.011%
Pachycerianthus fimbriatus	2	5	0.011%
Paraphoxus cf gracilis	1	5	0.011%
Phoronis sp	3	5	0.011%
Polydora limicola	1	5	0.011%
Scaphander sp	1	5	0.011%
Scleroplax granulata	2	5	0.011%
Americhelidium millsi	3	4	0.009%
Amphipholis sp	2	4	0.009%
Anonyx cf lilljeborgi	3	4	0.009%
Autolytus sp	2	4	0.009%
Boccardiella hamata	2	4	0.009%
Caligidae	1	4	0.009%
Chlamys rubida	1	4	0.009%
Deflexilodes enigmaticus	2	4	0.009%
C Demospongiae	4	4	0.009%
Diastylis sentosa	3	4	0.009%
Dulichia sp	2	4	0.009%
Gammaridea	2	4	0.009%
Gastropoda	2	4	0.009%
Harmothoinae	3	4	0.009%
Hoplonemertea	2	4	0.009%
Lepidasthenia berkeleyae	3	4	0.009%
Lepidonotus squamatus	3	4	0.009%
Majidae	2	4	0.009%
Megalomma splendida	2	4	0.009%
Melanochlamys diomedea	4	4	0.009%
Melinna oculata	4	4	0.009%
Naineris uncinata	3	4	0.009%
Neotrypaea sp	1	4	0.009%
Nephasoma sp	2	4	0.009%
Nephtys caeca	4	4	0.009%
Nephtys caecoides	3	4	0.009%
Ophiura luetkenii	2	4	0.009%
Pacifoculodes zernovi	2	4	0.009%
Paguridae	3	4	0.009%
Parapleustes americanus	2	4	0.009%
Phoxichilidium femoratum	2	4	0.009%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Phyllodoce groenlandica	3	4	0.009%
	Phyllodoce longipes	3	4	0.009%
	Pleusymtes coquilla	2	4	0.009%
	Polynoidae	2	4	0.009%
	Protolaeospira eximia	1	4	0.009%
	Pseudopotamilla occelata	2	4	0.009%
	Tubulanus cingulatus	1	4	0.009%
	Zygonemertes virescens	3	4	0.009%
C	*Alcyonidium* sp	3	3	0.007%
	Amphicteis scaphobranchiata	1	3	0.007%
	Amphitrite robusta	2	3	0.007%
	Balanophyllia elegans	1	3	0.007%
	Balanus crenatus	2	3	0.007%
C	*Barentsia parva*	3	3	0.007%
	Bivalvia	3	3	0.007%
XC	*Bowerbankia gracilis*	3	3	0.007%
	Bylgides macrolepidus	2	3	0.007%
	Caprella californica	1	3	0.007%
	Cerebratulus sp	3	3	0.007%
	Cheirimedeia sp	2	3	0.007%
	Chirimia similis	1	3	0.007%
	Chone magna	1	3	0.007%
	Cirrophorus branchiatus	2	3	0.007%
	Crangon sp	3	3	0.007%
	Crossaster papposus	2	3	0.007%
	Dendrochirotida	2	3	0.007%
	Diastylis bidentata	3	3	0.007%
	Dyopedos arcticus	2	3	0.007%
	Enopla	1	3	0.007%
	Enteropneusta	1	3	0.007%
	Gattyana treadwelli	3	3	0.007%
	Goniada maculata	3	3	0.007%
	Halcampa sp	1	3	0.007%
	Halocynthia igaboja	1	3	0.007%
	Harmothoe multisetosa	2	3	0.007%
	Harpacticoida	2	3	0.007%
	Humilaria kennerlyi	1	3	0.007%
	Imogine exiguus	2	3	0.007%
	Kurtziella crebricostata	3	3	0.007%
	Malmgreniella sp	2	3	0.007%
	Metacaprella kennerlyi	2	3	0.007%
	Microphthalmus sczelkowii	1	3	0.007%
	Molgula pugetiensis	1	3	0.007%
	Munna sp	2	3	0.007%
	Neomysis kadiakensis	2	3	0.007%
	Neotrypaea gigas	1	3	0.007%
	Nicomache lumbricalis	2	3	0.007%
	Ophiura leptoctenia	1	3	0.007%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Ophiuridae	3	3	0.007%
	Parandalia ocularis	1	3	0.007%
	Paranemertes californica	3	3	0.007%
	Parapleustinae	2	3	0.007%
	Parathemisto pacifica	2	3	0.007%
	Phoronida	1	3	0.007%
	Photis bifurcata	1	3	0.007%
	Phyllaplysia taylori	1	3	0.007%
	Pseudomma truncatum	1	3	0.007%
	Rictaxis punctocaelatus	1	3	0.007%
	Spionidae	3	3	0.007%
	Stylatula sp A	3	3	0.007%
	Syllidae	2	3	0.007%
	Tharyx parvus	1	3	0.007%
	Trichotropis cancellata	2	3	0.007%
	Actiniaria	1	2	0.004%
	Americhelidium rectipalmum	1	2	0.004%
	Americhelidium variabilum	2	2	0.004%
X	*Amphitrite edwardsi*	1	2	0.004%
	Amphiura sp	1	2	0.004%
	Anopla	2	2	0.004%
	Aphrodita sp	2	2	0.004%
	Arcteobia cf anticostiensis	2	2	0.004%
	Aricidea sp	2	2	0.004%
	Astarte esquimalti	2	2	0.004%
	Balanomorpha	1	2	0.004%
	Brisaster latifrons	2	2	0.004%
C	*Caberea ellisi*	2	2	0.004%
	Calocarides sp	2	2	0.004%
C	*Campanulariidae*	2	2	0.004%
	Chaetozone sp N1	2	2	0.004%
	Chirimia nr biceps	2	2	0.004%
C	*Clytia* sp	2	2	0.004%
	Cranopsis sp	1	2	0.004%
	Crepidula nummaria	1	2	0.004%
	Crucigera zygophora	1	2	0.004%
	Deflexilodes similis	1	2	0.004%
	Demonax sp	1	2	0.004%
	Dendraster excentricus	1	2	0.004%
C	*Diaperoecia* sp	2	2	0.004%
	Diopatra sp	2	2	0.004%
	Echiurus echiurus alaskanus	2	2	0.004%
	Euchone limnicola	1	2	0.004%
	Eulalia californiensis	2	2	0.004%
	Euphysa ruthae	2	2	0.004%
	Glycera sp	2	2	0.004%
	Golfingia vulgaris	1	2	0.004%
	Halcampa decemtentaculata	2	2	0.004%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Haplosyllis spongiphila	1	2	0.004%
C	*Lafoea* sp	2	2	0.004%
	Lanassa nordenskioeldi	1	2	0.004%
	Laonice pugettensis	2	2	0.004%
	Lepidochitona flectens	1	2	0.004%
	Lepidonotus sp	1	2	0.004%
	Leucon sp	1	2	0.004%
	Littorina sp	1	2	0.004%
	Lysippe labiata	2	2	0.004%
	Mactromeris polynyma	2	2	0.004%
	Malmgreniella liei	2	2	0.004%
	Megayoldia thraciaeformis	1	2	0.004%
C	*Membranipora membranacea*	2	2	0.004%
	Mesochaetopterus taylori	2	2	0.004%
C	*Micropora coriacea*	2	2	0.004%
	Munnogonium tillerae	2	2	0.004%
C	*Myosoma spinosa*	2	2	0.004%
C	*Myriozoum tenue*	2	2	0.004%
	Mysidacea	1	2	0.004%
	Nacellina	2	2	0.004%
	Nemertea	1	2	0.004%
	Nereididae	2	2	0.004%
	Nereis zonata	1	2	0.004%
	Ninoe gemmea	2	2	0.004%
	Notoplana sp	2	2	0.004%
C	*Obelia dichotoma*	2	2	0.004%
C	*Obelia* sp	2	2	0.004%
	Ophryotrocha sp	2	2	0.004%
	Ostracoda	2	2	0.004%
	Oweniidae	2	2	0.004%
	Pachynus cf barnardi	1	2	0.004%
	Palaeonemertea	2	2	0.004%
	Pandora sp	2	2	0.004%
	Phlebobranchiata	1	2	0.004%
	Phoronopsis sp	1	2	0.004%
	Phyllodoce citrina	1	2	0.004%
	Phyllodoce cuspidata	2	2	0.004%
C	Poecilosclerida	2	2	0.004%
	Raricirrus maculatus	1	2	0.004%
	Rhachotropis oculata	1	2	0.004%
	Rocinela propodialis	2	2	0.004%
	Sagitta sp	2	2	0.004%
	Sagittidae	1	2	0.004%
	Scintillona bellerophon	2	2	0.004%
	Sige bifoliata	1	2	0.004%
	Spirontocaris prionota	1	2	0.004%
	Stolidobranchiata	2	2	0.004%
X	*Streblospio benedicti*	1	2	0.004%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Styela sp	1	2	0.004%
	Thracia trapezoides	2	2	0.004%
C	*Tubulipora* sp	2	2	0.004%
	Acanthoptilum gracile	1	1	0.002%
	Acarina	1	1	0.002%
	Acteocina eximia	1	1	0.002%
	Aglaja ocelligera	1	1	0.002%
C	*Aglaophenia* sp	1	1	0.002%
	Alienacanthomysis macropsis	1	1	0.002%
	Americorophium salmonis	1	1	0.002%
	Americorophium sp	1	1	0.002%
	Americorophium spinicorne	1	1	0.002%
	Ampelisca lobata	1	1	0.002%
	Amphicteis glabra	1	1	0.002%
	Amphicteis mucronata	1	1	0.002%
	Amphilochus neapolitanus Cmplx	1	1	0.002%
	Amphiodia occidentalis	1	1	0.002%
	Amphipoda	1	1	0.002%
C	*Antropora tincta*	1	1	0.002%
	Aphrodita japonica	1	1	0.002%
	Aphrodita negligens	1	1	0.002%
	Archidistoma sp	1	1	0.002%
	Asabellides sibirica	1	1	0.002%
	Ascidia sp	1	1	0.002%
	Asclerocheilus beringianus	1	1	0.002%
	Asteroidea	1	1	0.002%
	Atylus levidensus	1	1	0.002%
	Balanus glandula	1	1	0.002%
	Balcis sp	1	1	0.002%
	Bankia setacea	1	1	0.002%
	Bispira elegans	1	1	0.002%
	Boltenia villosa	1	1	0.002%
	Bonelliidae	1	1	0.002%
C	*Bougainvilliidae*	1	1	0.002%
	Brada villosa	1	1	0.002%
C	*Bugula pacifica*	1	1	0.002%
C	*Bugula* sp	1	1	0.002%
	Calliostoma ligatum	1	1	0.002%
	Callipallene pacifica	1	1	0.002%
	Calocarides spinulicauda	1	1	0.002%
C	*Calycella syringa*	1	1	0.002%
	Cancer productus	1	1	0.002%
	Capitellidae	1	1	0.002%
	Caprella pilidigitata	1	1	0.002%
	Carinomella lactea	1	1	0.002%
C	*Caulibugula californica*	1	1	0.002%
C	*Caulibugula ciliata*	1	1	0.002%
C	*Cellaria* sp	1	1	0.002%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Ceradocus spinicaudus	1	1	0.002%
	Chaetognatha	1	1	0.002%
C	*Chapperiopsis patula*	1	1	0.002%
C	*Cheilopora praelonga*	1	1	0.002%
	Chone ecaudata	1	1	0.002%
	Cirratulus sp	1	1	0.002%
	Clinocardium blandum	1	1	0.002%
C	*Copidozoum adamantum*	1	1	0.002%
C	*Copidozoum protectum*	1	1	0.002%
C	*Crisia serrulata*	1	1	0.002%
C	*Crisia* sp	1	1	0.002%
	Cumacea	1	1	0.002%
C	*Dendrobeania lichenoides*	1	1	0.002%
	Diastylis sp	1	1	0.002%
	Diastylopsis tenuis	1	1	0.002%
	Doridacea	1	1	0.002%
	Drilonereis sp	1	1	0.002%
C	*Ectopleura* sp	1	1	0.002%
	Eteone pacifica	1	1	0.002%
	Eteone spilotus	1	1	0.002%
	Eudistylia catharinae	1	1	0.002%
	Eugyra arenosa	1	1	0.002%
	Eulalia sp N1	1	1	0.002%
	Eunoe sp	1	1	0.002%
	Euphausia pacifica	1	1	0.002%
	Euphausia sp	1	1	0.002%
	Euphilomedes sp	1	1	0.002%
	Eusirus columbianus	1	1	0.002%
	Eyakia robusta	1	1	0.002%
C	*Filicrisia* sp	1	1	0.002%
	Flabelligera affinis	1	1	0.002%
	Galatheidae	1	1	0.002%
X	*Geminosyllis ohma*	1	1	0.002%
	Glycinde sp	1	1	0.002%
	Goniada brunnea	1	1	0.002%
	Guernea reduncans	1	1	0.002%
	Gyptis sp	1	1	0.002%
C	*Halecium* sp	1	1	0.002%
C	*Hebella pocillum*	1	1	0.002%
	Hesperonoe complanata	1	1	0.002%
	Hesperonoe sp	1	1	0.002%
	Idanthyrsus saxicavus	1	1	0.002%
	Idotea fewkesi	1	1	0.002%
	Inusitatomysis insolita	1	1	0.002%
	Iphimedia rickettsi	1	1	0.002%
	Jaeropsis dubia	1	1	0.002%
	Kellia suborbicularis	1	1	0.002%
	Kurtziella plumbea	1	1	0.002%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Lacuna vincta	1	1	0.002%
C	Lafoeidae	1	1	0.002%
C	*Lagenicella neosocialis*	1	1	0.002%
	Lamprops carinatus	1	1	0.002%
	Lasaeidae	1	1	0.002%
	Laticorophium baconi	1	1	0.002%
	Lepidepecreum garthi	1	1	0.002%
	Lepidonotus spiculus	1	1	0.002%
	Leptoplanidae	1	1	0.002%
	Lumbrineris latreilli	1	1	0.002%
	Macoma moesta	1	1	0.002%
	Mactridae	1	1	0.002%
	Malmgreniella macginitiei	1	1	0.002%
	Metopa dawsoni	1	1	0.002%
	Metridium sp	1	1	0.002%
	Modiolus rectus	1	1	0.002%
	Mytilus sp	1	1	0.002%
	Myxicola infundibulum	1	1	0.002%
C	*Myxilla incrustans*	1	1	0.002%
	Naineris quadricuspida	1	1	0.002%
	Natica clausa	1	1	0.002%
	Nephtys sp	1	1	0.002%
C	*Nolella* sp	1	1	0.002%
	Notomastus sp	1	1	0.002%
	Notoproctus pacificus	1	1	0.002%
	Nudibranchia	1	1	0.002%
	Oenopota sp	1	1	0.002%
	Ophiuroidea	1	1	0.002%
	Pagurus armatus	1	1	0.002%
	Pagurus ochotensis	1	1	0.002%
	Pagurus setosus	1	1	0.002%
	Panomya ampla	1	1	0.002%
	Parvaplustrum sp A	1	1	0.002%
	Pentamera populifera	1	1	0.002%
	Pentamera pseudocalcigera	1	1	0.002%
C	*Perigonimus repens*	1	1	0.002%
C	*Perigonimus* sp	1	1	0.002%
	Pherusa plumosa	1	1	0.002%
	Pherusa sp	1	1	0.002%
	Phyllophoridae	1	1	0.002%
	Pinnixa tubicola	1	1	0.002%
	Pista elongata	1	1	0.002%
	Pista moorei	1	1	0.002%
	Pista sp	1	1	0.002%
C	*Plumularia corrugata*	1	1	0.002%
	Podarkeopsis perkinsi	1	1	0.002%
	Podoceridae	1	1	0.002%
	Podocerus cristatus	1	1	0.002%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Polydora sp	1	1	0.002%
	Pontoporeia femorata	1	1	0.002%
	Proceraea sp	1	1	0.002%
	Pseudopotamilla sp	1	1	0.002%
	Puncturella cucullata	1	1	0.002%
C	*Rhizocaulus verticillatus*	1	1	0.002%
	Saccocirridae	1	1	0.002%
	Scionella japonica	1	1	0.002%
C	*Selaginopsis triserialis*	1	1	0.002%
	Semele rubropicta	1	1	0.002%
	Serpulidae	1	1	0.002%
	Sipuncula	1	1	0.002%
C	*Smittina* sp	1	1	0.002%
	Spio filicornis	1	1	0.002%
	Spirontocaris arctuatus	1	1	0.002%
	Spirontocaris ochotensis	1	1	0.002%
	Spirontocaris sica	1	1	0.002%
	Stenothoidae	1	1	0.002%
	Sthenelais tertiaglabra	1	1	0.002%
	Styela coriacea	1	1	0.002%
	Styela gibbsii	1	1	0.002%
C	*Symplectoscyphus* sp	1	1	0.002%
	Synidotea consolidata	1	1	0.002%
	Synidotea sp	1	1	0.002%
	Tellina carpenteri	1	1	0.002%
	Terebellides kobei	1	1	0.002%
	Tetrastemma nigrifrons	1	1	0.002%
	Thracia challisiana	1	1	0.002%
	Travisia pupa	1	1	0.002%
	Tubulariidae	1	1	0.002%
	Typosyllis alternata	1	1	0.002%
	Typosyllis elongata	1	1	0.002%
	Velutina plicatilis	1	1	0.002%
	Total	**60**	**45717**	**100%**

Table C-2. Infauna taxa in order of decreasing abundance, all stations combined (2002). The ten most abundant taxa are in bold type. C = colonial, X = exotic.

