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Puget Sound Assessment and Monitoring Program

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State of Washington

Sediment Quality Assessment of the Bays and Inlets of the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet, 2002-2003

Spatial/Temporal Sediment Monitoring Element of the *Puget Sound Assessment and Monitoring Program*

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For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6764

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Cover photo: The Department of Ecology's Marine Sediment Monitoring Team sampling in the eastern Strait of Juan de Fuca (*photos courtesy of Charles M. Eaton, Bio Marine Enterprises*)

Sediment Quality Assessment of the Bays and Inlets of the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet, 2002-2003

Spatial/Temporal Sediment Monitoring Element of the *Puget Sound Assessment and Monitoring Program*

by
Edward Long, Sandra Aasen, Margaret Dutch,
Kathy Welch, and Valerie Partridge

Western Operations Section
Environmental Assessment Program
Washington State Department of Ecology
PO Box 47600
Olympia, WA 98504-7710

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Glossary and Acronyms

Glossary

Amphipod – a type of small, sediment-dwelling crustacean.

Assemblage – a group of organisms collected from the same location.

Benthic – bottom.

Benthic infauna (or **benthos**) – tiny sediment-dwelling invertebrates, including a wide variety of organisms that live on or in marine sediments.

Biota – animals.

Degree of response – in chemical and toxicity testing, the magnitude of the response, e.g., the percent normal in a sample or group of samples, percent survival, percent fertilization, or the Microtox EC50 photic response.

Demersal – living near the bottom.

Echinoderm – a group of invertebrates including brittle stars, sea urchins, and sea cucumbers.

Histopathology – the microscopic study of body tissues (e.g., muscle, organs), especially of abnormal tissue as a result of disease.

Incidence – for chemical contamination, toxicity, or the Sediment Quality Triad, the number and percentage of samples indicating a response.

Invertebrates – animals without backbones (e.g., crustaceans, worms, clams).

Occurrence – in toxicity testing, the presence or absence of a toxic response.

Pore water – the water filling the spaces between grains of sediment.

Spatial extent – for chemical contamination, toxicity, or the Sediment Quality Triad, the areal extent, in km^2, and percentage of total study area affected.

Surficial – relating to or occurring on a surface.

Taxa, taxon – lowest level of identification for organisms.

Taxa richness – number of different taxa.

Acronyms and Abbreviations

BCRI	BC Research Institute
BNA	Base/neutral/acid organic compounds
Cd	Cadmium
CL	Confidence limit
CSL	Cleanup screening levels

EC50	Median Effective Concentration (concentration required to induce a toxic response in 50% of the test population)
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERL	Effects range low
ERM	Effects range median
GRTS	Generalized random tessellation stratified
MEL	Manchester Environmental Laboratory
NOAA	National Oceanic and Atmospheric Administration
NOEC	No observed effect concentration
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyls
PSAMP	Puget Sound Assessment and Monitoring Program
PSEP	Puget Sound Estuary Program
SD	Standard deviation
SDS	Sodium dodecyl sulfate
SOP	Standard operation procedure
SQS	Sediment Quality Standards
USGS	U.S. Geological Survey

Abstract

The Washington State Department of Ecology conducted a sediment quality survey in the bays and inlets of the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet in 2002 and 2003. This survey was part of the Puget Sound Assessment and Monitoring Program. Characterization of sediment quality in these three regions completes the 1997-2003 eight-region, Puget Sound-wide sediment quality data baseline.

Sediment samples were collected and analyzed for 30 stations in each of the three regions. The Sediment Quality Triad of chemistry, toxicity, and sediment-dwelling invertebrate community structure (benthos) measured for each sample indicated that:

- Two samples had levels of chemical contaminants (one per station) which exceeded the Washington State Sediment Quality Standards.
- The incidence and spatial extent of toxic response generally were highest in the Eastern Strait of Juan de Fuca, lower in the San Juan Islands, and lowest in Admiralty Inlet.
- The highest number of stations with affected benthos occurred in the San Juan Islands, followed by the Eastern Strait of Juan de Fuca. The lowest number occurred in Admiralty Inlet.

Ecology's Sediment Quality Triad Index was calculated for each station, and then used to estimate the incidence and spatial extent of sediment quality degradation for each region. Findings indicated that:

- Highest sediment quality was measured in Admiralty Inlet (67% of area).
- The majority of the sediments measured in the San Juan Islands and the Eastern Strait of Juan de Fuca (70 and 71% of each area, respectively) were of intermediate quality.
- No sediments were of degraded quality in any of the three regions.

Periodic re-evaluation of regional sediment quality, using the Sediment Quality Triad Index and the spatial extent calculations derived from them, provides environmental managers with a measure of change over time useful in adaptive management.

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Executive Summary

During 2002 and 2003, the Washington State Department of Ecology conducted a sediment quality survey in the bays and inlets of the San Juan Islands (Archipelago), eastern Strait of Juan de Fuca, and Admiralty Inlet. The goal of this survey was to provide a baseline assessment of the spatial extent and geographic patterns in relative sediment quality throughout the three regions against which any changes in quality could be evaluated in the future. The survey was part of the Puget Sound Assessment and Monitoring Program (PSAMP).

The study area encompassed 212 km^2, which was distributed about equally among the three regions. Thirty randomly selected stations were sampled in each region for a total of 90 samples. All three regions were sampled in 2002 and again in 2003, and the data from the two years were merged. Admiralty Inlet was previously sampled in 1998, and data from that survey were merged with those obtained during 2002-03.

Analyses were performed on all samples to determine the concentrations of potentially toxic chemicals, the degree of response in four laboratory toxicity tests, and the composition of the resident benthos. These three measures represent the components of the Sediment Quality Triad (Long and Chapman, 1985). Most methods were similar to those used by Ecology in 1997 through 1999 during surveys of adjoining regions of Puget Sound, thus assuring that the data are comparable (Long, et al., 1999; 2000a; 2002).

Chemical Contamination

Laboratory analyses were performed for over 120 chemicals and sediment properties. None of the chemical concentrations were higher than the national Effects Range Median (ERM) sediment quality guideline values in any of the 90 samples. In contrast, there were 42 samples in which one or more of the Washington State Sediment Quality Standards were exceeded. However, the chemicals (phenol, 2-methylphenol, 4-methylphenol, benzoic acid, benzyl alcohol) that exceeded these standards in 40 of the samples were chemicals for which the analytical data were least reliable. Therefore, they were omitted from further evaluations.

Based on the amended data set, there were only two samples out of the 90 in which any of the other State standards were exceeded. Thus, the incidence of chemical contamination was 2.2% of the 90 samples. These two samples were estimated to represent 3.6 km^2, equivalent to 1.7% of the total study area. There was one sample each from the San Juan Islands and eastern Strait of Juan de Fuca that were defined as contaminated with one chemical each. There were no contaminated samples from Admiralty Inlet. Therefore, the spatial extent of contamination as defined with these methods was 2.7 km^2 (3.3% of the area) in the San Juan Islands, 0.9 km^2 (1.4% of the area) in the eastern Strait of Juan de Fuca, and 0 km^2 in Admiralty Inlet. Di-n-butylphthalate was measured in the San Juan Islands, while fluoranthene was measured in the eastern Strait of Juan de Fuca.

There were no obvious or distinct spatial gradients or patterns in sediment contamination among adjacent or neighboring stations, although some of the samples collected in southern Port Townsend and in Port Angeles were among the more contaminated. Sediments from around the perimeter of the San Juan Islands and in Dungeness, Sequim, Discovery, and Mutiny Bays were among the least contaminated. The three regions surveyed in 2002 and 2003 were among the least contaminated of the eight monitoring regions that have been studied thus far in this program using internally consistent methods.

Toxicity

Sediment samples were tested with four laboratory toxicity tests, including:

1. Echinoderm embryo test in exposures to sediment/water mixtures.
2. Sea urchin egg fertilization test of pore water extracted from the sediments.
3. Microtox® bioluminescence test of pore water.
4. Amphipod survival test of solid phase sediments.

Each test was given equal weight in determining which samples were toxic. There were 30 samples (33%) in which at least one toxicity test response was statistically significant. These samples represented a total of 80 km^2 or about 38% of the total study area.

Both the incidence and spatial extent of toxicity were highest in the San Juan Islands and eastern Strait of Juan de Fuca regions and lowest in the Admiralty Inlet region. The samples in which toxicity was observed represented 33% of the region in the San Juan Islands, 59% of the eastern Strait of Juan de Fuca, and 23% of the Admiralty Inlet region.

The echinoderm embryo test and the sea urchin fertilization test were the most sensitive, followed by the Microtox® bioluminescence test. Only one sample was toxic in the amphipod survival test of solid phase sediments. Therefore, the spatial extent of toxicity throughout the study area was greatest in the echinoderm embryo and urchin fertilization tests, affecting 64 km^2 (30%) and 24 km^2 (11%), respectively. Samples that were toxic in the Microtox® tests and amphipod tests affected much smaller areas, 11 km^2 (5%) and 3 km^2 (1%), respectively. There was very little concordance or agreement among results of the four toxicity tests in the identification of toxic samples.

The incidence of toxicity and the degree of response among the four tests generally were highest in Sequim and Discovery Bays and in East Sound. In addition, some samples from Lopez Sound, Useless Bay, and Oak Bay were toxic in one or more tests. No single area stood out as being most toxic, although Sequim Bay was the only area in which all samples were toxic in at least one of the tests, and one sample from there was toxic in two tests. Otherwise, samples from most of the other bays and coves that were classified as toxic were usually accompanied by non-toxic samples from neighboring stations.

Among the least toxic bays and coves were Port Townsend, Oak Bay, Dungeness Bay, Port Angeles, and many of the small bays and coves off the southern San Juan Islands. Both the incidence and spatial extent of toxicity in the sea urchin fertilization test, which has been performed throughout all regions of Puget Sound, were relatively low in the San Juan Islands and Admiralty Inlet and slightly higher in the eastern Strait of Juan de Fuca as compared to the results in the other regions. However, when compared to equivalent results from other U.S. estuaries and marine bays nationwide, toxicity in these tests was relatively low in Puget Sound.

Benthic Community Composition

Most of the benthic invertebrates were identified to the species level and were species that commonly populate sediments throughout Puget Sound. The composition, abundance, and diversity of the benthic assemblages differed considerably among the 90 stations, indicating a wide variety of assemblages and habitat types. Total abundance differed by two orders of magnitude among stations, with as few as 16 animals in one sample and over 1000 in others. The diversity (numbers of species) of the benthos was most variable within the San Juan Islands region and on average considerably lower than in the other two regions. There were two samples in which only two species occurred and 18 samples with more than 100 species (maximum of 199).

Polychaete annelids often were the most abundant taxonomic group, followed by the molluscs and the arthropods. Echinoderms and miscellaneous taxa occurred less frequently than the other taxa in these samples. Usually there were 10 to 30 dominant species with a minimum of 1 and a maximum of 46.

Among the 90 stations, the benthos were classified, based on the best professional judgment of Ecology staff, as adversely affected in 37 stations: 20 in the San Juan Islands, 14 in the eastern Strait of Juan de Fuca, and 3 in Admiralty Inlet. Adversely affected benthos were found throughout all or most of East Sound, Lopez Sound, Sequim Bay, and Discovery Bay, whereas unaffected assemblages were apparent throughout most or all of Port Angeles, Dungeness Bay, Port Townsend, Useless Bay, and Mutiny Bay.

Sediment Quality Triad

After amending the chemical data to omit the results for the five organic compounds for which the data were least reliable, the sediments were classified as either degraded, intermediate/degraded, intermediate/high, or high quality by considering the triad of measures. This method was used previously to determine sediment quality in the other regions of Puget Sound (Long et al., 2003) and proved to be a useful approach to sediment classification based on a weight of evidence.

Based on the triad of measures (chemistry, toxicity, benthic impairment), there were no samples in the 2002-03 study that were classified as degraded; therefore, the incidence and spatial extent of degraded conditions was zero.

The majority of stations (73%) and area (69%) in the Admiralty Inlet region were classified as high quality. The majority of stations (70%) and area (70%) were classified as either of the two intermediate classifications in the San Juan Islands. In the eastern Strait of Juan de Fuca, most of the samples (60%) and most of the area (72%) were classified as intermediate in quality. The stations classified as intermediate in quality included some from Lopez Sound, East Sound, Sequim Bay, Discovery Bay, inner Port Angeles, Port Townsend, Oak Bay, and Useless Bay. However, there were no obvious and consistent spatial patterns in overall sediment quality. Stations classified as intermediate in quality invariably were surrounded by or were near other stations classified as high quality.

Comparisons between Puget Sound Sediment Monitoring Regions

The materials and methods used to sample, test, and classify samples in the 1997 to 1999 baseline PSAMP/NOAA surveys were similar to those used in the 2002 to 2003 surveys, but not identical in every case. The chemical and benthic data are very comparable, whereas some of the toxicity tests used in the two studies were different. Nevertheless, to put the 2002 to 2003 survey results into perspective, they were compared to those from the PSAMP/NOAA surveys.

Whereas 12% of the samples and 1% of the area sampled in 1997 to 1999 were degraded, none of the samples analyzed in the 2002 to 2003 surveys were classified as degraded. A minority of both the samples and of the combined area surveyed in 1997 through 1999 was classified as either of two intermediate categories, whereas the majority of samples and areas in the San Juan Islands and eastern Strait of Juan de Fuca were intermediate in quality. In contrast, a majority of Admiralty Inlet was classified as high quality, slightly more than in the combined 1997 to 1999 baseline surveys.

Relevance of the PSAMP Sediment Quality Data

Characterization of sediment quality in these three regions completes the 1997-2003 eight-region, Puget Sound-wide sediment quality data baseline. Periodic re-evaluation of regional sediment quality, using the Sediment Quality Triad Index and the spatial extent calculations derived from them, provides environmental managers with a measure of change over time useful in adaptive management.

Introduction

Project Background

Toxic substances introduced into estuarine ecosystems, such as Puget Sound, can bind to suspended particles, settle to the bottom, and become incorporated into deposited soft sediments (NRC, 1989). Sediments that have accumulated in low-energy, depositional zones where they are not disturbed by physical processes or other factors can provide a relatively stable record of toxicant inputs (Power and Chapman, 1992). As a result, sediments are an important medium in which to estimate the degree and history of chemical contamination of environmental regimes such as estuaries and bays. Although this sedimentation process tends to rid the water column of toxicants, their concentrations in sediments can increase to the point that the toxicants eventually represent a potential toxicological threat to the resident benthic biota (Burton, 1992).

Toxic chemicals occur in a wide range of concentrations in surficial (recently deposited) sediments of Puget Sound (Llansó et al., 1998). Previous studies in Puget Sound have shown that high concentrations of toxic chemicals in water, biota, and sediments often were accompanied by a variety of adverse biological effects (Long, 1987). In studies conducted during 1978 to 1990, it was determined that acute mortality occurred in toxicity tests of water samples (Cardwell et al., 1979), sea surface microlayer samples (Hardy et al., 1987a, b; PTI, 1990) and surficial sediments (Chapman et al., 1982, 1983, 1984a, b). In sediments from the industrial waterways of Commencement Bay, low amphipod abundance in the benthic samples was coincidental with low amphipod survival in toxicity tests and elevated chemical concentrations (Swartz et al., 1982).

Data from the Sediment Quality Triad of analyses (chemical analyses, toxicity tests, benthic analyses) verified previous observations that degraded conditions existed in portions of Elliott Bay near Seattle and Commencement Bay near Tacoma (Chapman et al., 1984b; Long and Chapman, 1985). Histopathology studies of demersal fishes indicated that pollution-related disorders, such as hepatic neoplasms, were found most frequently in association with contaminated sediments near industrialized urban areas of Puget Sound (Malins et al., 1982; Becker et al., 1987).

From 1997 through 1999, the Washington State Department of Ecology (Ecology) Marine Sediment Monitoring Program conducted a large-scale sediment quality assessment of Puget Sound. This assessment was part of the Puget Sound Ambient Monitoring Program (PSAMP), in partnership with the National Oceanic and Atmospheric Administration (NOAA). Through this partnership, sediment quality data were collected in three regions of Puget Sound (north, central, and south), but the sampling design did not include the San Juan Islands (Archipelago) and eastern Strait of Juan de Fuca (Long et al., 2003). Because of the presence of sources of toxicants (e.g., marinas, pulp mills, municipal sewage discharges), there is a potential for chemical contamination in these regions. Relative to the regions of Puget Sound near Everett, Seattle, and Tacoma, there is little sediment quality information with which to assess sediment quality in these regions.

Following the 1997-1999 PSAMP/NOAA survey, the annual PSAMP sediment monitoring program was redesigned, and the survey area was expanded to include the northern portion of Admiralty Inlet, and the bays and inlets of the San Juan Islands and eastern Strait of Juan de Fuca. Five regions were defined within the original 1997-1999 PSAMP/NOAA survey area. A sixth and seventh region were defined in the bays and inlets of the San Juan Islands and the eastern Strait of Juan de Fuca. An eighth region, defined for Admiralty Inlet, included some new survey area and some overlap with the 1997-1999 survey area (Figure 1). To complete baseline sediment monitoring for the expanded Puget Sound study area, Ecology conducted a survey of the three newly defined regions encompassing the bays and inlets of the San Juan Islands, the eastern Strait of Juan de Fuca, and Admiralty Inlet.

Site Description

The overall study area sampled during 2002 and 2003 encompassed approximately 229 km^2 and focused on three monitoring regions: the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet (Figure 2). The study area is located in northwestern Washington State bordered by Canada to the north and northwest, and by the Olympic Peninsula and mainland to the south, northeast, and east. The area is composed of glacially formed submarine valleys, channels and passages, river mouths, and interconnected shallow estuaries and bays.

The majority of the freshwater entering the study area comes from the Fraser River to the north. Smaller freshwater contributions are made by the Dungeness River and numerous small streams. The large size of the area and convoluted network of islands and shallow tidal passes – combined with a major year-round source of freshwater (the Fraser River), relatively large tidal range, and marked seasonal cycle in the prevailing winds – give rise to complex flow dynamics and water property structure (Thomson, 1994). The area is characterized by a stratified system with freshwater moving seaward, and saline water from the Pacific Ocean gradually flowing landward.

Natural habitats in this region are a complex mixture of physical, chemical, and biological systems that support major populations of invertebrates and marine plants, as well as resident and migratory fish, birds, and mammals. Minimal contamination is vital to the health and sustainability of these habitats. Yet a rapidly increasing human population, with accompanying industrial activity, subjects the region to escalating contaminant burdens from sewage, pulp mills, petroleum industry, atmospheric transport, agricultural and urban runoff, spills, and ocean dumping.

The San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet are major coastal waterways linking the ports of British Columbia and Washington State to the Pacific Ocean. In addition to heavy tanker and barge traffic, thousands of recreational boaters travel though the region annually creating a significant potential for pollution. Urban centers within the study area include the cities of Port Angeles, Port Townsend, and Friday Harbor.

Sediment Quality Related Research

A review of literature indicates that only a limited amount of work has been done on contaminants in marine sediments in the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet. Several chemicals of concern have been identified for the three regions. These chemicals include chromium, copper, lead, mercury, nickel, zinc, tributyltin, polycyclic aromatic hydrocarbons (PAH), benzyl alcohol, and phenol (e.g. EPA, 1988, Crecelius et al., 1989; Golding, 1997; Serdar et al., 2001).

With the exception of Port Angeles Harbor, the study area has relatively few known or suspected sources of toxic substances. Potential sources of contamination include pulp mills, sewage outfalls, marinas, maritime vessels, and petroleum-based industry.

Goals and Objectives

The overall goals of the sediment monitoring component of the PSAMP are to:

1. Assess the health of Puget Sound sediments and document geographic patterns in the condition of the sediments on a regional scale.
2. Document natural and human-caused changes over time in Puget Sound sediments.
3. Identify existing sediment problems and, where possible, provide data to help target in-depth point (discrete) and nonpoint (diffuse) source investigations.
4. Provide sediment data to assist environmental managers and others in measuring the success of environmental programs.
5. Support sediment-related research activities by making available scientifically valid sediment quality data.

This study was designed to satisfy a specific set of programmatic goals and technical objectives. Therefore, methods were selected that were not necessarily the same as those frequently used in enforcement or other regulatory decisions. Rather, methods were selected that best met the goals and technical objectives of the monitoring program.

Specific objectives of the 2002 through 2003 survey were the same as those adopted for the previous surveys conducted during 1997 through 1999:

1. Determine the incidence and severity of toxicity, chemical contamination, and benthic impairment of sediments (i.e., the number and percent of stations with sediment quality degradation).
2. Describe the composition, abundance, and diversity of benthic infaunal assemblages at each sampling location.
3. Identify spatial patterns and gradients in sediment toxicity, chemical concentrations, and degree of benthic impairment as defined with the selected methods.

4. Estimate the spatial extent of toxicity, chemical contamination, and benthic impairment, as defined with the selected methods, in surficial sediments as km^2 and percentages of the total survey area.
5. Determine the spatial patterns and extent of degraded conditions based on a weight of evidence formed with the triad of measures.

The primary intent of these sediment quality surveys is to provide a basis for measuring long-term trends and changes in sediment quality in Puget Sound, using the best available scientific principles and methods. With the surveys completed in 2002 to 2003, all eight of the monitoring regions in the Sound have now been sampled and tested for sediment quality at least once using similar, internally consistent methods. The aim of the program is to re-sample and test each region on a 10-year cycle.

Methods

Sampling Design

Ecology conducted sediment sampling in 2002 and 2003 in the bays and inlets of the San Juan Islands, the eastern Strait of Juan de Fuca, and portions of Admiralty Inlet not previously sampled for the PSAMP program. The sampling was to complete the baseline of Puget Sound sediment quality data collected through the PSAMP/NOAA partnership in 1997 through 1999 (Long et al., 2003).

The stratified-random sampling design that was used for the 1997-1999 PSAMP/NOAA baseline sediment surveys was modified slightly with assistance from the U.S. Environmental Protection Agency (EPA) Monitoring Design and Analysis Team statisticians in Corvallis, Oregon. The 1997-1999 stratum boundaries, along with new sampling areas, were merged into 8 new monitoring regions (Figure 1), three of which were sampled in 2002-2003 (Figure 2). Areas of ≤ 1 fathom were excluded from the sampling area. Several of the toxicity tests selected for the 2002-2003 survey differed from those used previously. Sample collection and analytical methods followed the Puget Sound Estuary Program (PSEP) Protocols (www.psparchives.com/our_work/science/protocols.htm) as much as possible to ensure compatibility with data from previous studies.

The monitoring program selects sites using a probability-based survey design. Sites were selected using a generalized random tessellation stratified (GRTS) multi-density survey design, as described by Stevens (1997) and Stevens and Olsen (1999; 2002).

Generally in the site selection process, a hexagon grid is randomly located over the study region, and a random point is selected in each hexagon cell. The number of hexagon cells is sufficiently large to guarantee all sample size requirements are met. These random points are then assigned unequal weights before the final set of sites is selected. The GRTS design incorporates a hierarchical randomization process to ensure the sample is spatially-balanced across the PSAMP study region. It also allows sites to be selected with unequal probability to satisfy the sample size requirements by basin and category. The unequal probability (i.e., multi-density) selection is similar to defining explicit strata to meet all the sample size requirements. Extra sample sites were selected to be used as alternates in the event that a site could not be sampled for any reason (e.g., inaccessible, rocky).

Empirical experience suggests that 30 to 50 samples are sufficient to provide an accurate representation of environmental conditions within areas the size of these regions. During June of 2002 and 2003, 40 and 41 samples, respectively, were collected throughout the bays, harbors, and inlets of the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet (Figure 2). Together, these regions extend from the U.S./Canada border south to the southern shore of the Strait of Juan de Fuca, westward to the head of Port Angeles Harbor, and eastward to the vicinity of Port Townsend on the Olympic Peninsula and the southern extent of Admiralty Inlet.

Samples were collected in the relatively protected bays and inlets of each region. None were collected in the open channels or basins of the three regions due to a predominance of hard substratum (i.e., rocks, boulders, hard pan) and sand waves previously found in those high-energy areas. Of the 229 m^2 study area, only about 212 m^2 could actually be sampled. Surficial sediments (i.e., the upper 2-3 cm) were collected to ensure that the data represented sediment-sorbed toxicants that were recently introduced into the area. Data from nine samples collected in Admiralty Inlet during the 1998 PSAMP/NOAA survey of the Puget Sound central basin were merged with the 2002-03 data to provide a total of 90 samples, 30 for each of the three regions.

Station numbers, names, the stratum (habitat) type in which they were classified, and the spatial area that they represented, are listed in Table 1. This information is summarized in Table 2 for each of the three regions. The distribution of the 90 stations is illustrated on maps of each region in Figure 3. Final station coordinates are summarized in the navigation report (Appendix A).

Sample Collection

Sediments were collected during June 3 – 24 of 2002 and June 5 – 20 of 2003 with the 42' research vessel *Kittiwake*. Each station was sampled once. Vessel positioning at the pre-selected station locations followed PSEP (1998). Differential Global Positioning System (DGPS) with an accuracy of better than 5 meters (m) was used to position the vessel at the station coordinates. The grab sampler was deployed and retrieved with a hydraulic winch. All samples were collected in water depths of 2 m or more (mean lower low water), the operating limit of the sampling vessel.

Station coordinates that could not be sampled were first moved 100 m seaward and tried again. A site could be moved up to 300 m. If the site could not be sampled because of rocks or other hard substrates, the location was rejected and an alternate set of coordinates was sampled.

Collection of sediments for chemistry, toxicity, and benthic infauna followed the PSEP protocols (1987, 1997a). Prior to sampling each station, all equipment used for sample collection, toxicity testing, and chemical analyses was washed with seawater, Alconox soap, acetone, and rinsed with seawater. Sediment samples were collected with a double 0.1 m^2, stainless steel, modified vanVeen grab sampler.

Sediment for toxicity testing and chemical analyses was collected simultaneously with sediment collected for the benthic community analyses to ensure synoptic data. Upon retrieval of the sampler, the contents were visually inspected to determine if the sample was acceptable (jaws closed and no washout, clear overlying water, sufficient depth of penetration). If the sample was unacceptable, it was discarded overboard at a location away from the station. If the sample was acceptable, information on the sediment color, odor, and type was recorded in field logs.

One 0.1 m^2 grab sample from one side of the sampler was collected from each station for the benthic infaunal analyses. The sample was gently washed through a 1.0 mm sieve using a low-pressure stream of on-site seawater. Large or fragile animals were picked off of the screen with forceps and placed into sample bags as sieving proceeded. Material retained on the sieve was bagged and preserved with a 10% solution of formalin in seawater. From the other side of the sampler, the top two to three cm of sediment was removed for chemical and toxicity tests using a stainless steel spoon and accumulated in a HDPE bucket (2002) or a stainless steel pot (2003).

The sampler was deployed and retrieved from three to six times at each station, until a sufficient amount (about 5 liters (L)) of sediment was collected. The sample collection container was covered between deployments of the grab to avoid shipboard contamination and to reduce the effects of oxidation and photo-activation of sediment-sorbed toxicants. After 5 L of sediment were collected, the sample was stirred with a stainless steel spoon or a stainless steel paint stirrer to homogenize the sediment. The homogenized sediment was then transferred to individual jars for the various toxicity tests and chemical analyses.

A double volume sediment sample was collected at three stations during each of the two years for a total of six field replicates. Chemical analyses were conducted on these replicates as an estimate of lab variability. All samples were labeled and double-checked for station and sample codes, sampling date, and type of analysis to be performed. Chain-of-custody forms accompanied all sample shipments with signatures of individuals who released the samples from custody and those who received them.

Samples for chemical analyses and toxicity tests were stored on deck in sealed containers placed in insulated coolers filled with ice. These samples were off-loaded from the research vessel every 1-3 days, and transported to the walk-in refrigerator at Ecology's headquarters building in Lacey, WA. They were held there at 4°C until shipped on ice by overnight courier to either the contractor laboratories for toxicity tests or to Manchester Environmental Laboratory (MEL) for chemical analyses. Chain-of-custody forms accompanied all sample shipments. After a minimum of 24 hours following collection and fixation, the benthic samples were rescreened (i.e., removed from formalin) and placed in 70% ethanol.

Laboratory Analyses

Physical and Chemical Analyses

Laboratory analyses were performed for over 120 chemicals and sediment properties by MEL, (Table 3). Analytical procedures provided performance equivalent to those of the NOAA National Status and Trends (NS&T) Program and the PSEP Protocols, including those for analyses of blanks and standard reference materials. Information was reported on recovery of spiked blanks, analytical precision with standard reference materials, and duplicate analyses of every 20th sample. Practical Quantitation Limits (PQLs) were reported for chemicals that were at or below the detection limits and qualified as being undetected. Laboratory analytical methods and reporting limits for quantification of chemical concentrations followed those of the PSEP (1986, 1997b,c) (Table 4). Methods and resolution levels for field collection of temperature and salinity are listed in Table 5.

Grain Size

Analyses for grain size were performed according to the PSEP Protocols (PSEP, 1986) with salt correction. Laboratory triplicates were performed each year on each batch of samples for quality assurance purposes.

The PSEP grain size method is a sieve-pipette method. In this method, the sample is passed through a series of progressively smaller sieves, with each fraction being weighed. After this separation, the very fine material remaining is placed into a column of water, and allowed to settle. Aliquots are removed at measured intervals, and the amount of material in each settling fraction is measured. The PSEP method was modified to include percent gravel, sand, silt, and clay, with sand subdivided into 5 categories; very coarse, coarse, medium, fine, and very fine according to the Wentworth scale.

These analyses were conducted by Rosa Environmental and Geotechnical Laboratory, LLC (Seattle, WA) in 2002 and by Analytical Resources, Incorporated (ARI; Tukwila, WA) in 2003. (Rosa Environmental was purchased by ARI in 2003.)

Total Organic Carbon (TOC)

Total organic carbon analysis was performed according to PSEP Protocols (PSEP, 1986). The method involves drying sediment material, pretreatment and subsequent oxidation of the dried sediment, and determination of CO_2 concentrations by infra-red spectroscopy.

Metals

Priority pollutant metals preparation and analysis were performed according to EPA Methods SW-846 3050B, SW6020 (in 2002), and EPA 200.8 (in 2003). Method SW-846 3050B is a strong acid (aqua regia) digestion that has been used by the PSAMP since 1989 for quantification of trace metals concentrations in sediments. This method is also the recommended technique for digestion of sediments in the revised PSEP protocols (PSEP, 1996b) and accounts for the deposition and presence of metals in sediments that have resulted from anthropogenic sources. The SW6020 and EPA 200.8 analysis methods employ Inductively Coupled Plasma/ Mass Spectrometry (ICP/MS) to quantify metals concentrations.

Mercury

Mercury concentrations were determined by EPA Method 245.5. The method consists of a strong acid sediment digestion, followed by reduction of ionic mercury to Hg^+, and analysis of mercury by cold vapor atomic absorption (CVAA) as recommended by the PSEP Protocols (PSEP, 1997c).

Butyl Tins

For butyl tin analyses, samples were extracted and derivatized following Manchester Laboratory's standard operating procedure NOAA-TBT SOP730005. This method uses a 50:50 extraction mixture of hexane and ethyl acetate. The extracts are transferred to 50 ml volumetric flasks, and the solvent is evaporated to near dryness on the N-Evap. Two milliliters of hexane are added to the flask, and the butyltins are derivatized using the sodium tetraethylborate reaction to the ethyl derivatives followed by a cleanup step using silica gel (EPA Method SW-846 3630). The analyses were done by capillary gas chromatography using atomic emission detection (GC/AED) monitoring the tin channel for the 301 nm and 303 nm frequency.

Base/Neutral/Acid (BNA) Organic Chemicals

These semivolatile organics were analyzed by EPA Method SW-846 8270, a method recommended by PSEP (1996c). This method uses a capillary column Gas Chromatography/ Mass Spectrometry (GC/MS) system. Sediments were prepared by Soxhlet extraction with acetone (EPA Method SW-846 3540B). The extracts were analyzed without Gel Permeation Chromatography (GPC) cleanup to minimize contamination.

Polycyclic Aromatic Hydrocarbons (PAH)

Sediment samples analyzed for PAHs were air dried and extracted on the Accelerated Solvent Extractor (ASE) with methylene chloride, following EPA Method SW-846 3545. A silica gel-cleanup (EPA Method SW-846 3630B) was performed on the extracts, followed by quantitation using the MEL modification of EPA Method SW-846 8270. This method uses a capillary column GC/MS system with selective ion monitoring (SIM) isotopic dilution analysis of the sample extracts to quantify the concentrations of the PAHs.

Chlorinated Pesticides and Polychlorinated Biphenyls (PCB)

Chlorinated pesticides, PCBs, and PBDEs were analyzed using modifications of EPA SW 846 methods 3545 (extraction), 3620, 3665 (cleanup), and 8081/8082 (analysis). Samples were air dried and extracted into methylene chloride by accelerated solvent extraction (ASE) (EPA SW 846 3545). The extracts were then solvent exchanged into hexane and eluted through a macro Florisil® column (EPA SW 846 3620), first with 100% hexane which was collected as the 0% fraction and then by a 50% diethyl ether/hexane solution which was collected as the 50% fraction. Each 0% Florisil fraction of the sample extracts was solvent exchanged into hexane and extracted with Tetrabutylammonium hydrogen sulfate (TBA) to remove sulfur.

All extracts were then solvent exchanged into iso-octane and adjusted to 1 ml in volume. The 50% fraction was split into two portions. One portion was treated with concentrated sulfuric acid prior to analysis (EPA SW 846 3665A). Quantitation was performed using Gas Chromatography/ Electron Capture Detection (GC/ECD) methods (EPA SW 846 8081/8082).

Toxicity Testing

Several toxicity tests were performed on aliquots of each sample to provide a weight of evidence with which to evaluate the toxicological condition of each sample. Tests were selected for which there were widely accepted protocols that would represent the toxicological conditions within different phases (partitions) of the sediments. Solid-phase sediments, sediment/water mixtures (often referred to as elutriates), and pore water extracted from the sediments were tested. Test endpoints were selected to range from survival to rate of physiological activity. Test organisms included adult forms (amphipods), reproductive products (sperm cells and embryos), and bacteria.

In this scheme, samples classified as toxic were those that induced significant responses in one or more tests. In contrast, samples that induced no significant responses in any of the tests were classified as highest quality (i.e., non-toxic). All of these tests have been used previously in sediment analyses in Puget Sound, and the procedures outlined in this report largely follow those previously described (Washington Department of Ecology, 1995; PSEP, 1995).

All tests of the samples from the study area were accompanied by several quality control procedures, including tests of negative controls using the same methods. The negative control sediments were collected in uncontaminated areas outside the study area and had been shown to be non-toxic in previous tests. In all cases, the maximum holding time for the test samples and negative controls was no more than 10 days.

Four toxicity tests were performed during the baseline studies in 1997-1999. They included an 10-day amphipod (*Ampelisca abdita*) survival test on solid phase sediments, a 30-minute sea urchin (*Strongylocentrotus purpuratus*) fertilization test of pore water, a 5-minute Microtox® bioluminescence test on organic solvent extracts, and a 16-hr cytochrome P450 HRGS assay on solvent extracts.

During the present survey, four toxicity tests also were performed on each sample; however, only one of them was the same as that used during the 1997 through 1999 study. The tests performed included an 10-day amphipod (*Eohaustorius estuarius*) survival test of solid phase sediments, a 48-hr sand dollar (*Dendraster excentricus*) embryo survival and development test on sediment/water mixtures (elutriates), a 30-minute sea urchin (*S. purpuratus*) fertilization test of pore water, and a 15-minute Microtox® bioluminescence test of pore water. Detailed methods for the four toxicity tests for 2002-03 as well as quality assurance procedures are included in the BC Research Institute (BCRI) and U.S. Geological Survey (USGS) laboratory reports (Appendix B- 1 and B-2).

Amphipod (*Eohaustorius estuarius*) Survival in Solid Phase Sediments – 10 day

Amphipod survival tests were conducted by BCRI, Vancouver, BC. Methods used in the amphipod tests complied with recommendations of ASTM (1993) for marine and estuarine amphipods and those of DeWitt et al. (1989) for *E. estuarius*. Additional guidance was provided by PSEP (1995), Stinson (1995), BCRI (2000a), and Environment Canada (1992; 1998). The same methods were used in 2002 and 2003.

Sea Urchin (*Strongylocentrotus purpuratus*) Fertilization in Pore Water – 30 minute

Tests of fertilization success of sea urchin gametes in sediment pore water were conducted by the USGS using methods largely developed by the laboratory in Corpus Christi, TX, i.e., Carr and Chapman (1992, 1995), Carr et al. (1996a,b), Carr (1997), ASTM (1994, 1998). These methods were developed initially for *Arbacia punctulata* for sediment quality surveys along southeastern U.S. estuaries, but adapted for use in the Pacific Northwest with *Strongylocentrotus purpuratus*.

The methods used in the sea urchin fertilization test were the same in both the 2002 through 2003 and 1997 through 1999 surveys.

Echinoderm (*Dendraster excentricus*) Embryo Development in Sediment/Water Mixtures (Elutriates) – 48 hour

Tests of sand dollar embryo development were conducted by BCRI with *Dendraster excentricus* exposed to sediment/water mixtures (often referred to as elutriates) in 48 – 96 hour tests, according to the methods recommended by Dinnel and Stober (1985), ASTM (1994), and PSEP (1995). Supplemental guidance was obtained from the BCRI Draft "Standard Operating Procedure for the Echinoderm Embryo Sediment Bioassay" (BCRI, 2002a), BCRI "Standard Operating Procedure for the Echinoid 20 Minute Fertilization Test" (BCRI, 2001a), and from Environment Canada (1992; 1997).

Microbial (*Vibrio fisheri*) Bioluminescence (Microtox®) in Pore Water – 15 minute

Microtox® tests were conducted by BCRI. Methods used to determine the changes in metabolic activity as a result of exposures to pore water (as measured with bioluminescence of the bacterium *Vibrio fisheri*) were developed by Peter Adolphson of the Washington State Department of Ecology (Adolphson, 2002, 2003). Additional information on methods was provided by Williams et al. (1986) and PSEP (1995). Supplemental information on methods was provided in the operations manual for the Model 500 Analyzer (Microbics, 1995a) and a data analysis manual for Microtox® (Microbics, 1995b). A reference toxicant test was performed using methods described in the BCRI SOP 1701-3 for Microtox® tests (BCRI, 2001b) and an acute test procedures manual for Microtox® (Microbics, 1995c).

Benthic Community Analyses

Sample Processing and Sorting

All methods, procedures, and documentation (including chain-of-custody forms, tracking logs, and data sheets) were similar to those described in the PSEP Protocols (PSEP, 1987) and in the PSAMP quality assurance plan (Dutch et al., 1998). Also, they were the same as those used in the PSAMP/NOAA survey conducted in 1997 through 1999, except for the omission of the 0.5 mm sieves used in the earlier survey.

Upon completion of field collections, benthic infaunal samples were checked into the benthic laboratory at Ecology's headquarters. After a minimum fixation period of 24 hours (and maximum of 10 days), the samples were rinsed with tap water on a 0.5 mm sieve to remove the formalin and transferred to 70% ethanol.

After staining with Rose Bengal, samples were examined under dissection microscopes, and all macroinfaunal invertebrates that were alive at the time of collection were removed with forceps. The organisms were sorted into the following major taxonomic groups: Annelida, Arthropoda, Mollusca, Echinodermata, and miscellaneous taxa. Meiofaunal organisms such as nematodes and foraminiferans were not removed from samples, although 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 quality assurance/quality control (QA/QC) procedures consisted of resorting 25% of each sample by a second sorter to determine whether a sample sorting efficiency of 95% removal was met. If the 95% removal criterion was not met, the entire sample was resorted.

Taxonomic Identification

Upon completion of sorting and sorting QA/QC, the majority of the taxonomic work was contracted to recognized regional taxonomic specialists. Organisms were enumerated and identified to the lowest taxonomic level possible, generally to species. Usually anterior ends of organisms were counted, except for bivalves (hinges), gastropods (opercula), and ophiuroids (oral disks). When possible, at least two scientific references (preferably including original descriptions) were used for the identification of each species.

A maximum of three representative organisms of any species not found in previous Ecology sampling efforts was removed from the samples and placed in a voucher collection, housed at Ecology's Operations Center in Lacey, WA. Taxonomic identification quality control for all taxonomists included re-identification of 5% of all samples identified by the primary taxonomist and verification of voucher specimens generated by another qualified taxonomist.

Data Summary, Display, and Statistical Analysis

The data obtained in 2002-03 were merged for the San Juan Islands and the eastern Strait of Juan de Fuca. Comparable data acquired in 1998 at nine stations in Admiralty Inlet were merged with these data. Therefore, data were available for 30 stations in each region for a total of 90 in all three regions. Due to hard substrates, only 211.7 km^2 of the total 229 km^2 area of the survey region could be sampled. For the purposes of the analyses, 211.7 km^2 is considered to be the total study area on which all calculations are based.

Data from the chemical analyses, toxicity tests, and benthic infauna analyses were summarized for each of the three sampling regions (San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet) and for the three regions combined. These data were analyzed separately to determine incidence, severity, spatial patterns, and spatial extent of degraded conditions in each region and in the total study area. The three lines of evidence were then merged to form the triad of evidence which was used to calculate the overall quality of sediments.

Chemical Concentrations

The concentrations of chemicals in each sample were compared with the Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSL) specified in the Washington State Sediment Management Standards (Washington Department of Ecology, 1995) for 47 substances (Appendix C). This was done to determine the incidence and degree of contamination, and spatial patterns and spatial extent of contamination. The chemical concentrations also were compared to national Effects Range Low (ERL) and Effect Range Median (ERM) sediment quality guidelines derived for 25 chemicals (Long et al., 1995).

The incidence of contamination was calculated as the number of samples that were contaminated divided by the total number of samples. The degree of contamination was calculated as mean ERM quotients (Long et al., 2000b). These values were calculated for each sample to provide a single, unit-less index of contamination over a continuous range that accounted for both the presence of mixtures and their concentrations.

Spatial patterns in concentrations were illustrated by plotting stations on base maps in which the Washington State Sediment Management Standards were exceeded. In addition, mean ERM quotients for each station were plotted to illustrate regional patterns in the concentrations of chemical mixtures.

The spatial extent of sediment contamination was determined as the sum of the areas within each stratum type or region or total survey area in which the SQS or CSL values were exceeded. The chemical data were weighted to the areas (km^2) of each region, divided by the number of samples in each region. Using this method, results were expressed as total km^2 and percentages of the total regional area, total stratum area, or total survey area in which any of the standards were exceeded.

Several conventions were followed in these comparisons of the chemical data to the state standards and national guidelines. For comparisons with summed classes of chemicals (i.e., the sums of PAHs, PCB aroclors or congeners, and DDD/DDE/DDTs), the concentrations of individual compounds reported by the laboratory as undetected (laboratory symbol of U) or undetected and estimated (symbol of UJ) were eliminated from the analyses. The same procedure was followed with comparisons to the NOAA guidelines.

Concentrations for individual chemicals reported as estimated (coded as J or NJ) were examined on a sample-by-sample basis. If the estimate appeared to be reliable, the estimated value was treated as a real concentration. Because of the inconsistent nature of the analyses and quantification of five base neutral acid compounds (phenol, 2-methylphenol, 4-methylphenol, benzyl alcohol, benzoic acid) between years, the data for these substances were not included in the estimates of the spatial extent of contamination.

Toxicity Tests

Results of the amphipod, echinoderm embryo, and Microtox® tests were analyzed using Ecology's SEDQUAL software, in which comparisons are made between results in tests of control or reference sediments and test sediments (Washington State Department of Ecology, 1995).

In these analyses, amphipod survival must exceed 90% in controls and 75% in reference sediments. Samples were classified as toxic when mean survival in a test sample was significantly less than in the negative control sediment (t-test, $p \leq 0.05$). They were classified as highly toxic when mean survival was significantly less than in the controls and less than 80% of the control response.

The percent of echinoderm embryos that survived and had normal morphological development must exceed 70% at the end of exposures to sediment/water mixtures from the reference site. Samples were classified as highly toxic when mean survival of normal embryos was less than that in the reference sediment (t-test, $p \leq 0.05$) and was less than 85% of that in the Mackenzie Beach (Tofino, BC) reference sediment.

Results of the Microtox® tests were compared with those from the Deltaport reference site in tests of 100% pore water. Samples were classified as highly toxic when mean light output was significantly different from that in the reference site pore water (t-test, $p \leq .05$) and less than 80% of that in the reference.

Results of the sea urchin fertilization tests were analyzed by USGS using SPS software. Results of the tests of 100%, 50%, and 25% pore water were compared with those of the Redfish Bay controls. Samples in which mean percent fertilization in the sea urchin tests were significantly different from the controls, and less than 80% of Redfish Bay (TX) controls, were classified as toxic. This method is consistent with methods used in previous analyses of sea urchin fertilization results from tests of estuarine sediment pore water (Long et al., 1996; Turgeon et al., 1998).

The incidence of toxicity was determined as the percentage of the total numbers of samples tested that were classified as toxic. Spatial patterns, if any, in toxicity were illustrated by plotting results on base maps in which the heights of bars at each station are shown. The spatial extent of toxicity was determined as the sum of the areas that each sampling station represented in which toxicity was recorded in each test or in any test. In those analyses, the toxicity data were weighted to the areas (km^2) of the regions, divided by the number of samples in each region. Results were expressed as total km^2 and percentages of the total regional area in which toxicity was recorded.

Benthic Community Analyses

As per the sampling design, each infaunal sample served as a replicate for the study region.

All benthic infaunal data were reviewed and standardized for any taxonomic nomenclatural inconsistencies by Ecology personnel using an internally developed standardization process. This process involved comparing the species identified in the survey with a master species list based on the 1991 SCAMIT benthic invertebrate species list that has been continually updated with current taxonomic changes.

A series of benthic infaunal indices were then calculated to summarize the standardized raw data and characterize the infaunal invertebrate assemblages identified from each station. Nine indices were calculated, including total abundance, major taxa abundance (for Annelida, Mollusca, Echinodermata, Arthropoda, and miscellaneous taxa), taxa richness, Pielou's evenness (J'), and Swartz's Dominance Index (SDI). These indices are defined in Table 6.

Assessment of Infaunal Assemblages

The species composition of each assemblage, the presence of stress-tolerant species, the absence or rarity of stress-sensitive species, and the calculated index values were used together to classify stations as having adversely affected or unaffected infauna. This was done based on the best professional judgment of the Department of Ecology benthic ecologists. Stations classified as adversely affected were those in which there was a predominance of stress-tolerant species (Diaz and Rosenberg, 1975) and the numbers of species and other calculated indices were relatively low for Puget Sound. The lack of an accepted, empirically-derived, numerical benthic health index for Puget Sound necessitates using best professional judgment to classify the benthic samples as either adversely affected or unaffected.

The benthic indices for each station were displayed on base maps as bars, the heights of which indicated the relative benthic index value for each station to identify any spatial patterns or gradients. Following the classification of stations as adversely affected or not, the percentages of stations in each region that were affected were calculated. The ranges in benthic indices and index maps were used to identify the ranges and severity in index values. The benthic data were treated the same way as the chemistry and toxicity data to determine the spatial extent of benthic impairment. These data were expressed as km^2 and percentage of each region and the total study area.

Sediment Quality Triad Categories

The data from chemical analyses, toxicity tests, and benthic infaunal analyses in 1998, 2002, and 2003 were compiled to form a weight of evidence matrix with which to classify overall sediment quality for each station (Chapman, 1996). The same triad approach was developed and applied in the initial Ecology/NOAA baseline surveys (Long et al., 2003; 2005).

Sediments were classified as highest quality when no chemical concentrations exceeded any of the State standards, no significant results were recorded in any of the four toxicity tests, and the majority of the benthic indices indicated that the sediment supported an unaffected infauna, including the presence of stress-sensitive indicator species. Sediments with a significant result in one element of the triad (i.e., one or more chemical concentrations greater than any SQS, or a highly significant result in any toxicity test, or adversely affected infauna) were considered to be intermediate/high quality. Those with significant results in two of the triad elements were considered to be intermediate/degraded. Degraded sediments were those with one or more chemical concentrations greater than the SQSs, a significant outcome in at least one of the toxicity tests, and an affected benthos.

The triad classifications were illustrated on base maps for each station to help identify any regional spatial patterns. Color-coded symbols were used to identify the station triad classifications. The results of these evaluations were compared with similar data from other regions of Puget Sound to put them into perspective.

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Results

Station, Region, and Stratum Characteristics

Sampling station numbers, names, and locations, and the sizes of the areas that they represented, are listed in Table 1. Final station coordinates and water depths for all 81 stations and rejected stations sampled during 2002 and 2003 are listed in the navigation report (Appendix A). Station coordinates and depths for the nine samples collected in 1998 from Admiralty Inlet were included in a previous survey report (Long et al., 2000a).

The physical and visual characteristics of each sample, including water salinity, sediment temperature, observed sediment description, sediment color, odor, and sampler penetration depth, are included in the field notes (Appendix D). The same information for the nine samples collected in 1998 from Admiralty Inlet was included in a previous survey report (Long et al., 2000a).

Table 2 summarizes the sizes of the regions and stratum types within each region. The entire survey area was estimated to cover 229 km^2, 212 km^2 of which was feasible to sample. The San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet regions were 81, 62, and 69 km^2 in size, respectively. In addition, data were summarized for five stratum or habitat types that were classified as deep basins, industrialized harbors, passages between land masses, rural bays, and urban bays as defined previously (Long et al., 2003). In these three regions there were no basin stations, 4 harbor stations, 10 passage stations, 48 rural bay stations, and 28 urban bay stations.

The locations of these habitat strata are illustrated in Figure 3. The industrialized harbor stratum was confined to inner Port Angeles Harbor. The urban bay stratum included most of Port Townsend and outer Port Angeles Harbor. The rural bays included Discovery and Sequim bays and all of the bays and coves of the San Juan Islands. Stations in Mutiny Bay and Useless Bay on Whidbey Island, and Oak Bay south of Marrowstone Island, were considered passage stations.

Physical and Chemical Analyses

The degree and spatial patterns in chemical contamination can be influenced by both proximity to sources and by a battery of natural factors, including depth, sediment texture, and total organic carbon (TOC) content. The degree of contamination would be expected to increase with increasing station depth, percent fines, and percent TOC because all three factors would be indicative of low-energy accumulation zones. Figures 4-7 illustrate the spatial patterns in these natural factors.

Station Depth

Station depths ranged from 3 to 90 meters and often were lowest in the San Juan Islands and greatest in Discovery Bay and Useless Bay (Figure 4, Appendix A). Station depth was relatively high at one station in Dungeness Bay. Depths were intermediate in Port Townsend and Sequim Bay stations.

Grain Size

Percent gravel, sand, silt, and clay values measured for these samples (Appendix E, Table 1 and Figures 1-3) are summarized in Table 7 for the entire study area and in Table 8 for each region. These data indicated that a wide range in sediment types was encountered in the survey area. They also indicated that each of the four classes of sediment types was well represented among the 90 samples. Based on the four classes of sediment types, 16 stations were classified as sandy, 27 stations had silty sand, 26 stations had mixed sediments, and 21 stations were classified as silt-clay (Table 7). These groups of stations represented approximately 21%, 25%, 30%, and 24% of the total study area, respectively.

Among the 30 samples from the San Juan Islands, 14 samples, representing 37.3 km^2 or 18% of the total survey area, were classified as mixed sediment (Table 8). Seven and six samples were silty sand and silt-clay sediments, respectively, representing about 9% and 8% of the survey area. Only three samples were sand, representing about 4% of the area. In the eastern Strait of Juan de Fuca region, 14 of the 30 samples were silty sand sediments, representing 21% km^2 or 10% of the total survey area. Nine samples, representing 25 km^2 and 12% of the area, were silty clay. In the Admiralty Inlet region, sandy sediments occurred more often that did other sediment types. Ten of the samples were sandy, representing 29 km^2 and 14% of the area. Mixed sediments were found at eight stations, which represented 17 km^2 and 8% of the area.

The composition of the sediments differed considerably among stations; however, gravel was rarely an important component (Figure 5). Sands, silts, and clays were the predominant size classes. In the San Juan Islands, many of the samples were primarily sands or silts or both with relatively small amounts of clays. In Admiralty Inlet the more exposed stations off Whidbey Island and in the entrance to Port Townsend were composed mainly of sands. In the more protected Port Townsend embayment, the silts predominated and were accompanied in some samples by small amounts of clay. The sediment samples in Discovery Bay and Sequim Bay were primarily silts with small amounts of sand and clay, whereas those from Port Angeles and Dungeness Bay were primarily sand.

The spatial patterns in sediment texture are further illustrated in Figure 6, in which the total percent fines (silts plus clays) are compared among stations. Stations with lowest percent fines included those from the more exposed coves of the San Juan Islands, the entrance to Port Townsend, Useless Bay, and outer Port Angeles. Stations with highest percent fines included those in the more protected waters of East Sound, Lopez Sound, inner Port Townsend, Sequim Bay, and Discovery Bay.

Total Organic Carbon (TOC)

The data generated on total organic carbon (TOC) content for these samples (Appendix E, Table 2 and Figures 4-6) are summarized in Table 9, grouped by region. TOC concentrations ranged from 0.10% to 3.88% among all samples. The minimum, mean, and median values were somewhat lower in Admiralty Inlet than in the other two regions. The Admiralty Inlet region is subjected to strong tidal currents that would tend to carry away the finest grain, least dense sediment particles that would contain organic carbon. The more protected rural bays and maritime harbors would tend to accumulate such particles because of the lower current speeds in such areas.

The spatial patterns in TOC concentrations followed those of percent fines (Figures 6, 7). That is, the lowest concentrations usually occurred in the more exposed stations of Admiralty Inlet and in the open coves of the San Juan Islands and outer Port Angeles. The highest concentrations often occurred in Discovery Bay, Sequim Bay, inner Port Townsend, East Sound, and Lopez Sound.

Chemical Concentrations

Chemistry case narratives, with quality assurance data, are included in Appendix E-1. Concentrations of individual trace metals and organic compounds in each sample are listed by region in Appendix E, Tables 3-5). Many of the concentrations of individual chemicals were qualified values; that is, they were undetected at the detection limits attained by the lab, or detectable but estimated values because the concentrations were very low. In the samples in which lab duplicate analyses were performed, the two sets of concentrations often were in good agreement. Means, medians, and ranges in concentrations for each chemical are summarized along with the numbers of detectable concentrations for the 90 samples in Appendix E, Table 6. Chemical concentrations in the sediments were compared to NOAA guidelines and Washington State Sediment Management Standards (Appendix C).

The numbers of non-detectable concentrations ranged widely (from 0 to 90). The ranges in concentrations were narrow for some chemicals (e.g., 0.11 mg/kg for mercury) and relatively wide for others (e.g., 36,465 mg/kg for cholesterol). Histograms of each chemical concentration in each sample are provided for all three regions (Appendix E, Figures 7-9). In many cases, the concentrations of different chemicals paralleled each other from station to station, indicating that the concentrations of these chemicals often co-varied throughout the study areas.

Chemicals Excluded from Analyses

Most of the analyses of the chemical data were conducted after excluding the data for five organic compounds. These five compounds were benzyl alcohol, benzoic acid, phenol, 2-methylphenol, and 4-methylphenol. They were found throughout all three regions, occurring in concentrations greater than their respective SQS values in 42 of the 90 samples. They were also found frequently in our previous surveys of other regions of Puget Sound.

In this survey, the most elevated concentration of these five chemicals occurred in samples from Lopez Sound, East Sound, Port Angeles, and south Port Townsend. The highest concentration of phenol (17,000 ppb) occurred in the sample from station 153 in Lopez Sound. The samples exceeded the SQS and CSL values by factors of 40X and 14X, respectively. This was the highest degree of contamination for any sample and any chemical in this survey. The highest concentration of 4-methylphenol (7900 ppb) was 12 times greater than the SQS/CSL value and occurred in the sample from station 217 in Lopez Sound. Many of the samples in which 4-methylphenol was elevated were those in which phenol was also elevated, but their distributions were not duplicative.

The highest concentration of benzoic acid (3070 ppb) occurred in the sample from station 108 in Port Townsend and exceeded the SQS/CSL by a factor of 5X. The highest concentration of benzyl alcohol (210 ppb) exceeded the SQS by a factor of 4X and occurred in the samples from stations 115 and 211 collected in Port Townsend. The highest concentration of di-n-butylphthalate was 900 ppb, which exceeded the SQS by a factor of 4X.

The analytical precision and detection limits attained by the lab for analyses of these compounds were highly variable from year to year, and there were indications of laboratory contamination in some samples; thus, our ability to compare concentrations between years was considered questionable for these five compounds (Appendix E-2). To increase the reliability of subsequent data analyses and to improve comparability with previous data sets (Long et al., 2003), the data for these five compounds were omitted from further analyses in this report.

Incidence of Chemical Contamination

After excluding the data for these five chemicals, both mean ERM quotients and mean SQS quotients were calculated for each sample to account for the presence and concentrations of 25 and 47 chemicals, respectively. The mean ERM and SQS quotients calculated for each sample ranged from 0.02 to 0.24, and 0.02 to 0.37, respectively (Table 10). All mean and median values were <0.07. The mean ERM quotients were less than 0.1 in 81 of the 90 samples. None of the chemical concentrations exceeded any NOAA ERM values or any Washington State CSL values; therefore, the incidence of contamination relative to these two criteria was zero.

Among the three regions, only two chemical concentrations exceeded an SQS value (Table 11). The concentration of di-n-butylphthalate in the sample from Station 225 in the San Juan Islands and the concentration of fluoranthene in the sample from Station 449 in Port Angeles Harbor both exceeded their respective SQS values. The incidence of contamination relative to the SQS values was, therefore, 3.3% (1 of 30) for both the San Juan Island and eastern Strait of Juan de Fuca regions, and 0% for the Admiralty Inlet region (Table 12).

For the combined study area, only two of the 90 samples (2.2% of the total) exceeded one or more of the State standards by any amount (Table 12). Thus, the overall incidence of chemical contamination was 2.2%.

Spatial Patterns and Gradients in Chemical Contamination

The two sampling locations in which the State standards were exceeded are illustrated in Figure 8. Station 225 was located in Prevost Harbor on Stuart Island, a sparsely populated island bordering Haro Strait and the U.S./Canada border. Station 449 was located along the south shore of Port Angeles near the marinas and harbor for the city of Port Angeles. There were no apparent spatial patterns or gradients in chemical contamination among stations after excluding the data for the five organic compounds for which the data were unreliable.

The ranges, medians, and averages in both mean ERM and SQS quotients were very similar among the three regions. Therefore, there were no clear spatial patterns or differences among the three regions in chemical contamination based on the data for most of the chemicals. The sample with the highest mean ERM quotient (0.24) was from station 107 in southern Port Townsend. The sample with the second highest mean ERM quotient (0.19) came from station 449 located in Port Angeles. However, there were no obvious spatial gradients or patterns within any of the three regions (Figure 9).

Spatial Extent of Chemical Contamination

The combined study area was estimated to encompass a total of 212 km^2: 81 km^2 in the San Juan Islands, 62 km^2 in the eastern Strait of Juan de Fuca, and 69 km^2 in Admiralty Inlet (Table 12). After removal of the five compounds for which the data were unreliable, the two samples (2.2%) in which one or more SQSs were exceeded represented 3.6 km^2, equivalent to 1.7% of the total 2002-03 survey area. The areas affected in each region were 2.7 km^2 (3.3% of the region) in the San Juan Islands, 0.9 km^2 (1.4%) in the eastern Strait of Juan de Fuca, and 0 km^2 (0% of the region) in Admiralty Inlet. Therefore, the areas affected by contamination by one or more chemicals were very small or zero in the bays and inlets of the three regions.

Summary

None of the chemical concentrations exceeded any of the NOAA ERM values. Among all 90 samples, there were only seven chemicals that occurred in concentrations greater than the State standards: phenol, 2-methylphenol, 4-methylphenol, benzyl alcohol, benzoic acid, fluoranthene, and di-n-butylphthalate. However, because of the low reliability of the analytical results for phenol, 2-methylphenol, 4-methylphenol, benzyl alcohol, and benzoic acid, the data for these five compounds were not included in our data analyses.

None of the other chemical concentrations exceeded the remaining 42 CSL values, and only two samples had a concentration greater than an SQS value. Therefore, the incidence of chemical contamination relative to the SQS values was 2.2% (2 out of 90 samples). The two samples in which one or more SQS values were exceeded represented 3.6 km^2, equivalent to 1.7% of the total survey area. The areas affected in each region were 2.7 km^2 (3.3% of the region) in the San Juan Islands, 0.9 km^2 (1.4%) in the eastern Strait of Juan de Fuca, and 0 km^2 (0% of the region) in Admiralty Inlet. Overall, the areas affected by chemical contamination were very small or zero in the bays and inlets of the three regions.

Except for the five excluded organic compounds, chemical contamination was very low in all samples. There were no obvious or distinct spatial gradients or patterns in sediment contamination among stations, although some of the samples collected in southern Port Townsend and in Port Angeles were among the more contaminated. Sediments from Dungeness Bay, Sequim Bay, Discovery Bay, Mutiny Bay, and the exposed perimeter of the San Juan Islands were among the least contaminated.

Toxicity Tests

A review and summary of the toxicity QA/QC information, all toxicity test reports, and reference toxicant control charts, are summarized in Appendix B-1, B-2, and B-3, respectively.

Incidence and Severity of Toxicity

Amphipod (*Eohaustorius estuarius*) Survival in Solid Phase Sediments – 10 day

Among the 90 samples (81 samples tested with *Eohaustorius estuarius* in 2002-03, plus nine samples tested with *Ampelisca abdita* in 1998), mean survival ranged from 74% at station 153 to 100% at station 1355 (Table 13). Expressed as percentage of control survival, the range was 76% to 110%. Mean survival was significantly less than in the controls (t-test, $p<0.05$) at stations 153 (Lopez Sound), 649 (Discovery Bay), and 106 (South Port Townsend). Thus, the incidence of significant responses was 3.3% (3 of 90 samples).

There was only one sample (station 153) in which the control-adjusted response was less than 80%, and the response was significantly less than controls; thus the incidence of highly significant responses was 1.1% (1 of 90 samples). None of the nine samples from the Admiralty Inlet region tested in 1998 with *Ampelisca abdita* had a highly significant response, although the response was significantly less than controls at station 106.

Sea Urchin (*Strongylocentrotus purpuratus*) Fertilization in Pore Water – 30 minute

Among the 90 samples (81 from 2002-2003, plus 9 from 1998), mean fertilization success was significantly less than the Texas reference sediments in 10 samples (Table 14). Thus, the overall incidence of significant responses for the combined survey area was 11% (10 of 90): 7% (2 of 30) in the San Juan Islands region, 20% (6 of 30) in the eastern Strait of Juan de Fuca, and 7% (2 of 30) in the Admiralty Inlet region. Mean, control-adjusted, fertilization success was significantly lower than in the Texas controls and less than 80% in 9% of the samples (8 of 90): 3% (1 of 30) in the San Juan Islands region, 17% (5 of 30) in the eastern Strait of Juan de Fuca, and 7% (2 of 30) in Admiralty Inlet. Mean fertilization success was lowest (1% and 8%, respectively) in samples from stations 1355 in Oak Bay and 521 in Discovery Bay. A maximum of 99.8% fertilization was recorded in many samples.

Echinoderm (*Dendraster excentricus*) Embryo Development in Sediment/Water Mixtures (Elutriates) – 48 hour

The echinoderm embryo test was not performed on the nine samples from Admiralty Inlet collected in 1998; therefore, there are results for 81 of the 90 samples (Table 15). Results initially expressed as mortality/abnormality (Appendix B-1) were converted to mean normal survival. Mean normal survival among the 81 samples ranged from 18.2% in sample 441 from East Sound to 98.6% in sample 225 from Prevost Harbor on Stuart Island. This was a highly sensitive test, resulting in significant outcomes in the most samples as compared to the other three tests.

There were 48 samples (59%) among the 81 tested in which mean percent normal survival was significantly less than in the reference sediments (Table 15). Among these 48 samples, there were 25 in which the outcome was both significant and less than 85% of that in the reference sediments for an overall incidence of highly significant toxicity of 25 of 81 samples, or 30.9%. The incidence of highly significant results was highest in the San Juan Island and eastern Strait of Juan de Fuca regions (30% and 40%, respectively) and much lower (19%) in Admiralty Inlet. There were 34 out of 81 samples in which the outcomes were less than 50% of that in the reference.

Microbial (*Vibrio fisheri*) Bioluminescence (Microtox®) in Pore Water – 15 minute

Microtox® tests of pore water were not performed on the nine samples collected from Admiralty Inlet during the 1998 survey. Therefore, there are results for 81 of the 90 samples. Instead, in 1998, they were performed on organic solvent extracts of the sediments (Long et al., 2000a). None of the bioluminescence responses was significant in the nine samples tested from that region in 1998.

The results of the Microtox® tests of salinity-adjusted 100% pore water performed in 2002 and 2003 were expressed three different ways. They were expressed as the mean light readings at three different time periods (0 minutes, 5 minutes, 15 minutes). The mean responses after both the 5-min and 15-min exposures were calculated as percentages of the initial (0-min) light readings. Finally, light readings were calculated as percentages of the response in the seawater controls and in the Deltaport (reference sediment) porewater samples. However, to simplify the presentation of these data, they are summarized as mean light output at 15 minutes and as percent of mean dilution control response at 15 minutes (Table 16). In both methods, an increase in the degree of response is reflected in smaller numbers, indicating that it required less sediment to cause a greater response.