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Oligochaeta	**51**	**8496**	**12.533%**
	Mediomastus californiensis	**26**	**5434**	**8.016%**
X	***Pseudopolydora paucibranchiata***	**29**	**5204**	**7.677%**
	Pygospio elegans	**22**	**3359**	**4.955%**
X	***Streblospio benedicti***	**31**	**3327**	**4.908%**
X	***Pseudopolydora kempi***	**40**	**2473**	**3.649%**
X	***Polydora cornuta***	**35**	**2354**	**3.473%**
	Tharyx parvus	**28**	**2317**	**3.418%**
X	***Grandidierella japonica***	**36**	**2251**	**3.321%**
	Capitella capitata Cmplx	**37**	**2133**	**3.147%**
	Ampithoe sp	26	1920	2.832%
	Macoma balthica	46	1713	2.526%
X	*Monocorophium insidiosum*	23	1590	2.345%
	Chone duneri	2	1588	2.342%
X	*Monocorophium acherusicum*	21	1458	2.150%
X	*Mya arenaria*	33	1450	2.139%
	Leptochelia dubia	27	1242	1.832%
X	*Manayunkia aestuarina*	8	1131	1.669%
	Balanus sp	13	1069	1.578%
X	*Heteromastus filiformis*	23	966	1.424%
X	*Venerupis philippinarum*	19	805	1.188%
	Americorophium salmonis	14	655	0.966%
	Americorophium spinicorne	5	647	0.954%
	Glycinde polygnatha	48	623	0.919%
X	*Hobsonia florida*	3	577	0.852%
	Nephtys caeca	31	559	0.824%
	Edwardsiidae	2	537	0.792%
	Monocorophium sp	31	499	0.736%
	Owenia fusiformis	4	487	0.719%
	Cryptomya californica	22	440	0.649%
	Eohaustorius estuarius	11	411	0.606%
	Harpacticoida	15	390	0.575%
	Eteone californica	36	369	0.545%
	Anisogammarus pugettensis	5	364	0.538%
	Eogammarus confervicolus CMPLX	12	341	0.502%
	Clinocardium nuttallii	20	324	0.478%
X	*Sinelobus stanfordi*	11	314	0.463%
	Macoma nasuta	27	299	0.441%
	Caprella laeviuscula	2	297	0.438%
	Lottia sp	2	269	0.397%
	Rochefortia tumida	7	231	0.341%
	Phoronis pallida	6	223	0.329%
	Macoma sp	13	220	0.324%
	Scoloplos armiger alaskensis	15	207	0.305%
	Sphaerosyllis californiensis	13	204	0.301%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Haminoea vesicula	3	203	0.300%
	Chironomidae	16	193	0.285%
	Caprella sp	13	189	0.278%
	Rhynchospio glutaea	13	182	0.268%
x	*Ampithoe valida*	16	179	0.264%
	Dorvillea annulata	2	179	0.264%
x	*Nippoleucon hinumensis*	10	179	0.264%
	Lirobittium attenuatum	3	178	0.263%
	Platynereis bicanaliculata	17	171	0.252%
	Diadumenidae	11	133	0.196%
	Armandia brevis	10	132	0.194%
	Mytilus sp	11	128	0.189%
	Americorophium sp	9	119	0.176%
	Micrura sp	16	107	0.158%
	Hemigrapsus oregonensis	4	105	0.155%
	Lacuna vincta	9	104	0.154%
x	*Melita nitida*	2	102	0.151%
	Eusarsiella zostericola	6	100	0.148%
	Notomastus tenuis	7	95	0.140%
	Grandifoxus grandis	9	94	0.139%
	Corophiidae	19	92	0.135%
	Aphelochaeta sp	2	89	0.131%
	Cumella vulgaris	9	89	0.131%
	Ampelisca agassizi	1	87	0.128%
	Nephtys cornuta	9	86	0.127%
	Neanthes virens	2	84	0.125%
	Arenicolidae	10	84	0.124%
	Polycirrus californicus	4	83	0.122%
	Allorchestes angusta	7	79	0.116%
x	*Dipolydora quadrilobata*	8	78	0.115%
	Cyclopoida	5	74	0.109%
	Paraonella platybranchia	12	69	0.101%
	Caprella drepanochir	7	61	0.090%
	Protothaca staminea	5	60	0.089%
	Nereis vexillosa	5	59	0.087%
	Halcampidae	3	56	0.082%
	Exogone lourei	2	53	0.079%
	Dendraster excentricus	4	52	0.077%
	Asabellides sibirica	3	51	0.075%
	Myidae	1	51	0.075%
	Tellina modesta	4	50	0.074%
	Exogone dwisula	5	50	0.073%
	Barantolla nr americana	7	47	0.070%
	Mediomastus sp	6	47	0.069%
	Sphaerosyllis sp N1	5	46	0.067%
	Neanthes limnicola	7	44	0.065%
	Tetrastemma sp	14	44	0.065%
	Leuconidae	3	43	0.063%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Prionospio lighti	6	40	0.059%
	Magelona longicornis	1	40	0.059%
	Nereis sp	7	40	0.059%
	Parvilucina tenuisculpta	1	37	0.054%
	Lineus sp	6	36	0.054%
	Crangon franciscorum	15	35	0.052%
x	*Sabaco elongatus*	4	34	0.050%
	Lyonsia californica	2	33	0.049%
	Astyris gausapata	3	32	0.048%
	Nephtys caecoides	3	32	0.047%
	Caprella californica	4	32	0.046%
	Lineidae	10	31	0.046%
	Polycirrus sp	2	29	0.043%
	Mytilidae	7	28	0.042%
	Spiochaetopterus costarum	3	28	0.041%
	Ophiodromus pugettensis	2	28	0.041%
	Scolelepis squamata	11	27	0.040%
	Enteropneusta	7	26	0.038%
	Tubulanus sp A	9	24	0.035%
	Paranemertes peregrina	8	24	0.035%
	Glycinde sp	1	23	0.034%
	Harmothoe imbricata	5	22	0.033%
	Edwardsia sp G	3	22	0.032%
	Gnorimosphaeroma insulare	2	21	0.031%
	Zygonemertes virescens	8	21	0.031%
	Alvania compacta	2	20	0.029%
	Nereis procera	3	20	0.029%
	Gnorimosphaeroma oregonense	4	19	0.028%
	Typosyllis pigmentata	1	18	0.026%
	Balanus crenatus	1	17	0.025%
	Tubulanus polymorphus	3	16	0.024%
	Pagurus sp	5	16	0.023%
	Scoloplos armiger armiger	8	16	0.023%
	Bivalvia	3	15	0.023%
	Odostomia sp	3	15	0.023%
	Tubulanus sp	5	15	0.023%
	Circeis armoricana	1	13	0.020%
	Pinnixa sp	4	13	0.019%
	Leptoplanidae	6	13	0.019%
	Eulalia quadrioculata	3	13	0.018%
	Abarenicola pacifica	3	12	0.018%
	Scoloplos sp	5	12	0.018%
	Crangon sp	4	12	0.017%
	Lacuna sp	4	12	0.017%
	Littorina sp	5	11	0.017%
	Idotea fewkesi	5	11	0.017%
	Eteone columbiensis	3	10	0.015%
	Pagurus granosimanus	1	9	0.013%

	Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Hoplonemertea	4	9	0.013%
	Sphaerosyllis ranunculus	1	8	0.012%
	Nereididae	3	8	0.012%
	Nassarius mendicus	1	8	0.012%
	Nereis zonata	1	8	0.012%
	Podarkeopsis glabra	2	8	0.011%
	Spiophanes berkeleyorum	2	8	0.011%
	Carinoma mutabilis	3	8	0.011%
	Emplectonematidae	1	7	0.010%
	Anoplodactylus viridintestinalis	1	7	0.010%
	Eumida longicornuta	3	7	0.010%
	Neocrangon alaskensis	3	7	0.010%
	Boccardia sp	1	6	0.009%
	Calyptraeidae	1	6	0.008%
	Marphysa stylobranchiata	1	6	0.008%
	Clevelandia ios	2	6	0.008%
	Polycystididae	2	6	0.008%
	Saxidomus gigantea	3	6	0.008%
	Paranemertes californica	2	5	0.008%
	Hemipodia borealis	3	5	0.007%
	Dipolydora socialis	2	5	0.007%
	Clinocardium sp	1	4	0.006%
	Eteone fauchaldi	1	4	0.006%
	Nassariidae	1	4	0.006%
	Syllides sp	3	4	0.006%
	Boccardia columbiana	1	4	0.006%
	Chirimia similis	1	3	0.005%
	Crepipatella dorsata	2	3	0.005%
	Syllides japonica	1	3	0.005%
	Amphiporus sp	3	3	0.005%
	Boccardia pugettensis	1	3	0.005%
	Cancer sp	2	3	0.005%
	Cuthona albocrusta	1	3	0.005%
	Photis brevipes	2	3	0.005%
	Spio filicornis	2	3	0.005%
	Harmothoinae	3	3	0.004%
	Spionidae	3	3	0.004%
	Glycera americana	2	3	0.004%
	Lamprops quadriplicatus	2	3	0.004%
	Ampelisca sp	1	2	0.003%
	Archaeomysis grebnitzkii	1	2	0.003%
	Axiothella rubrocincta	1	2	0.003%
	Cerebratulus sp	2	2	0.003%
x	*Dipolydora caulleryi*	2	2	0.003%
	Euphilomedes carcharodonta	2	2	0.003%
	Leitoscoloplos pugettensis	1	2	0.003%
	Phoronis sp	2	2	0.003%
	Phoronopsis harmeri	2	2	0.003%

Taxon	Number of Stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Tenonia priops	1	2	0.003%
Tresus sp	2	2	0.003%
Turbonilla sp	1	2	0.003%
Paleanotus bellis	2	2	0.003%
Imogine exiguus	2	2	0.002%
Acteocina harpa	1	1	0.002%
Ampharete labrops	1	1	0.002%
Aplysiopsis enteropmorphae	1	1	0.002%
Cancer magister	1	1	0.002%
Desdimelita desdichada	1	1	0.002%
Diastylopsis tenuis	1	1	0.002%
Eteone spilotus	1	1	0.002%
Eualus townsendi	1	1	0.002%
Exosphaeroma inornata	1	1	0.002%
Gattyana cirrosa	1	1	0.002%
Hemigrapsus sp	1	1	0.002%
Heteropodarke heteromorpha	1	1	0.002%
Kurtziella crebricostata	1	1	0.002%
Lirabuccinum dirum	1	1	0.002%
Lucinoma annulatum	1	1	0.002%
Lumbrineridae	1	1	0.002%
Melanochlamys diomedea	1	1	0.002%
Microphthalmus hystrix	1	1	0.002%
Microphthalmus sp	1	1	0.002%
Nutricola lordi	1	1	0.002%
Nuttallia nuttallii	1	1	0.002%
Onuphis elegans	1	1	0.002%
Phyllodoce hartmanae	1	1	0.002%
Podocopida	1	1	0.002%
X *Potamopyrgus antipodarum*	1	1	0.002%
Scaphopoda	1	1	0.002%
Scolelepis sp	1	1	0.002%
Spiophanes bombyx	1	1	0.002%
Tellina carpenteri	1	1	0.002%
Tellina sp	1	1	0.002%
Astyris permodesta	1	1	0.001%
C *Campanularia gelatinosa*	1	1	0.001%
Collembola	1	1	0.001%
Eohaustorius sp	1	1	0.001%
Halacaridae	1	1	0.001%
X *Mercenaria mercenaria*	1	1	0.001%
Pododesmus macrochisma	1	1	0.001%
Polinices lewisii	1	1	0.001%
Total	**61**	**67789**	**100%**

Table C-3. Infauna taxa in order of decreasing abundance, all stations combined (2003). The ten most abundant taxa are in bold type. X = exotic.

Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Axinopsida serricata	**46**	**1920**	**11.057%**
Magelona longicornis	**27**	**1421**	**8.184%**
Owenia fusiformis	**13**	**1176**	**6.773%**
Spiophanes bombyx	**29**	**893**	**5.143%**
Ampelisca agassizi	**15**	**833**	**4.797%**
Euphilomedes carcharodonta	**22**	**670**	**3.859%**
Galathowenia oculata	**34**	**632**	**3.640%**
Scoletoma luti	**31**	**413**	**2.378%**
Rhepoxynius boreovariatus	**31**	**358**	**2.062%**
Ampelisca careyi	**35**	**353**	**2.033%**
Euclymeninae sp A	31	314	1.808%
Polygordius sp	1	261	1.503%
Amphiodia sp	32	243	1.399%
Prionospio (Prionospio) jubata	23	216	1.244%
Macoma carlottensis	18	212	1.221%
Acila castrensis	28	204	1.175%
Myriochele olgae	14	180	1.037%
Euclymeninae	36	171	0.985%
Leitoscoloplos pugettensis	30	169	0.973%
Diastylopsis dawsoni	27	163	0.939%
Sternaspis cf fossor	20	162	0.933%
Macoma calcarea	18	162	0.933%
Nutricola lordi	4	152	0.875%
Tellina modesta	15	139	0.801%
Cylichna attonsa	31	134	0.772%
Decamastus gracilis	27	134	0.772%
Mediomastus sp	20	132	0.760%
Onuphis iridescens	26	127	0.731%
Rhabdus rectius	17	127	0.731%
Spiophanes berkeleyorum	35	124	0.714%
Pectinaria californiensis	24	118	0.680%
Adontorhina cyclia	15	103	0.593%
Protomedeia sp	24	99	0.570%
Hemilamprops californicus	23	95	0.547%
Pectinaria sp	13	94	0.541%
Macoma elimata	20	91	0.524%
Paraprionospio pinnata	24	88	0.507%
Amphiuridae	30	84	0.484%
Glycinde armigera	23	84	0.484%
Ennucula tenuis	23	79	0.455%
Mytilus sp	4	74	0.426%
Glycera nana	20	73	0.420%
Lumbrineris cruzensis	17	71	0.409%
Nephtys californiensis	27	67	0.386%
Maldane sarsi	13	64	0.369%

Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Chaetoderma sp	16	63	0.363%
Macoma sp	15	61	0.351%
Chaetozone nr setosa	13	60	0.346%
Odostomia sp	27	59	0.340%
Tubulanus polymorphus	22	59	0.340%
Carinoma mutabilis	12	56	0.323%
Yoldia seminuda	25	55	0.317%
Bathycopea daltonae	7	55	0.317%
Tellina nuculoides	5	55	0.317%
Astyris gausapata	25	54	0.311%
Siliqua patula	19	53	0.305%
Aricidea (Allia) ramosa	9	53	0.305%
Chaetozone columbiana	14	51	0.294%
Photis sp	18	49	0.282%
Eudorellopsis longirostris	16	49	0.282%
Gadila aberrans	15	49	0.282%
Microclymene caudata	8	49	0.282%
Notomastus hemipodus	14	47	0.271%
Pulsellum salishorum	14	47	0.271%
Glycinde polygnatha	14	46	0.265%
Lyonsia californica	19	45	0.259%
Tubulanidae sp A	6	45	0.259%
Pinnixa sp	15	44	0.253%
Mediomastus californiensis	15	42	0.242%
Echinoidea	11	42	0.242%
Ampelisca sp	10	42	0.242%
Praxillella sp	5	41	0.236%
Thyasira flexuosa	14	40	0.230%
Magelona hartmanae	11	39	0.225%
Rhepoxynius stenodes	7	39	0.225%
Parandalia ocularis	10	38	0.219%
Levinsenia gracilis	15	37	0.213%
Onuphis sp	8	36	0.207%
Olivella baetica	13	34	0.196%
Prionospio (Minuspio) lighti	12	34	0.196%
Nephtys caecoides	11	34	0.196%
Eohaustorius estuarius	10	34	0.196%
Turbonilla sp	15	33	0.190%
Aricidea (Acmira) lopezi	13	33	0.190%
Pista estevanica	12	33	0.190%
Myriochele gracilis	7	33	0.190%
Phoronis sp	15	31	0.179%
Typosyllis heterochaeta	14	30	0.173%
Heteromastus filobranchus	3	30	0.173%
Euchone hancocki	5	28	0.161%
Micrura sp	15	27	0.155%
Calanoida	12	27	0.155%
Spiochaetopterus pottsi	19	26	0.150%

Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Echiurus echiurus alaskanus	12	26	0.150%
Polycirrus californicus	11	25	0.144%
Ampelisca brevisimulata	9	25	0.144%
Ampelisca hancocki Cmplx	13	23	0.132%
Ophiurida	12	23	0.132%
Magelona sacculata	11	23	0.132%
Ophelia limacina	4	23	0.132%
Enteropneusta	14	22	0.127%
Chaetopterus variopedatus Cmplx	7	22	0.127%
Rhodine bitorquata	12	21	0.121%
Barantolla nr americana	4	21	0.121%
Phyllodoce hartmanae	14	20	0.115%
Aphelochaeta glandaria	8	20	0.115%
Typosyllis cornuta	8	20	0.115%
Ninoe gemmea	9	19	0.109%
Apistobranchus ornatus	8	19	0.109%
Chaetozone bansei	8	19	0.109%
Tenonia priops	12	18	0.104%
Lumbrineris latreilli	8	18	0.104%
Pilargis maculata	8	18	0.104%
Dendraster excentricus	6	18	0.104%
Pholoe sp N1	9	17	0.098%
Polycirrus sp	9	17	0.098%
Foxiphalus cognatus	5	17	0.098%
Thysanocardia nigra	8	16	0.092%
Westwoodilla caecula	8	16	0.092%
Compsomyax subdiaphana	12	15	0.086%
Boccardia pugettensis	11	15	0.086%
Praxillella pacifica	10	15	0.086%
Travisia brevis	10	15	0.086%
Oenopota fidicula	13	14	0.081%
Phyllodoce sp	11	14	0.081%
Eranno bicirrata	9	14	0.081%
Pholoe minuta	9	14	0.081%
Ampharete cf crassiseta	8	14	0.081%
Edwardsia sp G	7	14	0.081%
Olivella pycna	3	14	0.081%
Goniada maculata	8	13	0.075%
Spio filicornis	8	13	0.075%
Amphioplus macraspis	7	13	0.075%
Exogone lourei	7	13	0.075%
Cylindroleberididae	10	12	0.069%
Diastylis bidentata	6	12	0.069%
Streblosoma bairdi	5	12	0.069%
Magelona pitelkai	3	12	0.069%
x *Laonice cirrata*	8	11	0.063%
Terebellidae	8	11	0.063%
Aphelochaeta sp	7	11	0.063%

	Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Sigalion spinosus	7	11	0.063%
	Thracia trapezoides	7	11	0.063%
	Cossura bansei	6	11	0.063%
	Halcampa decemtentaculata	6	11	0.063%
X	*Trochochaeta multisetosa*	6	11	0.063%
	Eudorella pacifica	7	10	0.058%
	Protomedeia prudens	7	10	0.058%
	Pachycerianthus sp	6	10	0.058%
	Rochefortia tumida	6	10	0.058%
	Cardiomya pectinata	4	10	0.058%
	Edotia sublittoralis	3	10	0.058%
	Aoroides sp	2	10	0.058%
	Euchone sp 1	1	10	0.058%
	Cerebratulus sp	8	9	0.052%
	Monticellina sp	7	9	0.052%
	Onuphidae	7	9	0.052%
	Pacifoculodes zernovi	7	9	0.052%
	Synidotea magnifica	6	9	0.052%
	Gastropteron pacificum	5	9	0.052%
	Hippomedon sp	5	9	0.052%
	Melinna cristata	5	9	0.052%
	Sthenelais verruculosa	5	9	0.052%
	Pholoe glabra	3	9	0.052%
	Notomastus latericeus	8	8	0.046%
	Acteocina culcitella	6	8	0.046%
	Monticellina tesselata	6	8	0.046%
	Notocirrus californiensis	6	8	0.046%
	Photis brevipes	6	8	0.046%
	Praxillella gracilis	6	8	0.046%
	Tubulanus sp	6	8	0.046%
	Aricidea (Aedicira) pacifica	5	8	0.046%
	Decapoda	5	8	0.046%
	Solamen columbianum	5	8	0.046%
	Sthenelais berkeleyi	5	8	0.046%
	Terebellides californica	5	8	0.046%
	Typosyllis caeca	3	8	0.046%
	Pleustidae	2	8	0.046%
	Goniada brunnea	7	7	0.040%
	Halcampidae	7	7	0.040%
	Aphelochaeta tigrina	6	7	0.040%
	Dipolydora cardalia	6	7	0.040%
X	*Heteromastus filiformis*	6	7	0.040%
	Lumbrineridae	5	7	0.040%
	Mesochaetopterus sp	5	7	0.040%
	Nebalia pugettensis Cmplx	5	7	0.040%
	Photis macinerneyi	5	7	0.040%
	Scoloplos armiger armiger	4	7	0.040%
	Orchomene pacificus	3	7	0.040%

	Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
	Scoloplos sp	3	7	0.040%
	Dipolydora socialis	6	6	0.035%
	Leptoplanidae	6	6	0.035%
	Lucinoma annulatum	6	6	0.035%
	Olivella sp	6	6	0.035%
	Pherusa plumosa	6	6	0.035%
	Americhelidium shoemakeri	5	6	0.035%
	Chaetozone sp N2	5	6	0.035%
	Neotrypaea sp	5	6	0.035%
	Phylo felix	5	6	0.035%
	Rhepoxynius barnardi	5	6	0.035%
	Scoloplos acmeceps	5	6	0.035%
	Sthenelais tertiaglabra	5	6	0.035%
X	*Anobothrus gracilis*	4	6	0.035%
	Cirratulidae	4	6	0.035%
	Monticellina serratiseta	4	6	0.035%
	Pandora bilirata	4	6	0.035%
	Clymenura gracilis	3	6	0.035%
	Aricidea (Acmira) catherinae	1	6	0.035%
	Malmgreniella bansei	5	5	0.029%
	Nephtys punctata	5	5	0.029%
	Nereis procera	5	5	0.029%
	Paranemertes californica	5	5	0.029%
	Hoplonemertea	4	5	0.029%
	Magelona berkeleyi	4	5	0.029%
	Nassarius fossatus	4	5	0.029%
	Solariella vancouverensis	4	5	0.029%
	Spio cirrifera	4	5	0.029%
	Brada sachalina	3	5	0.029%
	Cancer magister	3	5	0.029%
	Chone duneri	3	5	0.029%
	Cyclostremella cf concordia	3	5	0.029%
	Synidotea bicuspida	3	5	0.029%
	Glycera tenuis	2	5	0.029%
	Oligochaeta	2	5	0.029%
	Aricidea (Acmira) cerrutii	1	5	0.029%
	Argissa hamatipes	4	4	0.023%
	Baseodiscus sp	4	4	0.023%
	Bylgides macrolepidus	4	4	0.023%
	Drilonereis longa	4	4	0.023%
	Goniada sp	4	4	0.023%
	Lineidae	4	4	0.023%
	Majoxiphalus major	4	4	0.023%
	Neotrypaea californiensis	4	4	0.023%
	Nephtys ferruginea	4	4	0.023%
	Phyllodoce groenlandica	4	4	0.023%
	Pista wui	4	4	0.023%
	Tetrastemma nigrifrons	4	4	0.023%

Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Tetrastemma sp	4	4	0.023%
Virgularia cf agassizi	4	4	0.023%
Aphelochaeta monilaris	3	4	0.023%
Apistobranchus sp	3	4	0.023%
Chirimia nr biceps	3	4	0.023%
Diastylis santamariensis	3	4	0.023%
Eteone californica	3	4	0.023%
Metasychis disparidentatus	3	4	0.023%
Orchomene pinguis	3	4	0.023%
Pandora filosa	3	4	0.023%
Pista moorei	3	4	0.023%
Solen sicarius	3	4	0.023%
Streblosoma sp	3	4	0.023%
Tellina carpenteri	3	4	0.023%
Terebellides sp	3	4	0.023%
Cyclocardia ventricosa	2	4	0.023%
Heterophoxus ellisi	2	4	0.023%
Laonice sp	2	4	0.023%
Pentamera populifera	2	4	0.023%
Cossura candida	1	4	0.023%
Ampharete sp	3	3	0.017%
Brada villosa	3	3	0.017%
Diastylis paraspinulosa	3	3	0.017%
X *Dipolydora caulleryi*	3	3	0.017%
Euphilomedes producta	3	3	0.017%
Haliophasma geminatum	3	3	0.017%
Heterophoxus affinis	3	3	0.017%
Hirudinea	3	3	0.017%
Onuphis geophiliformis	3	3	0.017%
Pagurus sp	3	3	0.017%
Paradiopatra parva	3	3	0.017%
Pholoe sp	3	3	0.017%
Phyllodoce cuspidata	3	3	0.017%
Podarkeopsis glabrus	3	3	0.017%
Uromunna ubiquita	3	3	0.017%
Aeolidacea	2	3	0.017%
Amphitritinae	2	3	0.017%
Brisaster latifrons	2	3	0.017%
Dyopedos arcticus	2	3	0.017%
Mediomastus ambiseta	2	3	0.017%
Melanochlamys diomedea	2	3	0.017%
Monticellina secunda	2	3	0.017%
Nassarius mendicus	2	3	0.017%
Ophiodermella cancellata	2	3	0.017%
Prionospio (Prionospio) steenstrupi	2	3	0.017%
Synidotea pettiboneae	2	3	0.017%
Glycera oxycephala	1	3	0.017%
Prionospio (Minuspio) multibranchiata	1	3	0.017%

Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Tritella laevis	1	3	0.017%
Ampharete finmarchica	2	2	0.012%
Amphioplus sp	2	2	0.012%
Amphiporus macracanthus	2	2	0.012%
Aphrodita sp	2	2	0.012%
Campylaspis canaliculata	2	2	0.012%
Campylaspis rubromaculata	2	2	0.012%
Chirimia similis	2	2	0.012%
Chirimia sp	2	2	0.012%
Chone gracilis	2	2	0.012%
Crangon alaskensis	2	2	0.012%
Echiuridae	2	2	0.012%
Epitonium sawinae	2	2	0.012%
Eteone sp	2	2	0.012%
Eulalia sp N1	2	2	0.012%
Euspira pallida	2	2	0.012%
Gastropoda	2	2	0.012%
Glycinde sp	2	2	0.012%
Harmothoinae	2	2	0.012%
Lepidasthenia berkeleyae	2	2	0.012%
Lineus sp	2	2	0.012%
Lirobittium sp	2	2	0.012%
Listriella sp	2	2	0.012%
Mactridae	2	2	0.012%
Melinna oculata	2	2	0.012%
Musculus discors	2	2	0.012%
Nephtys sp	2	2	0.012%
Ophiura luetkenii	2	2	0.012%
Pinnixa occidentalis	2	2	0.012%
Podarkeopsis perkinsi	2	2	0.012%
Rutiderma lomae	2	2	0.012%
Stylatula sp	2	2	0.012%
Terebellides reishi	2	2	0.012%
Terebellides stroemi	2	2	0.012%
Typosyllis sp	2	2	0.012%
Archaeomysis grebnitzkii	1	2	0.012%
Chaetozone sp N1	1	2	0.012%
Flabellina sp	1	2	0.012%
Nephasoma diaphanes	1	2	0.012%
Nicolea sp	1	2	0.012%
Ophiodermella inermis	1	2	0.012%
Photis pachydactyla	1	2	0.012%
Solemya reidi	1	2	0.012%
Acidostoma hancocki	1	1	0.006%
Acteocina eximia	1	1	0.006%
Alvania compacta	1	1	0.006%
Amage anops	1	1	0.006%
Ampharete acutifrons	1	1	0.006%

Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Ampharetidae	1	1	0.006%
Amphicteis mucronata	1	1	0.006%
Amphicteis scaphobranchiata	1	1	0.006%
Amphiporus sp	1	1	0.006%
Antiplanes sp	1	1	0.006%
Araphura breviaria	1	1	0.006%
Arcteobia sp	1	1	0.006%
Aricidea (Acmira) simplex	1	1	0.006%
Aricidea sp	1	1	0.006%
Artacama coniferi	1	1	0.006%
Buccinidae	1	1	0.006%
Byblis millsi	1	1	0.006%
Campanulariidae	1	1	0.006%
Caprella equilibra	1	1	0.006%
Caulleriella sp	1	1	0.006%
Chone mollis	1	1	0.006%
Cirripedia	1	1	0.006%
Cossura pygodactylata	1	1	0.006%
Dentinephtys glabra	1	1	0.006%
Diastylis pellucida	1	1	0.006%
Diastylis quadriplicata	1	1	0.006%
Diopatra ornata	1	1	0.006%
Diopatra sp	1	1	0.006%
Dorvillea (Schistomeringos) longicornis	1	1	0.006%
Drilonereis sp	1	1	0.006%
Echiuroidea	1	1	0.006%
Epitonium sp	1	1	0.006%
Eranno lagunae	1	1	0.006%
Eudistylia catharinae	1	1	0.006%
Eudorellopsis integra	1	1	0.006%
Eulalia sp	1	1	0.006%
Eumida longicornuta	1	1	0.006%
Euphysa sp	1	1	0.006%
Exogone molesta	1	1	0.006%
Glycera americana	1	1	0.006%
Glycera sp	1	1	0.006%
Gnorimosphaeroma insulare	1	1	0.006%
Halcampa sp	1	1	0.006%
Harpacticoida	1	1	0.006%
Hesionura coineaui difficilis	1	1	0.006%
Heteromastus sp	1	1	0.006%
Heteronemertea	1	1	0.006%
Heterophoxus conlanae	1	1	0.006%
Heteropodarke heteromorpha	1	1	0.006%
Jasmineira sp	1	1	0.006%
Kurtziella plumbea	1	1	0.006%
x *Lanassa venusta*	1	1	0.006%
Lepidasthenia longicirrata	1	1	0.006%

Taxon	Number of stations	Total Abundance (# indiv/0.1 sq.m)	Percent
Lumbrineris californiensis	1	1	0.006%
Magelona sp	1	1	0.006%
Maldanidae	1	1	0.006%
Malmgreniella scriptoria	1	1	0.006%
Malmgreniella sp	1	1	0.006%
Megayoldia thraciaeformis	1	1	0.006%
Microphthalmus sp	1	1	0.006%
Molgula pugetiensis	1	1	0.006%
Molgulidae	1	1	0.006%
Neorhabdocoelida	1	1	0.006%
Neosabellaria cementarium	1	1	0.006%
Nereiphylla castanea	1	1	0.006%
Nuculana hamata	1	1	0.006%
Pacifacanthomysis nephrophthalma	1	1	0.006%
Palaeonemertea	1	1	0.006%
Paradiopatra sp	1	1	0.006%
Paradoneis sp	1	1	0.006%
Pherusa sp	1	1	0.006%
Polycirrus sp V	1	1	0.006%
Pygospio elegans	1	1	0.006%
Rictaxis punctocaelatus	1	1	0.006%
Sabrotrophon pacifica	1	1	0.006%
Saxidomus giganteus	1	1	0.006%
Scalibregma californicum	1	1	0.006%
Scaphopoda	1	1	0.006%
Spio sp	1	1	0.006%
Sthenelais sp	1	1	0.006%
Synidotea pallida	1	1	0.006%
Tetrastemma bicolor	1	1	0.006%
Travisia gigas	1	1	0.006%
Travisia pupa	1	1	0.006%
Travisia sp	1	1	0.006%
Tubulanus cingulatus	1	1	0.006%
Turridae	1	1	0.006%
Virgulariidae	1	1	0.006%
Total	**50**	**17364**	**100%**

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Appendix D. Demersal Fish

Table D-1. Fish-tissue chemistry analyses and bioassays, by station and species (2000).