Mean responses expressed as percentages of controls were greatest (26%, 29%, 34%) in the samples from stations 275, 1355, and 119, respectively (Table 16). However, these results were not statistically significant because of the high degree of variability among replicates. There were 55 samples in which the response was equal to or greater than 100% of the control response, indicating that this was not a very sensitive test. Mean response was statistically significant in five samples, including: two samples each from the San Juan Islands (stations 305 and 313) and the eastern Strait of Juan de Fuca (stations 545 and 1313), and one sample from Admiralty Inlet (station 681). The mean response was significant and less than 80% of control in only four samples: two each from the San Juan Islands and the eastern Strait of Juan de Fuca, and none from Admiralty Inlet.

Spatial Patterns and Gradients in Toxicity

Amphipod (*Eohaustorius estuarius*) Survival in Solid Phase Sediments – 10 day

None of the nine samples from the Admiralty Inlet region tested in 1998 with *Ampelisca abdita* was highly toxic, although the response was statistically significant in one sample (106) collected south of Port Townsend. The three samples in which mean amphipod survival was significantly less than in controls were scattered among the three regions; one in each region (Figure 10). The sample in which the response was significantly less than controls and less than 80% was collected at station 153 in Lopez Sound within the San Juan Islands region. Lopez Sound is located to the east of Lopez Island.

Mean survival was less than 80% in the sample from station 313 in East Sound, but not statistically significant because of high variability among replicates. East Sound is located to the south of Orcas Island in the San Juan Islands region. Mean control-adjusted survival was 80% (but not < 80%); it was significant in the sample from station 649 in Discovery Bay and significant in the sample from station 106 from south Port Townsend. The geographic distribution of these data did not show any obvious spatial patterns or gradients in toxicity.

Sea Urchin (*Strongylocentrotus purpuratus*) Fertilization in Pore Water – 30 minute

Samples were classified as toxic in tests of 100% pore water when mean fertilization success was significantly lower than in the Texas control sediment, and highly toxic when significant and less than 80% of the control response. The samples that were highly toxic in this test were collected in Sequim and Discovery Bays along the eastern Strait of Juan de Fuca, Lopez Sound in the San Juan Islands, and in Useless and Oak Bays in the Admiralty Inlet region **(**Figure 11**)**. None from Port Angeles were toxic in this test.

None of the nine samples from the Port Townsend/Admiralty Inlet region sampled during 1998 were toxic in this test. The most toxic sample (1% fertilization) was from station 1355 in Oak Bay in the Admiralty Inlet region (Table 14, Figure 11). The second most toxic sample (8% fertilization, station 521) was collected in Discovery Bay. Although there were no obvious or discernible spatial patterns or gradients in toxicity with this test, the frequency of toxicity was highest in Sequim and Discovery Bays adjoining the eastern Strait of Juan de Fuca.

Echinoderm (*Dendraster excentricus*) Embryo Development in Sediment/Water Mixtures (Elutriates) – 48 hour

The sand dollar embryo tests were not performed on the nine Admiralty Inlet samples collected during the 1998 survey. Therefore, there are data from this test for 21 samples from that region and a total of 81 in the total survey area sampled during 2002-03. Mean percent normal survival was very low in many samples, but because of high variability among replicates was not significant in many of those samples (Table 15, Figure 12).

Based on the combined survival/normality endpoint, most of the samples classified as toxic in this test came from various coves and bays in the San Juan Islands. There were a few samples from the eastern Strait of Juan de Fuca (Sequim Bay, Discovery Bay, and Port Angeles) that were toxic. In the Admiralty Inlet region, there were some samples from Port Townsend, Oak Bay, and Useless Bay that were toxic. Stations in bays and coves in which toxicity was indicated in this test invariably were accompanied by neighboring stations that were not toxic.

Microbial (*Vibrio fisheri*) Bioluminescence (Microtox®) in Pore Water – 15 minute

The responses in all nine samples collected in Admiralty Inlet during the 1998 survey were not significant in Microtox® tests performed with organic solvent extracts. These samples were collected west and south of Marrowstone Island. The Microtox® tests of pore water performed in 2002 and 2003 proved to be among the least sensitive, therefore, precluding the identification of any meaningful spatial gradients or patterns among the sampling stations. The response was significant in samples from East Sound, a small cove off southern Lopez Island, outer Dungeness Bay, and Sequim Bay (Figure 13). Otherwise, this test was mostly non-responsive and failed to indicate any obvious spatial patterns in response.

Summary

The echinoderm (sand dollar) embryo test proved to be the most sensitive of the four toxicity tests performed in this study, and spatial gradients or patterns in toxicity are largely attributable to the results of that test (Figure 14). The occurrence of toxicity and the degree of response among the four tests generally were highest in Sequim and Discovery Bays, Lopez Sound, and East Sound. In addition, some samples from Useless Bay and Oak Bay were toxic in one or more tests.

Among the three regions, the occurrence of toxicity and the degree of response generally were highest in the eastern Strait of Juan de Fuca region, lower in the San Juan Islands region, and lowest in the Admiralty Inlet region. No single area stood out as being most toxic, although Sequim Bay was the only area in which all samples were toxic in at least one of the tests, and one sample from there was toxic in three of the tests. Otherwise, samples from most of the other bays and coves that were classified as toxic were usually accompanied by non-toxic samples from neighboring stations.

Among the least toxic bays and coves were Port Townsend, Oak Bay, Dungeness Bay, Port Angeles Harbor, and many of the small bays and inlets off the southern San Juan Islands. There was very little concordance among the four toxicity tests, with significant responses in three tests occurring in only one sample (station 1313 in Sequim Bay). Of the 90 samples tested, none had four significant responses (Tables 13-16, Figures 10-14.)

Spatial Extent of Toxicity

Both the incidence and spatial extent of toxicity in each test and each region are summarized in Table 17 along with a combined summary for the total study area. Throughout the entire study area of 212 km^2, there were 30 samples (33% of 90) in which at least one test response was significant. These 30 samples represented a total of 80 km^2 or about 38% of the total study area.

Both the incidence and spatial extent of toxicity were highest in the eastern Strait of Juan de Fuca region, lower in the San Juan Islands region, and lowest in the Admiralty Inlet region. The 14 samples from the eastern Strait of Juan de Fuca that were classified as toxic represented about 37 km^2, equivalent to about 59% of that region. The ten samples from the San Juan Islands in which a significant response was recorded in any test represented 27 km^2 or 33% of that region. The six samples from the Admiralty Inlet region that were toxic represented 16 km^2 or about 23% of that region.

The spatial extent of toxicity throughout the study area was greatest in the echinoderm (sand dollar) embryo and urchin fertilization tests, affecting 64 km^2 (30%) and 24 km^2 (11%), respectively (Table 17). Samples that were toxic in the Microtox® tests and amphipod tests affected much smaller areas, 11 km^2 (5%) and 3 km^2 (1%), respectively. The largest areas affected by the echinoderm embryo test were in the eastern Strait of Juan de Fuca and the San Juan Islands. The largest area affected by the urchin fertilization test was in the eastern Strait of Juan de Fuca.

Benthic Community Analyses

Community Composition and Benthic Indices

The benthic taxa found in this survey are listed in Appendix F, Table 1; sorting and taxonomy quality assurance results are included in Appendix F, Tables 2 and 3. The spatial distributions of the calculated benthic condition indices are illustrated in Figures 15-24. Histograms of these values in each sample are provided for all three regions (Appendix F, Figures 1-3).

Total Abundance

Total abundance is a count of all animals in a sample and is indicative of how many organisms can be supported by the environment at each station. Among all 90 stations, total abundance ranged from 16 at station 275 in Discovery Bay to 2370 at station 112 in Oak Bay south of Marrowstone Island (Table 18). There were 17 stations that had over 1000 infaunal organisms, including nine in the Admiralty Inlet region. Lowest total abundance (<100) occurred in samples from four stations (193, 305, 313, 441) in the San Juan Islands, station 1289 in Sequim Bay, and station 16 in Discovery Bay.

Stations with the highest and lowest total abundance were scattered throughout all areas in each region. Stations with the lowest total abundance typically occurred in the long terminal inlets with poor water circulation (e.g., Discovery and Sequim Bays in the eastern Strait of Juan de Fuca, and East Sound and MacKaye Harbor in the San Juan Islands) (Tables 18, 19; Figure 15).

Based on the mean, median, minimum, and maximum values, total abundance tended to be much higher in the Admiralty Inlet region than in the other two regions, and slightly higher in the San Juan Islands than in the eastern Strait of Juan de Fuca.

Major Taxa Abundance

The annelids, including polychaete worms, are often the most abundant taxonomic group in the benthos of Puget Sound. Many annelids are active burrowers while others form relatively stationary tubes. Some species of annelids are opportunistic and proliferate in environmental conditions that other more sensitive groups cannot tolerate (Diaz and Rosenberg, 1995). The annelids comprised as little as 10% and as much as 99% of the total abundance (Table 18). In most of the 90 samples, the annelids represented 30% to 60% of the total abundance, the most of any phylum.

As indicated by the regional mean and median values, the annelids were considerably less abundant in the Admiralty Inlet region than in the other two regions. For example, the annelids represented a mean of 35% of total abundance there, as compared to 61% and 57% in the eastern Strait of Juan de Fuca and San Juan Islands, respectively (Figures 16, 17).

The arthropods include shrimps, crabs, amphipods, and other crustaceans, many of which are sensitive indicators of stressed conditions. They typically occur in lowest abundance where toxicant concentrations are highest and/or dissolved oxygen concentrations are lowest (Diaz and Rosenberg, 1995). The percent contribution of arthropods to total abundance ranged from 0% (station 777) to 62% (station 527). Typically, the arthropods represented from 2% to about 20% of the total abundance among the 90 stations (Table 18). The arthropods tended to be more abundant in the Admiralty Inlet region than in the other two regions with a mean abundance there of 16%, compared to 11% and 10% in the other two regions (Figures 16, 18).

The molluscs in Puget Sound include many species of bivalves (clams) and gastropods (snails) and can be relatively abundant in most habitat types. Some species are sensitive indicators of stress while others are among the more tolerant taxa (Diaz and Rosenberg, 1995). The percent contribution of the molluscs to total abundance ranged from 0% in two samples (stations 193, 313) to a maximum of 76% (station 115) (Table 18). Molluscs were absent only at stations 193 and 313. They represented over 50% of the total abundance in 17 samples. Typically, the molluscs represented from 20% to 40% of total abundance in these 90 samples. The molluscs were slightly more abundant on average in the Admiralty Inlet region than in the other two regions (Figures 16, 19).

The echinoderms include brittle stars, sea stars, heart urchins, and sea cucumbers and are relatively sensitive to polluted conditions (Diaz and Rosenberg, 1995). They have been found to be more abundant in northern Puget Sound, but considerably less abundant south of Admiralty Inlet and in Hood Canal (Long et al, 2003), although normally they are less abundant than annelids, molluscs, and crustaceans in Puget Sound. The abundance of these animals also was relatively low in the 2002-03 study areas (Table 18).

The percent contribution of echinoderms to total abundance ranged from 0% in many samples to a high of 59% (station 108, south Port Townsend). In most of the 90 samples, the echinoderms represented from 0% to about 1% of total abundance. However, there were a number of stations in south Port Townsend in which the echinoderms represented from 10% to 30% of total abundance. Region-wide, the echinoderms were much more abundant in the Admiralty Inlet region than in the other two regions with a regional mean of 8% of total abundance, as compared to 0.1% and 0.5% in the eastern Strait of Juan de Fuca and the San Juan Islands (Figures 16, 20).

Miscellaneous (or “other”) taxa include cnidarians, bryozoans, phoronid worms, nemertean worms, echiurids, and other small phyla, some of which can be stress-sensitive while others tend to be more stress-tolerant (Diaz and Rosenberg, 1995). As a rule, the miscellaneous taxa are not as abundant as the other taxa in Puget Sound. The miscellaneous taxa had relatively low abundance in the 90 samples of the study area, representing 0% of total abundance in many samples up to a maximum of 9% (Table 18). Typically, they represented 1% to 3% of total abundance in the 90 samples. The miscellaneous taxa were slightly more abundant in the Admiralty Inlet region than in the other two regions, comprising 2% of total abundance as compared to 0.6% and 1.1%, (Figures 16, 21).

Taxa Richness

The number of taxa recorded in each sample ranged from a minimum of 2 in two samples to a maximum of 199 in one sample (Table 19). There were 18 samples in which taxa richness was 100 or more. This is a very high number of taxa, but not extraordinary for Puget Sound (Long et al., 2003). In contrast, there were six samples in which there were less than ten taxa, which is an unusually low number for Puget Sound.

Some of the stations with lowest taxa richness were those in East Sound and Lopez Sound; many of the stations in south Port Townsend had the highest taxa richness. There were no other obvious spatial patterns in taxa richness among stations (Figure 22). However, mean and median values were considerably lower in the San Juan Islands than in the other two regions. For example, mean taxa richness was 55 in the San Juan Islands region, whereas the means were 86 and 61 in the other two regions.

Evenness

The index of evenness is indicative of the equitability of the distribution of organisms among the taxa found in each sample. A high numerical value is often viewed as indicative of a healthy assemblage. Among the 90 samples, evenness ranged from low values of 0.10 and 0.23 in the two samples with only 2 taxa to a maximum value of 0.86 (Table 19). There were 20 samples with evenness indices of 0.80 or greater, indicating very high equitability among taxa. The majority of samples had indices of 0.50 or greater.

Some of the stations with the lowest values were in Lopez Sound, East Sound, and other bays in the San Juan Islands, whereas many of the stations in Port Townsend had some of the highest index values (Figure 23). Accordingly, the mean evenness index was lowest in the San Juan Islands region (0.64) and highest in the Admiralty Inlet and eastern Strait of Juan de Fuca regions (0.71 and 0.72, respectively).

Swartz's Dominance Index (SDI)

The SDI is the number of taxa that makes up 75% of the total abundance in a sample. A high value indicates that multiple taxa contribute to 75% of the abundance; a low value indicates that only a few taxa contribute to 75% of the abundance. SDI scores ranged from one taxon in three samples to a maximum of 46 taxa at station 119 in Port Townsend (Table 19). Most of the SDI scores ranged from about 10 to about 30. SDI values were noticeably lower in the San Juan Island region than in the two other regions (Figure 24).

Values of five or fewer occurred at many stations scattered throughout the San Juan Island region, Sequim and Discovery Bays, and a few Port Townsend stations. There was only one dominant taxon in samples from stations 193 (East Sound), 313 (East Sound), and 275 (Discovery Bay). Both the mean and median values were considerably lower in the San Juan Islands region than in the other two regions. For example, there was a mean of 10 dominant taxa in the San Juan Islands, whereas there were means of 12 and 16 dominant taxa in the Strait of Juan de Fuca and Admiralty Inlet, respectively.

Species Composition and Station Classification

As indicated by the ten most abundant taxa and the calculated indices of benthic assemblage condition, the composition of the assemblages differed considerably among stations (Appendix G). There were 20 stations classified as having an adversely affected benthos in the San Juan Islands region, 14 in the eastern Strait of Juan de Fuca, and 3 in the Admiralty Inlet region, for a total of 37 in the study area (Appendix G).

In general, the stations with unaffected benthic assemblages were dominated by multiple species of bivalves and annelids, included species of arthropods, echinoderms, and miscellaneous taxa. They also had an SDI of 10 or greater, and had a taxa richness of about 50 or more. The molluscs often included *Alvania compacta*, *Parvilucina tenuisculpta, Cyclocardia ventricosa*, *Nutricola lordi*, and *Acila castrensis* among the dominant species. The arthropods often included various species of amphipods (e.g., *Ampelisca* spp., *Gammaropsis thompsoni, Heterophoxus* spp.), cumaceans and decapods (crabs) among the dominant species.

In contrast, the adversely affected infauna assemblages often were dominated by a variety of species of polychaetes known to be stress-tolerant in Puget Sound (Diaz and Rosenberg, 1995), including *Aphelochaeta* spp., *Paraprionospio pinnata*, *Nephtys cornuta, Capitella capitata, Mediomastus californiensis*, *Heteromastus* spp. Various oligochaetes often were also dominant. These assemblages had taxa richness indices of 20 or less, SDI scores of 10 or less, and very few stress-sensitive species.

In the San Juan Islands, the 20 stations with benthic assemblages classified as affected were scattered throughout the region (Figure 25). All of the samples from East Sound (south of Orcas Island) and all samples from Lopez Sound (east of Lopez Island) had affected benthos. The ten stations in this region with unaffected benthos were in the northwest corner of the region, in terminal bays of San Juan Island, and at the north and south ends of Lopez Island.

In the eastern Strait of Juan de Fuca region, the stations with affected benthos were primarily in Sequim Bay and Discovery Bay. Three stations along the western shoreline of Discovery Bay, two in Dungeness Bay, and all except one in Port Angeles were unaffected. In Port Angeles, only the innermost station (station 41) had affected benthos.

In the Admiralty Inlet region, the three affected benthic assemblages were at one station in Port Townsend and two stations in Oak Bay. The majority of the benthic assemblages in Port Townsend and all of them in Useless and Mutiny Bays were considered unaffected.

Summary

The composition, abundance, and diversity of the benthic assemblages differed considerably among the 90 stations, indicating a wide variety of assemblages and habitat types. Total abundance differed by two orders of magnitude among stations with as few as 16 animals in one sample and over 1000 in others. There were some samples in which only two species occurred and many samples with more than 100 species. Polychaete annelids often were the most abundant taxonomic group, followed by the molluscs and arthropods. Echinoderms and miscellaneous taxa occurred less frequently than the other taxa in these three regions.

Usually, there were 10 to 30 dominant species with a minimum of 1 and a maximum of 46. Among the 90 stations, the benthos were classified as adversely affected in 37 stations: 20 in the San Juan Islands, 14 in the eastern Strait of Juan de Fuca, and 3 in Admiralty Inlet. The diversity of the benthos was most variable within the San Juan Islands region and on average considerably lower than in the other two regions. Affected benthos were found throughout all or most of East Sound, Lopez Sound, Sequim Bay, and Discovery Bay, whereas unaffected assemblages were apparent throughout most or all of Port Angeles, Dungeness Bay, Port Townsend, Useless Bay, and Mutiny Bay.

Triad Synthesis: A Compilation of Chemistry, Toxicity, and Infaunal Data

The chemistry, toxicity, and benthic data were compiled together to classify the overall sediment quality at each station as was done in the previous PSAMP sediment quality surveys (Figure 26, Appendix G). Stations were classified as high quality when none of the three parameters indicated impairment. Others were classified as intermediate/high quality, intermediate/degraded, and degraded when one, two, or three parameters, respectively, indicated degraded conditions. Therefore, in this scheme, the chemistry, toxicity, and benthic data were treated with equal weight in classifying sediment quality. Stations classifications were then used to generate the incidence and spatial extent of sediment quality degradation for each region (Table 20).

Incidence and Spatial Extent of Sediment Quality Degradation

In the San Juan Islands, there were 9, 11, 10, and 0 stations in the high quality, intermediate/high, intermediate/degraded, and degraded categories, respectively. These stations represented 24 km^2 (30%), 30 km^2 (37%), 27 km^2 (33%), and 0 km^2 (0%) of that region. In the eastern Strait of Juan de Fuca, there were 12, 7, 11, and 0 stations in the same categories, respectively, and they represented 18 km^2 (28%), 14 km^2 (23%), 30 km^2 (49%), and 0 km^2 (0%) of that region. In the Admiralty Inlet region, there were 22, 7, 1, and 0 stations in these categories, respectively, representing 48 km^2 (69%), 18 km^2 (26%), 4 km^2 (5%), and 0 km^2 (0%) of that region (Table 20).

Based on the Sediment Quality Triad of measures, high quality sediments were most prevalent in Admiralty Inlet (48 km^2 and 69% of the region). They were lower in the San Juan Islands (24 km^2 and 30% of the region) and the Eastern Strait of Juan de Fuca (18 km^2 and 28% of region).

Intermediate quality sediments (i.e., both intermediate/high and intermediate/ degraded) were dominant in the San Juan Islands and Eastern Strait of Juan de Fuca (57 and 44 km^2; 70 and 72% of the respective study areas). Only 21 km^2 (31%) of the Admiralty Inlet study area sediments were of intermediate quality.

The areas affected by intermediate/degraded sediments were largest in the eastern Strait of Juan de Fuca (30 km^2 and 49% of region), less in the San Juan Islands (27 km^2 and 33% of region), and smallest in Admiralty Inlet (4 km^2 and 5% of the region). Most of the intermediate quality sediment samples were classified as such due to toxicity and/or adversely affected benthos.

Degraded sediments which were contaminated, toxic, and supported adversely affected benthic assemblages were not found in any of the three study regions.

These data indicated that sediment quality was highest in the Admiralty Inlet, poorer in the San Juan Islands, and poorest in the eastern Strait of Juan de Fuca.

Spatial Patterns and Gradients in Sediment Quality Degradation

Although the random, stratified sampling design was not developed to examine spatial patterns or gradients, some limited information can be gathered about this in the three regions. Some stations in Lopez Sound and East Sound in the San Juan Islands were classified as intermediate in quality (Figure 26). Other intermediate quality stations were scattered throughout the region and occasionally were accompanied by neighboring stations that were classified as high quality. There were no obvious spatial gradients or patterns in quality. The Lopez Sound and East Sound sediments were toxic in either the echinoderm (sand dollar) embryo development test or amphipod survival test (Appendix G). The benthos at these stations generally had only a few dominant species (often only stress-tolerant polychaetes, oligochaetes, or molluscs) and very few stress-sensitive arthropods, echinoderms, or miscellaneous taxa.

In the eastern Strait of Juan de Fuca region, the majority of stations classified as intermediate in quality were in Sequim and Discovery Bays (Figure 26). There were three stations in inner Port Angeles that were intermediate in quality, but they were accompanied by many other stations that were classified as high quality. Therefore, no spatial gradient in quality was obvious in Port Angeles. The four stations in Sequim Bay were classified as intermediate/ degraded, whereas the two stations outside the entrance to Sequim Bay had higher quality sediments. Therefore, the relatively degraded conditions in Sequim Bay improved beyond the mouth of this bay.

Most of the stations in Discovery Bay were classified as intermediate/degraded. There was a general, but inconsistent, pattern of increasing sediment quality from the head of the bay to the mouth. The intermediate/degraded stations in this region often were toxic in either the echinoderm embryo development test or sea urchin fertilization test and the species composition of the benthos was invariably dominated by stress-tolerant annelids, whereas the arthropods, echinoderms, and miscellaneous species were either absent or very rare (Appendix G).

The one station (1355) in the Admiralty Inlet region that was classified as intermediate/degraded was located in Oak Bay, south of Marrowstone Island (Figure 26). The nearest neighboring stations were classified as either high quality or intermediate/high quality. The eight stations scattered throughout Port Townsend, Oak Bay, and Useless Bay that were intermediate/high quality were surrounded by multiple stations with higher quality sediments. Therefore, there was considerable spatial heterogeneity and no obvious gradients or spatial patterns in relative sediment quality in this region. Station 1355 was toxic in the sea urchin fertilization test, and the benthos there had only eight dominant species, mostly oligochaetes, polychaetes, and molluscs with very low numbers of arthropods, echinoderm, and miscellaneous species (Appendix G).

Summary

Based on the Sediment Quality Triad of measures, highest quality sediments were most prevalent in the Admiralty Inlet region (48 km^2 and 69% of the study area).

Intermediate quality sediments were dominant in the San Juan Islands and Eastern Strait of Juan de Fuca (57 and 44 km^2; 70 and 72% of the respective study areas). Only 21 km^2 (31%) of the Admiralty Inlet study area sediments were of intermediate quality.

The areas affected by intermediate/degraded sediments were largest in the eastern Strait of Juan de Fuca (30 km^2 and 49% of region), less in the San Juan Islands (27 km^2 and 33% of region), and smallest in Admiralty Inlet (4 km^2 and 5% of the region). Most of the intermediate quality sediment samples were classified as such due to toxicity and/or adversely affected benthos.

None of the stations were classified as degraded (0% of 90).

These data indicated that sediment quality was highest in the Admiralty Inlet, poorer in the San Juan Islands, and poorest in the eastern Strait of Juan de Fuca.

There was considerable spatial heterogeneity in sediment quality throughout the three regions and very few consistent spatial gradients. However, the majority of stations in East Sound, Lopez Sound, Sequim Bay, and Discovery Bay were intermediate in quality. Sequim Bay and Discovery Bay were among the few bays in which relatively degraded conditions in the middle or inner reaches improved seaward, either beyond the entrance or toward the mouth of the bay.

Discussion

Levels of Chemical Contamination

In this 2002-03 study, there were 42 out of the 90 samples (47%) in which one or more of the Washington State standards (SQS values) were not met. However, in all except two samples, the chemicals that exceeded the SQS values were chemicals for which the analytical results were least reliable. Substantial problems with variability in detection limits, inconsistent analytical precision, and inconsistent outcomes among lab replicates precluded using the data for five organic compounds in analyses for this report.

With the data for the five compounds omitted, there were only two samples in which a state standard was exceeded. The concentration of di-n-butylphthalate in one sample from the San Juan Islands, and the concentration of fluoranthene in one sample from the eastern Strait of Juan de Fuca, exceeded their respective SQS values. Therefore, with the amended data set, the incidence of contamination relative to the state standards was 2 of 90 or 2.2%. The two samples together represented about 3.6 km^2 of the study area, equivalent to 1.7% of the total study area.

Within the San Juan Island and eastern Strait of Juan de Fuca regions, the two samples represented 2.7 km^2 (3.3% of area) and 0.9 km^2 (1.4% of area), respectively. The spatial extent of chemical contamination in the Admiralty Inlet region was zero (0%) relative to the state SQS values. None of the ERM values derived for NOAA was exceeded in the 90 samples; therefore, the spatial extent of contamination relative to that set of guidelines was zero (0%).

Comparison with Other Puget Sound Surveys

In the PSAMP/NOAA survey of Puget Sound, both the incidence of contamination (181 of 300 samples, 60.3%) and spatial extent of contamination (53.1% of the area) relative to the SQS values were considerably higher than in the present study (Long et al., 2003). With the data for benzoic acid, phenol, and 4-methylphenol excluded from the PSAMP/NOAA survey data set, the incidence of contamination was reduced to 21% and the spatial area affected was reduced to 6% (Long et al., 2003). One or more ERM values were exceeded in 13% of the 300 samples in the PSAMP/NOAA survey, representing 1.3% of the total survey area.

Ecology and EPA surveyed the estuaries and bays of the outer coast of Washington in 1999, performing analyses on 41 sediment samples. None of the SQS or ERM values was exceeded in any samples, resulting in spatial extent estimates of zero (0%) relative to both sets of values (Wilson and Partridge, 2007). More than 100 locations were sampled in intertidal and offshore stations in 2002 and 2003 in this project and, again, none had chemical concentrations that exceeded either the SQS or ERM values (Partridge, 2007).

The incidence and spatial extent of chemical contamination relative to the state SQS values in the eight monitoring regions of Puget Sound are compared in Table 21. Two regions (Admiralty Inlet, Hood Canal) have been surveyed twice thus far. However, the data from the 1998 survey of Admiralty Inlet were merged with the data from the 2002-03 survey there, so only one entry is shown for that region in Table 21. Both the incidence and spatial extent of contamination in the three regions surveyed in 2002-03 were toward the lower end of the ranges relative to the other Puget Sound regions and are comparable to the spatial extent of contamination found in central and south Puget Sound and Hood Canal.

The incidence and spatial extent of contamination were greatest in the Whidbey Basin, Strait of Georgia, and Central Puget Sound regions, and lowest in the Admiralty Inlet and Hood Canal (2004) regions (Table 21). The list of chemical analytes (excluding the 5 BNAs), the analytical laboratory, analytical methods, and the SQS values were the same in all surveys. However, some differences in detection limits and laboratory precision among years may have had an influence on the outcome of these comparisons. In any case, based on these comparisons, the levels of contamination in the three regions surveyed in 2002-03 appeared to be somewhat lower than most of the other regions.

Within the greater Puget Sound basin, the areas in which contamination was greatest in the PSAMP surveys included the industrialized harbors and urban bays near the cities of Seattle, Tacoma, Everett, and Bremerton (Long et al., 2003). The sediments sampled in this study near the cities of Port Angeles and Port Townsend were not as contaminated as the sediments from these four urban areas.

The chemical composition of the mixtures differed between the areas sampled in the PSAMP/NOAA survey and the present 2002-03 survey. Sediments sampled during 1997-99 often were contaminated with elevated concentrations of trace metals (e.g., copper, mercury, silver), PAHs, and chlorinated organic compounds, including PCBs. For example, phenol, 4-methylphenol, benzoic acid and PAHs were chemicals of greatest concern in Everett Harbor. In Sinclair Inlet, benzoic acid, and mercury were most frequently elevated in concentrations. Benzoic acid, PAHs, PCBs, phenol, and mercury contaminated much of Elliott Bay. Copper, mercury, PAHs, PCBs, and hexachlorobenzene contaminated some samples from the Commencement Bay waterways.

Therefore, the nature of the sources of contamination in the urban bays and harbors of Seattle, Tacoma, Everett, and Bremerton differed from those in Port Angeles and Port Townsend. Although obvious differences among the industrial bays of Puget Sound occurred in the composition of the chemical mixtures, all regions were contaminated by varying degrees with both phenol and benzoic acid. However, both of these chemicals were among those for which laboratory analytical results were least reliable.

Comparison with Other Surveys Nationwide

To provide additional perspective to these data, similar information was compiled from several nationwide inventories and many regional, estuarine surveys conducted along the east, west, and Gulf of Mexico coastlines of the U.S. (Table 22**)**. Nearly all of these studies reported the percentages of samples in which sediment quality guidelines (ERM values, unless specified otherwise) were exceeded by one or more chemicals. Most also reported the areas affected and the percentages of total survey areas studied.

Sampling and analytical methods comparable to those used in the present study were applied in most of the other studies; however, differences in both sampling and analytical methods could account for some proportion of apparent differences among regions and data inventories. Data for the five organic compounds deleted from the present study were either not generated in the other studies or were not considered in Table 22.

EPA (1997) compiled the largest sediment quality database currently available as a part of a national inventory of sediment contamination (Table 22). Data were compiled from freshwater and saltwater studies with broad nationwide coverage, but with a bias toward industrialized areas. Among the 21,000 samples for which chemistry data were reported, 26% were classified as contaminated (concentrations exceeded at least two guideline values) or were toxic in an acute amphipod survival test.

In another study, a database was compiled from NOAA and EMAP studies of estuaries to quantify the predictive ability of guidelines. These data were more comparable to those developed in the present study of Puget Sound because studies were conducted only in estuaries and the analytical methods generally were the same. Chemical concentrations in 1,068 samples were compared to the ERM values and to Probable Effect Level (PEL; MacDonald et al., 1996) values. Among the 1,068 samples, 27% and 36% exceeded at least one ERM or PEL value, respectively.

In Ecology's SEDQUAL database, largely populated with data from samples collected during enforcement or other regulatory actions in urbanized bays of Puget Sound (excluding PSAMP/NOAA samples), 27% of 8523 samples had at least one chemical concentration that exceeded an SQS value (Table 22).

In multiple surveys conducted either by NOAA or EMAP in marine and estuarine regions, from 5% to 27% of samples had at least one concentration greater than an ERM value. When expressed as percentages of survey areas, the results ranged from 0% to 29% among nine studies. In intensive studies of New York/New Jersey (NY/NJ) harbor, California bays and harbors, and Pearl Harbor (Hawaii), the sampling designs focused on urbanized and industrialized areas known or suspected of being contaminated. Therefore, these studies were unlike the EMAP and NOAA surveys, but, nevertheless, were conducted with random-stratified designs of each harbor.

In two surveys of the New York/New Jersey harbor, the estimates of the spatial extent of chemical contamination were very similar, 50% in 1993 and 47% in 1998 (Table 22). In the California bays and harbors, 71% of samples had at least one chemical concentration greater than an ERM value, and in Pearl Harbor 80% of samples were contaminated at equivalent levels. In targeted (i.e., non-random) studies of industrialized harbors of Australia (Sydney Harbor), bays and harbors of England, and maritime harbors of The Netherlands, the incidence of contamination ranged from 44% to 75%.

Summary

In summary, the incidence of chemical contamination in the 2002-03 study area was considerably less than in many other estuarine areas in the U.S. and other countries. The incidence, degree, and spatial extent of chemical contamination relative to the NOAA ERM values in the present study was the same as that observed along the outer coast of Washington State and in the estuaries of Mississippi (i.e., 0%). The percentages of areas affected by concentrations exceeding the ERM values was 0% only in two other areas sampled with similar random sampling designs (Washington outer coast and Mississippi estuaries).

In all other areas studied with similar designs, the percentages of areas affected ranged from 0.7% (Biscayne Bay) to 50% (NY/NJ harbor). The sediments from the three regions studied in 2002-03 were less contaminated than those from the Strait of Georgia, Whidbey Basin, and central Puget Sound regions studied in the 1997-99 PSAMP/NOAA surveys.