Station	EMAP Station ID	Composite ID	Species	Common Name	Tissue Chemistry	H4IIE
7	WA00-0001	9764	*Lepidopsetta bilineata*	rock sole		x
		9767	*Platichthys stellatus*	starry flounder	x	x
12	WA00-0002	9756	*Parophrys vetulus*	English sole	x	x
17	WA00-0003	9744	*Parophrys vetulus*	English sole	x	x
29	WA00-0004	9760	*Parophrys vetulus*	English sole	x	x
		9766	*Platichthys stellatus*	starry flounder		x
38	WA00-0005	9749	*Parophrys vetulus*	English sole	x	x
42	WA00-0006	9755	*Parophrys vetulus*	English sole	x	
50	WA00-0007	9751	*Platichthys stellatus*	starry flounder	x	x
51	WA00-0008	9750	*Parophrys vetulus*	English sole	x	x
66	WA00-0009	9753	*Parophrys vetulus*	English sole	x	x
69	WA00-0010	9769	*Parophrys vetulus*	English sole	x	x
71	WA00-0011	9763	*Parophrys vetulus*	English sole	x	x
76	WA00-0012	9713	*Eopsetta exilis*	slender sole	x	
85	WA00-0013	9726	*Parophrys vetulus*	English sole	x	x
90	WA00-0014	9747	*Parophrys vetulus*	English sole	x	x
116	WA00-0017	9739	*Parophrys vetulus*	English sole	x	x
118	WA00-0018	9729	*Parophrys vetulus*	English sole	x	x
126	WA00-0019	9746	*Parophrys vetulus*	English sole	x	x
145	WA00-0020	9758	*Platichthys stellatus*	starry flounder	x	x
179	WA00-0021	9736	*Parophrys vetulus*	English sole	x	x
200	WA00-0022	9735	*Parophrys vetulus*	English sole	x	x
207	WA00-0023	9740	*Parophrys vetulus*	English sole	x	x
209	WA00-0024	9727	*Parophrys vetulus*	English sole	x	x
214	WA00-0025	9728	*Parophrys vetulus*	English sole	x	x
218	WA00-0026	9711	*Parophrys vetulus*	English sole	x	
220	WA00-0027	9705	*Parophrys vetulus*	English sole	x	
221	WA00-0028	9717	*Eopsetta exilis*	slender sole	x	
226	WA00-0030	9738	*Parophrys vetulus*	English sole	x	x
229	WA00-0031	9768	*Cymatogaster aggregata*	shiner perch	x	x
237	WA00-0032	9742	*Citharichthys stigmaeus*	speckled sanddab		x
243	WA00-0033	9724	*Leptocottus armatus*	Pacific staghorn sculpin		x
		9745	*Cymatogaster aggregata*	shiner perch		x
		9754	*Parophrys vetulus*	English sole	x	
252	WA00-0034	9741	*Platichthys stellatus*	starry flounder	x	x
260	WA00-0035	9706	*Microstomus pacificus*	Dover sole		x
		9715	*Parophrys vetulus*	English sole	x	

Station	EMAP Station ID	Composite ID	Species	Common Name	Tissue Chemistry	H4IIE
268	WA00-0036	9743	*Parophrys vetulus*	English sole	x	x
269	WA00-0037	9759	*Parophrys vetulus*	English sole	x	x
273	WA00-0038	9703	*Microstomus pacificus*	Dover sole		x
		9707	*Lepidopsetta bilineata*	rock sole		x
		9716	*Parophrys vetulus*	English sole	x	
274	WA00-0039	9710	*Parophrys vetulus*	English sole	x	
286	WA00-0040	9701	*Parophrys vetulus*	English sole	x	
		9714	*Microstomus pacificus*	Dover sole		x
304	WA00-0041	9748	*Parophrys vetulus*	English sole	x	x
E01	WA00-0042	9737	*Parophrys vetulus*	English sole	x	
		9762	*Lepidopsetta bilineata*	rock sole		x
E02	WA00-0043	9721	*Microstomus pacificus*	Dover sole	x	
E04	WA00-0045	9702	*Parophrys vetulus*	English sole	x	
		9719	*Microstomus pacificus*	Dover sole		x
E05	WA00-0046	9730	*Lepidopsetta bilineata*	rock sole	x	x
E06	WA00-0047	9757	*Parophrys vetulus*	English sole	x	x
E07	WA00-0048	9732	*Parophrys vetulus*	English sole	x	x
E08	WA00-0049	9723	*Parophrys vetulus*	English sole	x	x
E09	WA00-0050	9733	*Parophrys vetulus*	English sole	x	x
E10	WA00-0051	9720	*Microstomus pacificus*	Dover sole	x	
E12	WA00-0053	9704	*Microstomus pacificus*	Dover sole	x	
E13	WA00-0054	9722	*Platichthys stellatus*	starry flounder	x	x
E14	WA00-0055	9752	*Parophrys vetulus*	English sole	x	x
E15	WA00-0056	9765	*Lepidopsetta bilineata*	rock sole	x	x
E17	WA00-0058	9770	*Parophrys vetulus*	English sole	x	x
E18	WA00-0059	9761	*Microgadus proximus*	Pacific tomcod	x	x
E25	WA00-0066	9731	*Parophrys vetulus*	English sole	x	x
E27	WA00-0068	9734	*Parophrys vetulus*	English sole	x	x
E28	WA00-0069	9708	*Lepidopsetta bilineata*	rock sole		x
		9725	*Parophrys vetulus*	English sole	x	x
E29	WA00-0070	9700	*Parophrys vetulus*	English sole	x	
		9718	*Lepidopsetta bilineata*	rock sole		x
E30	WA00-0071	9709	*Microstomus pacificus*	Dover sole		x
		9712	*Parophrys vetulus*	English sole	x	

Table D-2. Fish caught in trawls (first successful trawl only), by station (2000).

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
7	WA00-0001	*Citharichthys sordidus*	Pacific sanddab	1
		Lepidopsetta bilineata	rock sole	3
		Parophrys vetulus	English sole	6
		Platichthys stellatus	starry flounder	28
12	WA00-0002	*Citharichthys sordidus*	Pacific sanddab	2
		Clupea pallasi	Pacific herring	7
		Hippoglossoides elassodon	flathead sole	6
		Microgadus proximus	Pacific tomcod	17
		Parophrys vetulus	English sole	6
		Platichthys stellatus	starry flounder	1
		Porichthys notatus	plainfin midshipman	7
		Spirinchus thaleichthys	longfin smelt	162
		Squalus acanthias	spiny dogfish	1
		Theragra chalcogramma	walleye pollock	25
		Trichodon trichodon	Pacific sandfish	10
17	WA00-0003	*Citharichthys sordidus*	Pacific sanddab	28
		Clupea pallasi	Pacific herring	1
		Hexagrammos stelleri	whitespotted greenling	9
		Isopsetta isolepis	butter sole	5
		Leptocottus armatus	Pacific staghorn sculpin	1
		Parophrys vetulus	English sole	69
		Platichthys stellatus	starry flounder	9
		Podothecus acipenserinus	sturgeon poacher	2
		Porichthys notatus	plainfin midshipman	1
		Psettichthys melanostictus	sand sole	5
		Spirinchus thaleichthys	longfin smelt	2
		Squalus acanthias	spiny dogfish	2
29	WA00-0004	*Clupea pallasi*	Pacific herring	14
		Cymatogaster aggregata	shiner perch	160
		Isopsetta isolepis	butter sole	60
		Microgadus proximus	Pacific tomcod	596
		Parophrys vetulus	English sole	23
		Platichthys stellatus	starry flounder	17
		Spirinchus thaleichthys	longfin smelt	6
		Squalus acanthias	spiny dogfish	2
		Trichodon trichodon	Pacific sandfish	132
38	WA00-0005	*Clupea pallasi*	Pacific herring	4
		Isopsetta isolepis	butter sole	500*
		Microgadus proximus	Pacific tomcod	200*
		Parophrys vetulus	English sole	26
		Platichthys stellatus	starry flounder	14
		Psettichthys melanostictus	sand sole	1
		Spirinchus thaleichthys	longfin smelt	4
		Squalus acanthias	spiny dogfish	10
42	WA00-0006	*Clupea pallasi*	Pacific herring	13

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Cymatogaster aggregata	shiner perch	1
		Parophrys vetulus	English sole	2
50	WA00-0007	*Clupea pallasi*	Pacific herring	1
		Cymatogaster aggregata	shiner perch	9
		Hexagrammos decagrammus	kelp greenling	1
		Leptocottus armatus	Pacific staghorn sculpin	5
		Parophrys vetulus	English sole	23
		Pholis ornata	saddleback gunnel	1
		Platichthys stellatus	starry flounder	4
51	WA00-0008	*Cymatogaster aggregata*	shiner perch	7
		Hexagrammos decagrammus	kelp greenling	8
		Hypsurus caryi	rainbow seaperch	2
		Leptocottus armatus	Pacific staghorn sculpin	3
		Myoxocephalus polyacanthocephalus	great sculpin	1
		Parophrys vetulus	English sole	30
		Platichthys stellatus	starry flounder	14
66	WA00-0009	*Clupea pallasi*	Pacific herring	7
		Cymatogaster aggregata	shiner perch	6
		Eopsetta exilis	slender sole	17
		Hippoglossoides elassodon	flathead sole	5
		Hydrolagus colliei	spotted ratfish	3
		Leptocottus armatus	Pacific staghorn sculpin	2
		Lycodopsis pacifica	blackbelly eelpout	90
		Merluccius productus	Pacific hake	1
		Microgadus proximus	Pacific tomcod	1
		Parophrys vetulus	English sole	6
		Psettichthys melanostictus	sand sole	2
		Spirinchus thaleichthys	longfin smelt	16
		Squalus acanthias	spiny dogfish	3
69	WA00-0010	*Cymatogaster aggregata*	shiner perch	8
		Lycodes palearis	wattled eel-pout	80
		Parophrys vetulus	English sole	29
		Squalus acanthias	spiny dogfish	2
71	WA00-0011	*Clupea pallasi*	Pacific herring	1
		Cymatogaster aggregata	shiner perch	3
		Hydrolagus colliei	spotted ratfish	2
		Lycodopsis pacifica	blackbelly eelpout	7
		Microgadus proximus	Pacific tomcod	6
		Parophrys vetulus	English sole	3
		Spirinchus thaleichthys	longfin smelt	6
		Squalus acanthias	spiny dogfish	3
		Trichodon trichodon	Pacific sandfish	1
76	WA00-0012	*Citharichthys sordidus*	Pacific sanddab	1
		Clupea pallasi	Pacific herring	3
		Eopsetta exilis	slender sole	91
		Hydrolagus colliei	spotted ratfish	27

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Lepidopsetta bilineata	rock sole	1
		Lycodes palearis	wattled eel-pout	50
		Merluccius productus	Pacific hake	2000*
		Parophrys vetulus	English sole	1
		Raja rhina	longnose skate	3
		Squalus acanthias	spiny dogfish	21
85	WA00-0013	*Bathyagonus pentacanthus*	bigeye poacher	23
		Eopsetta exilis	slender sole	259
		Errex zachirus	rex sole	1
		Hydrolagus colliei	spotted ratfish	57
		Lycodes diapterus	black eelpout	5
		Lycodes palearis	wattled eel-pout	66
		Merluccius productus	Pacific hake	153
		Mustelus henlei	brown smoothhound	4
		Parophrys vetulus	English sole	8
		Porichthys notatus	plainfin midshipman	2
		Raja rhina	longnose skate	3
		Sebastes maliger	quillback rockfish	2
		Squalus acanthias	spiny dogfish	13
90	WA00-0014	*Citharichthys sordidus*	Pacific sanddab	2
		Lepidopsetta bilineata	rock sole	1
		Nautichthys oculofasciatus	sailfin sculpin	1
		Parophrys vetulus	English sole	30
		Sebastes maliger	quillback rockfish	2
107	WA00-0015	*Citharichthys sordidus*	Pacific sanddab	1
		Icelus spiniger	thorny sculpin	2
		Lepidopsetta bilineata	rock sole	1
		Microgadus proximus	Pacific tomcod	10
		Porichthys notatus	plainfin midshipman	1
		Psettichthys melanostictus	sand sole	1
112	WA00-0016	*Hydrolagus colliei*	spotted ratfish	1
		Lepidopsetta bilineata	rock sole	4
		Parophrys vetulus	English sole	1
		Triglops pingeli	ribbed sculpin	2
116	WA00-0017	*Citharichthys sordidus*	Pacific sanddab	13
		Cymatogaster aggregata	shiner perch	1
		Parophrys vetulus	English sole	28
		Platichthys stellatus	starry flounder	2
		Psettichthys melanostictus	sand sole	1
118	WA00-0018	*Eopsetta exilis*	slender sole	11
		Hydrolagus colliei	spotted ratfish	348
		Lycodes diapterus	black eelpout	2
		Merluccius productus	Pacific hake	7
		Microstomus pacificus	Dover sole	2
		Mustelus henlei	brown smoothhound	3
		Parophrys vetulus	English sole	32

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Raja rhina	longnose skate	12
		Reinhardtius stomias	arrowtooth flounder	1
		Sebastes maliger	quillback rockfish	3
		Squalus acanthias	spiny dogfish	3
		Theragra chalcogramma	walleye pollock	2
126	WA00-0019	*Clupea pallasi*	Pacific herring	13
		Cymatogaster aggregata	shiner perch	2
		Hydrolagus colliei	spotted ratfish	3
		Lycodopsis pacifica	blackbelly eelpout	1
		Microgadus proximus	Pacific tomcod	29
		Nautichthys oculofasciatus	sailfin sculpin	1
		Parophrys vetulus	English sole	9
		Porichthys notatus	plainfin midshipman	1
		Squalus acanthias	spiny dogfish	5
145	WA00-0020	*Citharichthys stigmaeus*	speckled sanddab	22
		Cymatogaster aggregata	shiner perch	18
		Hexagrammos decagrammus	kelp greenling	1
		Leptocottus armatus	Pacific staghorn sculpin	2
		Parophrys vetulus	English sole	24
		Platichthys stellatus	starry flounder	12
		Porichthys notatus	plainfin midshipman	2
		Psettichthys melanostictus	sand sole	1
179	WA00-0021	*Citharichthys sordidus*	Pacific sanddab	2
		Eopsetta exilis	slender sole	7
		Gymnocanthus galeatus	armorhead sculpin	2
		Hippoglossoides elassodon	flathead sole	12
		Lepidopsetta bilineata	rock sole	3
		Microgadus proximus	Pacific tomcod	1
		Parophrys vetulus	English sole	12
		Porichthys notatus	plainfin midshipman	4
200	WA00-0022	*Citharichthys sordidus*	Pacific sanddab	1
		Clupea pallasi	Pacific herring	3
		Cymatogaster aggregata	shiner perch	2
		Gymnocanthus galeatus	armorhead sculpin	6
		Hippoglossoides elassodon	flathead sole	8
		Lepidopsetta bilineata	rock sole	6
		Leptocottus armatus	Pacific staghorn sculpin	2
		Microgadus proximus	Pacific tomcod	15
		Microstomus pacificus	Dover sole	5
		Parophrys vetulus	English sole	20
		Porichthys notatus	plainfin midshipman	5
		Psettichthys melanostictus	sand sole	4
		Spirinchus thaleichthys	longfin smelt	23
207	WA00-0023	*Cymatogaster aggregata*	shiner perch	3
		Hippoglossoides elassodon	flathead sole	2
		Microgadus proximus	Pacific tomcod	4

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Parophrys vetulus	English sole	18
		Platichthys stellatus	starry flounder	15
		Psettichthys melanostictus	sand sole	1
		Raja rhina	longnose skate	1
209	WA00-0024	*Clupea pallasi*	Pacific herring	3
		Eopsetta exilis	slender sole	1
		Hippoglossoides elassodon	flathead sole	4
		Hydrolagus colliei	spotted ratfish	151
		Merluccius productus	Pacific hake	2
		Microgadus proximus	Pacific tomcod	3
		Microstomus pacificus	Dover sole	1
		Parophrys vetulus	English sole	23
		Porichthys notatus	plainfin midshipman	2
214	WA00-0025	*Cymatogaster aggregata*	shiner perch	30
		Gobiidae sp.	goby	1
		Lepidopsetta bilineata	rock sole	1
		Leptocottus armatus	Pacific staghorn sculpin	120*
		Microgadus proximus	Pacific tomcod	1
		Parophrys vetulus	English sole	180*
		Platichthys stellatus	starry flounder	6
		Psettichthys melanostictus	sand sole	17
		Raja rhina	longnose skate	2
		Rhacochilus vacca	pile perch	1
		Squalus acanthias	spiny dogfish	4
218	WA00-0026	*Bathyagonus nigripinnis*	blackfin poacher	1
		Citharichthys sordidus	Pacific sanddab	1
		Clupea pallasi	Pacific herring	316
		Engraulis mordax	northern anchovy	2
		Eopsetta exilis	slender sole	480*
		Hippoglossoides elassodon	flathead sole	30
		Lycodes palearis	wattled eel-pout	780*
		Malacocottus kincaidi	blackfin sculpin	2
		Merluccius productus	Pacific hake	22
		Microgadus proximus	Pacific tomcod	2
		Microstomus pacificus	Dover sole	1
		Parophrys vetulus	English sole	160
		Porichthys notatus	plainfin midshipman	354
		Psettichthys melanostictus	sand sole	1
		Raja rhina	longnose skate	1
		Squalus acanthias	spiny dogfish	50
220	WA00-0027	*Bathyagonus nigripinnis*	blackfin poacher	4
		Eopsetta exilis	slender sole	136
		Errex zachirus	rex sole	1
		Hydrolagus colliei	spotted ratfish	5
		Lycodes diapterus	black eelpout	5
		Lycodes palearis	wattled eel-pout	1

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Malacocottus kincaidi	blackfin sculpin	4
		Merluccius productus	Pacific hake	21
		Parophrys vetulus	English sole	30
		Raja rhina	longnose skate	6
		Sebastes diploproa	splitnose rockfish	37
		Sebastes maliger	quillback rockfish	1
221	WA00-0028	*Bathyagonus nigripinnis*	blackfin poacher	1
		Eopsetta exilis	slender sole	117
		Errex zachirus	rex sole	1
		Hippoglossoides elassodon	flathead sole	1
		Hydrolagus colliei	spotted ratfish	1
		Lycodes palearis	wattled eel-pout	23
		Malacocottus kincaidi	blackfin sculpin	80
		Merluccius productus	Pacific hake	19
		Parophrys vetulus	English sole	1
		Porichthys notatus	plainfin midshipman	13
		Raja rhina	longnose skate	13
		Sebastes diploproa	splitnose rockfish	1
		Sebastes maliger	quillback rockfish	2
		Squalus acanthias	spiny dogfish	1
		Theragra chalcogramma	walleye pollock	2
225	WA00-0029	no fish caught in trawl	--	0
226	WA00-0030	*Eopsetta exilis*	slender sole	160*
		Hydrolagus colliei	spotted ratfish	12
		Lycodopsis pacifica	blackbelly eelpout	100*
		Malacocottus kincaidi	blackfin sculpin	15
		Merluccius productus	Pacific hake	700*
		Mustelus henlei	brown smoothhound	1
		Parophrys vetulus	English sole	80*
		Podothecus acipenserinus	sturgeon poacher	5
		Porichthys notatus	plainfin midshipman	140*
		Raja binoculata	big skate	3
		Raja rhina	longnose skate	3
229	WA00-0031	*Cymatogaster aggregata*	shiner perch	6
		Psettichthys melanostictus	sand sole	2
237	WA00-0032	*Citharichthys stigmaeus*	speckled sanddab	12
		Cymatogaster aggregata	shiner perch	9
		Leptocottus armatus	Pacific staghorn sculpin	2
		Lumpenus sagitta	snake prickleback	1
		Porichthys notatus	plainfin midshipman	1
		Rhacochilus vacca	pile perch	1
243	WA00-0033	*Cymatogaster aggregata*	shiner perch	5
		Leptocottus armatus	Pacific staghorn sculpin	13
		Microgadus proximus	Pacific tomcod	2
252	WA00-0034	*Citharichthys sordidus*	Pacific sanddab	1
		Clupea pallasi	Pacific herring	3

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Cymatogaster aggregata	shiner perch	1
		Eopsetta exilis	slender sole	8
		Gymnocanthus galeatus	armorhead sculpin	1
		Hippoglossoides elassodon	flathead sole	1
		Hydrolagus colliei	spotted ratfish	1
		Leptocottus armatus	Pacific staghorn sculpin	2
		Lycodes palearis	wattled eel-pout	24
		Microgadus proximus	Pacific tomcod	18
		Platichthys stellatus	starry flounder	3
		Porichthys notatus	plainfin midshipman	1
260	WA00-0035	*Bathyagonus nigripinnis*	blackfin poacher	7
		Citharichthys sordidus	Pacific sanddab	14
		Eopsetta exilis	slender sole	53
		Hydrolagus colliei	spotted ratfish	209
		Leptocottus armatus	Pacific staghorn sculpin	1
		Lycodes palearis	wattled eel-pout	570
		Merluccius productus	Pacific hake	97
		Microgadus proximus	Pacific tomcod	519
		Microstomus pacificus	Dover sole	5
		Parophrys vetulus	English sole	93
		Platichthys stellatus	starry flounder	9
		Porichthys notatus	plainfin midshipman	5
		Raja rhina	longnose skate	1
		Sebastes auriculatus	brown rockfish	1
		Squalus acanthias	spiny dogfish	3
		Theragra chalcogramma	walleye pollock	2
268	WA00-0036	*Chitonotus pugetensis*	roughback sculpin	2
		Clinocottus embryum	calico sculpin	9
		Enophrys bison	buffalo sculpin	2
		Gymnocanthus galeatus	armorhead sculpin	16
		Lepidopsetta bilineata	rock sole	8
		Leptocottus armatus	Pacific staghorn sculpin	1
		Microgadus proximus	Pacific tomcod	1
		Microstomus pacificus	Dover sole	1
		Parophrys vetulus	English sole	5
		Platichthys stellatus	starry flounder	1
		Podothecus acipenserinus	sturgeon poacher	2
		Psettichthys melanostictus	sand sole	3
		Squalus acanthias	spiny dogfish	1
		Triglops macellus	roughspine sculpin	1
269	WA00-0037	*Citharichthys stigmaeus*	speckled sanddab	8
		Eopsetta exilis	slender sole	1
		Lepidopsetta bilineata	rock sole	6
		Leptocottus armatus	Pacific staghorn sculpin	2
		Parophrys vetulus	English sole	18
		Platichthys stellatus	starry flounder	1

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Porichthys notatus	plainfin midshipman	1
273	WA00-0038	*Eopsetta exilis*	slender sole	2
		Gadus macrocephalus	Pacific cod	3
		Hydrolagus colliei	spotted ratfish	1880*
		Lepidopsetta bilineata	rock sole	171
		Merluccius productus	Pacific hake	3
		Microgadus proximus	Pacific tomcod	130
		Microstomus pacificus	Dover sole	100
		Parophrys vetulus	English sole	98
		Pleuronichthys coenosus	C-O sole	5
		Pleuronichthys decurrens	curlfin sole	2
		Porichthys notatus	plainfin midshipman	3
		Squalus acanthias	spiny dogfish	10
274	WA00-0039	*Bathyagonus nigripinnis*	blackfin poacher	1
		Clupea pallasi	Pacific herring	1
		Eopsetta exilis	slender sole	3
		Errex zachirus	rex sole	12
		Gadus macrocephalus	Pacific cod	2
		Hemilepidotus hemilepidotus	red Irish lord	5
		Hydrolagus colliei	spotted ratfish	1386*
		Lepidopsetta bilineata	rock sole	63
		Merluccius productus	Pacific hake	2
		Microgadus proximus	Pacific tomcod	66
		Microstomus pacificus	Dover sole	36
		Parophrys vetulus	English sole	57
		Pleuronichthys coenosus	C-O sole	7
		Pleuronichthys decurrens	curlfin sole	3
		Raja rhina	longnose skate	1
		Sebastes auriculatus	brown rockfish	9
		Sebastes caurinus	copper rockfish	1
		Sebastes maliger	quillback rockfish	12
		Squalus acanthias	spiny dogfish	17
		Theragra chalcogramma	walleye pollock	1
286	WA00-0040	*Clupea pallasi*	Pacific herring	1
		Eopsetta exilis	slender sole	10
		Errex zachirus	rex sole	4
		Hydrolagus colliei	spotted ratfish	1155*
		Merluccius productus	Pacific hake	1
		Microgadus proximus	Pacific tomcod	10
		Microstomus pacificus	Dover sole	5
		Parophrys vetulus	English sole	63
		Porichthys notatus	plainfin midshipman	1
		Raja rhina	longnose skate	3
		Sebastes maliger	quillback rockfish	2
		Squalus acanthias	spiny dogfish	34
304	WA00-0041	*Citharichthys sordidus*	Pacific sanddab	1

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Cymatogaster aggregata	shiner perch	1
		Hippoglossoides elassodon	flathead sole	4
		Hydrolagus colliei	spotted ratfish	1
		Lepidopsetta bilineata	rock sole	4
		Microgadus proximus	Pacific tomcod	38
		Parophrys vetulus	English sole	40
		Psettichthys melanostictus	sand sole	1
		Raja binoculata	big skate	1
		Squalus acanthias	spiny dogfish	2
E01	WA00-0042	*Citharichthys sordidus*	Pacific sanddab	6
		Lepidopsetta bilineata	rock sole	12
		Ophiodon elongatus	lingcod	1
		Parophrys vetulus	English sole	7
		Platichthys stellatus	starry flounder	2
E02	WA00-0043	*Bathyraja interrupta*	sandpaper skate	2
		Clupea pallasi	Pacific herring	1
		Eopsetta exilis	slender sole	3
		Hydrolagus colliei	spotted ratfish	93
		Merluccius productus	Pacific hake	19
		Microstomus pacificus	Dover sole	17
		Raja rhina	longnose skate	4
		Sebastolobus alascanus	shortspine thornyhead	1
		Squalus acanthias	spiny dogfish	16
E04	WA00-0045	*Eopsetta exilis*	slender sole	6
		Errex zachirus	rex sole	3
		Gadus macrocephalus	Pacific cod	2
		Hydrolagus colliei	spotted ratfish	440*
		Lycodes palearis	wattled eel-pout	4
		Merluccius productus	Pacific hake	71
		Microstomus pacificus	Dover sole	55
		Parophrys vetulus	English sole	26
		Raja binoculata	big skate	1
		Raja rhina	longnose skate	4
		Squalus acanthias	spiny dogfish	25
		Theragra chalcogramma	walleye pollock	2
E05	WA00-0046	*Citharichthys sordidus*	Pacific sanddab	3
		Clupea pallasi	Pacific herring	3
		Hydrolagus colliei	spotted ratfish	1
		Lepidopsetta bilineata	rock sole	3
		Microgadus proximus	Pacific tomcod	2
E06	WA00-0047	*Eopsetta exilis*	slender sole	1
		Lycodes cortezianus	bigfin eelpout	3
		Microstomus pacificus	Dover sole	3
		Parophrys vetulus	English sole	12
		Porichthys notatus	plainfin midshipman	11
		Theragra chalcogramma	walleye pollock	17

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
E07	WA00-0048	*Citharichthys sordidus*	Pacific sanddab	4
		Eopsetta exilis	slender sole	2
		Gadus macrocephalus	Pacific cod	1
		Hippoglossoides elassodon	flathead sole	5
		Isopsetta isolepis	butter sole	1
		Lepidopsetta bilineata	rock sole	4
		Lycodes palearis	wattled eel-pout	4
		Microgadus proximus	Pacific tomcod	6
		Parophrys vetulus	English sole	35
		Platichthys stellatus	starry flounder	1
		Porichthys notatus	plainfin midshipman	4
		Squalus acanthias	spiny dogfish	4
		Theragra chalcogramma	walleye pollock	7
E08	WA00-0049	*Cymatogaster aggregata*	shiner perch	1
		Eopsetta exilis	slender sole	8
		Errex zachirus	rex sole	1
		Hippoglossoides elassodon	flathead sole	2
		Hydrolagus colliei	spotted ratfish	2
		Lycodes cortezianus	bigfin eelpout	21
		Merluccius productus	Pacific hake	1
		Microgadus proximus	Pacific tomcod	5
		Parophrys vetulus	English sole	67
		Porichthys notatus	plainfin midshipman	3
		Theragra chalcogramma	walleye pollock	3
E09	WA00-0050	*Clupea pallasi*	Pacific herring	2
		Hippoglossoides elassodon	flathead sole	1
		Microgadus proximus	Pacific tomcod	3
		Platichthys stellatus	starry flounder	1
		Spirinchus thaleichthys	longfin smelt	3
E10	WA00-0051	*Gadus macrocephalus*	Pacific cod	1
		Hydrolagus colliei	spotted ratfish	25
		Liparis dennyi	marbled snailfish	1
		Microgadus proximus	Pacific tomcod	1
		Microstomus pacificus	Dover sole	7
		Parophrys vetulus	English sole	1
		Sebastes auriculatus	brown rockfish	1
		Sebastes maliger	quillback rockfish	9
		Squalus acanthias	spiny dogfish	5
		Theragra chalcogramma	walleye pollock	204
E12	WA00-0053	*Eopsetta exilis*	slender sole	1
		Errex zachirus	rex sole	1
		Gadus macrocephalus	Pacific cod	5
		Hydrolagus colliei	spotted ratfish	282
		Microgadus proximus	Pacific tomcod	1
		Microstomus pacificus	Dover sole	29
		Parophrys vetulus	English sole	1