Levels of Toxicity

In the PSAMP/NOAA survey of 1997 through 1999, sediments were tested for amphipod survival, sea urchin fertilization, microbial bioluminescence (organic extract), and induction of cytochrome P-450 (Long et al., 2003). The amphipod survival, sea urchin fertilization, echinoderm development/survival, and the microbial bioluminescence (porewater) tests were performed in the 2002-03 surveys. Only the sea urchin fertilization tests were performed in the Hood Canal survey in 2004. Therefore, only the sea urchin fertilization tests were performed for all of the Puget Sound monitoring regions and survey years.

The percent incidence and spatial extent of toxicity in the sea urchin fertilization test are compared among monitoring regions in Table 23. Thus far, Hood Canal and Admiralty Inlet are the only regions that have been surveyed twice. As with the chemistry data, the toxicity data for Admiralty Inlet in 1998 were merged with those from the 2002-03 survey. The percent incidence of toxicity ranged from 3% to 26% in tests of 100% pore water, and the spatial extent of toxicity in these tests ranged from 1% to 22% of the survey areas. Both the incidence and spatial extent were the lowest (3% and 3%) in the San Juan Islands region, intermediate (7% and 11%, respectively) in the Admiralty Inlet region, and among the highest (17% and 22%) in the eastern Strait of Juan de Fuca in the 2002-03 surveys.

Relative to the overall estimates for the PSAMP/NOAA survey area (11% of stations, 4% of survey area), the outcomes were lower in the San Juan Islands, similar in the Admiralty Inlet region, and higher in the eastern Strait of Juan de Fuca region. The incidence of toxicity was highest in the Whidbey Basin, but the toxic samples there represented a very small area. The percentage of area affected was greatest in the eastern Strait of Juan de Fuca.

The sea urchin fertilization test was performed on sediment pore water from many marine bays and estuaries of the U.S. by NOAA and USGS, using the gametes of the Gulf of Mexico species *Arbacia punctulata* (Long, 2000; Long and Sloane, 2005). The sensitivity of *Strongylocentrotus purpuratus* used in the Puget Sound surveys and *A. punctulata* used elsewhere proved to be somewhat different to different chemicals in side-by-side tests done for the PSAMP/NOAA survey. Overall, however, results were sufficiently similar to warrant comparisons in the incidence and spatial extent of toxicity in tests of pore water among the eight monitoring regions of Puget Sound and other areas.

In data sets compiled from 22 U.S. marine bays and estuaries in which sea urchin fertilization was tested in 100% sediment porewater concentrations, the spatial extent of toxicity ranged from 0% to 98% (Table 13 in Long et al., 2003). The median of these 22 results was 33%, and the average among all data sets nationwide was 35% as calculated with data compiled through 1999. Therefore, the percentages of areas affected by toxicity in the 2002-03 surveys of Puget Sound were low to intermediate relative to other estuarine and marine areas of the U.S. and the 1997-1999 Puget Sound samples.

Sediment Quality Triad Categories

The percent incidence of stations in each of the four Sediment Quality Triad categories and the spatial areas that they represented have been estimated and compiled for all eight of the Puget Sound monitoring regions (Table 24). Two areas (Hood Canal, Admiralty Inlet) have been surveyed twice thus far. The sample collection, chemical analysis, and benthic infaunal processing and identification methods were comparable in all surveys. The suites of toxicity tests differed between 1997-1999, 2002-2003, and 2004. Methods used to classify the benthic infaunal assemblages as affected or unaffected differed for 2004. These differences may have influenced comparisons among regions and/or study periods. Nevertheless, the outcomes of the triad analyses are compared among the eight regions in Table 24.

For the purpose of these comparisons, the unreliable data for the 5 BNAs previously discussed were deleted and not considered. Therefore, the estimates in Table 24 will not agree with those previously published in which all chemical concentrations for which there are state standards were compared.

Throughout the combined PSAMP/NOAA survey area, 46% of samples were high quality, 28% were intermediate/high, 13% were intermediate/degraded, and 12% were degraded. These samples represented 68%, 27%, 4%, and 1%, respectively, of the total survey area (Table 24). Therefore, throughout the total survey area, about 1% of the area was classified as degraded.

Among all eight regions, the percentages of samples classified as degraded with the triad of measures ranged from 0% to 21%, and the percentages of areas affected ranged from 0% to 2.3%. There were no stations in the three regions studied in 2002-03 that were classified as degraded. This was similar to sediment quality examined previously in the Strait of Georgia and Hood Canal/2004 regions, which also had no sediments in the degraded category. The San Juan Islands and eastern Strait of Juan de Fuca regions had relatively high percentages of samples and areas in either of the two intermediate categories, whereas the Admiralty Inlet region sediments were predominantly high quality.

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Summary and Conclusions

A survey of sediment quality in the bays and inlets of three adjoining PSAMP monitoring regions (eastern Strait of Juan de Fuca, San Juan Islands, and Admiralty Inlet) was conducted in 2002-03 by the Washington State Department of Ecology as a part of the Puget Sound Assessment and Monitoring Program.

Samples were collected at 30 locations in each region, for a total of 90 in the study. The entire study area encompassed a total of 212 km^2, which was distributed about equally among the three regions. Laboratory analyses were performed on all samples to determine the concentrations of potentially toxic chemicals, the degree of response in four laboratory toxicity tests, and the composition of the resident benthos. The primary objective of the study was to estimate the incidence and spatial extent of degraded conditions as determined with the Sediment Quality Triad of information.

Chemical Contamination

Among the 90 samples, there were 42 in which one or more of the Washington State Sediment Quality Standards were exceeded. However, the chemicals that exceeded these standards in 40 of the samples (phenol, 2-methylphenol, 4-methylphenol, benzoic acid, benzyl alcohol) were chemicals for which the analytical data were least reliable. Therefore, they were omitted from further evaluation in this report.

Based on the amended data set, there were only 2 samples out of the 90 in which any of the other State standards were exceeded. Thus, the incidence of contamination was 2.2% of the 90 samples. These two samples were estimated to represent 3.6 km^2 of the total study area, equivalent to 1.7% of the total study area. There was one sample each from the San Juan Islands and eastern Strait of Juan de Fuca that was defined as contaminated with one chemical and none from Admiralty Inlet. Therefore, the spatial extent of contamination as defined with these methods was 2.7 km^2 (3.3% of the area) in the San Juan Islands, 0.9 km^2 (1.4% of area) in the eastern Strait of Juan de Fuca, and 0 km^2 (0% of area) in Admiralty Inlet.

There were no obvious or distinct spatial gradients or patterns in sediment contamination among stations within each region, although some of the samples collected in southern Port Townsend and in inner Port Angeles were slightly more contaminated than others. The three regions surveyed in 2002-03 were among the least contaminated of the eight Puget Sound monitoring regions that have been studied thus far in this program using internally consistent methods.

Toxicity

The incidence of toxicity and the degree of response among the four toxicity tests generally were highest in Sequim and Discovery Bays along the eastern Strait of Juan de Fuca and in East Sound in the San Juan Islands. Samples from most of the bays and coves that were classified as toxic were usually accompanied by non-toxic samples from neighboring stations, thereby indicating considerable spatial heterogeneity. The echinoderm (sand dollar) embryo test of sediment/water mixtures and the sea urchin test of pore water were the most sensitive. The Microtox® test of pore water and the amphipod survival test of solid phase sediments were the least sensitive.

There was very little concordance or agreement among the four toxicity tests in the identification of toxic samples. There was only one sample with significant responses in three tests and none with significant responses in all four tests.

Throughout the entire 2002-03 study area, there were 30 samples (33% of 90) in which at least one test response was statistically significant. These samples represented a total of 80 km^2 or about 38% of the total survey area. Toxicity of sediments as determined with any one of the four tests was most widespread in the eastern Strait of Juan de Fuca (37 km^2 or 59% of the study area), followed by the San Juan Island regions (27 km^2 or 33% of the study area), and least widespread in Admiralty Inlet (16 km^2 or 23% of the study area).

The pore water of sediments collected in all eight Puget Sound monitoring regions have been tested with the same sea urchin test. Among all eight Puget Sound monitoring regions surveyed by Ecology, the percent incidence of toxicity ranged from 3% to 26% in tests of 100% pore water, and the spatial extent of toxicity ranged from 1% to 22%. In the 2002-03 surveys, both the incidence and spatial extent were among the lowest in the San Juan Islands region, higher in the Admiralty Inlet region, and highest in the eastern Strait of Juan de Fuca. The Whidbey Basin and Hood Canal regions were among the more toxic regions, roughly equivalent to that for the eastern Strait of Juan de Fuca. The percentages of areas affected by toxicity in the 2002-03 surveys were low to intermediate relative to other estuarine and marine areas of the United States tested with similar methods.

Benthic Invertebrates

The composition, abundance, and diversity of the benthic assemblages differed considerably among the 90 stations, indicating a wide variety of assemblages and habitat types among the inlets and coves of these three regions. Among the 90 stations, the benthos were classified as adversely affected in 37 stations: 20 in the San Juan Islands, 14 in the eastern Strait of Juan de Fuca, and 3 in Admiralty Inlet. The diversity of the benthos was most variable within the San Juan Islands region and on average considerably lower than in the other two regions. Adversely affected benthos were found throughout all or most of East Sound, Lopez Sound, Sequim Bay, and Discovery Bay, whereas unaffected assemblages were apparent throughout most or all of Port Angeles, Dungeness Bay, Port Townsend, Useless Bay, and Mutiny Bay.

Sediment Quality Triad

Based on the Sediment Quality Triad of measures (chemistry, toxicity, adversely affected benthos), there were no samples in the 2002-03 study that were classified as degraded. Therefore, the incidence and spatial extent of degraded conditions was zero based on the methods that were used. The majority of stations (73%) and area (69%) in the Admiralty Inlet region were classified as high quality with these methods. The majority of stations (70%) and area (70%) were classified as either of the two intermediate classifications in the San Juan Islands. In the eastern Strait of Juan de Fuca, the majority of stations (60%) and area (72%) were classified as intermediate in quality.

The stations classified as intermediate in quality included some from Lopez Sound, East Sound, Sequim Bay, Discovery Bay, inner Port Angeles, Port Townsend, Oak Bay, and Useless Bay. However, there were no obvious and consistent spatial patterns in overall sediment quality. Stations classified as intermediate in quality invariably were surrounded by or were near other stations classified as high quality.

Comparisons between Puget Sound Sediment Monitoring Regions

The methods used to sample, test, and classify samples in the 1997-99 baseline PSAMP/NOAA surveys were similar to those used in the 2002-03 surveys, but not exactly the same. The chemical and benthic data are based on internally consistent methods and are directly comparable. Some of the toxicity tests used in the studies from 1997 to 2004 were different. In the combined data from the PSAMP/NOAA surveys, 46% of samples were high quality, 28% were intermediate/high, 13% were intermediate/degraded, and 12% were degraded. These samples represented 68%, 27%, 4%, and 1%, respectively, of the total survey area sampled from 1997 through 1999.

Relative to the 1997-99 baseline of outcomes, the results for 2002-03 indicate a mix of comparative results. Whereas 12% of the samples and 1% of the area sampled in 1997-99 were degraded, none of the samples analyzed in the 2002-03 surveys were classified as degraded. A minority of both the samples and of the combined area surveyed in 1997-99 was classified as either of the two intermediate categories, whereas the majority of samples and areas in the San Juan Islands and eastern Strait of Juan de Fuca were intermediate in quality. In contrast, a large majority of Admiralty Inlet was classified as high quality, more so than in the combined 1997-99 baseline surveys.

Relevance of the PSAMP Sediment Quality Data

Characterization of sediment quality in these three regions completes the 1997-2003 eight-region, Puget Sound-wide sediment quality data baseline. Periodic re-evaluation of regional sediment quality, using the Sediment Quality Triad Index and the spatial extent calculations derived from them, provides environmental managers with a measure of change over time useful in adaptive management.

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Recommendations

The sediment quality data collected for this survey and report complete the 1997-2003 baseline of data for the PSAMP Sediment Component's eight Puget Sound monitoring regions and five strata. Calculation of the spatial extent of sediment quality degradation for the five regions sampled for the 1997-99 PSAMP/NOAA monitoring program (Long et al, 2003, 2004) will be updated to include data from these three additional regions. This will complete the first set of probability-based, quantitative, spatial estimates (km^2) for the eight sediment monitoring regions, five strata, and whole-Puget Sound sampling frame.

The PSAMP Sediment Component baseline data provide environmental managers and scientists with a unique "effectiveness monitoring" tool for regional and Puget Sound-wide examination of sediment quality. Region and stratum estimates of the spatial extent of sediment quality degradation, as measured by the Sediment Quality Triad Index, characterizes the cumulative effects of natural and human-influenced toxic loading events, as well as source control and cleanup activities, occurring in each of the major oceanographic basins of Puget Sound.

Re-evaluation of sediments in each region, stratum, and sound-wide on a rotating annual cycle will allow evaluation of change over time, indicating improvement, degradation, or no change in sediment quality since the previous monitoring event.

To effectively generate and use the Sediment Quality Triad measures as an index of sediment health in Puget Sound, the following actions are recommended:

- **Continue annual PSAMP Spatial/Temporal sediment monitoring:** The PSAMP Sediment Component Spatial/Temporal monitoring should continue, with sampling rotating through each of the eight sediment monitoring regions; one region per year.

- **Conduct annual revision and comparison of data:** The spatial extent of sediment quality degradation should be revised and compared annually for regions, strata, and Puget Sound-wide as new data are generated. Sediment quality status revisions should be brought to the attention of Puget Sound environmental managers, highlighting any significant changes occurring over time.

- **Conduct surveys on sediment deposition, mixing, and resuspension rates in Puget Sound:** The rates of sediment deposition, mixing, and resuspension in different regions of Puget Sound should be quantified to help determine optimal intervals between sediment sampling events.

- **Use monitoring results to guide adaptive management strategies:** Environmental managers should review ambient monitoring results on a routine basis, and implement adaptive management strategies as needed, based on changes to and the current status of sediment quality in Puget Sound.

- **Ensure comparability of data:** While improvement and revision of analytical methods is sometimes necessary, methods used in Puget Sound ambient sediment monitoring surveys should remain similar over time to ensure continued generation of comparable data.

- **Monitor sediment quality at the "bay-scale":** Similar sediment monitoring and analyses should occur at the "bay-scale" for selected urban and non-urban Puget Sound embayments. This would provide environmental managers and scientists with a unique tool for examination of overall sediment quality of embayments of interest nested within larger regions. These data could be used as an "effectiveness monitoring" tool to determine whether source control and cleanup activities within embayments effectively improve the overall quality of the embayment. Adaptive management strategies can then be implemented to address problems. "Bay-scale" pilot studies are currently being conducted in Elliott Bay/Lower Duwamish and Commencement Bay (sampled by Ecology in 2007 and 2008, respectively), and should be extended to other embayments.

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Figures

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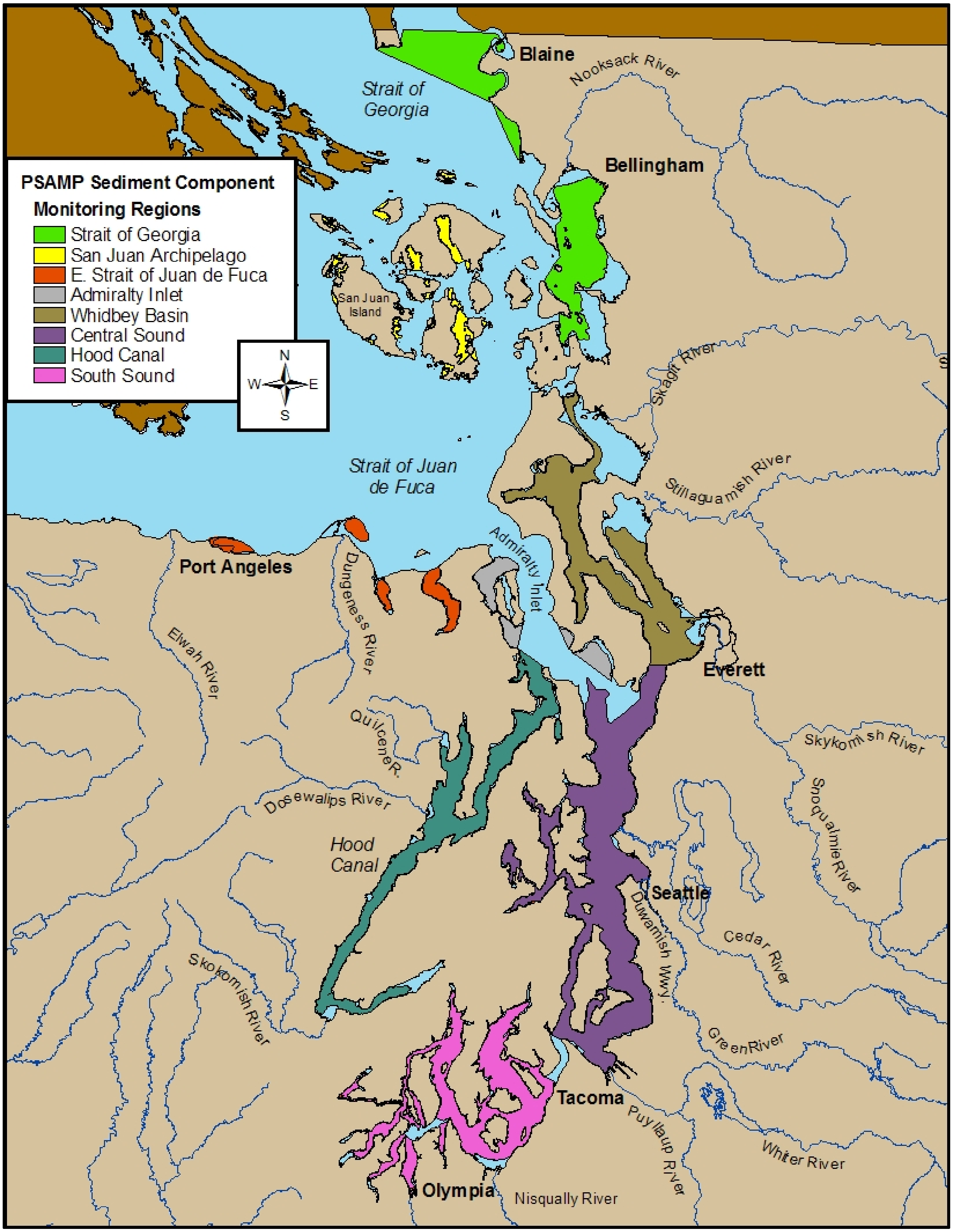


Figure 1. Eight sediment monitoring regions defined for the PSAMP Sediment Component.

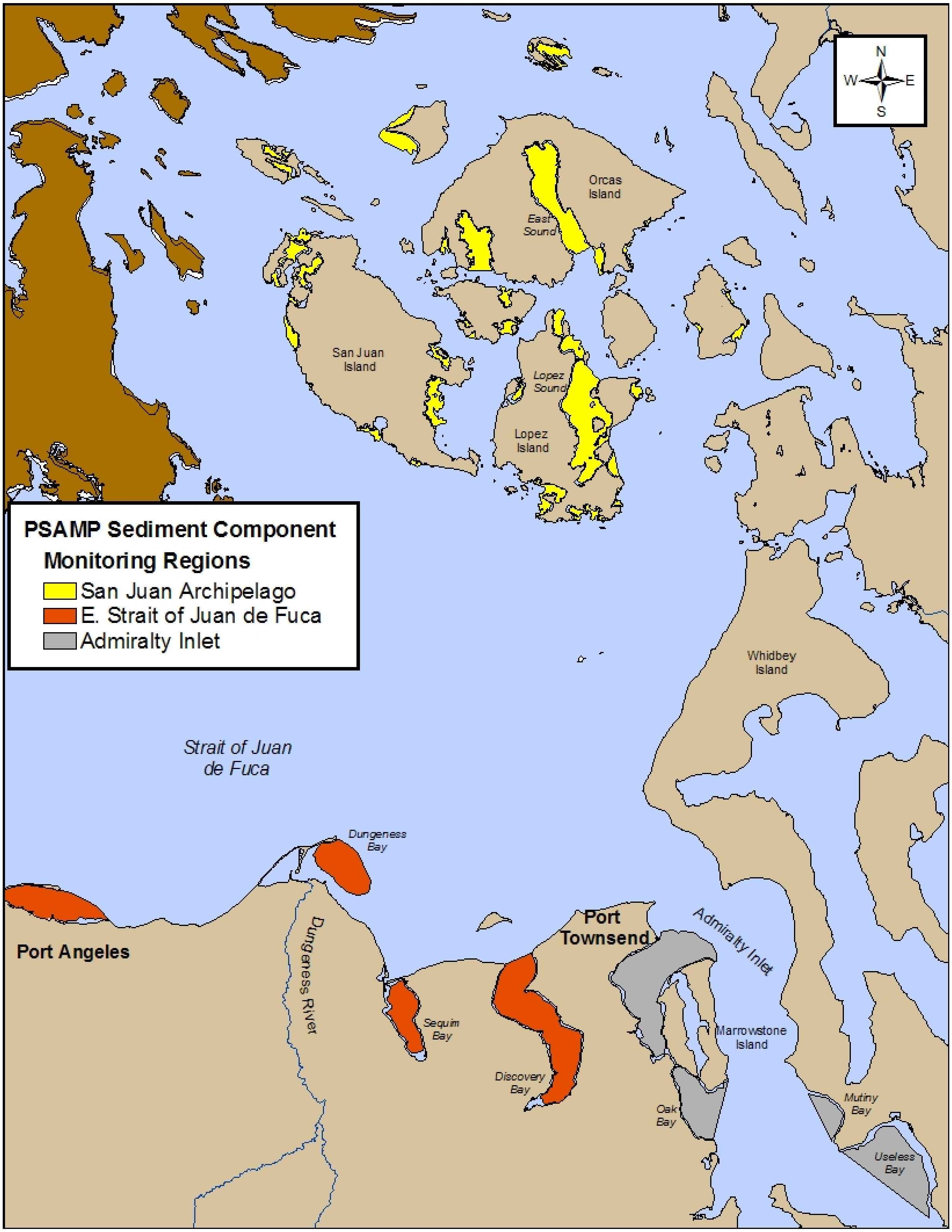


Figure 2. The 2002-2003 PSAMP Sediment Component monitoring regions, San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet.

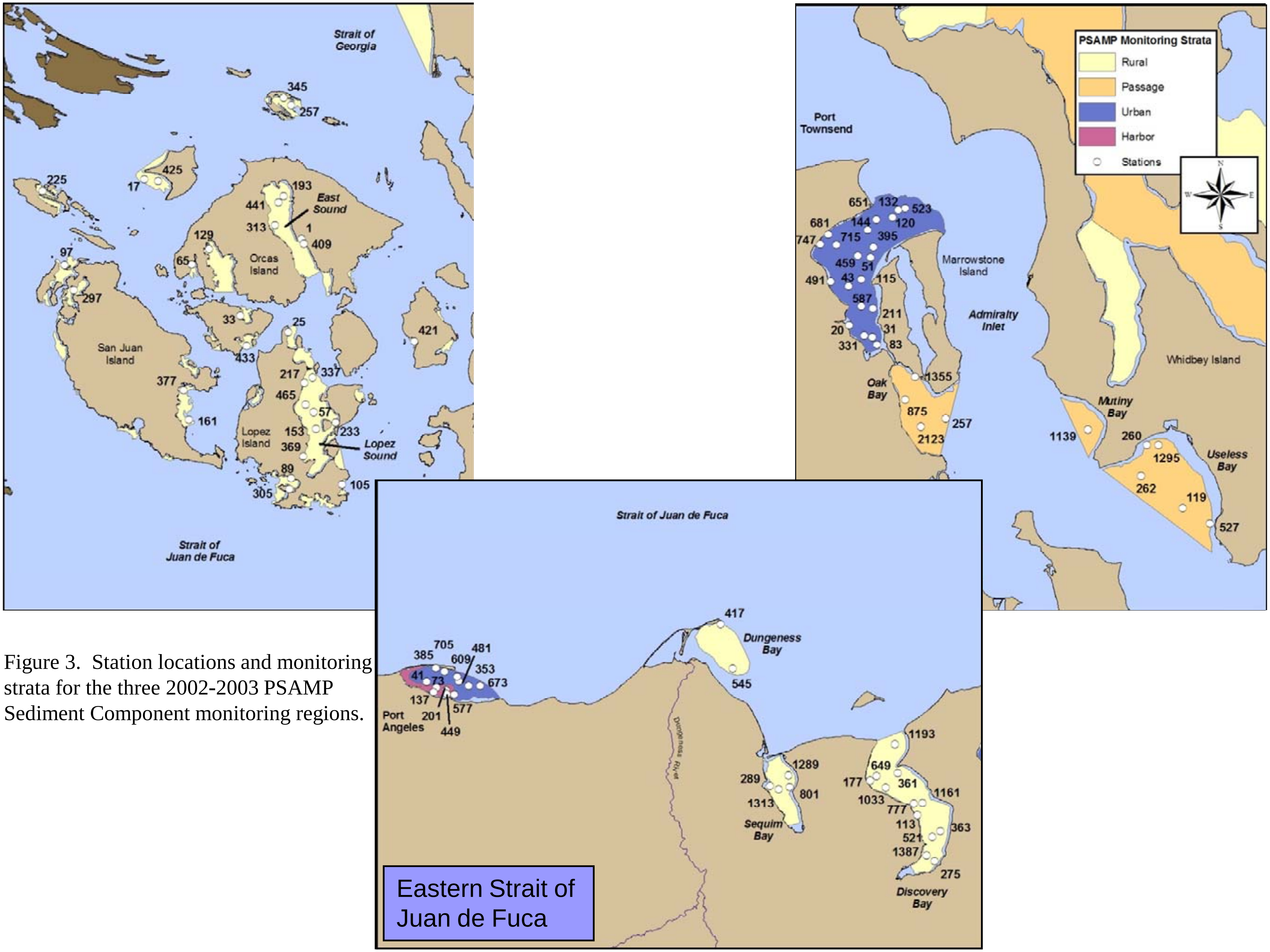
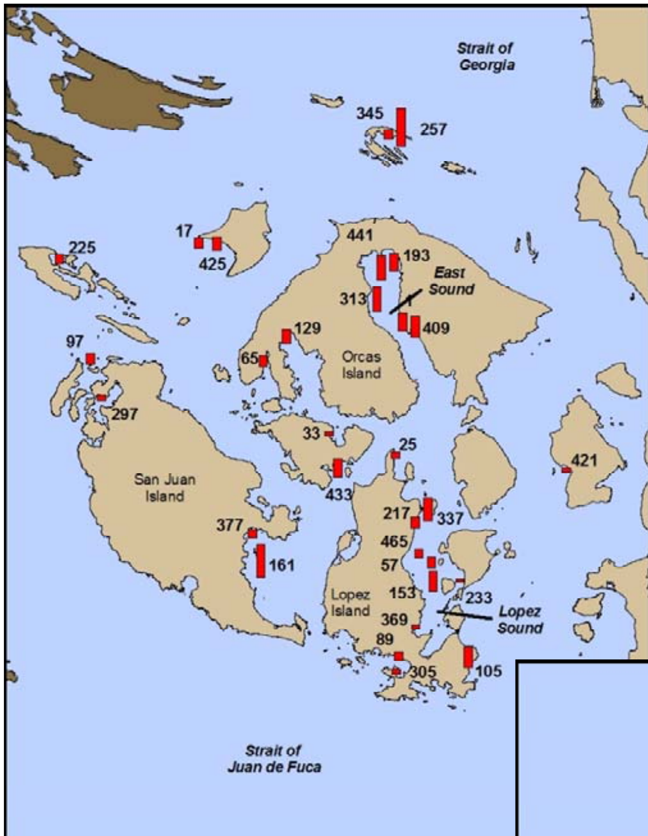
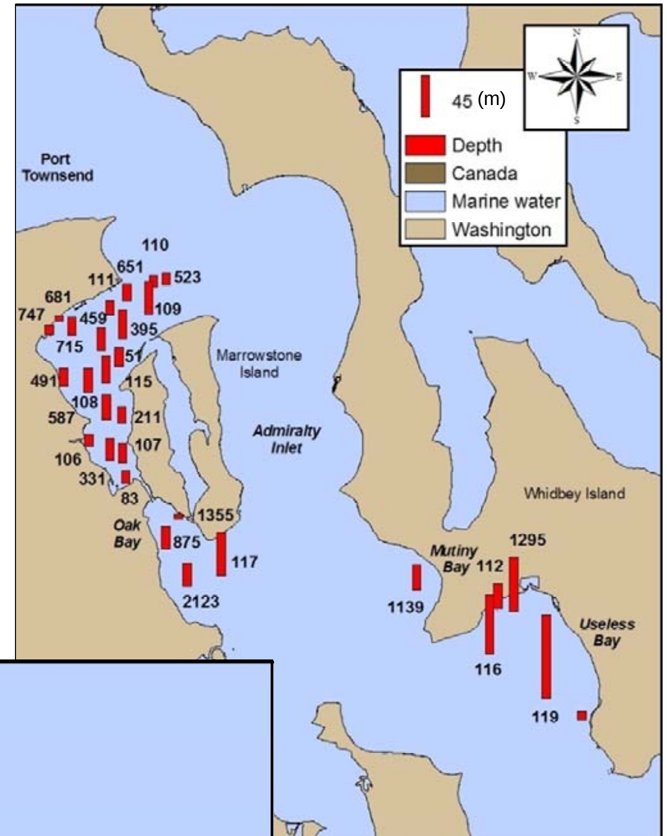


Figure 3. Station locations and monitoring strata for the three 2002-2003 PSAMP Sediment Component monitoring regions.





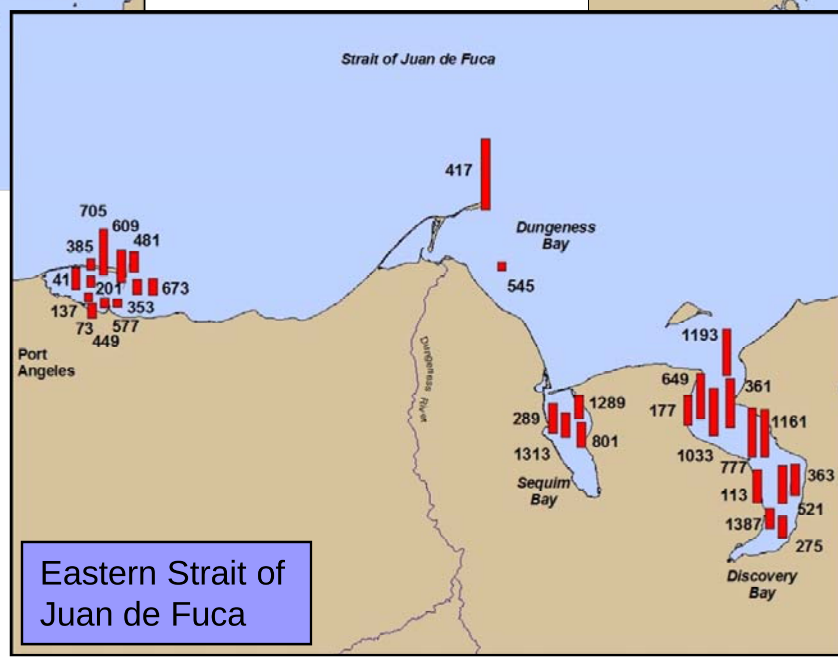


Figure 4. Depth: Spatial patterns for the three 2002-2003 PSAMP Sediment Component monitoring regions.

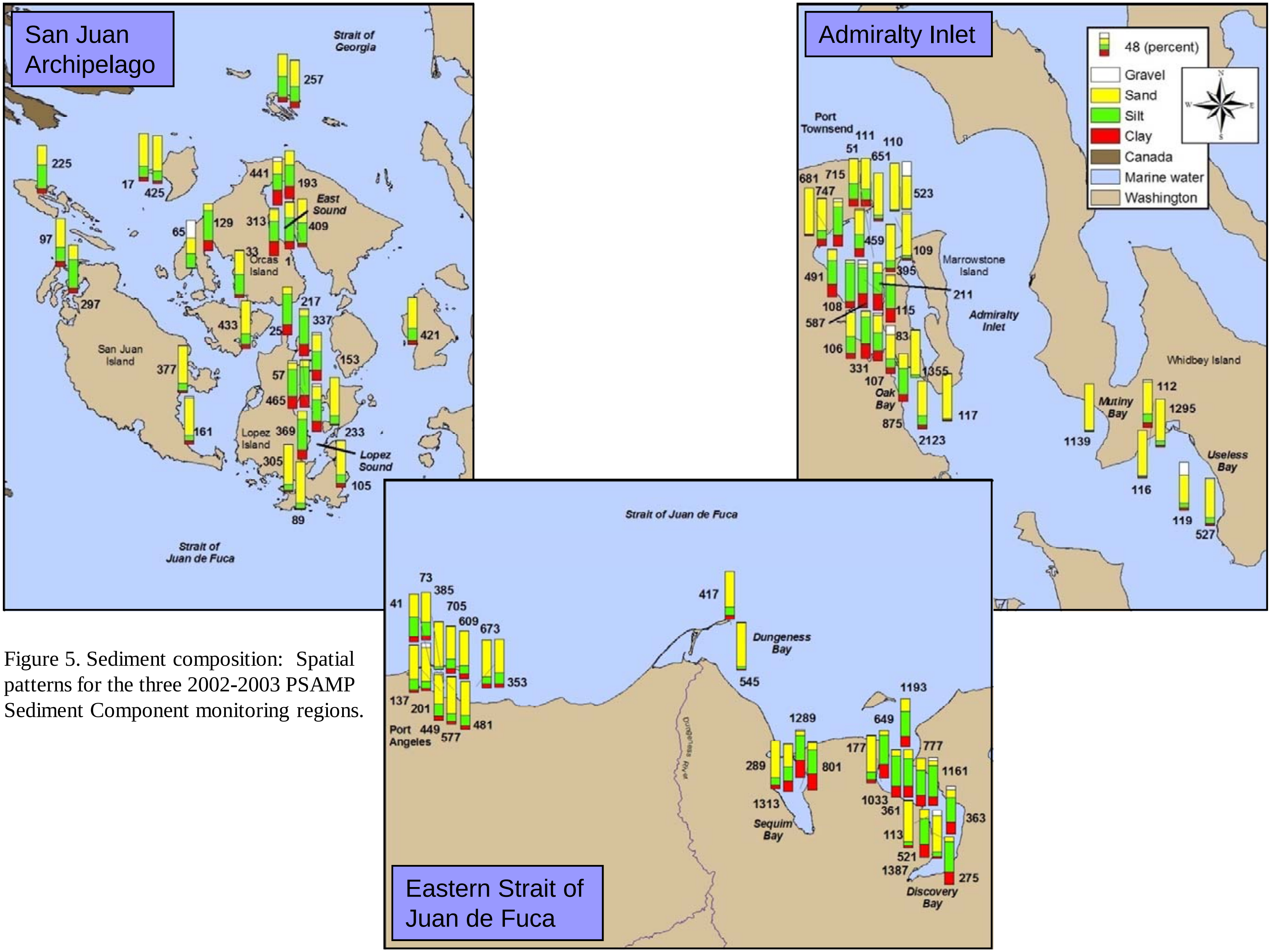
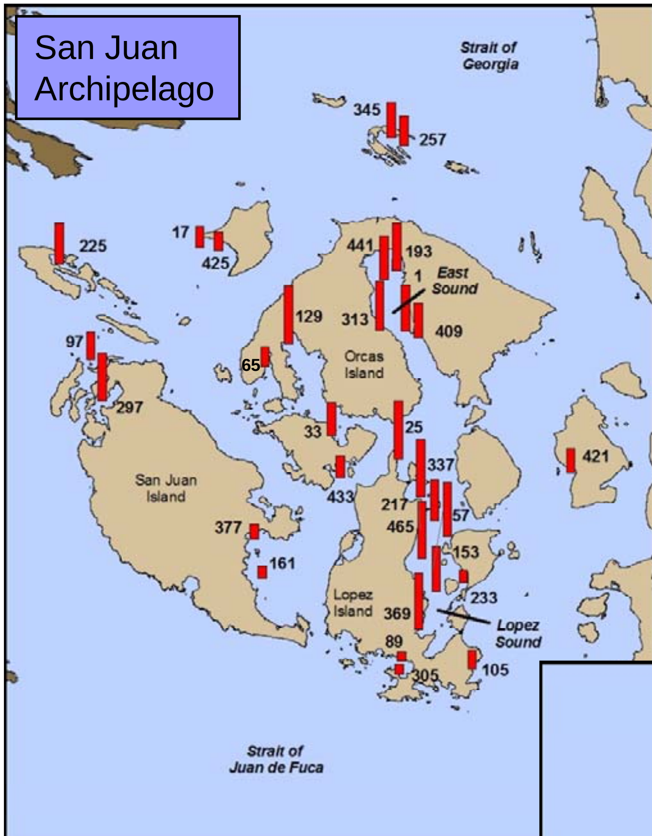
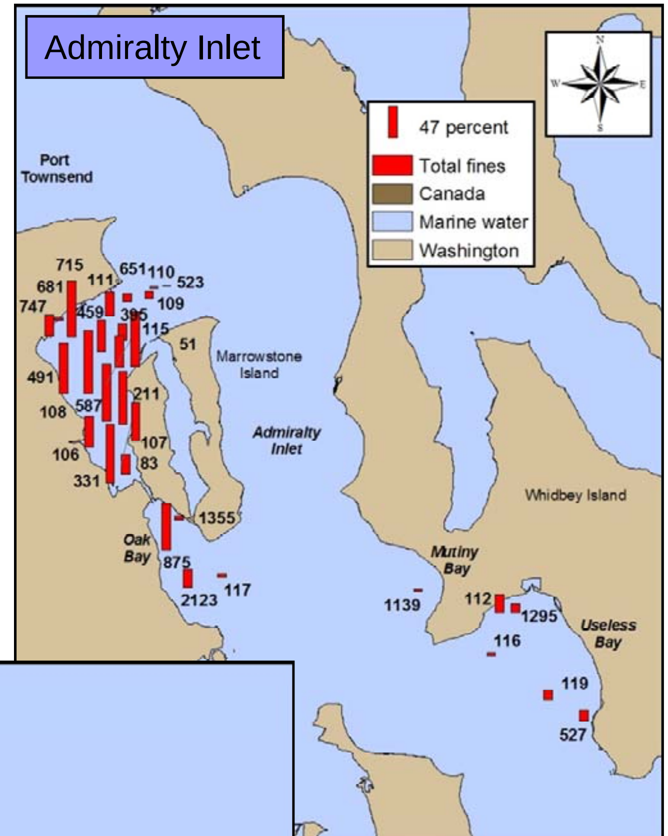


Figure 5. Sediment composition: Spatial patterns for the three 2002-2003 PSAMP Sediment Component monitoring regions.





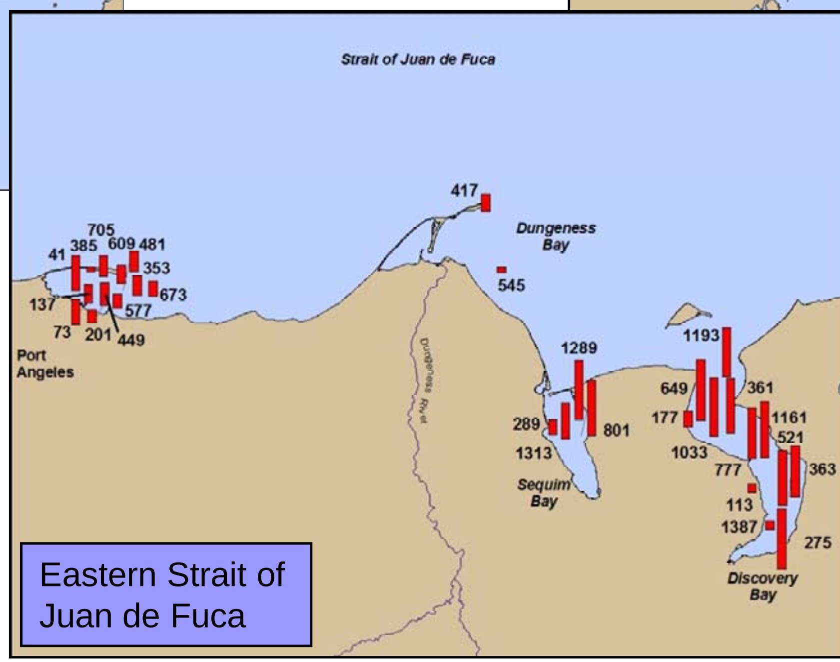


Figure 6. Percent fines: Spatial patterns for the three 2002-2003 PSAMP Sediment Component monitoring regions.

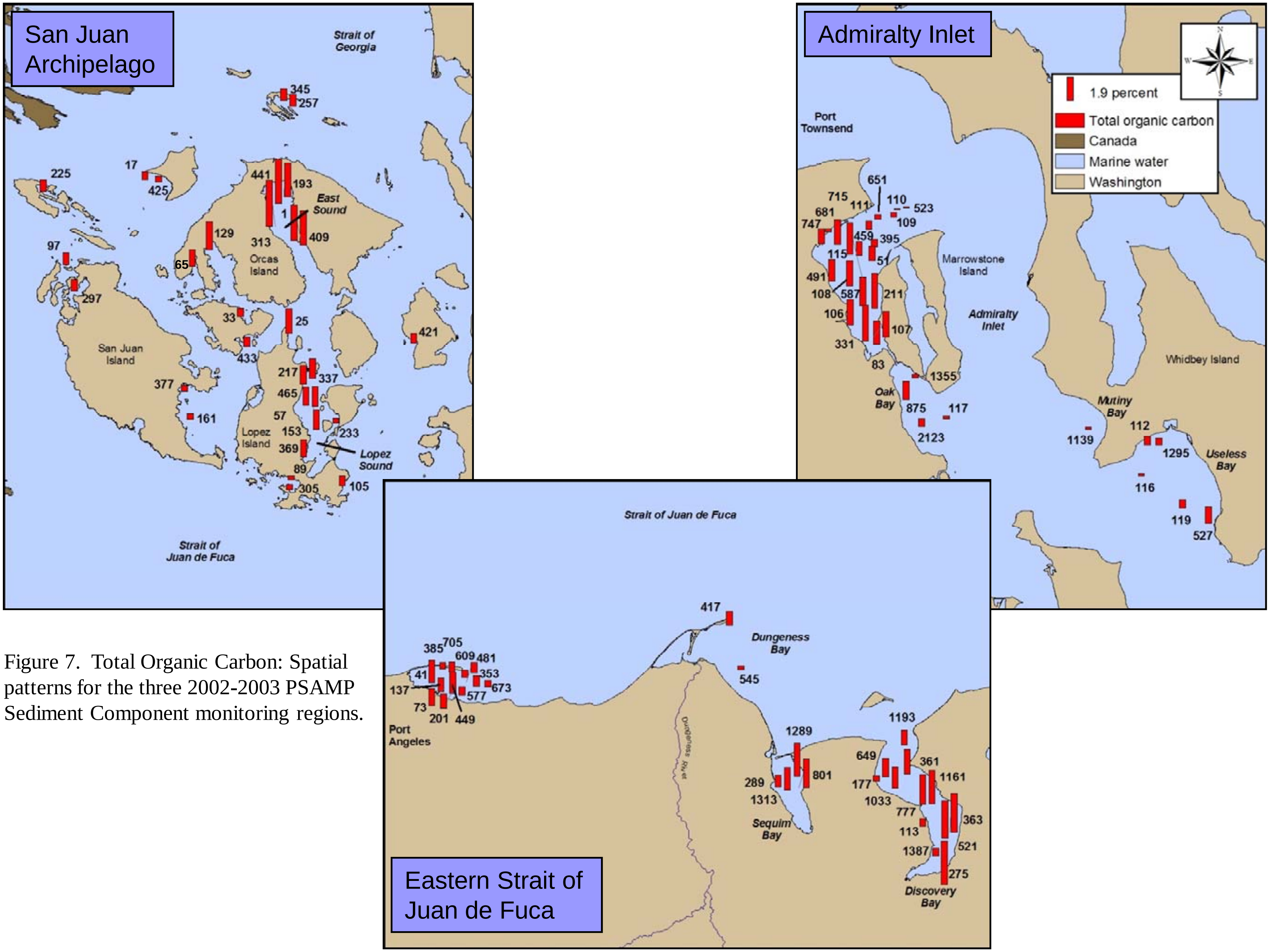


Figure 7. Total Organic Carbon: Spatial patterns for the three 2002-2003 PSAMP Sediment Component monitoring regions.

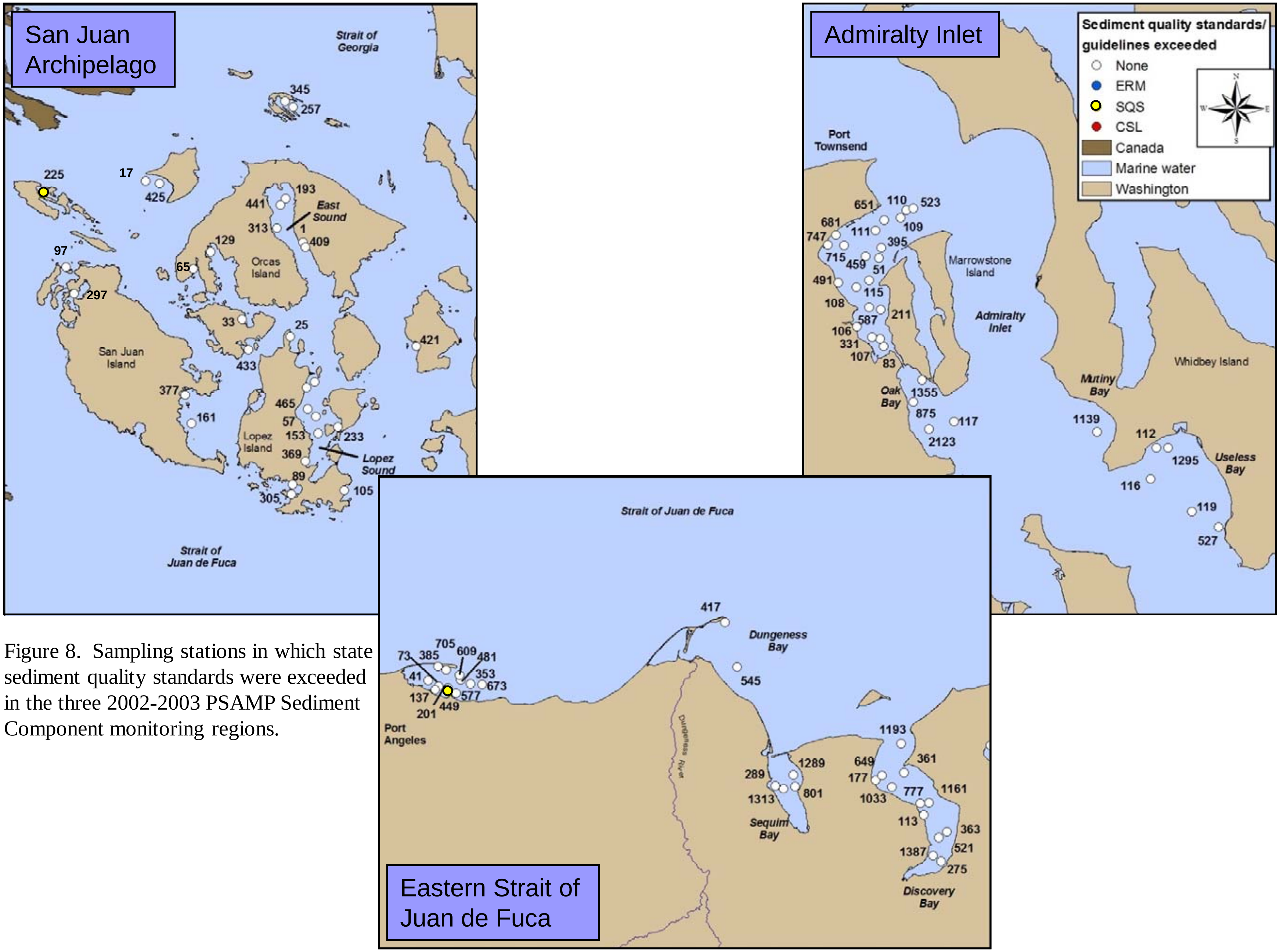
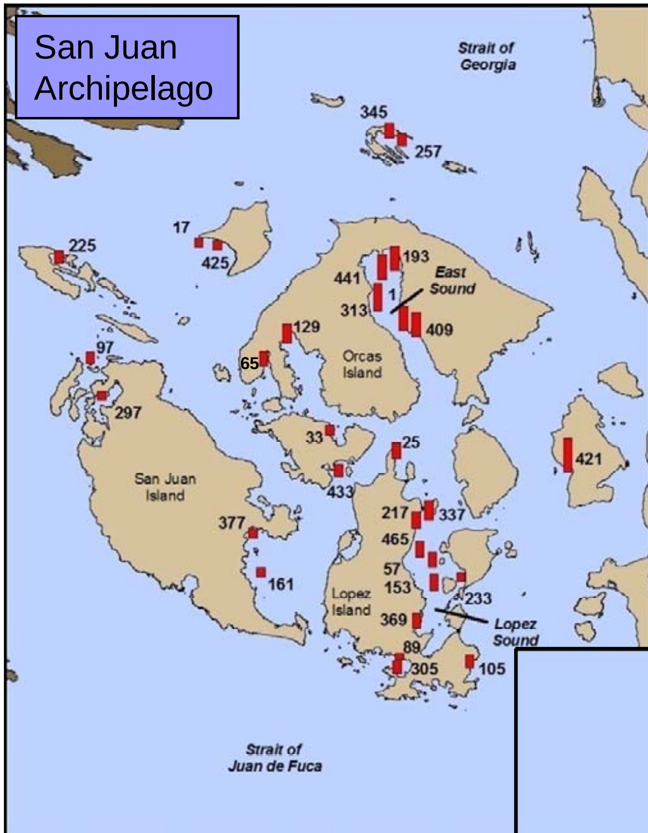
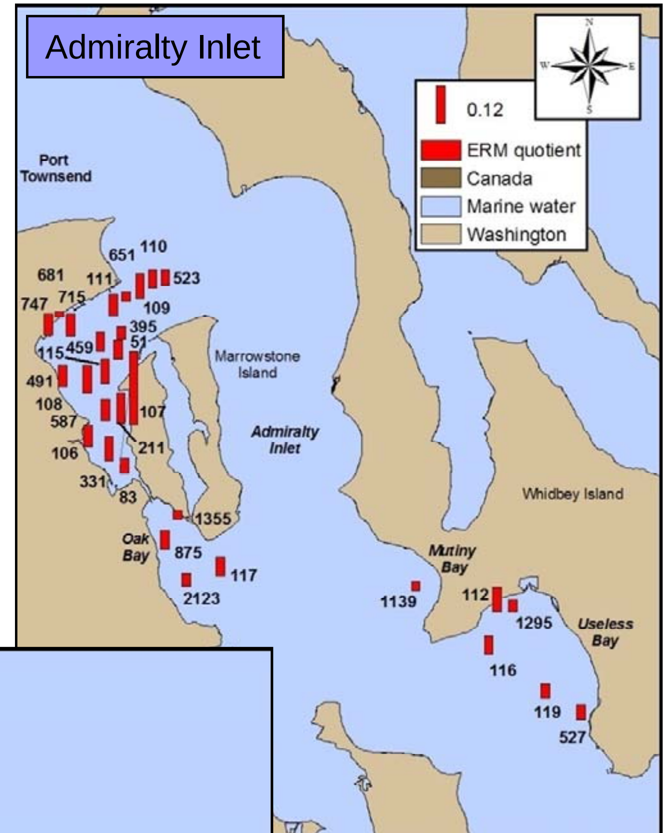


Figure 8. Sampling stations in which state sediment quality standards were exceeded in the three 2002-2003 PSAMP Sediment Component monitoring regions.





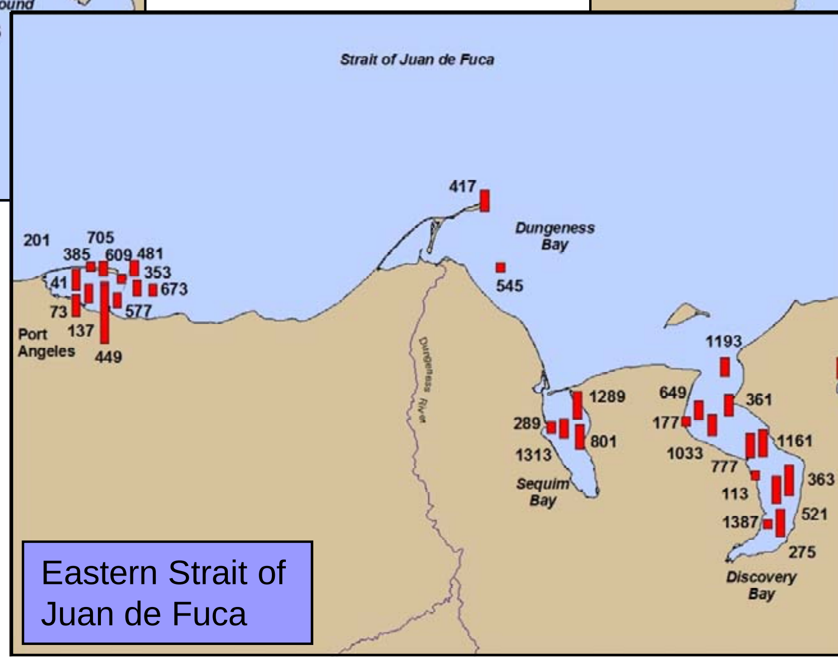
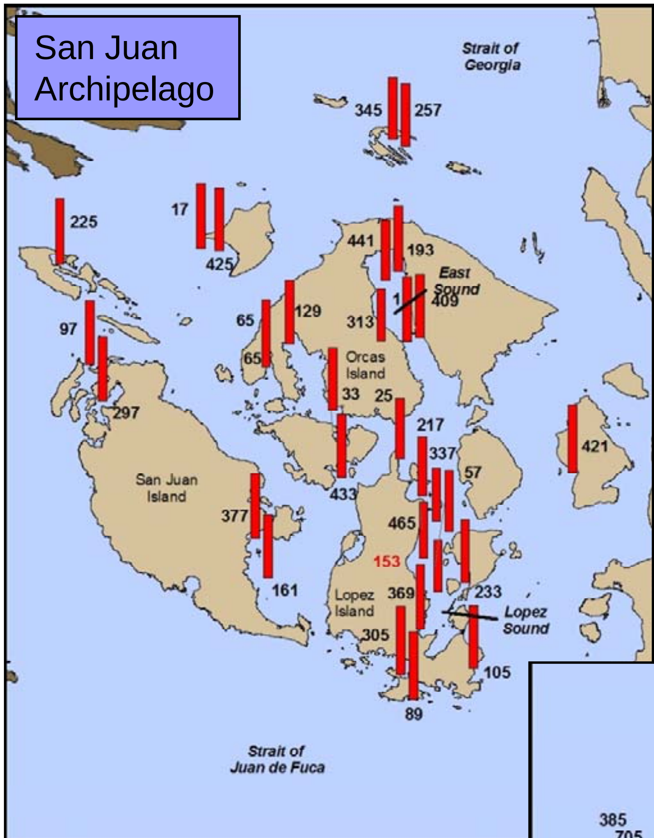
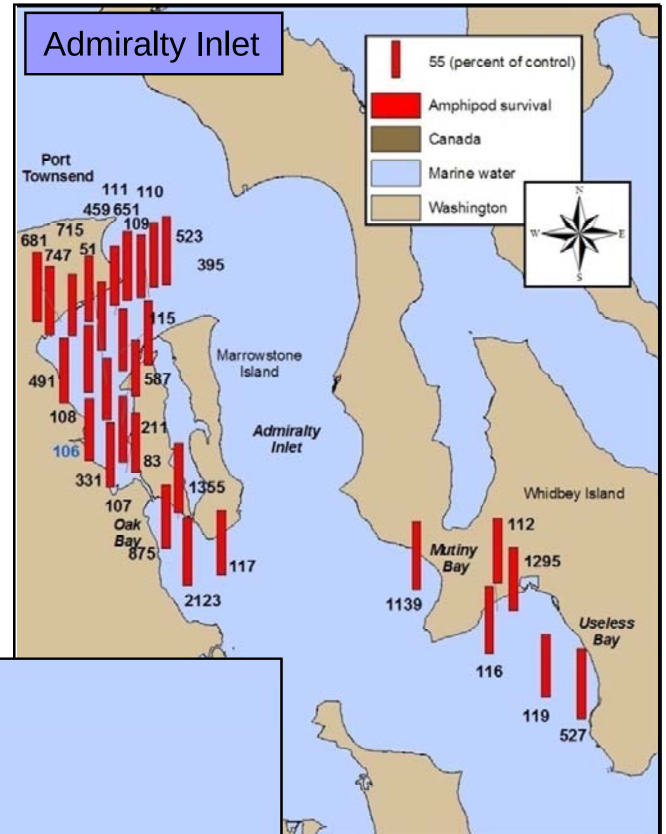


Figure 9. ERM quotients: Spatial patterns for the three 2002-2003 PSAMP Sediment Component monitoring regions.





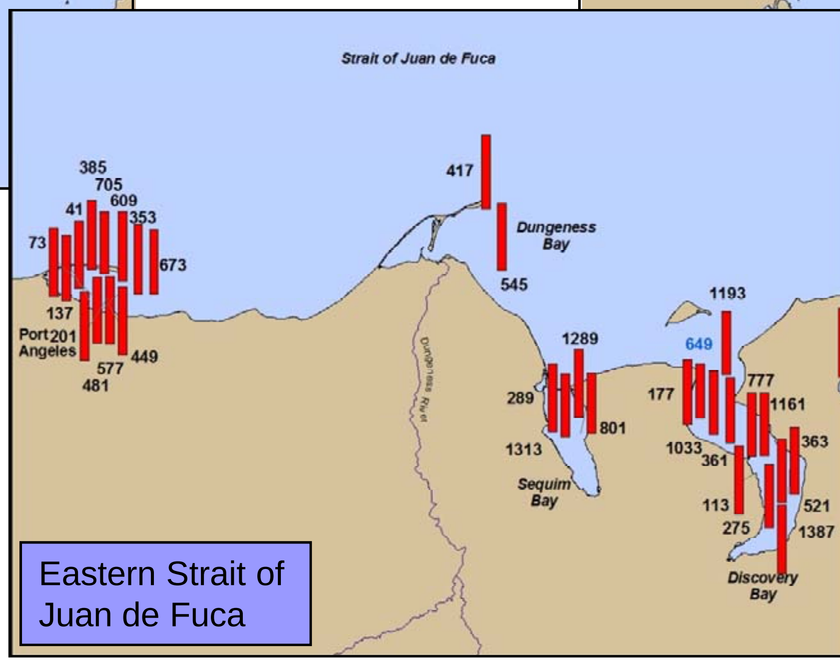
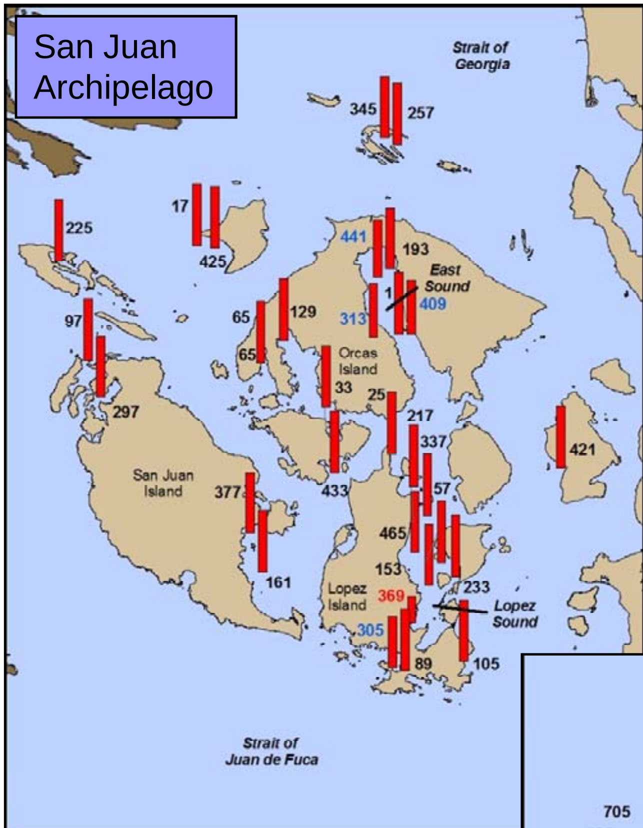
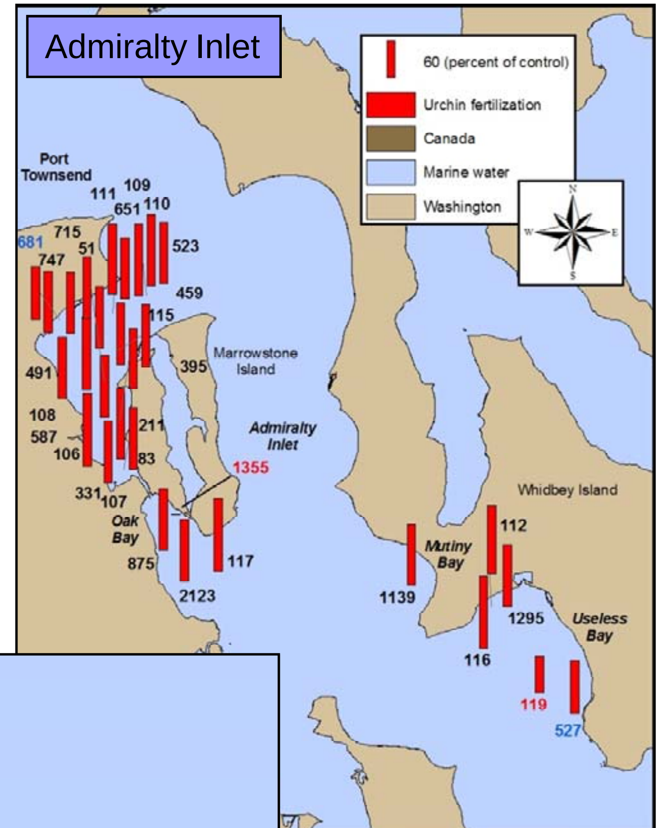


Figure 10. Spatial patterns in toxicity determined with the amphipod *Eohaustorius estuarius* in tests of solid phase sediments for the three 2002-2003 PSAMP Sediment Component monitoring regions.

Note:
Blue station numbers indicate results statistically significant (p-value <0.05, t-test).

Red station numbers indicate results statistically significant and a mean survival <80% of control (p-value <0.05, t-test).