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Raja binoculata	big skate	1
		Raja rhina	longnose skate	1
		Squalus acanthias	spiny dogfish	7
		Theragra chalcogramma	walleye pollock	15
E13	WA00-0054	*Lepidopsetta bilineata*	rock sole	1
		Parophrys vetulus	English sole	3
		Platichthys stellatus	starry flounder	5
E14	WA00-0055	*Citharichthys sordidus*	Pacific sanddab	2
		Clupea pallasi	Pacific herring	3
		Cymatogaster aggregata	shiner perch	27
		Hexagrammos stelleri	whitespotted greenling	1
		Microgadus proximus	Pacific tomcod	1
		Parophrys vetulus	English sole	4
		Platichthys stellatus	starry flounder	2
		Psettichthys melanostictus	sand sole	9
E15	WA00-0056	*Citharichthys sordidus*	Pacific sanddab	1
		Lepidopsetta bilineata	rock sole	6
		Leptocottus armatus	Pacific staghorn sculpin	1
		Parophrys vetulus	English sole	3
		Porichthys notatus	plainfin midshipman	1
E17	WA00-0058	*Citharichthys stigmaeus*	speckled sanddab	1
		Cymatogaster aggregata	shiner perch	5
		Lepidopsetta bilineata	rock sole	9
		Microgadus proximus	Pacific tomcod	2
		Parophrys vetulus	English sole	15
		Psettichthys melanostictus	sand sole	1
E18	WA00-0059	*Lepidopsetta bilineata*	rock sole	1
		Liparis dennyi	marbled snailfish	2
		Microgadus proximus	Pacific tomcod	21
		Myoxocephalus polyacanthocephalus	great sculpin	1
		Squalus acanthias	spiny dogfish	7
		Theragra chalcogramma	walleye pollock	7
E19	WA00-0060	*Citharichthys stigmaeus*	speckled sanddab	2
		Cymatogaster aggregata	shiner perch	1
		Gadus macrocephalus	Pacific cod	3
		Hexagrammos stelleri	whitespotted greenling	2
		Lepidopsetta bilineata	rock sole	1
		Liparis fucensis	slipskin snailfish	1
		Myoxocephalus polyacanthocephalus	great sculpin	1
E21	WA00-0062	*Bathyagonus alascanus*	gray starsnout	1
		Citharichthys sordidus	Pacific sanddab	1
		Parophrys vetulus	English sole	1
E22	WA00-0063	*Apodichthys flavidus*	penpoint gunnel	1
		Hemilepidotus hemilepidotus	red Irish lord	1
E25	WA00-0066	*Citharichthys sordidus*	Pacific sanddab	1
		Clupea pallasi	Pacific herring	1

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Hippoglossoides elassodon	flathead sole	1
		Hydrolagus colliei	spotted ratfish	1
		Microgadus proximus	Pacific tomcod	1
		Parophrys vetulus	English sole	3
		Squalus acanthias	spiny dogfish	4
E26	WA00-0067	*Citharichthys sordidus*	Pacific sanddab	2
E27	WA00-0068	*Agonopsis vulsa*	northern spearnose poacher	1
		Citharichthys sordidus	Pacific sanddab	2
		Hydrolagus colliei	spotted ratfish	41
		Icelus spiniger	thorny sculpin	2
		Microgadus proximus	Pacific tomcod	8
		Microstomus pacificus	Dover sole	4
		Parophrys vetulus	English sole	32
		Raja binoculata	big skate	2
		Sebastes emphaeus	Puget Sound rockfish	4
		Squalus acanthias	spiny dogfish	1
E28	WA00-0069	*Agonopsis vulsa*	northern spearnose poacher	1
		Chitonotus pugetensis	roughback sculpin	10
		Citharichthys sordidus	Pacific sanddab	16
		Hydrolagus colliei	spotted ratfish	465
		Lepidopsetta bilineata	rock sole	24
		Microgadus proximus	Pacific tomcod	3
		Microstomus pacificus	Dover sole	1
		Myoxocephalus polyacanthocephalus	great sculpin	1
		Nautichthys oculofasciatus	sailfin sculpin	2
		Parophrys vetulus	English sole	25
		Platichthys stellatus	starry flounder	1
		Podothecus acipenserinus	sturgeon poacher	3
		Radulinus asprellus	slim sculpin	15
		Sebastes caurinus	copper rockfish	1
		Squalus acanthias	spiny dogfish	12
E29	WA00-0070	*Chitonotus pugetensis*	roughback sculpin	5
		Citharichthys sordidus	Pacific sanddab	108
		Cymatogaster aggregata	shiner perch	2
		Hydrolagus colliei	spotted ratfish	31
		Isopsetta isolepis	butter sole	10
		Lepidopsetta bilineata	rock sole	102
		Microgadus proximus	Pacific tomcod	5
		Microstomus pacificus	Dover sole	3
		Parophrys vetulus	English sole	181
		Podothecus acipenserinus	sturgeon poacher	1
		Porichthys notatus	plainfin midshipman	1
		Sebastes caurinus	copper rockfish	1
		Squalus acanthias	spiny dogfish	16
		Xeneretmus triacanthus	bluespotted poacher	1
E30	WA00-0071	*Eopsetta exilis*	slender sole	4

Station	EMAP Station ID	Species	Common Name	Abundance (*=estimated)
		Errex zachirus	rex sole	1
		Gadus macrocephalus	Pacific cod	1
		Hydrolagus colliei	spotted ratfish	696
		Liparis sp.	snailfish	1
		Lycodes diapterus	black eelpout	4
		Merluccius productus	Pacific hake	6
		Microstomus pacificus	Dover sole	33
		Mustelus henlei	brown smoothhound	1
		Parophrys vetulus	English sole	8
		Raja rhina	longnose skate	4
		Sebastes maliger	quillback rockfish	2
		Squalus acanthias	spiny dogfish	1

Table D-3. Fish catch per area swept (2000).

EMAP Station ID	Number of Fish Taxa in Trawl	Total Fish Caught in Trawl	Area Swept (km^2)	Catch per Area Swept (equiv. # fish/km^2)
WA00-0001	4	38	0.0071	5,336
WA00-0002	11	244	0.0076	32,290
WA00-0003	12	134	0.0078	17,263
WA00-0004	9	1010	0.0071	141,435
WA00-0005	8	759	0.0080	95,420
WA00-0006	3	16	0.0031	5,159
WA00-0007	7	44	0.0025	17,584
WA00-0008	7	65	0.0058	11,186
WA00-0009	13	159	0.0082	19,302
WA00-0010	4	119	0.0071	16,756
WA00-0011	9	32	0.0071	4,511
WA00-0012	10	2198	0.0221	99,355
WA00-0013	13	596	0.0266	22,382
WA00-0014	5	36	0.0042	8,580
WA00-0015	6	16	0.0086	1,868
WA00-0016	4	8	0.0041	1,950
WA00-0017	5	45	0.0085	5,302
WA00-0018	12	426	0.0156	27,269
WA00-0019	9	64	0.0091	7,035
WA00-0020	8	82	0.0056	14,557
WA00-0021	8	43	0.0068	6,296
WA00-0022	13	100	0.0049	20,460
WA00-0023	7	44	0.0081	5,408
WA00-0024	9	190	0.0119	15,953
WA00-0025	11	363	0.0079	46,232
WA00-0026	16	2203	0.0230	95,866
WA00-0027	12	251	0.0218	11,489
WA00-0028	15	276	0.0188	14,671
WA00-0029	0	0	0.0071	0
WA00-0030	11	1219	0.0147	83,004
WA00-0031	2	8	0.0040	1,993
WA00-0032	6	26	0.0077	3,398
WA00-0033	3	20	0.0033	6,084
WA00-0034	12	64	0.0101	6,328
WA00-0035	16	1589	0.0227	69,858
WA00-0036	14	53	0.0071	7,499
WA00-0037	7	37	0.0042	8,790
WA00-0038	12	2407	0.0145	166,386
WA00-0039	20	1685	–	–
WA00-0040	12	1289	0.0160	80,513
WA00-0041	10	93	0.0064	14,506

EMAP Station ID	Number of Fish Taxa in Trawl	Total Fish Caught in Trawl	Area Swept (km^2)	Catch per Area Swept (equiv. # fish/km^2)
WA00-0042	5	28	0.0067	4,176
WA00-0043	9	156	0.0522	2,989
WA00-0045	12	639	0.0431	14,820
WA00-0046	5	12	0.0055	2,174
WA00-0047	6	47	0.0051	9,277
WA00-0048	13	78	0.0104	7,501
WA00-0049	11	114	0.0105	10,891
WA00-0050	5	10	0.0074	1,352
WA00-0051	10	255	0.0165	15,481
WA00-0053	11	344	0.0269	12,786
WA00-0054	3	9	0.0071	1,275
WA00-0055	8	49	0.0063	7,770
WA00-0056	5	12	0.0064	1,862
WA00-0058	6	33	0.0061	5,404
WA00-0059	6	39	0.0100	3,903
WA00-0060	7	11	0.0079	1,391
WA00-0062	3	3	0.0050	603
WA00-0063	2	2	0.0027	733
WA00-0066	7	12	0.0131	914
WA00-0067	1	2	0.0096	209
WA00-0068	10	97	0.0129	7,543
WA00-0069	15	580	0.0198	29,313
WA00-0070	14	467	0.0122	38,206
WA00-0071	13	762	0.0187	40,732

Table D-4. Visible pathologies on fish, all stations combined (2000).

	Deformity			Fin Erosion	Lesion		Parasite										Tumor					
	Skin / Fins		Musculo-skeleton	Skin / Fins	Skin / Fins		Musculo-skeleton	Skin / Fins					Branchial Chamber				Skin / Fins				Branchial Chamber	Internal Organs
Species	bent and/or fused rays	thickened ray	scoliosis	fin erosion	epidermal hyperplasia	lesion	*Philometra*	*Philometra*	copepods/sea lice	leeches	trematode metacecaria	unidentified/unknown parasite	copepods	unidentified/unknown parasite	white spots on gills	x-cell pseudotumor	lymphocystis	trematode metacecaria	x-cell pseudotumor	tumor	white spots on gills	possible tumor on liver
Parophrys vetulus	8		1				131	102	3	1							3	1	1	2		2
Platichthys stellatus	1			3	1			12	18		7											
Merluccius productus													2	4	12	1					17	
Pleuronectes bilineatus		1				1	6	7	6		2	1						1				
Sebastes maliger													11									
Lycodes palearis							5	1														
Microstomus pacificus																			5			
Psettichthys melanostictus								3	1				1									
Pleuronectes isolepis								4														
Sebastes auriculatus													4									
Gadus macrocephalus									3													
Lycodes diapterus							3															
Microgadus proximus													3									
Raja rhina									1	2												
Theragra chalcogramma													3									
Bathyraja interrupta										1												
Citharichthys sordidus								1														
Errex zachirus							1															
Pleuronichthys coenosus										1												

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Table D-5. Fish caught by hook-and-line, by station (2003).

Station	EMAP Station ID	Success/Species	Size Class (cm)	Number of Fish
3002	WA03-0001	Attempted fishing; no luck; strong current - reached bottom, not biting!		
3006	WA03-0002	*Citharichthys sordidus*	28	2
			26	1
			23	1
			22	1
3010	WA03-0003	*Citharichthys sordidus*	30	1
			28	1
			27	2
			26	1
			25	1
3014	WA03-0004	Too deep for fish.		
3015	WA03-0005	*Citharichthys sordidus*	22	1
3018	WA03-0006	*Citharichthys sordidus*	30	1
			26	2
			25	2
			24	1
3022	WA03-0007	No fish caught.		
3023	WA03-0008	Attempted but no fish caught.		
3026	WA03-0009	Attempted but no fish caught.		
3030	WA03-0010	Attempted but no fish caught.		
3031	WA03-0011	*Citharichthys sordidus*	29	2
			28	1
			26	1
			24	1
			19	1
3034	WA03-0012	*Citharichthys sordidus*	23	1
			21	1
			20	1
3038	WA03-0013	Too rough to fish.		
3042	WA03-0014	*Citharichthys sordidus*	31	1
			29	1
			25	1
			24	1
			22	1
3046	WA03-0015	*Citharichthys sordidus*	27	1
3047	WA03-0016	Station rejected due to rocks in grab. No fishing attempted.		
3050	WA03-0017	*Citharichthys sordidus*	28	1
			26	1
			25	1
			24	1
			21	2
		Isopsetta isolepis	28	1
			24	1
			24	1
			22	1
			20	1

Station	EMAP Station ID	Success/Species	Size Class (cm)	Number of Fish
3054	WA03-0018	Attempted but no fish caught.		
3055	WA03-0019	*Citharichthys sordidus*	29	1
			27	1
			24	1
			22	1
			20	1
3058	WA03-0020	Attempted but no fish caught.		
3063	WA03-0021	Too deep to fish.		
3066	WA03-0022	No fishing - too deep.		
3070	WA03-0023	Too deep for fishing.		
3074	WA03-0024	*Citharichthys sordidus*	30	1
			28	1
			27	1
			24	1
			22	1
			19	1
3078	WA03-0025	*Citharichthys sordidus*	29	1
			23	1
			18	1
		Merluccius productus	55	1
3079	WA03-0026	Attempted but no fish caught.		
3082	WA03-0027	Too deep to fish.		
3086	WA03-0028	Station abandoned due to gravelly sediment in grab.		
3087	WA03-0029	*Citharichthys sordidus*	26	1
			25	1
			24	1
			22	2
			21	1
3090	WA03-0030	Attempted but no fish caught.		
3094	WA03-0031	*Citharichthys sordidus*	30	1
			26	1
3095	WA03-0032	Too deep to fish.		
3098	WA03-0033	Too deep to fish.		
3102	WA03-0034	Attempted but no fish caught.		
3103	WA03-0035	Attempted but no fish caught.		
3106	WA03-0036	Station rejected due to rocky bottom. No fishing attempted.		
3110	WA03-0037	Attempted but no fish caught.		
3111	WA03-0038	*Citharichthys sordidus*	26	2
			25	2
			24	1
			23	2
			22	3
3114	WA03-0039	Too deep to fish.		
3119	WA03-0041	Attempted but no fish caught.		
3122	WA03-0042	*Citharichthys sordidus*	28	1
			25	1
			22	1

Station	EMAP Station ID	Success/Species	Size Class (cm)	Number of Fish
			21	1
			20	1
			not recorded	2
3127	WA03-0043	Too deep to fish.		
3130	WA03-0044	Fishing attempts failed - current too strong.		
3138	WA03-0046	*Citharichthys sordidus*	29	2
			28	1
			25	1
			22	1
3142	WA03-0047	Attempted but no fish caught.		
3143	WA03-0048	Too deep to fish.		
3146	WA03-0049	Station rejected due to cobbles in grab. No fishing attempted.		
3150	WA03-0050	Too rough to fish. Station abandoned due to rocks in grab.		
3152	WA03-0051	Too deep to fish.		
3160	WA03-0053	*Citharichthys sordidus*	25	1
			24	1
			23	2
			20	1
3180	WA03-0060	*Citharichthys sordidus*	29	1
			28	1
			25	1
			20	2
		Isopsetta isolepis	19	1
3204	WA03-0068	Attempted but no fish caught.		
3208	WA03-0070	*Citharichthys sordidus*	30	1
			28	1
			26	2
			25	1
			24	1
			23	4
			22	2
			21	1
3244	WA03-0081	Attempted but no fish caught.		
3260	WA03-0086	*Citharichthys sordidus*	30	1
			28	1
			25	1
		Merluccius productus	52	1
			46	1
		Microstomus pacificus	22	1

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Appendix E. Vegetation and Burrowing Shrimp (Intertidal)

Table E-1. Occurrence of plant species (number of stations) by sampling method (2002).

Species	Plant quadrat	Plant transect	Benthos quadrat	Total stations
Eelgrass	23	26	25	29
Nanozostera americana	0	2	0	2
Zostera japonica	17	16	18	20
Zostera marina	10	14	10	14
Green algae	25	26	19	29
Cladophora sp.	3	5	2	6
Enteromorpha linza	7	3	3	8
Enteromorpha prolifera	7	5	5	9
Enteromorpha sp.	7	9	4	9
Ulva sp.	3	5	2	5
Ulvoid sp.	6	1	5	7
Saltmarsh grass	3	4	3	4
Juncus gerardii	0	1	0	1
Spartina alterniflora	3	3	3	3
Brown algae	2	0	0	2
Fucus gardneri	1	0	0	1
unspecified species	1	0	0	1
Red algae	1	0	0	1
Gracilaria sp.	1	0	0	1
None	15	13	22	10

Table E-2. Vegetation total percent cover by station and sampling method (2002). Percent cover may exceed 100% if plants overlie each other.