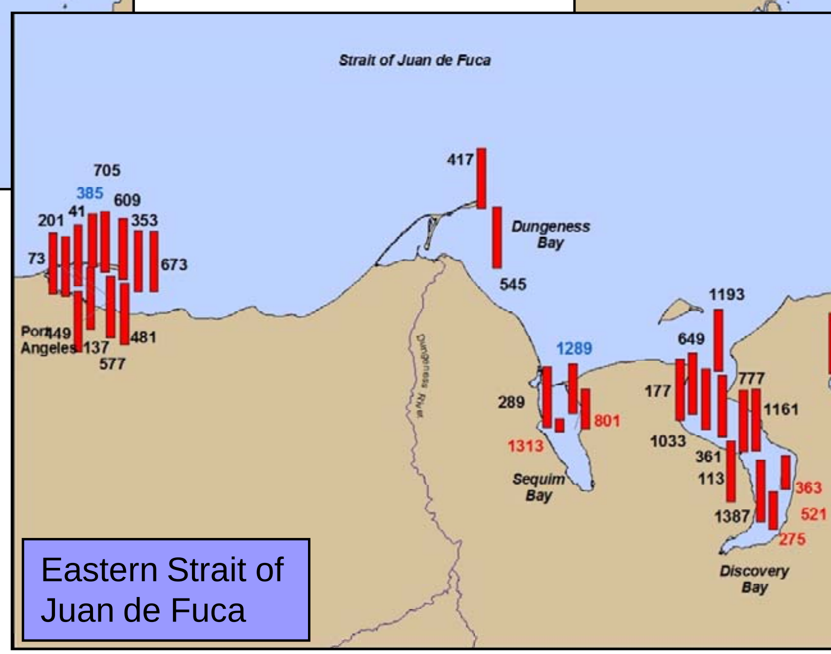
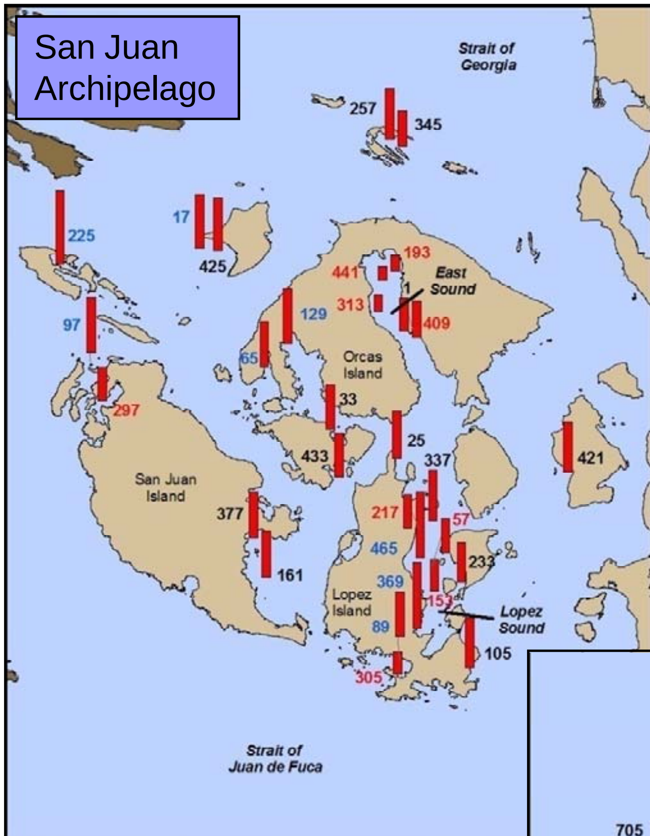
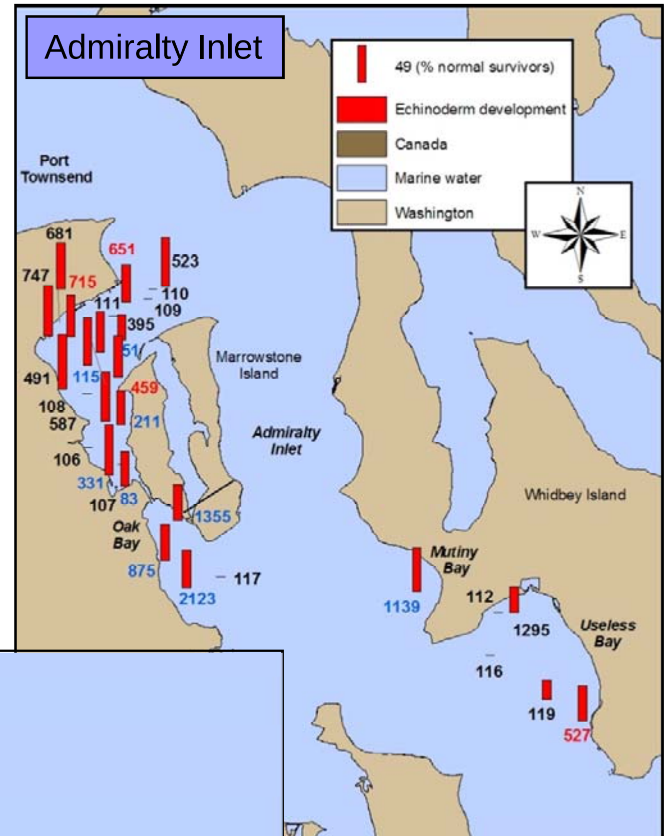


Figure 11. Spatial patterns in toxicity as determined with the sea urchin *Strongylocentrotus purpuratus* in porewater from sediments collected in the 2002-2003 PSAMP Sediment Component monitoring regions, San Juan Archipelago, Eastern Strait in Juan de Fuca, and Admiralty Inlet.

Note:
Blue station numbers indicate results statistically significant (p-value <0.05, t-test).

Red station numbers indicate results statistically significant and a mean fertilization <80% of control (p-value <0.05, t-test).





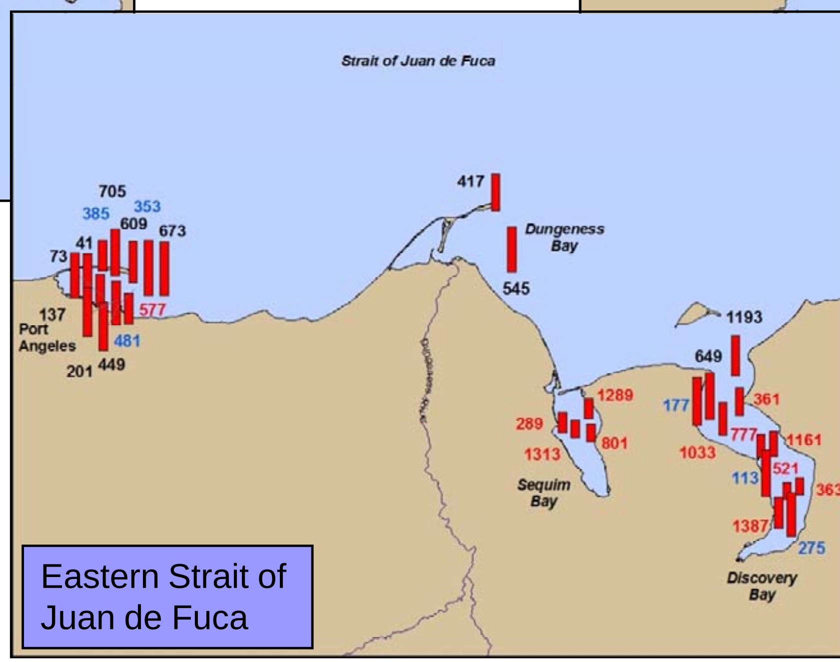


Figure 12. Spatial patterns in toxicity as determined with the echinoderm *Dendraster excentricus* in elutriates from sediments collected in the 2002-2003 PSAMP Sediment Component monitoring regions, San Juan Archipelago, Eastern Strait in Juan de Fuca, and Admiralty Inlet.

Note:
NS = Not sampled.

Blue station numbers indicate results statistically significant (p-value <0.05, t-test).

Red station numbers indicate results statistically significant and a mean normal survivorship <85% of control (p-value <0.05, t-test).

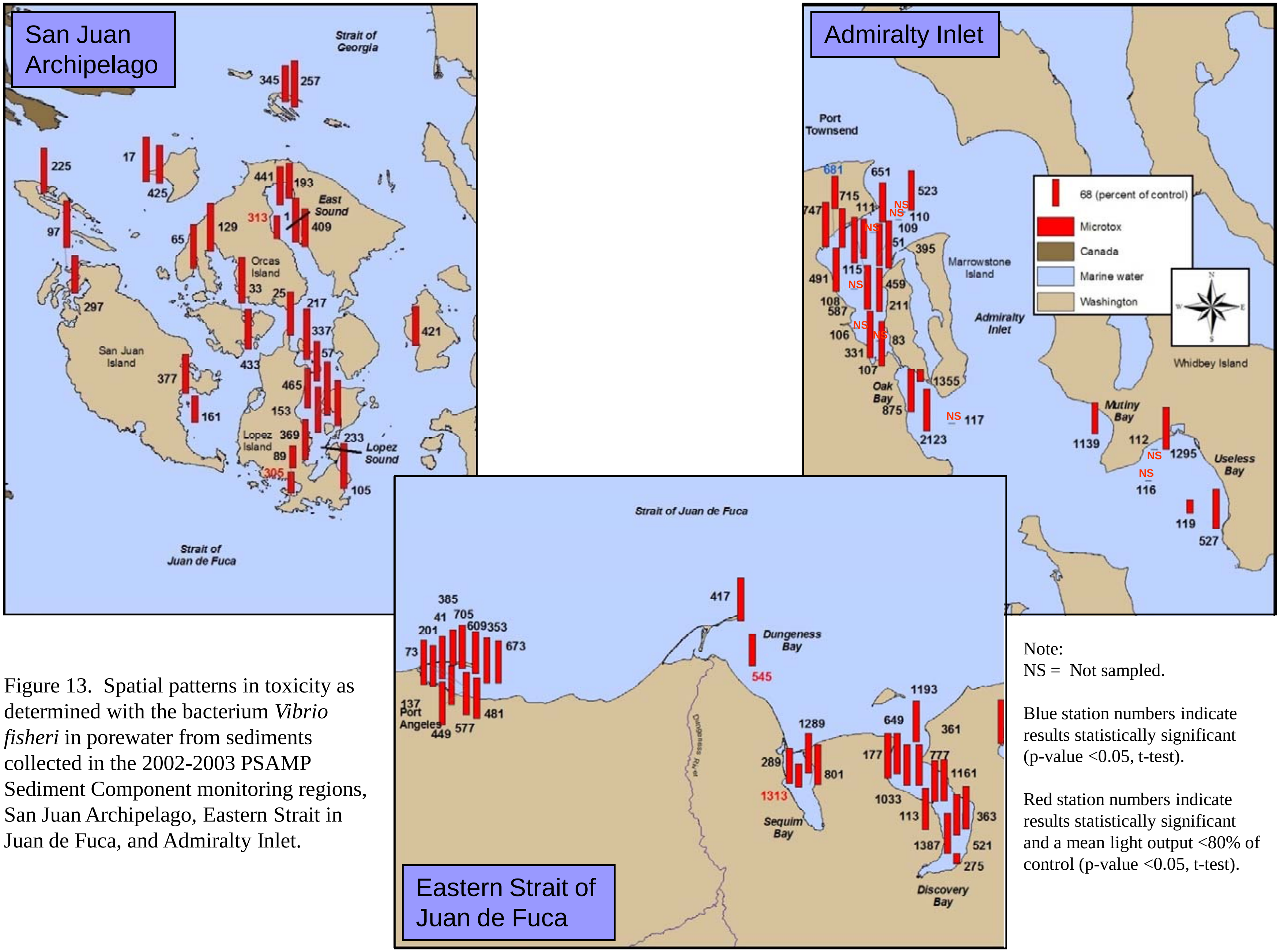


Figure 13. Spatial patterns in toxicity as determined with the bacterium *Vibrio fisheri* in porewater from sediments collected in the 2002-2003 PSAMP Sediment Component monitoring regions, San Juan Archipelago, Eastern Strait in Juan de Fuca, and Admiralty Inlet.

Note:
NS = Not sampled.

Blue station numbers indicate results statistically significant (p-value <0.05, t-test).

Red station numbers indicate results statistically significant and a mean light output <80% of control (p-value <0.05, t-test).

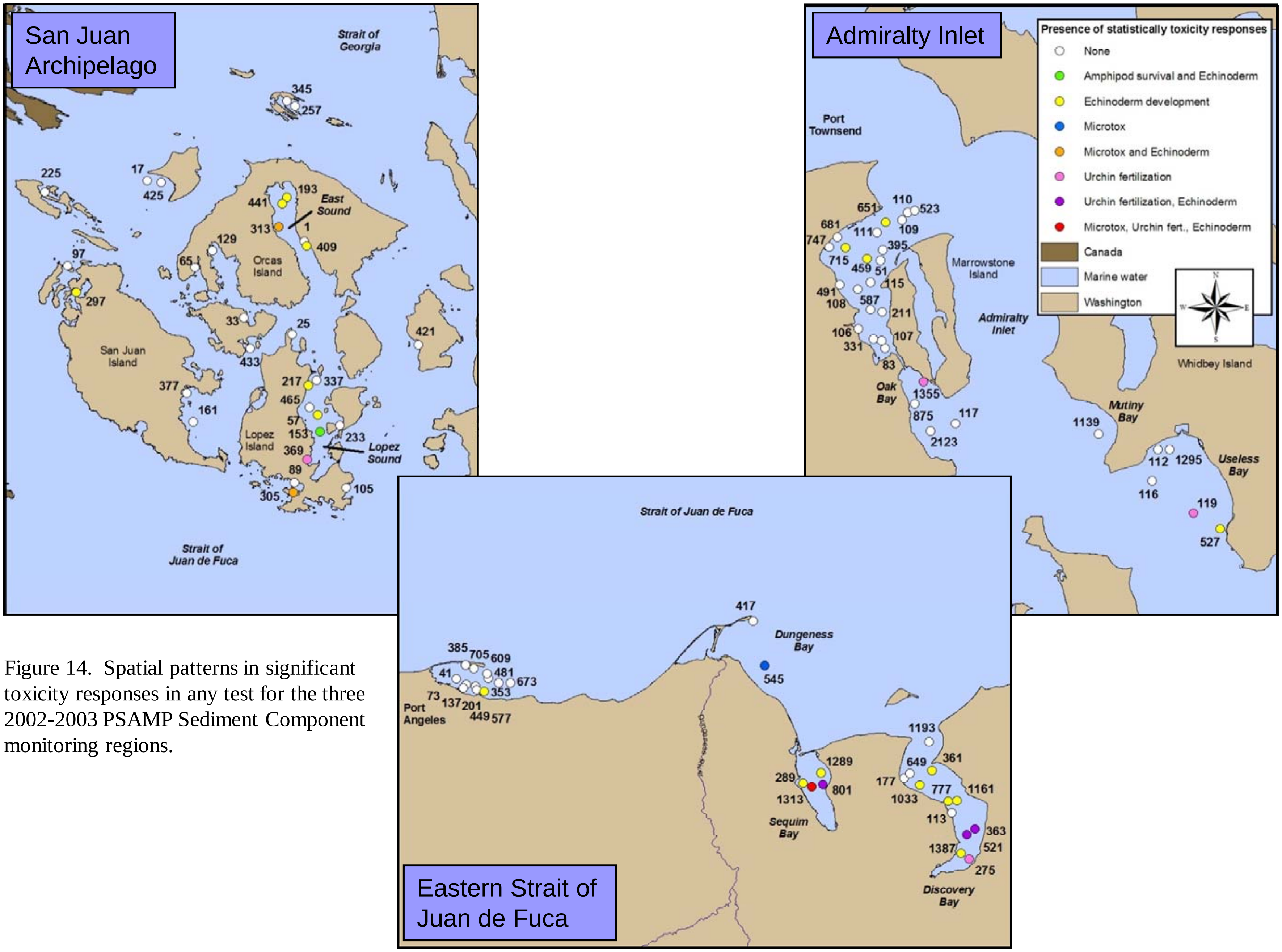


Figure 14. Spatial patterns in significant toxicity responses in any test for the three 2002-2003 PSAMP Sediment Component monitoring regions.

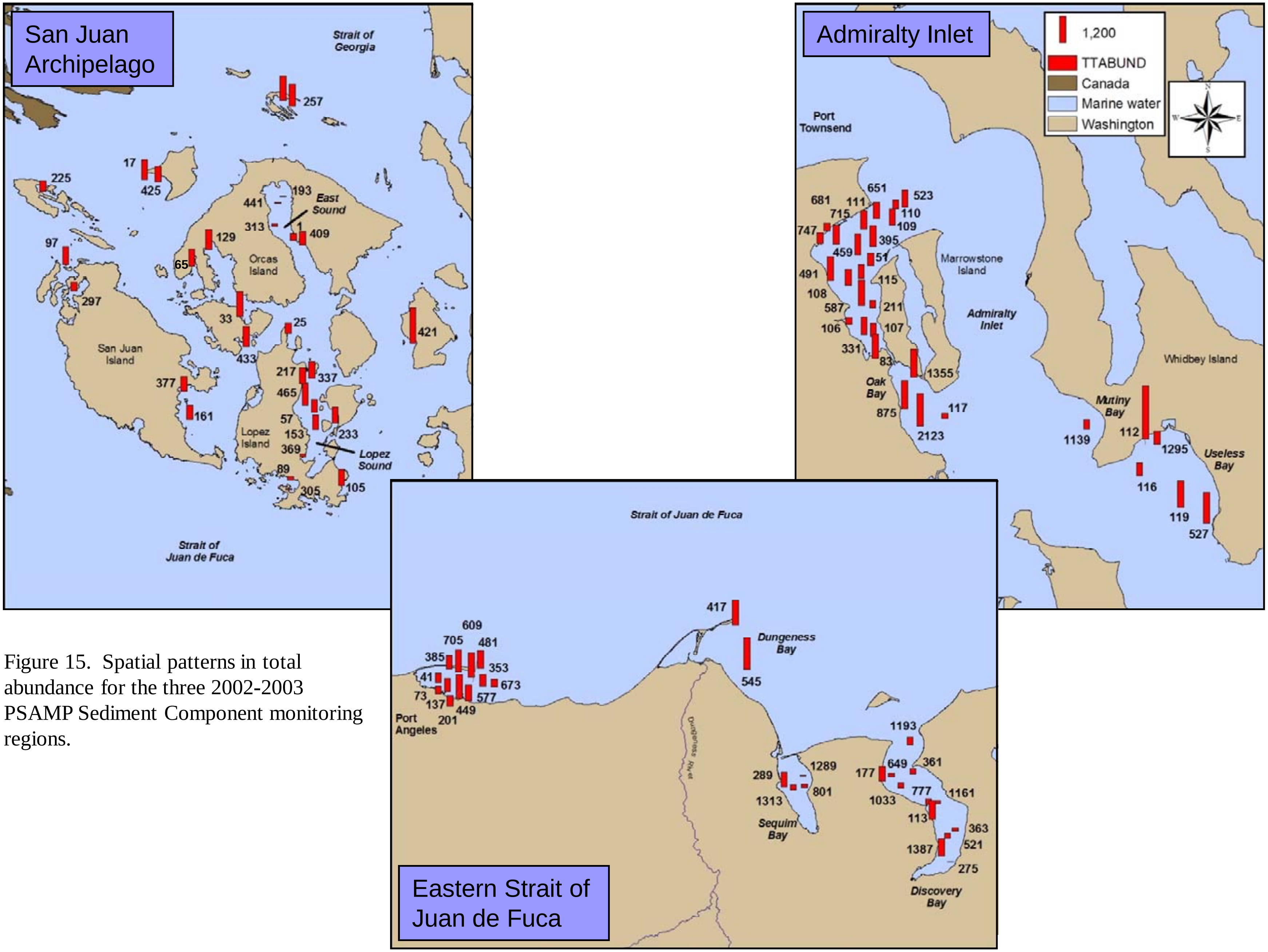
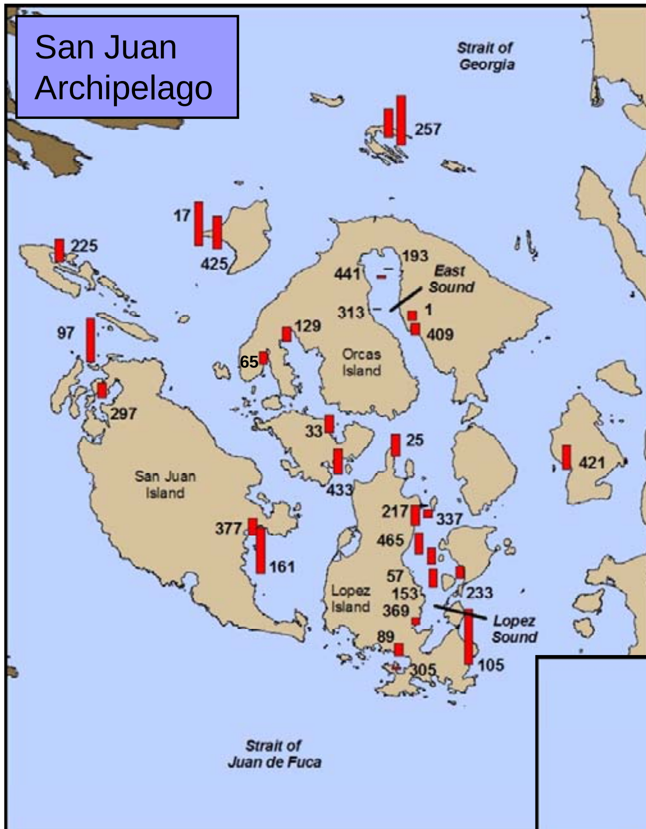
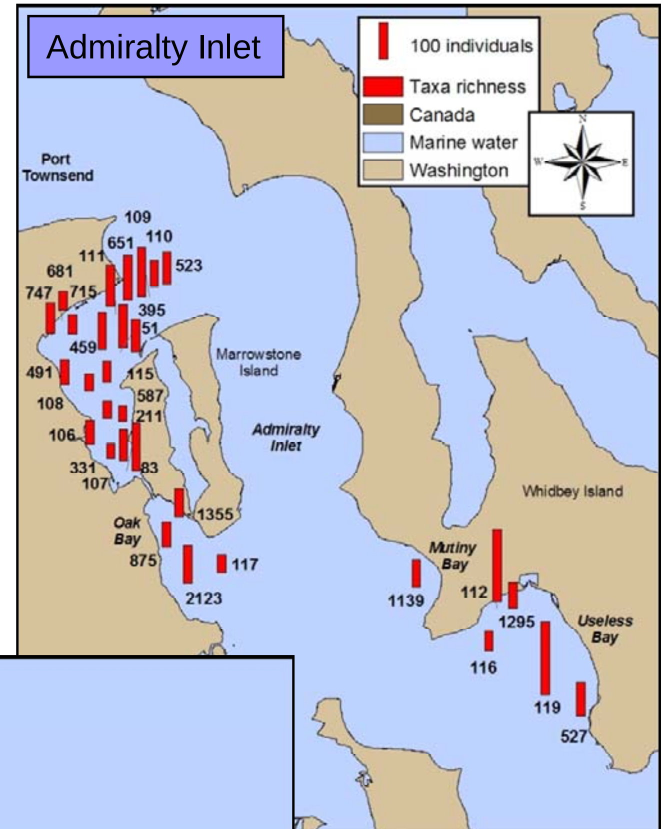


Figure 15. Spatial patterns in total abundance for the three 2002-2003 PSAMP Sediment Component monitoring regions.





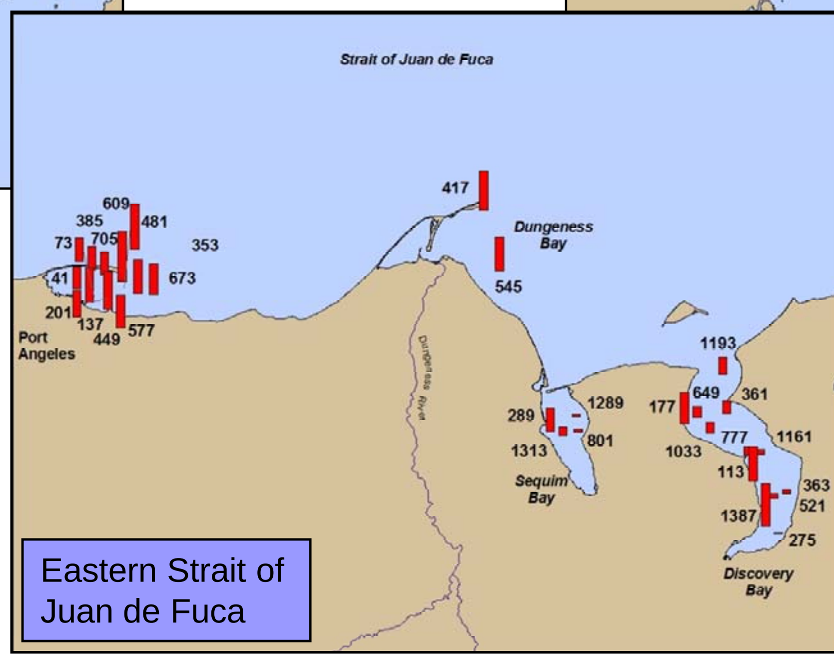


Figure 16. Spatial patterns in taxa richness for the three 2002-2003 PSAMP Sediment Component monitoring regions.

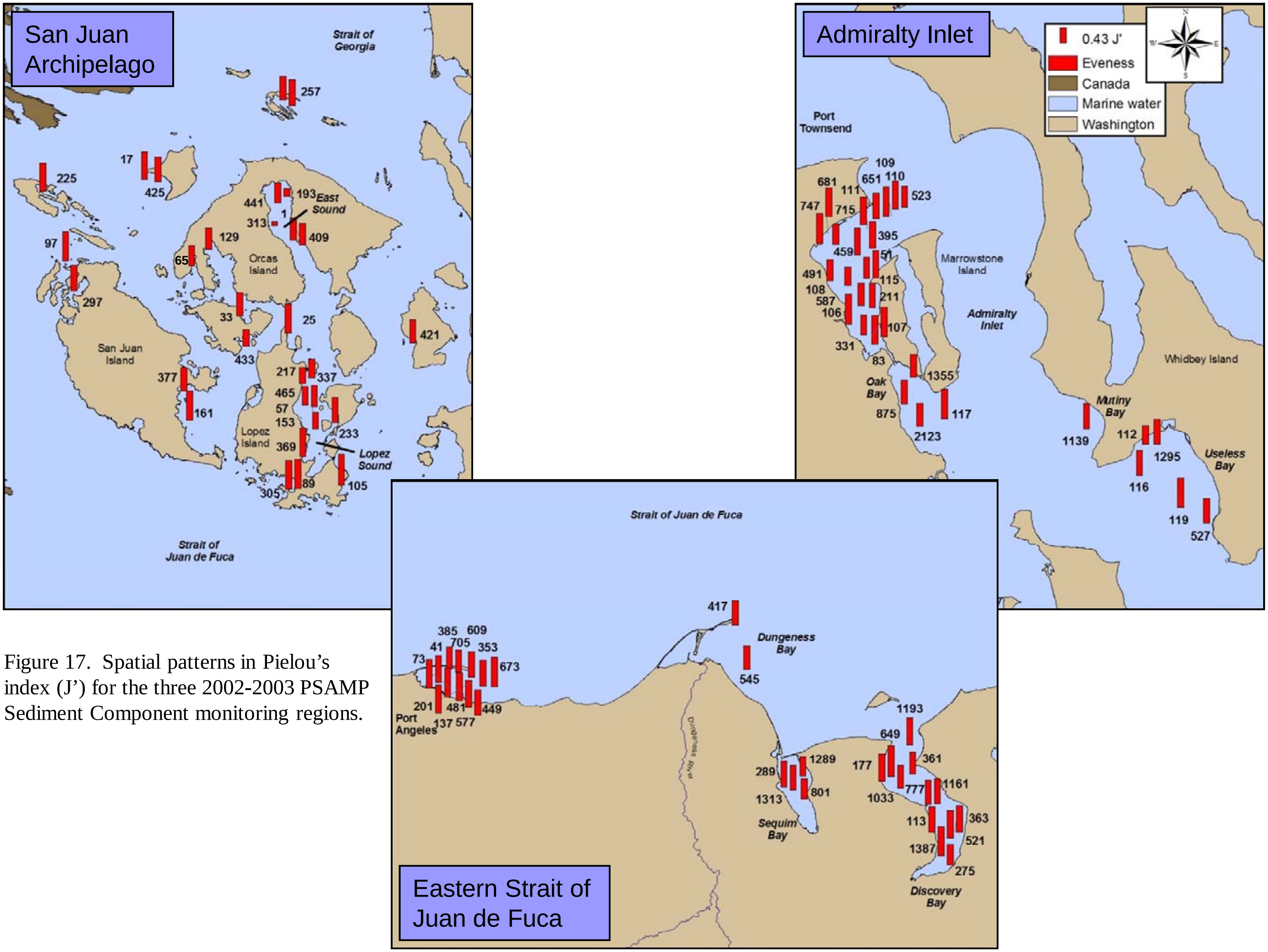
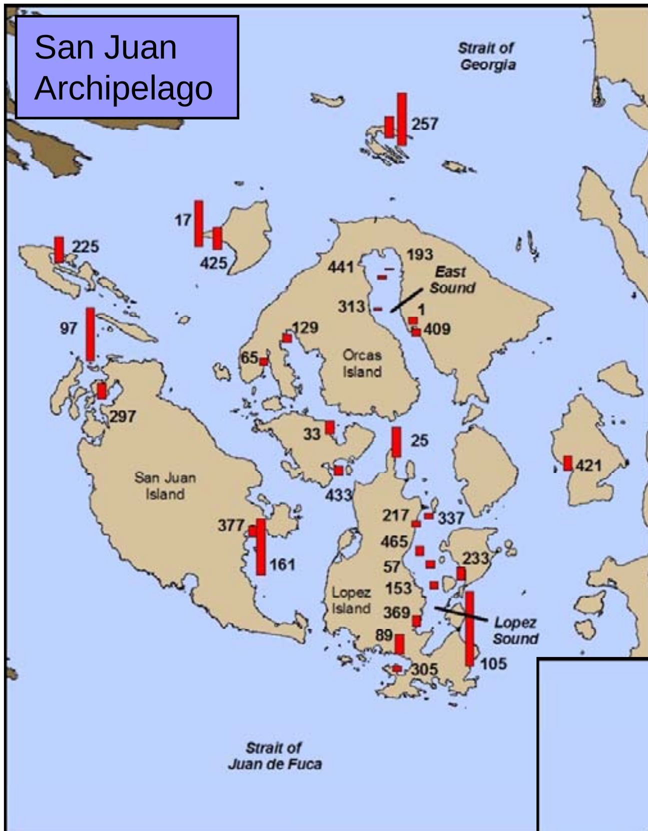
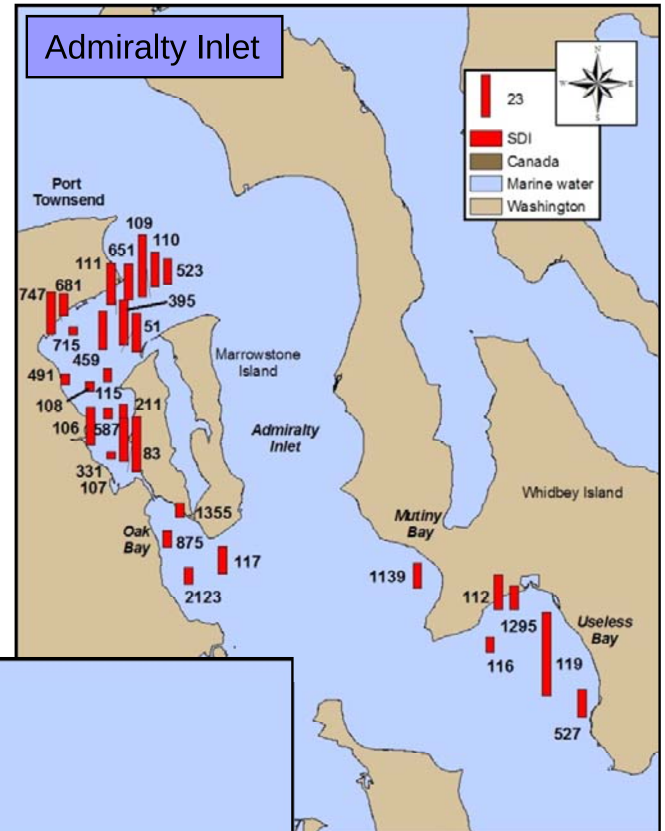


Figure 17. Spatial patterns in Pielou's index (J') for the three 2002-2003 PSAMP Sediment Component monitoring regions.





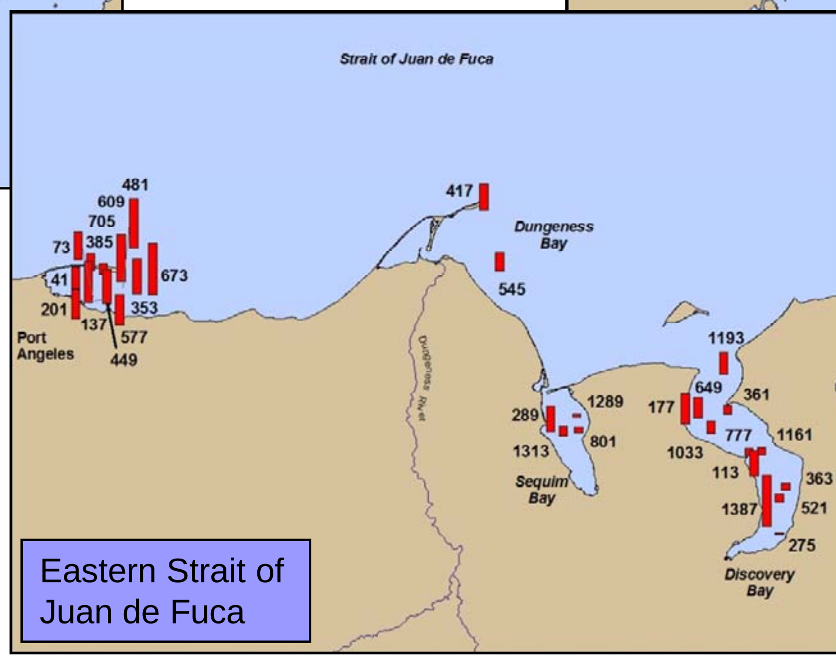


Figure 18. Spatial patterns in Swartz's Dominance Index (SDI) for the three 2002-2003 PSAMP Sediment Component monitoring regions.

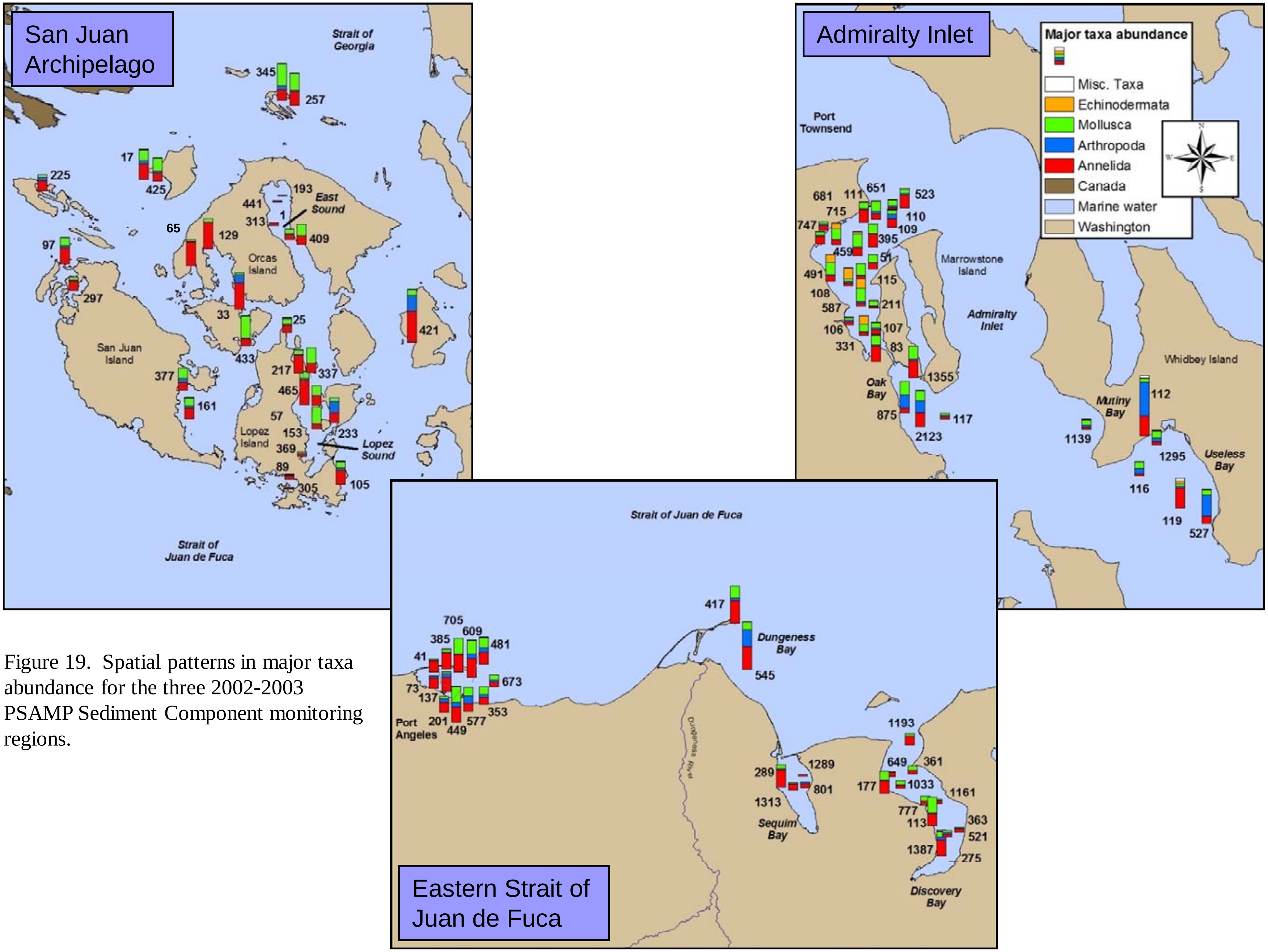


Figure 19. Spatial patterns in major taxa abundance for the three 2002-2003 PSAMP Sediment Component monitoring regions.

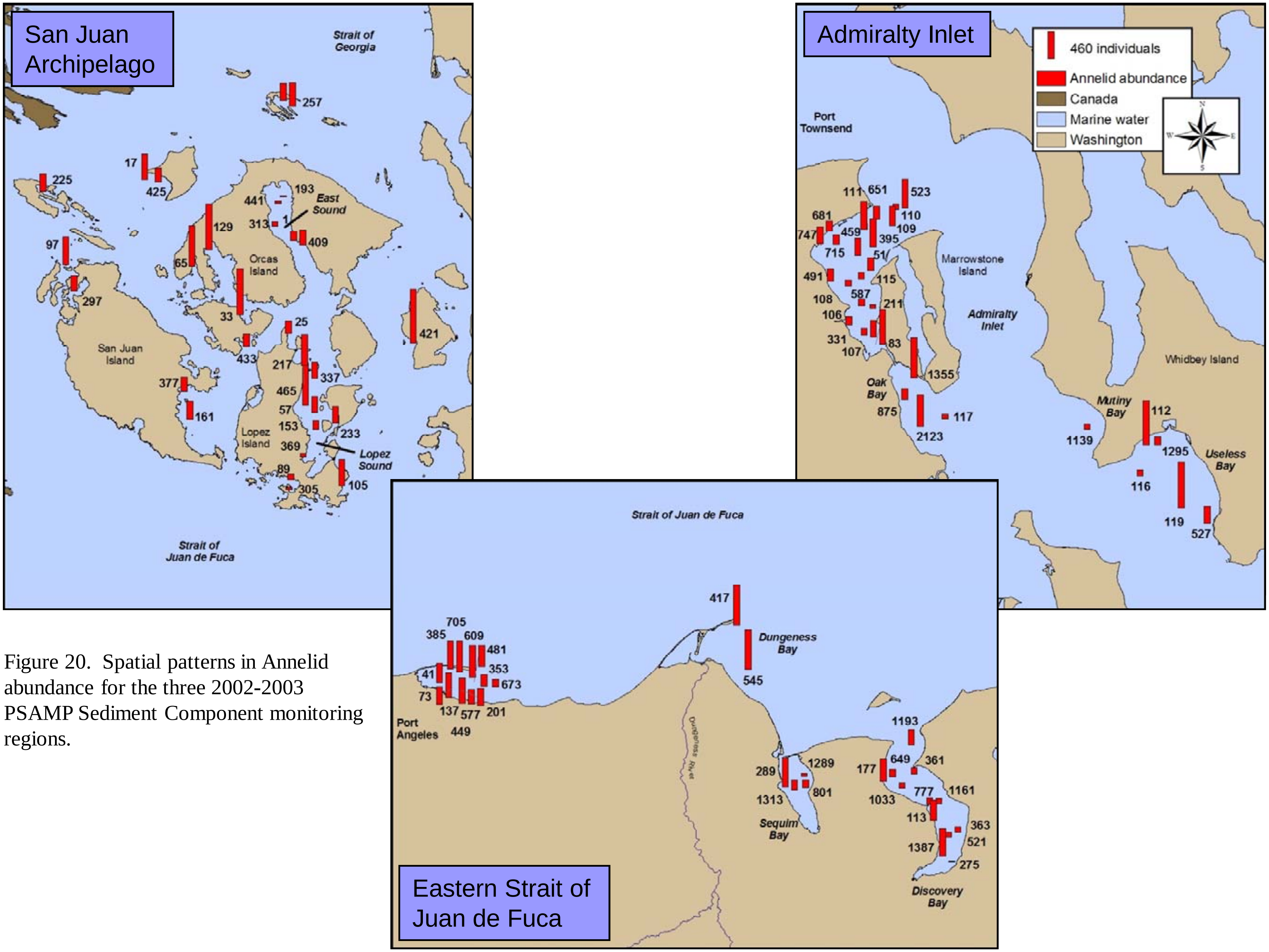


Figure 20. Spatial patterns in Annelid abundance for the three 2002-2003 PSAMP Sediment Component monitoring regions.

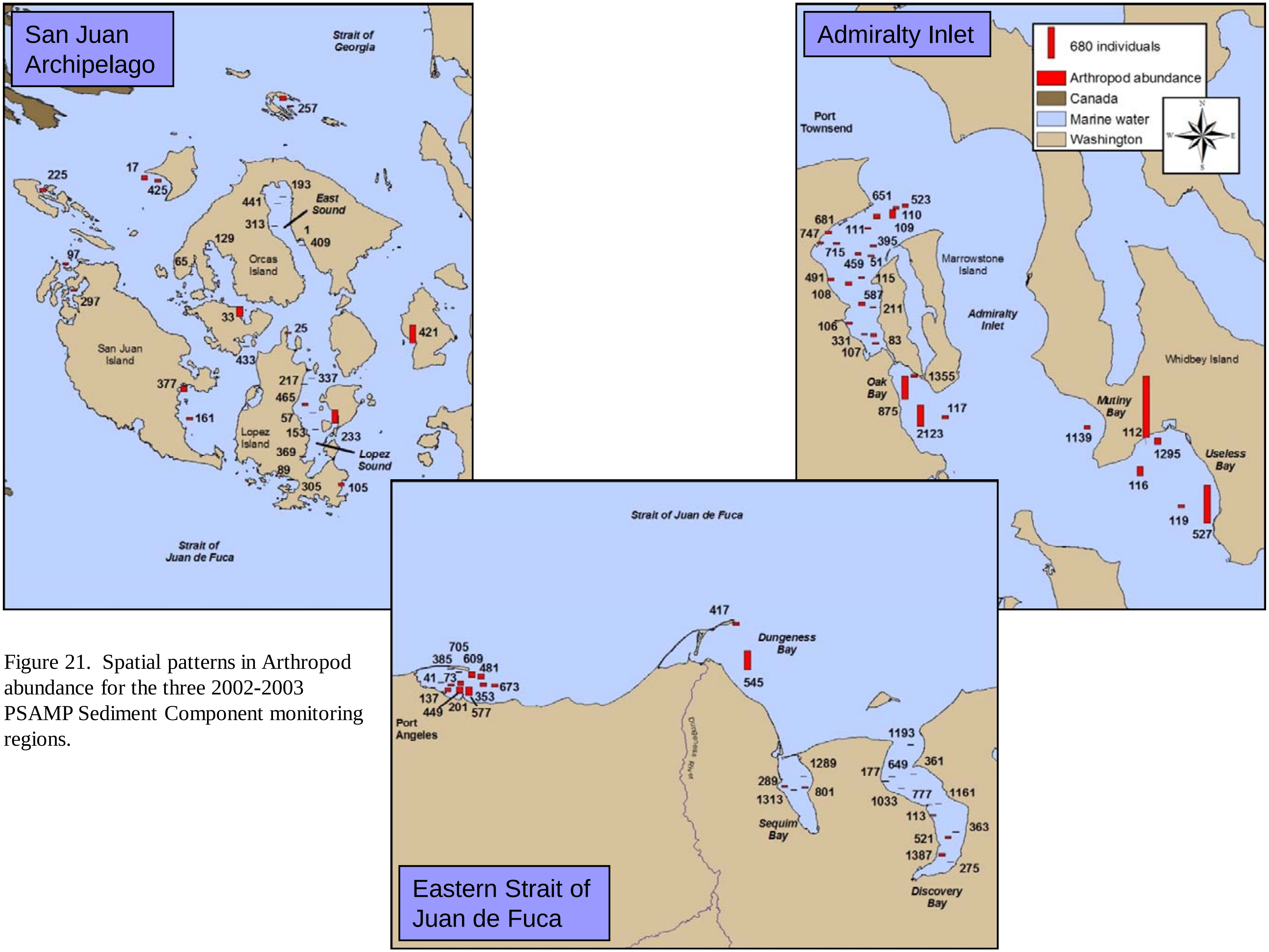
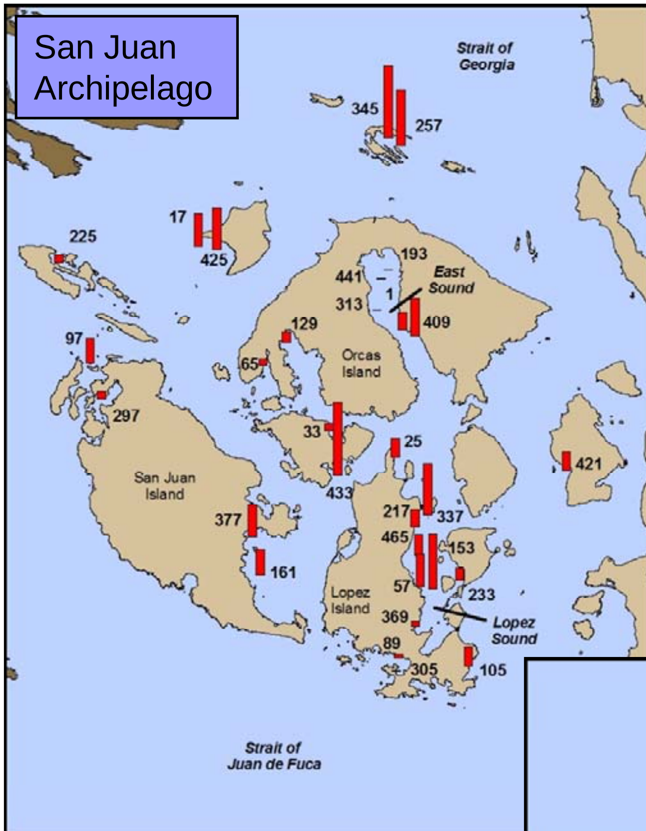


Figure 21. Spatial patterns in Arthropod abundance for the three 2002-2003 PSAMP Sediment Component monitoring regions.



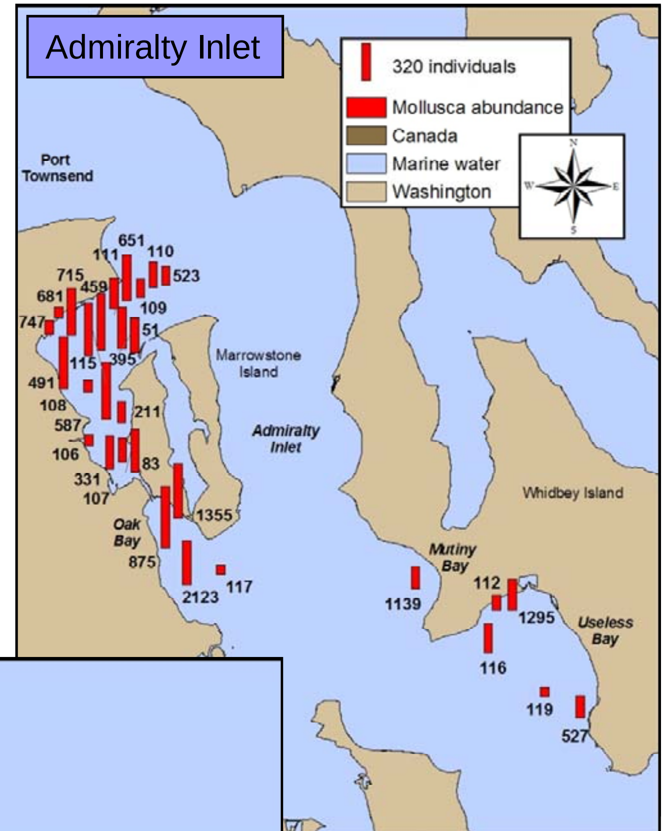
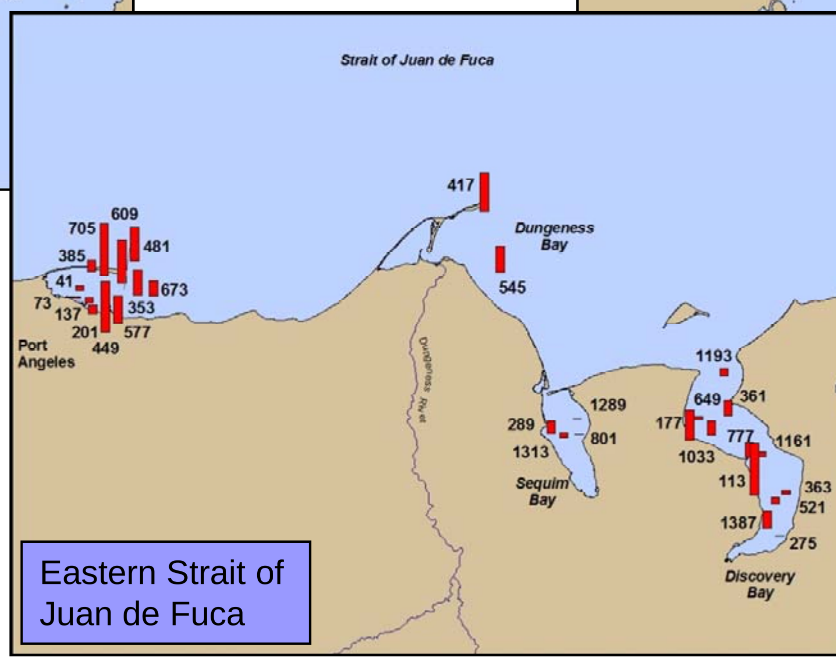


Figure 22. Spatial patterns in Mollusca abundance for the three 2002-2003 PSAMP Sediment Component monitoring regions.



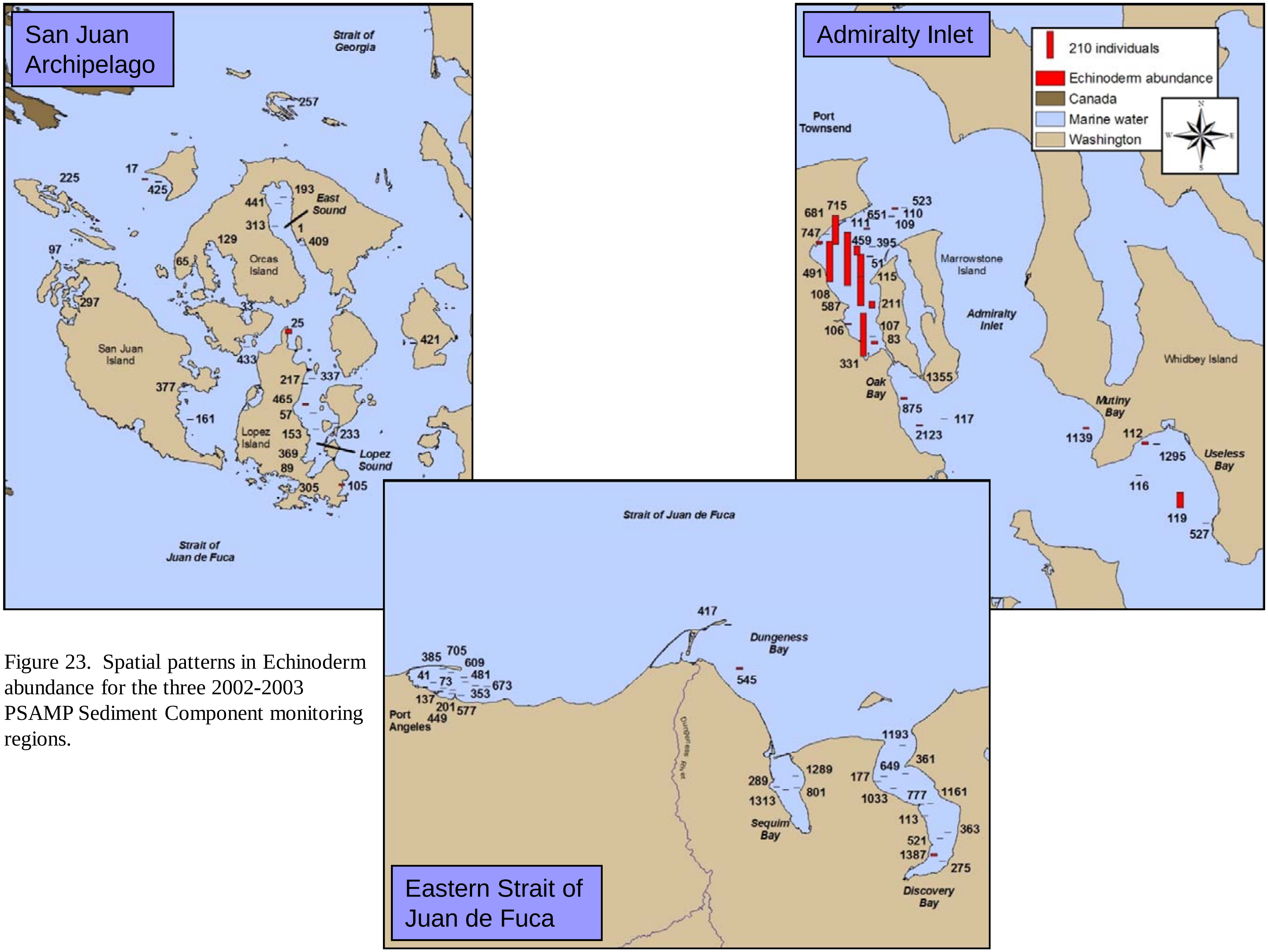


Figure 23. Spatial patterns in Echinoderm abundance for the three 2002-2003 PSAMP Sediment Component monitoring regions.

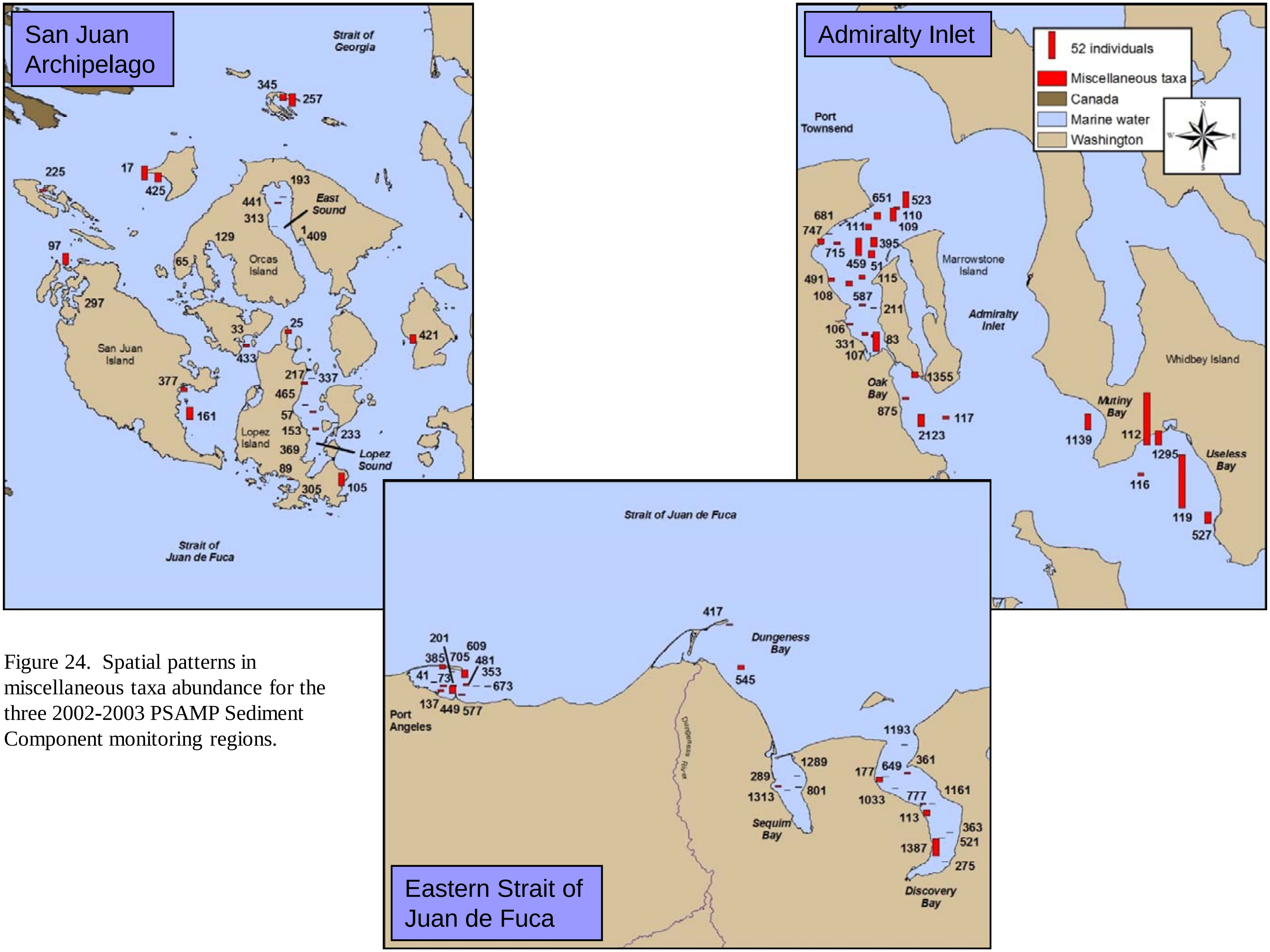


Figure 24. Spatial patterns in miscellaneous taxa abundance for the three 2002-2003 PSAMP Sediment Component monitoring regions.

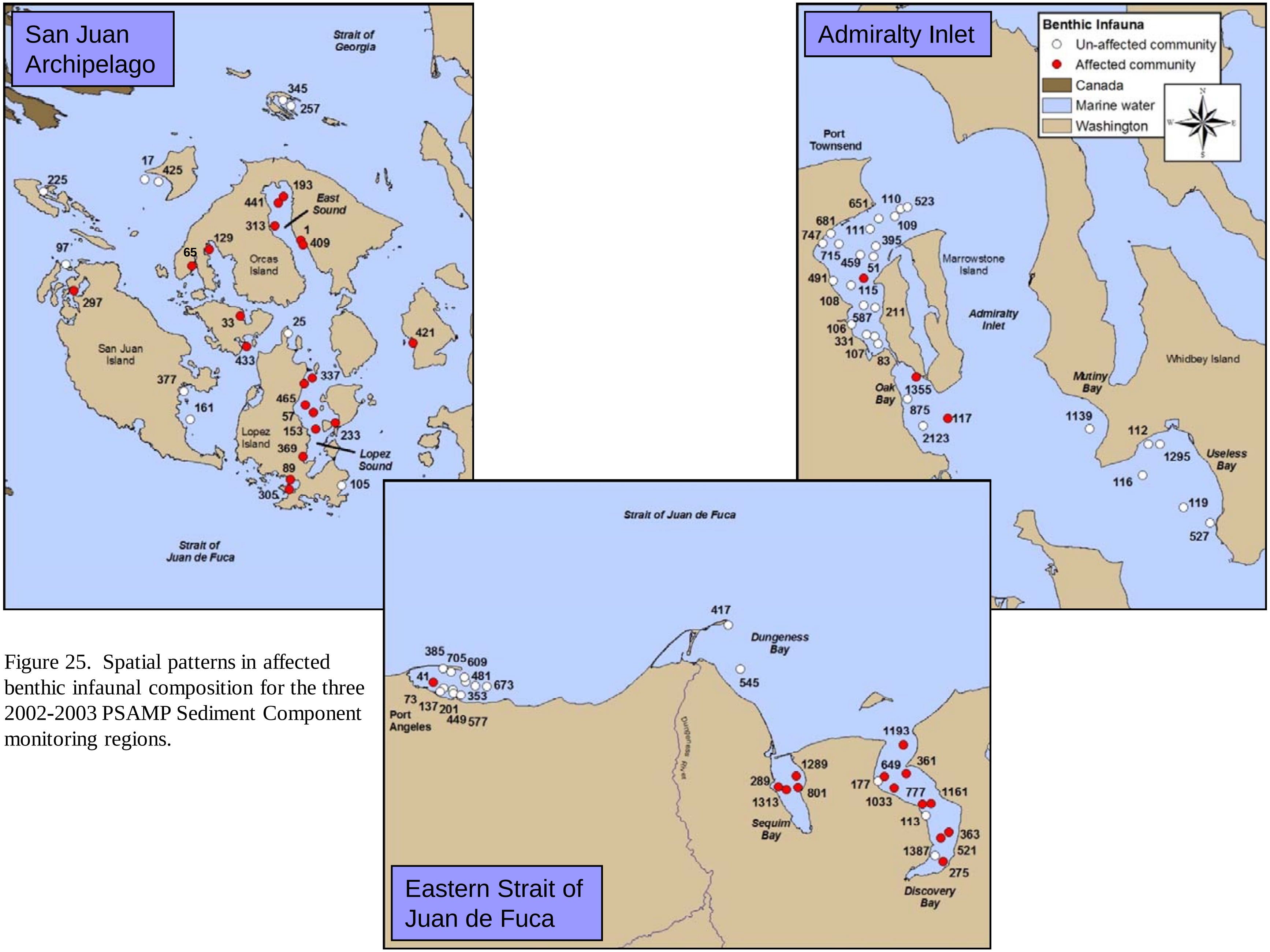


Figure 25. Spatial patterns in affected benthic infaunal composition for the three 2002-2003 PSAMP Sediment Component monitoring regions.

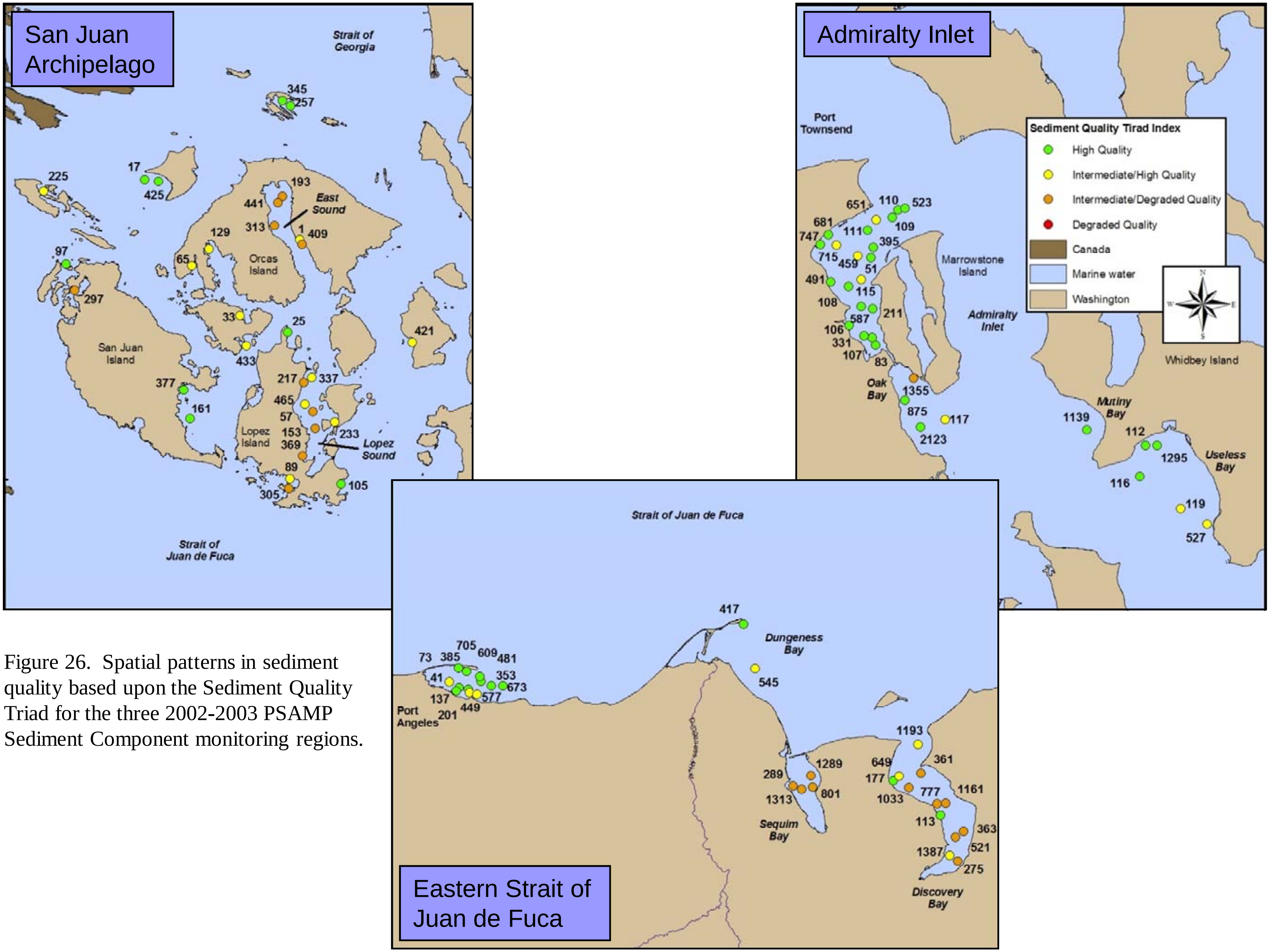


Figure 26. Spatial patterns in sediment quality based upon the Sediment Quality Triad for the three 2002-2003 PSAMP Sediment Component monitoring regions.

Tables

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Table 1. Station numbers, names, stratum types, and weights (area in km^2) for the 2002-2003 PSAMP Sediment Component.