EMAP Station ID	Stratum	Percent Cover		
		Plant Quadrat	Plant Transect	Benthos Quadrat
WA02-0002	Willapa Bay	85	92	75
WA02-0003	Willapa Bay	100	48	100
WA02-0004	Puget Sound	80	72	70
WA02-0005	remainder of WA	95.5	96	98
WA02-0006	Puget Sound	0	0	0
WA02-0007	Willapa Bay	100	152	100
WA02-0010	Puget Sound	0	0	0
WA02-0011	Willapa Bay	0	88	0
WA02-0012	Puget Sound	2	0	0
WA02-0014	Puget Sound	65	52	43
WA02-0016	Puget Sound	1	12	2
WA02-0017	Willapa Bay	1	12	18
WA02-0018	Willapa Bay	15	36	0
WA02-0019	Willapa Bay	0	0	0
WA02-0020	Puget Sound	30	16	8
WA02-0021	remainder of WA	35	44	0
WA02-0022	Puget Sound	0	8	0
WA02-0023	Willapa Bay	100	96	100
WA02-0024	Puget Sound	100	92	125
WA02-0025	remainder of WA	100.5	100	0
WA02-0026	remainder of WA	80.5	72	90
WA02-0027	Willapa Bay	45	88	80
WA02-0028	Puget Sound	10	8	2
WA02-0032	Puget Sound	0	0	0
WA02-0035	Willapa Bay	4	48	10
WA02-0036	Puget Sound	0	0	0
WA02-0037	remainder of WA	1	8	0
WA02-0039	Willapa Bay	50	60	50
WA02-0040	Puget Sound	30	16	40
WA02-0041	remainder of WA	75	8	15
WA02-0043	Willapa Bay	100	100	100
WA02-0044	Puget Sound	75	32	60
WA02-0045	remainder of WA	10	32	0
WA02-0046	Puget Sound	0	0	0
WA02-0048	Puget Sound	0	0	0
WA02-0049	Willapa Bay	18	12	3
WA02-0050	Willapa Bay	0	28	0
WA02-0051	Willapa Bay	0	0	0

EMAP Station ID	Stratum	Percent Cover		
		Plant Quadrat	Plant Transect	Benthos Quadrat
WA02-0052	Puget Sound	28	8	20
WA02-0054	Puget Sound	25	24	15
WA02-0056	Puget Sound	1	8	0
WA02-0059	Willapa Bay	20	56	5
WA02-0060	Puget Sound	100	72	100
WA02-0061	Willapa Bay	0.5	16	25
WA02-0062	Puget Sound	15	20	30
WA02-0064	Puget Sound	0	20	0
WA02-0065	Willapa Bay	0	0	0
WA02-0066	Willapa Bay	85	100	98
WA02-0067	Willapa Bay	45	64	10
WA02-0068	Puget Sound	65	80	75
WA02-0070	Willapa Bay	100	92	100
WA02-0071	Willapa Bay	80	72	75
WA02-0072	Puget Sound	0	0	0
WA02-0075	Willapa Bay	2	0	1
WA02-0078	Willapa Bay	100	96	65
WA02-0087	Willapa Bay	20	80	60
WA02-0091	Willapa Bay	60	52	60
WA02-0102	Willapa Bay	45	52	50
WA02-0123	Willapa Bay	0	0	5
WA02-0127	Willapa Bay	75	68	67
WA02-0143	Willapa Bay	3	8	0

Table E-3. Vegetation maximum plant length by station (2002).

EMAP Station ID	Plant Species	Plant Quadrat Maximum Plant Length (cm)		Transect Maximum Plant Length (cm)	
		Mean	Maximum	Mean	Maximum
WA02-0002	*Zostera japonica*	38	38	–	–
WA02-0003	*Zostera japonica*	97	157	–	–
WA02-0004	*Zostera japonica*	27	27	–	–
WA02-0005	*Zostera marina*	78	78	78	78
WA02-0007	*Zostera marina*	52.5	84	–	–
WA02-0017	*Zostera japonica*	7	7	–	–
WA02-0020	*Zostera marina*	29	29	15	15
WA02-0023	*Zostera japonica*	25	25	–	–
WA02-0024	*Ulva* sp.	–	–	32	32
	Zostera japonica	35	35	–	–
WA02-0026	*Zostera marina*	90	90	154	154
WA02-0027	*Zostera japonica*	17	17	–	–
WA02-0037	*Enteromorpha linza*	40	40	–	–
WA02-0039	*Spartina alterniflora*	185	185	–	–
WA02-0040	*Zostera japonica*	18	18	18	18
WA02-0043	*Zostera japonica*	16	16	–	–
WA02-0049	*Zostera marina*	98	98	–	–
WA02-0050	*Zostera marina*	–	–	100	100
WA02-0054	*Zostera japonica*	15	15	–	–
WA02-0056	*Enteromorpha linza*	–	–	200	200
WA02-0059	*Zostera marina*	40	60	–	–
WA02-0060	*Zostera marina*	119	119	–	–
WA02-0062	*Enteromorpha* sp.	–	–	1	1
	Ulvoid sp.	2	2	–	–
WA02-0064	*Juncus gerardii*	–	–	20	20
WA02-0068	*Zostera japonica*	19	19	18	18
WA02-0070	*Zostera marina*	69	108	–	–
WA02-0071	*Zostera marina*	115	115	–	–
WA02-0087	*Zostera japonica*	38	38	–	–
WA02-0091	*Spartina alterniflora*	188	188	–	–
WA02-0102	*Zostera japonica*	12	12	12	12
WA02-0127	*Zostera marina*	37	54	–	–

Table E-4. Vegetation dry biomass (g/0.25 m^2) by station (2002).

EMAP Station ID	*Cladophora* sp.	*Enteromorpha linza*	*Enteromorpha prolifera*	*Enteromorpha* sp.	*Fucus gardneri*	*Gracilaria* sp.	*Spartina alterniflora*	*Ulvoid* sp.	*Ulva* sp.	*Zostera japonica*	*Zostera marina*
WA02-0002	–	–	–	–	–	–	–	–	–	16.84	–
WA02-0003	–	–	–	–	–	–	92.95	–	–	1.08	–
WA02-0004	–	–	–	12.73	–	–	–	–	–	1.92	–
WA02-0005	–	0.15	60.95	–	–	–	–	–	–	–	2.2
WA02-0006	–	–	–	–	–	–	–	–	–	–	–
WA02-0007	–	–	–	–	–	–	–	–	–	15.62	7.56
WA02-0010	–	–	–	–	–	–	–	–	–	–	–
WA02-0011	–	–	–	–	–	–	–	–	–	–	–
WA02-0012	–	–	0.78	–	–	–	–	–	–	–	–
WA02-0014	–	–	15.15	–	–	–	–	–	–	–	–
WA02-0016	–	–	–	0.07	–	–	–	–	–	–	–
WA02-0017	–	–	–	–	–	–	–	–	–	0.28	–
WA02-0018	–	–	–	5.18	–	–	–	–	–	–	–
WA02-0019	–	–	–	–	–	–	–	–	–	–	–
WA02-0020	–	–	–	–	–	–	–	–	–	–	6.19
WA02-0021	–	–	–	9.87	–	–	–	0.58	–	–	–
WA02-0022	–	–	–	–	–	–	–	–	–	–	–
WA02-0023	–	–	–	–	–	–	–	–	–	28.53	–
WA02-0024	–	–	–	–	–	–	–	–	–	89.91	–
WA02-0025	–	38.7	–	–	–	–	–	21.17	–	–	–
WA02-0026	–	1.47	0.41	–	–	–	–	7.1	–	–	10
WA02-0027	–	–	–	–	–	–	–	–	–	20	–
WA02-0028	–	1.55	–	–	–	–	–	–	–	–	–
WA02-0032	–	–	–	–	–	–	–	–	–	–	–
WA02-0035	–	–	–	0.09	–	–	–	–	–	–	–
WA02-0036	–	–	–	–	–	–	–	–	–	–	–
WA02-0037	–	0.22	–	–	–	–	–	–	–	–	–
WA02-0039	–	–	–	–	–	–	252.69	–	–	–	–
WA02-0040	–	–	–	–	–	–	–	3.62	–	0.71	–
WA02-0041	–	4.38	4.82	–	–	–	–	8.39	–	–	–
WA02-0043	–	–	–	–	–	–	–	–	–	42	–
WA02-0044	–	–	–	–	–	–	–	–	26.38	–	–
WA02-0045	0.23	–	–	–	–	–	–	–	2.09	–	–
WA02-0046	–	–	–	–	–	–	–	–	–	–	–
WA02-0048	–	–	–	–	–	–	–	–	–	–	–
WA02-0049	–	–	–	–	–	–	–	–	–	–	0.9
WA02-0050	–	–	–	–	–	–	–	–	–	–	–

EMAP Station ID	*Cladophora* sp.	*Enteromorpha linza*	*Enteromorpha prolifera*	*Enteromorpha* sp.	*Fucus gardneri*	*Gracilaria* sp.	*Spartina alterniflora*	*Ulvoid* sp.	*Ulva* sp.	*Zostera japonica*	*Zostera marina*
WA02-0051	–	–	–	–	–	–	–	–	–	–	–
WA02-0052	–	–	–	–	–	–	–	–	7.17	–	–
WA02-0054	–	–	1.83	–	–	–	–	–	–	0.71	–
WA02-0056	–	–	–	–	–	–	–	–	–	–	–
WA02-0059	–	–	–	–	–	–	–	–	–	2.2	1.59
WA02-0060	–	–	–	8.68	–	–	–	–	–	–	44.48
WA02-0061	–	–	–	–	–	–	–	–	–	–	–
WA02-0062	–	–	–	–	–	–	–	–	–	–	–
WA02-0064	–	–	–	–	–	–	–	–	–	–	–
WA02-0065	–	–	–	–	–	–	–	–	–	–	–
WA02-0066	15.83	–	–	–	–	–	–	–	–	–	–
WA02-0067	–	–	–	–	–	–	–	–	–	–	–
WA02-0068	–	–	–	–	–	–	–	–	–	8.27	–
WA02-0070	–	–	–	–	–	–	–	–	–	1.87	43.2
WA02-0071	–	–	–	–	–	–	–	–	–	–	19.22
WA02-0072	–	–	–	–	–	–	–	–	–	–	–
WA02-0075	–	–	–	–	0.41	0.01	–	–	–	–	–
WA02-0078	9.35	–	–	–	–	–	–	–	–	–	–
WA02-0087	–	–	–	–	–	–	–	–	–	2.04	–
WA02-0091	–	–	–	–	–	–	539.92	–	–	–	–
WA02-0102	–	–	–	–	–	–	–	–	–	2.83	–
WA02-0123	–	–	–	–	–	–	–	–	–	–	–
WA02-0127	–	–	–	–	–	–	–	–	–	7.69	6.68
WA02-0143	–	–	–	0.08	–	–	–	–	–	–	–

Table E-5. Occurrence of shrimp burrows in burrow-count quadrat, by species (2002).

EMAP Station ID	Stratum	*Crangon* sp.	*Neotrypaea* sp.	*Upogebia pugettensis*	Unknown species	No shrimp present
WA02-0002	Willapa Bay	–	7	–	–	–
WA02-0003	Willapa Bay	–	–	–	–	0
WA02-0004	Puget Sound	–	–	–	–	0
WA02-0005	remainder of WA	–	11	–	–	–
WA02-0006	Puget Sound	–	–	–	17	–
WA02-0007	Willapa Bay	–	–	–	–	0
WA02-0010	Puget Sound	–	–	–	10	–
WA02-0011	Willapa Bay	–	8	–	–	–
WA02-0012	Puget Sound	–	6	–	–	–
WA02-0014	Puget Sound	–	16	–	–	–
WA02-0016	Puget Sound	–	–	–	1	–
WA02-0017	Willapa Bay	–	–	–	7	–
WA02-0018	Willapa Bay	–	–	–	6	–
WA02-0019	Willapa Bay	–	27	–	–	–
WA02-0020	Puget Sound	–	–	–	–	0
WA02-0021	remainder of WA	–	7	–	–	–
WA02-0022	Puget Sound	–	25	–	–	–
WA02-0023	Willapa Bay	–	–	–	7	–
WA02-0024	Puget Sound	–	–	–	–	0
WA02-0025	remainder of WA	–	10	–	–	–
WA02-0026	remainder of WA	–	–	5	–	–
WA02-0027	Willapa Bay	–	–	–	–	0
WA02-0028	Puget Sound	–	–	–	–	0
WA02-0032	Puget Sound	–	–	–	–	0
WA02-0035	Willapa Bay	–	–	–	34	–
WA02-0036	Puget Sound	–	–	–	–	0
WA02-0037	remainder of WA	–	–	–	12	–
WA02-0039	Willapa Bay	–	–	–	–	0
WA02-0040	Puget Sound	–	–	–	1	–
WA02-0041	remainder of WA	–	–	–	–	0
WA02-0043	Willapa Bay	–	2	–	–	–
WA02-0044	Puget Sound	–	–	–	–	0
WA02-0045	remainder of WA	–	–	1	–	–
WA02-0046	Puget Sound	–	–	–	–	0
WA02-0048	Puget Sound	–	–	–	1	–
WA02-0049	Willapa Bay	–	–	–	11	–
WA02-0050	Willapa Bay	–	–	2	–	–
WA02-0051	Willapa Bay	–	–	–	57	–
WA02-0052	Puget Sound	–	–	–	–	0
WA02-0054	Puget Sound	1	–	–	–	–
WA02-0056	Puget Sound	–	–	–	3	–

EMAP Station ID	Stratum	*Crangon* sp.	*Neotrypaea* sp.	*Upogebia pugettensis*	Unknown species	No shrimp present
WA02-0059	Willapa Bay	–	–	–	24	–
WA02-0060	Puget Sound	–	–	–	–	0
WA02-0061	Willapa Bay	–	–	32	–	–
WA02-0062	Puget Sound	–	–	–	–	0
WA02-0064	Puget Sound	–	–	–	–	0
WA02-0065	Willapa Bay	–	–	–	–	0
WA02-0066	Willapa Bay	–	–	–	–	0
WA02-0067	Willapa Bay	–	38	–	–	–
WA02-0068	Puget Sound	–	–	–	–	0
WA02-0070	Willapa Bay	–	–	–	–	0
WA02-0071	Willapa Bay	–	–	–	6	–
WA02-0072	Puget Sound	–	–	–	2	–
WA02-0075	Willapa Bay	–	–	–	–	0
WA02-0078	Willapa Bay	–	–	–	–	0
WA02-0087	Willapa Bay	–	–	–	–	0
WA02-0091	Willapa Bay	–	–	–	–	0
WA02-0102	Willapa Bay	–	–	–	13	–
WA02-0123	Willapa Bay	–	–	–	42	–
WA02-0127	Willapa Bay	–	–	–	2	–
WA02-0143	Willapa Bay	–	5	–	–	–

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Appendix F. Epibenthos (Subtidal)

Table F-1: Epibenthic invertebrates caught in trawls, 2000

Table F-1: Epibenthic invertebrates caught in trawls (2000).

Station	EMAP Station ID	Species	Abundance	Comments
7	WA00-0001	*Cancer magister*	1	
		Pycnopodia helianthoides	1	sunflower star
		Tunicata	1	tunicate, not specified
12	WA00-0002	*Crangon*	4	crangonid shrimp
		Pandalus danae	1	coon-stripe shrimp
17	WA00-0003	Asteroidea	2	starfish, not specified
		Cancer magister	185	
		Cancer productus	2	
		Pugettia producta	5	kelp crab
29	WA00-0004	Asteroidea	20	starfish, not specified
		Crangon	4	crangonid shrimp
		Metridium	1	
		Natantia	1	shrimp, not specified
38	WA00-0005	*Cancer magister*	100	
		Nudibranchia	5	nudibranch, not specified
		Ophiopholis aculeata	30	daisy brittle star
		Scyphozoa	10	jellyfish, not specified
42	WA00-0006	*Cancer magister*	8	
50	WA00-0007	*Cancer magister*	9	
		Crangon	15	crangonid shrimp
		Ophiopholis aculeata	10	daisy brittle star
		Pugettia producta	2	kelp crab
51	WA00-0008	*Cancer gracilis*	10	
		Cancer magister	350	
		Holothurioidea	3	sea cucumber, not specified
		Pycnopodia helianthoides	1	sunflower star
66	WA00-0009	*Cancer magister*	4	
		Crangon	40	crangonid shrimp
69	WA00-0010	*Cancer gracilis*	4	
		Cancer magister	8	
		Echinoidea	1	sea urchin, not specified
71	WA00-0011	Cephalopoda	1	squid, not specified
		Crangon	50	crangonid shrimp
76	WA00-0012	Anthozoa	1	sea anemone, not specified
		Cancer magister	9	
		Crangon	4	crangonid shrimp
		Munida quadrispina	4	squat lobster, AKA Galatheid crab
		Pandalus stenolepis	5	Rough patch shrimp
		Pycnopodia helianthoides	1	sunflower star
85	WA00-0013	*Cancer magister*	11	
		Crangon	21	crangonid shrimp
		Metridium	5	
		Pandalopsis dispar	67	sidestripe shrimp
		Pandalus platyceros	1	spot shrimp

Station	EMAP Station ID	Species	Abundance	Comments
		Pandalus sp	300	pink shrimp
		Scyphozoa	5	jellyfish, not specified
90	WA00-0014	*Pandalus danae*	5	coon-stripe shrimp
107	WA00-0015	Anthozoa	4	sea anemone, not specified
		Heptacarpus	1	broken back shrimp
		Oxyrhyncha	4	decorator crab, unspecified
		Pandalus danae	1000	coon-stripe shrimp
		Tunicata	60	tunicate, not specified
112	WA00-0016	*Armina californica*	1	nudibranch, Armina sp.
		Cancer gracilis	3	
		Chlamys sp	1	pink scallop
		Cucumaria miniata	2	red sea cucumber
		Henricia	1	
		Oxyrhyncha	2	decorator crab, unspecified
		Pisaster	1	
		Solaster	1	
		Stichopus	3	red-brown sea cucumber, not specified
		Strongylocentrotus drobachiensis	1	green sea urchin
		Tritonia	3	
		Tunicata	50	tunicate, not specified
116	WA00-0017	No invertebrates caught in trawl	0	
118	WA00-0018	*Cancer magister*	2	
		Echinoidea	1	sea urchin, not specified
		Natantia	4	shrimp, not specified
		Pandalopsis dispar	1	sidestripe shrimp
		Pandalus platyceros	1	spot shrimp
		Solaster stimpsoni	1	Stimson's sun star
		Stichopus	1	red-brown sea cucumber, not specified
126	WA00-0019	*Cancer gracilis*	1	
145	WA00-0020	*Cancer gracilis*	5	
		Pugettia producta	3	kelp crab
179	WA00-0021	Anthozoa	1	sea anemone, not specified
		Asteroidea	10	starfish, not specified
		Crangon	2	crangonid shrimp
		Pycnopodia helianthoides	1	sunflower star
200	WA00-0022	*Cancer gracilis*	3	
		Crangon	4	crangonid shrimp
		Holothuroidea	1	sea cucumber, not specified
		Metridium	3	
207	WA00-0023	*Cancer gracilis*	5	
		Cancer productus	1	
		Crangon	1	crangonid shrimp
209	WA00-0024	*Cancer magister*	2	
		Pandalus platyceros	50	spot shrimp
		Pycnopodia helianthoides	1	sunflower star

Station	EMAP Station ID	Species	Abundance	Comments
214	WA00-0025	Anthozoa	10	sea anemone, not specified
		Asteroidea	10	starfish, not specified
		Cancer gracilis	50	
		Cancer magister	8	
		Cancer productus	1	
		Natantia	10	shrimp, not specified
218	WA00-0026	*Chionoecetes tanneri*	3	tanner crab
		Munida quadrispina	72	squat lobster, AKA Galatheid crab
220	WA00-0027	*Cancer magister*	4	
		Crangon	1	crangonid shrimp
		Ctenophora	100	comb jellies, not specified
		Munida quadrispina	1	squat lobster, AKA Galatheid crab
		Natantia	10	shrimp, not specified
		Pandalopsis dispar	4	sidestripe shrimp
		Scyphozoa	2	jellyfish, not specified
221	WA00-0028	Callianassidae	3	ghost shrimp, not specified
		Cancer magister	4	
		Crangon	3	crangonid shrimp
		Pandalopsis dispar	32	sidestripe shrimp
		Pandalus platyceros	3	spot shrimp
		Pandalus sp	6	pink shrimp
225	WA00-0029	Polychaeta	1000	polychaete. not specified
		Scyphozoa	20	jellyfish, not specified
226	WA00-0030	*Cancer magister*	5	
		Pandalopsis dispar	30	sidestripe shrimp
229	WA00-0031	Asteroidea	1	starfish, not specified
		Cancer gracilis	10	
		Crangon	15	crangonid shrimp
		Pandalus danae	1	coon-stripe shrimp, AKA dock shrimp
237	WA00-0032	Anthozoa	1	sea anemone, not specified
		Asteroidea	7	starfish, not specified
		Cancer gracilis	18	
		Crangon	2	crangonid shrimp
		Oxyrhyncha	23	decorator crab, unspecified
		Pugettia producta	11	kelp crab
		Pycnopodia helianthoides	6	sunflower star
243	WA00-0033	*Cancer gracilis*	10	
		Pugettia producta	1	kelp crab
252	WA00-0034	*Armina californica*	1	nudibranch, Armina sp.
		Cancer gracilis	2	
		Crangon	100	crangonid shrimp
		Metridium	10	
		Oxyrhyncha	1	decorator crab, unspecified
		Pandalus danae	200	coon-stripe shrimp
		Pandalus sp	1500	pink shrimp
		Yoldia limatula	1	

Station	EMAP Station ID	Species	Abundance	Comments
260	WA00-0035	Asteroidea	1	starfish, not specified
		Cancer magister	3	
		Cancer productus	1	
		Cephalopoda	1	squid, not specified
		Crangon	4	crangonid shrimp
		Metridium senile	2	
		Pandalus danae	2	coon-stripe shrimp, AKA dock shrimp
		Pandalus platyceros	2	spot shrimp
		Pandalus sp	58	pink shrimp
		Pycnopodia helianthoides	3	sunflower star
		Solaster stimpsoni	3	Stimson's sun star
268	WA00-0036	Ascidiacea	2	sea squirt, not specified
		Cancer gracilis	3	starfish, not specified
		Natantia	1	shrimp, not specified
		Pandalus danae	4	coon-stripe shrimp
		Pugettia producta	3	kelp crab
		Pycnopodia helianthoides	1	sunflower star
269	WA00-0037	*Cancer gracilis*	10	
		Cancer productus	1	
		Dermasterias imbricata	1	leather star
		Holothuroidea	25	sea cucumber, not specified
		Metridium senile	6	
		Pandalus danae	1	coon-stripe shrimp, AKA dock shrimp
		Pugettia producta	11	kelp crab
273	WA00-0038	*Crangon*	2	crangonid shrimp
		Octopoda	1	octopus, not specified
		Pisaster	3	
		Pycnopodia helianthoides	1	sunflower star
274	WA00-0039	*Cancer magister*	1	
		Cancer productus	6	
		Cephalopoda	1	squid, not specified
		Fusitriton oregonsis	1	Oregon hairy triton
		Metridium	150	
		Pandalus danae	10	coon-stripe shrimp, AKA dock shrimp
		Pandalus sp	10	pink shrimp
		Polinices lewisii	1	moon snail
		Pycnopodia helianthoides	10	sunflower star
		Solaster dawsoni	4	Morning sun star
		Solaster stimpsoni	2	Stimson's sun star
		Strongylocentrotus drobachiensis	1	green sea urchin
286	WA00-0040	Asteroidea	15	starfish, not specified
		Cancer magister	2	
		Metridium	9	
		Pandalopsis dispar	7	sidestripe shrimp
		Pandalus sp	4	pink shrimp

Station	EMAP Station ID	Species	Abundance	Comments
304	WA00-0041	*Cancer gracilis*	8	
		Cancer productus	3	
		Metridium	2	
		Pugettia producta	3	kelp crab
		Pycnopodia helianthoides	1	sunflower star
E01	WA00-0042	Anthozoa	25	sea anemone, not specified
		Cancer productus	1	
		Crangon	3	crangonid shrimp
		Luidia foliolata	2	
		Pandalus danae	516	coon-stripe shrimp
		Pycnopodia helianthoides	5	sunflower star
		Scyphozoa	50	jellyfish, not specified
		Solaster	1	
E02	WA00-0043	Cephalopoda	8	squid, not specified
		Chionoecetes tanneri	1	tanner crab
		Crangon	1	crangonid shrimp
		Gastropoda	3	gastropod. not specified
		Pandalus danae	1	
		Pisaster	1	
E04	WA00-0045	Asteroidea	2	starfish, not specified
		Cancer magister	12	
		Gastropoda	3	gastropod. not specified
		Natantia	4	shrimp, not specified
		Pandalus sp	2	
E05	WA00-0046	Anthozoa	1	sea anemone, not specified
		Asteroidea	1	starfish, not specified
		Crangon	1	crangonid shrimp
		Pugettia producta	2	kelp crab
E06	WA00-0047	*Cancer magister*	2	
		Luidia foliolata	2	
		Natantia	4	shrimp, not specified
		Pandalopsis dispar	5	sidestripe shrimp
		Pandalus sp	2	pink shrimp
E07	WA00-0048	Anthozoa	22	sea anemone, not specified
		Cancer magister	15	
		Chrysaora	1	
		Coenobitoidea	1	hermit crab, not specified
		Luidia foliolata	2	
		Pandalus danae	3	
		Pandalus sp	540	
		Parastichopus californicus	1	
E08	WA00-0049	*Aeolidia papillosa*	1	
		Anthozoa	3	sea anemone, not specified
		Crossaster	3	sun star, not specified
		Luidia foliolata	1	
		Octocorallia	10	sea whip, not specified
		Pandalopsis dispar	30	sidestripe shrimp

Station	EMAP Station ID	Species	Abundance	Comments
		Pandalus danae	2	
		Pandalus platyceros	7	spot shrimp
		Pandalus sp	53	
		Pycnopodia	1	
		Scyphozoa	10	jellyfish, not specified
E09	WA00-0050	*Pisaster*	1	
		Pugettia producta	1	kelp crab
		Pycnopodia helianthoides	1	sunflower star
E10	WA00-0051	Anthozoa	1	sea anemone, not specified
		Ascidiacea	1	sea squirt, not specified
		Asteroidea	2	starfish, not specified
		Cancer magister	1	
		Ceratostoma foliatum	1	leafy hornmouth whelk
		Coenobitoidea	1	hermit crab, not specified
		Crangon	1	crangonid shrimp
		Gorgonocephalus caryi	2	basket star
		Nudibranchia	1	nudibranch, not specified
		Pandalus sp	11	pink shrimp
		Paracrangon echinata	1	
		Pectinidae	6	scallop, unspecified
		Porifera	1	sponge, unspecified
		Pteraster	2	
		Strongylocentrotus drobachiensis	2	green sea urchin
E12	WA00-0053	Coenobitoidea	1	hermit crab, not specified
		Crangon	1	crangonid shrimp
		Natantia	1	shrimp, not specified
		Pandalus sp	1	pink shrimp
		Pectinidae	59	scallop, unspecified
		Strongylocentrotus drobachiensis	15	green sea urchin
E13	WA00-0054	Amphipoda	2	
		Cancer magister	4	
		Crangon	1	crangonid shrimp
		Isopoda	4	
		Luidia foliolata	1	
		Opisthobranchia	1	
		Pandalus danae	4	coon-stripe shrimp
		Pycnopodia helianthoides	3	sunflower star
		Scutellidae	5	sand dollars, unspecified
E14	WA00-0055	Ascidiacea	1	sea squirt, not specified
		Cancer magister	13	
		Chaetopoda	4	tube worms, unspecified
		Crangon	3	crangonid shrimp
		Heptacarpus	1	broken back shrimp
		Oxyrhyncha	3	decorator crab, unspecified
		Pandalus danae	98	coon-stripe shrimp
		Pandalus sp	57	pink shrimp
		Stichopus	1	

Station	EMAP Station ID	Species	Abundance	Comments
E15	WA00-0056	*Cancer gracilis*	1	
		Cancer magister	5	
		Crangon	1	crangonid shrimp
		Cryptochiton stelleri	1	giant chiton
		Heptacarpus	2	broken back shrimp
		Oxyrhyncha	10	decorator crab, unspecified
		Pandalus danae	21	coon-stripe shrimp
		Phyllochaetopterus prolifica	1	
E17	WA00-0058	Ascidiacea	1	sea squirt, not specified
		Cancer gracilis	1	
		Oxyrhyncha	5	decorator crab, unspecified
		Strongylocentrotus drobachiensis	1	green sea urchin
E18	WA00-0059	*Balanus balanus*	4	giant barnacle
		Crangon	1	crangonid shrimp
		Natantia	27	shrimp, not specified
		Pectinidae	1	scallop, unspecified
		Pycnopodia helianthoides	1	sunflower star
		Strongylocentrotus drobachiensis	2	green sea urchin
E19	WA00-0060	*Cancer magister*	4	
		Crangon	7	crangonid shrimp
		Oxyrhyncha	4	decorator crab, unspecified
		Pandalus danae	50	coon-stripe shrimp
E21	WA00-0062	Ascidiacea	2	sea squirt, not specified
		Cancer gracilis	2	
		Coenobitoidea	2	hermit crab, not specified
		Crangon	1	crangonid shrimp
		Henricia	2	
		Heptacarpus	5	broken back shrimp
		Lottiidae	2	limpet, unspecified
		Oxyrhyncha	23	decorator crab, unspecified
		Pandalus danae	75	coon-stripe shrimp
		Parastichopus californicus	3	
		Pectinidae	6	scallop, unspecified
		Phyllochaetopterus prolifica	1	
		Sabellaria	1	
E22	WA00-0063	Ascidiacea	1	sea squirt, not specified
		Cancer productus	2	
		Oxyrhyncha	53	decorator crab, unspecified
		Pandalus danae	101	coon-stripe shrimp
		Parastichopus californicus	1	
		Pectinidae	1	scallop, unspecified
		Polychaeta	2	polychaete. not specified
		Porifera	1	sponge, unspecified
		Pugettia producta	4	kelp crab
		Pycnopodia	1	
E25	WA00-0066	Asteroidea	1	starfish, not specified
		Cancer magister	1	

Station	EMAP Station ID	Species	Abundance	Comments
		Pandalopsis dispar	700	sidestripe shrimp
		Pandalus sp	1000	pink shrimp
		Pugettia producta	1	kelp crab
E26	WA00-0067	*Chlamys* sp	36	pink scallop
		Fusitriton	12	
		Henricia leviuscula	1	
		Heptacarpus	6	broken back shrimp
		Orthasterias koehleri	1	
		Pandalus danae	75	coon-stripe shrimp
		Pandalus sp	1	pink shrimp
		Porifera	1	sponge, unspecified
		Solaster dawsoni	1	Dawson's sun star
		Strongylocentrotus drobachiensis	23	green sea urchin
E27	WA00-0068	*Chlamys* sp	38	pink scallop
		Cirripidea	20	barnacles, not specified
		Cucumaria miniata	1	red sea cucumber
		Gastropoda	1	whelk, not specified
		Heptacarpus	6	broken back shrimp
		Nudibranchia	1	nudibranch, not specified
		Oxyrhyncha	1	decorator crab, unspecified
		Pandalus danae	75	coon-stripe shrimp
		Pteraster tesselatus	1	slime star
		Solaster dawsoni	2	Dawson's sun star
		Strongylocentrotus drobachiensis	5	green sea urchin
E28	WA00-0069	*Cancer productus*	2	
		Cephalopoda	1	squid, not specified
		Pycnopodia	1	
		Strongylocentrotus drobachiensis	2	green sea urchin
		Strongylocentrotus purpuratus	1	purple sea urchin
		Triopha catalinae	1	sea clown nudibranch
E29	WA00-0070	*Balanus balanus*	1	giant barnacle
		Cancer magister	1	
		Chlamys sp	1	pink scallop
		Strongylocentrotus drobachiensis	1	green sea urchin
E30	WA00-0071	No invertebrates caught in trawl	0	

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Appendix G. Data Tables and Graphical Summaries, 2000

This appendix is available only on the web and on CD

Appendix H. Data Tables and Graphical Summaries, 2002

This appendix is available only on the web and on CD

Appendix I. Data Tables and Graphical Summaries, 2003

This appendix is available only on the web and on CD