San Juan Islands	
Rural (each station represents 2.69 km^2)	
1	East Sound
17	Cowlitz Bay
25	Shoal Bay
33	Blind Bay
57	Lopez Sound, Hunter and Mud Bay
65	Deer Harbor
89	Mackaye Harbor and Outer Bay
97	Roche Harbor
105	Telegraph Bay
129	West Sound, Massacre Bay
153	Lopez Sound, Hunter and Mud Bay
161	Griffin and North Bay
193	East Sound
217	Lopez Sound, Hunter and Mud Bay
225	Prevost Harbor, Stuart Island
233	Lopez Sound, Hunter and Mud Bay
257	Echo Bay
297	Westcott Bay
305	Mackaye Harbor and Outer Bay
313	East Sound
337	Lopez Sound, Hunter and Mud Bay
345	Echo and Fossil Bay
369	Lopez Sound, Hunter and Mud Bay
377	Griffin and North Bay
409	East Sound
421	Strawberry Bay
425	West of Waldron Island and North Cowlitz Bay
433	Squaw Bay and Indian Cove
441	East Sound
465	Lopez Sound, Hunter and Mud Bay
Strait of Juan de Fuca	
Harbor (each station represents 0.88 km^2)	
73	Port Angeles
137	Port Angeles
201	Port Angeles
449	Port Angeles (inner harbor)
Rural (each station represents 2.74 km2)	
113	Discovery Bay
177	Discovery Bay
275	Discovery Bay
289	Sequim Bay
361	Discovery Bay
363	Discovery Bay
417	Dungeness Bay
521	Discovery Bay
545	Dungeness Bay
649	Discovery Bay

777	Discovery Bay
801	Sequim Bay
1033	Discovery Bay
1161	Discovery Bay
1193	Discovery Bay
1289	Sequim Bay
1313	Sequim Bay
1387	Discovery Bay
Urban (each station represents 1.13 km2)	
41	Port Angeles
353	Port Angeles
385	Port Angeles
481	Port Angeles
577	Port Angeles
609	Port Angeles
673	Port Angeles
705	Port Angeles
Admiralty Inlet	
Passage (each station represents 3.84 km^2)	
112	Useless Bay
116	Useless Bay
117	Useless Bay
119	Useless Bay
527	Useless Bay
875	Oak Bay
1139	Mutiny Bay
1295	Useless Bay
1355	Oak Bay
2123	Oak Bay
Urban (each station represents 1.54 km^2)	
51	Port Townsend
83	South Port Townsend
106	South Port Townsend
107	South Port Townsend
108	South Port Townsend
109	Port Townsend
110	Port Townsend
111	Port Townsend
115	Port Townsend
211	South Port Townsend
331	South Port Townsend
395	Port Townsend
459	Port Townsend
491	Port Townsend
523	Port Townsend
587	South Port Townsend
651	Port Townsend
681	Port Townsend
715	Port Townsend
747	Port Townsend

Table 2. Number of stations and area (km^2) represented in each sampling region and stratum type for the 2002-2003 PSAMP Sediment Component.

PSAMP Sampling region	Number of stations sampled	Area that was feasible to sample (km^2)	Total Area (km^2)
San Juan Islands	**30**	**80.7**	**83.4**
Basin	0	0.0	0.0
Harbor	0	0.0	0.0
Passages	0	0.0	0.0
Rural	30	80.7	83.4
Urban	0	0.0	0.0
Eastern Strait of Juan de Fuca	**30**	**61.8**	**69.6**
Basin	0	0.0	0.0
Harbor	4	3.5	3.5
Passages	0	0.0	0.0
Rural	18	49.3	54.7
Urban	8	9.0	11.3
Admiralty Inlet	**30**	**69.2**	**76.1**
Basin	0	0.0	0.0
Harbor	0	0.0	0.0
Passages	10	38.4	42.3
Rural	0	0.0	0.0
Urban	20	30.8	33.8
Total by stratum type			
Basin	0	0.0	0.0
Harbor	4	3.5	3.5
Passages	10	38.4	42.3
Rural	48	130.0	138.2
Urban	28	39.8	45.1
Total	**90**	**211.7**	**229.1**

Table 3. Chemical and physical parameters measured in sediments collected from the bays and inlets of the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet for the 2002-2003 PSAMP Sediment Component.

Related Parameters
Grain Size
Total organic carbon

Priority Pollutant Metals
Arsenic
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Zinc

Trace Element
Tin

Organic Compounds

Chlorinated Alkanes
Hexachlorobutadiene

Chlorinated and Nitro-Substituted Phenols
Pentachlorophenol

Chlorinated Aromatic Chemicals
1,2,4-trichlorobenzene
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
2-chloronaphthalene
Hexachlorobenzene

Chlorinated Pesticides
2,4'-DDD
2,4'-DDE
2,4'-DDT
4,4'-DDD
4,4'-DDE
4-4'DDT
Aldrin
Alpha-chlordane
Dieldrin
Endosulfan I (Alpha-endosulfan)
Endosulfan II (Beta-endosulfan)
Endosulfan sulfate
Endrin
Endrin ketone
Endrin aldehyde
Trans-chlordane (Gamma)
Trans-nonachlor
Gamma-HCH
Heptachlor
Heptachlor epoxide
Lindane
Mirex
Oxychlordane
Toxaphene

Polycyclic Aromatic Hydrocarbons (PAHs)
Low Molecular Weight (LPAHs)
1,6,7-Trimethylnaphthalene
1-Methylnaphthalene
1-Methylphenanthrene
2,6-Dimethylnaphthalene
2-methylnaphthalene
2-methylphenanthrene
Acenaphthene
Acenaphthylene
Anthracene
Biphenyl
Dibenzothiophene
Fluorene
Naphthalene
Phenanthrene
Retene
calculated value:
LPAH

High Molecular Weight (HPAHs)
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(e)pyrene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Carbazole
Chrysene
Dibenzo(a,h)anthracene
Fluoranthene
Indeno(1,2,3-c,d)pyrene
Perylene
Pyrene
calculated values:
Total Benzofluoranthenes
Total HPAH

Miscellaneous Extractable Chemicals
Benzoic acid
Benzyl alcohol
Beta-coprostanol
Beta-sitosterol
Cholesterol
Cymene
Dibenzofuran

Organonitrogen Chemicals
Caffeine
N-nitrosodiphenylamine

Organotins
Butyl tins: Di-, Mono-, Tetra-, Tri-butyltin (only at selected stations)

Phenols
2,4-dimethylphenol
2-methylphenol
4-methylphenol
Phenol
P-nonylphenol

Phthalate Esters
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Diethyl phthalate
Dimethyl phthalate
Di-n-butyl phthalate
Di-n-octyl phthalate

Polychlorinated Biphenyls (PCBs)

PCB Congeners:
8
18
28
44
52
66
77
101
105
118
126
128
138
153
169
170
180
187
195
206
209
calculated values:
Total PCBs

PCB Aroclors:
1016
1221
1232
1242
1248
1254
1260
1262
1268
calculated values:
Total Aroclors

Table 4. Laboratory analytical methods and reporting limits for the 2002-2003 PSAMP Sediment Component chemical variables.

Parameter	Extraction Method	Clean-up Method	Analysis Method	Technique/ instrument	Required Reporting limit
Grain size	N/A	N/A	PSEP, 1986	Sieve-pipette method	>2000 to <3.9 microns
Total Organic Carbon	Drying sediment material	N/A	PSEP, 1986	Non-dispersive infrared detector	0.1%
Metals except mercury	EPA 3050B	N/A	EPA 6020 (2002) EPA 200.8 (2003)	ICP-MS	0.1 mg/kg dry weight (0.2 for Sn, 0.5 for Cr and Se, 5.0 for Zn)
Mercury	EPA 245.5	N/A	EPA 245.5	CVAA	0.005 mg/kg dry weight
Butyl Tins	MEL's SOP: NOAA-TBT SOP730005	EPA Method SW-846 3630	MEL's SOP: NOAA-TBT SOP730005	Capillary GC/AED	40 µg/kg dry weight
Base/Neutral/Acid Organic Compounds (BNAs)	EPA 3540	N/A	EPA 8270	Capillary GC/MS	20 µg/kg dry weight (for ≥ 50% solids)
Polycyclic Aromatic Hydrocarbons (PAHs)	EPA 3545	EPA 3630B	EPA 8270 with isotopic dilution	Capillary GC/MS, GC/MS-SIM	0.5-2.0 µg/kg dry weight
Chlorinated Pesticides	EPA 3545	EPA 3620 and EPA 3665	EPA 8081	GC/ECD	1 µg/kg dry weight (20 for toxaphene)
PCB Aroclors	EPA 3545	EPA 3620 and EPA 3665	EPA 8082	GC/ECD	10 µg/kg dry weight
PCB Congeners	EPA 3545	EPA 3620 and EPA 3665	EPA 8082	GC/ECD	1 µg/kg dry weight

Table 5. Field analytical methods and resolution for the 2002-2003 PSAMP Sediment Component.

Parameter	Method	Resolution
Temperature	Mercury Thermometer	1.0 °C
Surface salinity	Refractometer	1.0 ppt

Table 6. Benthic infaunal indices calculated to characterize the infaunal invertebrate assemblages identified for the 2002-2003 PSAMP Sediment Component.

Infaunal index	Definition	Calculation
Total Abundance	A measure of density equal to the total number of organisms per sample area	Sum of all organisms counted in each sample
Major Taxa Abundance	A measure of density equal to the total number of organisms in each major taxa group (Annelida, Mollusca, Echinodermata, Arthropoda, Miscellaneous Taxa) per sample area	Sum of all organisms counted in each major taxa group per sample
Taxa Richness	Total number of taxa (taxa = lowest level of identification for each organism) per sample area	Sum of all taxa identified in each sample
Pielou's Evenness (J') (Pielou, 1966, 1974)	Relates the observed diversity in benthic assemblages as a proportion of the maximum possible diversity for the data set (the equitability (evenness) of the distribution of individuals among species)	$J' = H'/\log s$ Where: $H' = -\sum_{i=1}^{s} p_i \log p_i$ where p_i = the proportion of the assemblage that belongs to the ith species ($p=n_i/N$, where n_I=the number of individuals in the i species and N= total number of individuals), and where s = the total number of species
Swartz's Dominance Index (SDI)(Swartz et al., 1985)	The minimum number of taxa whose combined abundance accounted for 75 percent of the total abundance in each sample	Sum of the minimum number of taxa whose combined abundance accounted for 75 percent of the total abundance in each sample

Table 7. Sediment types characterizing the 90 samples collected for the 2002-2003 PSAMP Sediment Component.

Sediment Type	Percent Sand	Percent Silt + clay	Percent Gravel (range of data for each station type)	No. of stations with this sediment type	Area (km^2) with this sediment type	Percent of total study area
Sand	> 80	<20	0.0 - 3.38	16	43.9	21
Silty sand	60 - 80	20 -<60	0.03 - 30.77	27	53.9	25
Mixed	20 -<60	60 - 80	0.03 - 36.75	26	63.9	30
Silt clay	<20	> 80	0.0 - 7.12	21	50.0	24

Table 8. Sediment types characterizing the samples collected from the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet for the 2002-2003 PSAMP Sediment Component.

Region Sediment type	Percent Sand	Percent Silt + clay	Range of Percent gravel for sediment type	No. of stations with this sediment type	Area (km^2) with this sediment type	Percent of total study area
San Juan Islands						
Sand	> 80	< 20	0.0 - 0.9	3	8.1	3.8
Silty sand	60-80	20- >40	0.0 - 4.3	7	18.8	8.9
Mixed	20-< 60	40-80	0.0 - 36.7	14	37.7	17.8
Silt + clay	< 20	> 80	0.0 - 4.8	6	16.2	7.6
Eastern Strait of Juan de Fuca						
Sand	> 80	< 20	0.1 - 0.8	3	6.6	3.1
Silty sand	60-80	20- >40	0.1 - 11.0	14	21.3	10.0
Mixed	20-< 60	40-80	0.1 - 0.7	4	9.3	4.4
Silt + clay	< 20	> 80	0.0 - 6.7	9	24.6	11.6
Admiralty Inlet						
Sand	> 80	< 20	0.0 - 1.3	10	29.2	13.8
Silty sand	60-80	20- >40	0.1 - 30.8	6	13.8	6.5
Mixed	20-< 60	40-80	0.0 - 25.9	8	16.9	8.0
Silt + clay	< 20	> 80	0.4 - 9.0	6	9.2	4.4

Table 9. Ranges, means, standard deviations, and medians of TOC concentrations for three sediment monitoring regions for the 2002-2003 PSAMP Sediment Component.

Regions	Minimum	Maximum	Mean	Standard Deviation	Median
Admiralty Inlet	0.10	3.01	1.12	0.94	0.75
Eastern Strait of Juan De Fuca	0.33	3.88	1.47	1.03	1.04
San Juan Islands	0.29	3.65	1.49	0.91	1.26

Table 10. Ranges, averages, and medians in mean ERM quotients and mean SQS quotients for samples from the three regions surveyed in 2002 – 2003.

Region and quotient	N	Minimum	Maximum	Median	Mean
San Juan Islands					
Mean ERM quotient	30	0.02	0.11	0.05	0.05
Mean SQS quotient	30	0.02	0.09	0.04	0.04
Eastern Strait of Juan de Fuca					
Mean ERM quotient	30	0.03	0.19	0.06	0.06
Mean SQS quotient	30	0.02	0.37	0.05	0.07
Admiralty Inlet					
Mean ERM quotient	30	0.02	0.24	0.06	0.07
Mean SQS quotient	30	0.02	0.12	0.04	0.05

Table 11. Stations in the 2002-2003 PSAMP Sediment Component survey in which national sediment quality guidelines or Washington State Sediment Management Standards for one or more chemicals were exceeded.

Station ID	Location	Mean ERM Quotient	Number of ERMs[1] exceeded	Number of SQSs[2] exceeded	Chemicals exceeding SQSs	Number of CSLs[3] exceeded
225	Prevost Harbor, Stuart Island	0.04	0	1	Other: Di-n-butylphthalate	0
449	Port Angeles (inner harbor)	0.19	0	1	PAH: Fluoranthene	0

[1] ERM – Effects Range Median (Long et al., 1995)
[2] SQS – Sediment Quality Standard (Washington Dept. of Ecology, 1995)
[3] CSL – Cleanup Screening Level (Washington Dept. of Ecology, 1995)

Table 12. Estimated incidence and spatial extent of chemical contamination in the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet regions and for the entire 2002-2003 PSAMP Sediment Component survey area.

(The number and percent of stations and the number and percent of each study area (km^2) were calculated for those stations where at least one chemical concentration was measured at levels above state standards (shaded area = total number of stations and area of each region.)) No chemical concentrations were measured above national sediment guidelines.

Sediment Standard/ Guideline Exceeded	Incidence		Spatial Extent	
	No.	(%) of stations	km^2	(%) of total study area
San Juan Islands	**30**	**(100.0)**	**80.7**	**(100.0)**
Di-N-Butylphthalate				
SQS (220 ppm organic carbon)	1	(3.3)	2.7	(3.3)
CSL (1700 ppm organic carbon)	0	(0.0)	0.0	(0.0)
Eastern Strait of Juan De Fuca	**30**	**(100.0)**	**61.8**	**(100.0)**
Fluoranthene				
SQS (160 ppm organic carbon)	1	(3.3)	0.9	(1.4)
CSL (1200 ppm organic carbon)	0	(0.0)	0.0	(0.0)
Admiralty Inlet	**30**	**(100.0)**	**69.2**	**(100.0)**
SQS	0	(0.0)	0.0	(0.0)
CSL	0	(0.0)	0.0	(0.0)
Total Study Area	**90**	**(100.0)**	**211.7**	**(100.0)**
Di-N-Butylphthalate				
SQS (220 ppm organic carbon)	1	(1.1)	2.7	(1.3)
CSL (1700 ppm organic carbon)	0	(0.0)	0.0	(0.0)
Fluoranthene				
SQS (160 ppm organic carbon)	1	(1.1)	0.9	(0.4)
CSL (1200 ppm organic carbon)	0	(0.0)	0.0	(0.0)
Any one chemical				
SQS	2	(2.2)	3.6	(1.7)
CSL	0	(0.0)	0.0	(0.0)

Table 13. Results of amphipod survival tests for 90 sediment samples from the 2002-2003 PSAMP Sediment Component. Data are expressed as mean percent survival and as percentage of control response. Tests performed with *Eohaustorius estuarius except where noted*.

Station, location	Mean amphipod survival (%)	Mean amphipod survival as % of control	Statistical significance (p value <0.05, t-test)
San Juan Islands			
1, East Sound	94	97	
17, Cowlitz Bay	93	96	
25, Shoal Bay	88	91	
33, Blind Bay	90	93	
57, Lopez Sound, Hunter and Mud Bay	88	91	
65, Deer Harbor	98	101	
89, Mackaye Harbor and Outer Bay	99	102	
97, Roche Harbor	93	96	
105, Telegraph Bay	91	94	
129, West Sound, Massacre Bay	92	95	
153, Lopez Sound, Hunter and Mud Bay	74	76	**
161, Griffin and North Bay	92	95	
193, East Sound	96	99	
217, Lopez Sound, Hunter and Mud Bay	86	89	
225, Prevost Harbor, Stuart Island	95	98	
233, Lopez Sound, Hunter and Mud Bay	92	95	
257, Echo Bay	91	94	
297, Westcott Bay	89	96	
305, Mackaye Harbor and Outer Bay	94	101	
313, East Sound	76	78	
337, Lopez Sound, Hunter and Mud Bay	77	79	
345, Echo and Fossil Bay	85	91	
369, Lopez Sound, Hunter and Mud Bay	95	97	
377, Griffin and North Bay	91	98	
409, East Sound	93	95	
421, Strawberry Bay	94	101	
425, West of Waldron Island and North Cowlitz Bay	87	94	
433, Squaw Bay and Indian Cove	93	95	
441, East Sound	89	91	
465, Lopez Sound, Hunter and Mud Bay	82	84	

Station, location	Mean amphipod survival (%)	Mean amphipod survival as % of control	Statistical significance (p value <0.05, t-test)
Eastern Strait of Juan de Fuca			
41, Port Angeles	94	100	
73, Port Angeles	96	102	
113, Discovery Bay	94	101	
137, Port Angeles	91	98	
177, Discovery Bay	91	97	
201, Port Angeles	97	103	
275, Discovery Bay	96	103	
289, Sequim Bay	96	102	
353, Port Angeles	96	103	
361, Discovery Bay	89	98	
363, Discovery Bay	92	101	
385, Port Angeles	96	102	
417, Dungeness Bay	96	110	
449, Port Angeles (inner harbor)	89	102	
481, Port Angeles	92	99	
521, Discovery Bay	87	96	
545, Dungeness Bay	86	99	
577, Port Angeles	87	100	
609, Port Angeles	91	105	
649, Discovery Bay	70	80	*
673, Port Angeles	84	97	
705, Port Angeles	82	94	
777, Discovery Bay	86	95	
801, Sequim Bay	82	90	
1033, Discovery Bay	86	95	
1161, Discovery Bay	85	93	
1193, Discovery Bay	82	94	
1289, Sequim Bay	93	102	
1313, Sequim Bay	85	93	
1387, Discovery Bay	86	95	
Admiralty Inlet			
51, Port Townsend	93	97	
83, South Port Townsend	88	90	
106, South Port Townsend[1]	92	94	*
107, South Port Townsend[1]	98	100	

Station, location	Mean amphipod survival (%)	Mean amphipod survival as % of control	Statistical significance (p value <0.05, t-test)
108, South Port Townsend[1]	98	100	
109, Port Townsend[1]	92	94	
110, Port Townsend[1]	96	98	
111, Port Townsend[1]	88	90	
112, Useless Bay[1]	95	97	
115, Port Townsend	95	99	
116, Useless Bay[1]	99	101	
117, Useless Bay[1]	94	96	
119, Useless Bay	91	95	
211, South Port Townsend	83	86	
331, South Port Townsend	93	97	
395, Port Townsend	89	93	
459, Port Townsend	93	102	
491, Port Townsend	89	98	
523, Port Townsend	93	102	
527, Useless Bay	96	105	
587, South Port Townsend	84	92	
651, Port Townsend	95	104	
681, Port Townsend	95	104	
715, Port Townsend	84	92	
747, Port Townsend	94	103	
875, Oak Bay	92	96	
1139, Mutiny Bay	98	102	
1295, Useless Bay	91	95	
1355, Oak Bay	100	104	
2123, Oak Bay	97	101	

[1] Tests performed with *Ampelisca abdita*
* Results statistically significant
** Results statistically significant and mean survival <80% of control.

Table 14. Results of sea urchin fertilization tests in undiluted pore water from 90 sediment samples for the 2002-2003 PSAMP Sediment Component. Data are expressed as mean percent fertilization and as percentage of control response. Tests performed with *Strongylocentrotus purpuratus*.

Station, location	100% pore water			50% pore water			25% pore water		
	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)
1, East Sound	99.8	101.0		98.8	100.8		99.8	100.5	
17, Cowlitz Bay	99.6	100.8		99.4	101.4		99.6	100.3	
25, Shoal Bay	99.6	100.8		99.8	101.8		99.6	100.3	
33, Blind Bay	98.2	99.4		99.2	101.2		99.4	100.1	
57, Lopez Sound, Hunter and Mud Bay	99.8	101.0		99.6	101.6		99.6	100.3	
65, Deer Harbor	99.6	100.8		99.6	101.6		99.4	100.1	
89, Mackaye Harbor and Outer Bay	99.6	100.8		99.6	101.6		99.8	100.5	
97, Roche Harbor	99.6	100.8		99.4	101.4		99.8	100.5	
105, Telegraph Bay	99	100.2		99.0	101.0		99.6	100.3	
129, West Sound, Massacre Bay	99.6	100.8		99.6	101.6		99.4	100.1	
153, Lopez Sound, Hunter and Mud Bay	97.8	98.9		99.8	101.8		99.5	100.2	
161, Griffin and North Bay	99.5	100.7		99.3	101.3		99.8	100.5	
193, East Sound	98.5	99.0		98.8	99.4		99.2	99.8	
217, Lopez Sound, Hunter and Mud Bay	99.8	100.8		99.8	100.4		99.2	99.8	
225, Prevost Harbor, Stuart Island	99.4	100.4		99.8	100.4		99.8	100.4	
233, Lopez Sound, Hunter and Mud Bay	99.6	100.6		99.6	100.2		99.6	100.2	
257, Echo Bay	99.6	100.6		99.2	99.8		100	100.6	

Station, location	100% pore water			50% pore water			25% pore water		
	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)
297, Westcott Bay	98.4	99.2		99.0	99.8		98.8	99.9	
305, Mackaye Harbor and Outer Bay	81.8	82.5	*	99.0	99.8		99.4	100.5	
313, East Sound	88.4	89.1		99.0	99.8		99.4	100.5	
337, Lopez Sound, Hunter and Mud Bay	99.2	100.0		98.8	99.6		99.4	100.5	
345, Echo and Fossil Bay	98.4	99.2		98.2	99.0		99.2	100.3	
369, Lopez Sound, Hunter and Mud Bay	42.2	42.5	**	94.4	95.2		95.6	96.7	
377, Griffin and North Bay	98.2	99.0		99.0	99.8		98.6	99.7	
409, East Sound	87.2	87.9		94.6	95.4		96.8	97.9	
421, Strawberry Bay	99.6	100.4		99.4	100.2		99.6	100.7	
425, West of Wadron Island and North Cowlitz Bay	99.4	100.2		99.4	100.2		99.4	100.5	
433, Squaw Bay and Indian Cove	99.6	100.4		99.8	100.6		98.4	99.5	
441, East Sound	92.8	93.5		98.4	99.2		98.8	99.9	
465, Lopez Sound, Hunter and Mud Bay	98.4	99.2		98.4	99.2		98.6	99.7	
41, Port Angeles	99.2	100.4		99.4	101.4		99.6	100.3	
73, Port Angeles	99.6	100.8		99.4	101.4		99.2	99.9	
113, Discovery Bay	99.2	100.4		99.6	101.6		99.6	100.3	
137, Port Angeles	99.4	100.6		99.0	101.0		99.25	99.9	
177, Discovery Bay	99.6	100.6		99.8	100.0		99.4	100.0	
201, Port Angeles	96.8	97.8		99.2	99.8		98.6	99.2	
275, Discovery Bay	61.4	62.0	**	91.8	92.4		98.6	99.2	

Station, location	100% pore water			50% pore water			25% pore water		
	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)
289, Sequim Bay	98.6	99.6		99.4	100.0		99.6	100.2	
353, Port Angeles	99.2	100.2		99.6	100.2		99.2	99.8	
361, Discovery Bay	98.8	99.6		99.8	100.6		98.8	99.9	
363, Discovery Bay	54.6	55.0	**	98.0	98.8		97.8	98.9	
385, Port Angeles	86.4	87.3		97.2	97.8		99.8	100.4	
417, Dungeness Bay	98.0	98.8		99.4	100.2		98.2	99.3	
449, Port Angeles (inner harbor)	99.0	99.8		99.2	100.0		100.0	101.1	
481, Port Angeles	99.6	100.6		99.4	100.0		99.6	100.2	
521, Discovery Bay	8.0	8.1	**	99.4	100.2		98.8	99.9	
545, Dungeness Bay	99.4	100.2		99.0	99.8		99.6	100.7	
577, Port Angeles	99.6	100.4		99.4	100.2		99.8	100.9	
609, Port Angeles	99.4	100.2		99.6	100.4		99.4	100.5	
649, Discovery Bay	99.4	100.2		99.8	100.6		99.2	100.3	
673, Port Angeles	99.4	100.2		99.0	99.8		99.2	100.3	
705, Port Angeles	98.4	99.2		99.4	100.2		99.6	100.7	
777, Discovery Bay	99.4	100.2		99.8	100.6		99.4	100.5	
801, Sequim Bay	65.0	65.5	**	99.0	99.8		99.4	100.5	
1033, Discovery Bay	98.8	99.6		99.2	100.0		99.4	100.5	
1161, Discovery Bay	99.2	100.0		99.8	100.6		99.0	100.1	
1193, Discovery Bay	99.8	100.6		99.4	100.2		99.8	100.9	
1289, Sequim Bay	81.6	82.3	*	99.2	100.0		99.8	100.9	
1313, Sequim Bay	20.8	21.0	**	99.2	100.0		99.2	100.3	
1387, Discovery Bay	99.8	100.6		99.4	100.2		99.2	100.3	

Station, location	100% pore water			50% pore water			25% pore water		
	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)
51, Port Townsend	99.8	101.0		99.6	101.6		99.6	100.3	
83, South Port Townsend	99.6	100.8		99.8	101.8		100.0	100.7	
106, South Port Townsend	99.8	118.6		98.8	99.7		99.6	101.0	
107, South Port Townsend	98.4	117.0		99.0	99.9		99.4	100.8	
108, South Port Townsend	99.4	118.2		98.4	99.3		99.6	101.0	
109, Port Townsend	98.2	116.7		100	100.9		99.0	100.4	
110, Port Townsend	98.2	116.7		99.4	100.3		99.4	100.8	
111, Port Townsend	97	115.3		98.4	99.3		97.8	99.2	
112, Useless Bay	94.2	112.0		96.4	97.3		99.2	100.6	
115, Port Townsend	99.4	100.6		99.6	101.6		99.4	100.1	
116, Useless Bay	99.6	118.4		99.2	100.1		99.0	100.4	
117, Useless Bay	99.2	117.9		99.8	100.7		98.6	100.0	
119, Useless Bay	59.0	59.7	**	99.4	101.4		99.4	100.1	
211, South Port Townsend	98.0	99.0		99.3	99.8		98.5	99.1	
331, South Port Townsend	99.8	100.8		99.0	99.6		100.0	100.6	
395, Port Townsend	99.4	100.4		99.2	99.8		99.2	99.8	
459, Port Townsend	99.2	100.0		99.0	99.8		98.4	99.5	
491, Port Townsend	99.8	100.6		99.6	100.4		99.0	100.1	
523, Port Townsend	98.6	99.4		98.8	99.6		99.4	100.5	
527, Useless Bay	86.2	86.9		98.6	99.4		99.0	100.1	

Station, location	100% pore water			50% pore water			25% pore water		
	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)	Mean fertilization (%)	Mean fertilization as % of control	Statistical significance (p value <0.05, t-test)
587, South Port Townsend	99.2	100.0		99.2	100.0		98.8	99.9	
651, Port Townsend	99.2	100.0		98.8	99.6		99.8	100.9	
681, Port Townsend	84.6	85.3		98.6	99.4		99.2	100.3	
715, Port Townsend	98.6	99.4		99.6	100.4		99.4	100.5	
747, Port Townsend	99.2	100.0		99.6	100.4		99.6	100.7	
875, Oak Bay	99.6	100.6		99.6	100.2		99.0	99.6	
1139, Mutiny Bay	99.2	100.2		99.6	100.2		99.4	100.0	
1295, Useless Bay	99.4	100.4		99.8	100.4		100.0	100.6	
1355, Oak Bay	1.0	1.0	**	68.5	69.0	**	95.6	96.2	
2123, Oak Bay	99.2	100.2		99.8	100.4		99.8	100.4	

* Results statistically significant.
** Results statistically significant and mean percent fertilization <80% of control.

Table 15. Results of echinoderm embryo tests for 81 sediment samples from the 2002-2003 PSAMP Sediment Component. Data are expressed as combined mean normal development and survival for each sample. Tests performed with *Dendraster excentricus*.

Station, location	Mean normal survival (%)	Statistical significance (p value <0.05, t-test)
San Juan Islands		
1, East Sound	44.4	
17, Cowlitz Bay	71.5	*
25, Shoal Bay	63.4	
33, Blind Bay	58.7	
57, Lopez Sound, Hunter and Mud Bay	47.1	**
65, Deer Harbor	60.6	*
89, Mackaye Harbor and Outer Bay	59.4	*
97, Roche Harbor	73.8	*
105, Telegraph Bay	67.0	
129, West Sound, Massacre Bay	73.5	*
153, Lopez Sound, Hunter and Mud Bay	41.4	**
161, Griffin and North Bay	62.2	
193, East Sound	21.9	**
217, Lopez Sound, Hunter and Mud Bay	44.9	**
225, Prevost Harbor, Stuart Island	98.6	*
233, Lopez Sound, Hunter and Mud Bay	53.3	
257, Echo Bay	47.9	
297, Westcott Bay	44.5	**
305, Mackaye Harbor and Outer Bay	29.0	**
313, East Sound	21.4	**
337, Lopez Sound, Hunter and Mud Bay	67.7	
345, Echo and Fossil Bay	66.8	
369, Lopez Sound, Hunter and Mud Bay	88.9	*
377, Griffin and North Bay	61.5	
409, East Sound	48.2	**
421, Strawberry Bay	67.5	
425, West of Waldron Island and North Cowlitz Bay	70.5	
433, Squaw Bay and Indian Cove	59.2	
441, East Sound	18.2	**
465, Lopez Sound, Hunter and Mud Bay	87.0	*

Station, location	Mean normal survival (%)	Statistical significance (p value <0.05, t-test)
Eastern Strait of Juan de Fuca		
41, Port Angeles	48.4	
73, Port Angeles	60.0	
113, Discovery Bay	62.6	*
137, Port Angeles	42.8	
177, Discovery Bay	64.2	*
201, Port Angeles	66.0	
275, Discovery Bay	58.6	*
289, Sequim Bay	27.5	**
353, Port Angeles	73.7	*
361, Discovery Bay	36.8	**
363, Discovery Bay	24.0	**
385, Port Angeles	41.2	*
417, Dungeness Bay	49.8	
449, Port Angeles (inner harbor)	64.7	
481, Port Angeles	59.2	*
521, Discovery Bay	23.2	**
545, Dungeness Bay	60.0	
577, Port Angeles	41.5	**
609, Port Angeles	56.2	
649, Discovery Bay	62.4	
673, Port Angeles	71.8	
705, Port Angeles	63.1	
777, Discovery Bay	30.6	**
801, Sequim Bay	24.1	**
1033, Discovery Bay	43.2	**
1161, Discovery Bay	33.9	**
1193, Discovery Bay	53.9	
1289, Sequim Bay	26.4	**
1313, Sequim Bay	22.9	**
1387, Discovery Bay	40.9	**
Admiralty Inlet		
51, Port Townsend	55.1	*
83, South Port Townsend	46.3	*
106, South Port Townsend	Not Analyzed	
107, South Port Townsend	Not Analyzed	

Station, location	Mean normal survival (%)	Statistical significance (p value <0.05, t-test)
108, South Port Townsend	Not Analyzed	
109, Port Townsend	Not Analyzed	
110, Port Townsend	Not Analyzed	
111, Port Townsend	Not Analyzed	
112, Useless Bay	Not Analyzed	
115, Port Townsend	63.6	*
116, Useless Bay	Not Analyzed	
117, Useless Bay	Not Analyzed	
119, Useless Bay	27.0	
211, South Port Townsend	45.2	*
331, South Port Townsend	67.9	*
395, Port Townsend	34.1	
459, Port Townsend	53.2	**
491, Port Townsend	72.5	
523, Port Townsend	65.6	
527, Useless Bay	48.0	**
587, South Port Townsend	65.9	
651, Port Townsend	49.5	**
681, Port Townsend	61.3	
715, Port Townsend	55.9	**
747, Port Townsend	67.6	
875, Oak Bay	48.4	*
1139, Mutiny Bay	58.4	*
1295, Useless Bay	34.6	
1355, Oak Bay	47.8	*
2123, Oak Bay	49.6	*

* Results statistically significant.
** Results statistically significant and mean percent fertilization <85% of reference.

Table 16. Results of Microtox® tests in undiluted pore water from 81 sediment samples for the 2002-2003 PSAMP Sediment Component. Data are expressed as mean light output and as percent of control response after 15-min exposures. Tests performed with *Vibrio fischeri*.

Station, location	Mean light output in test samples @ 15 min	Mean response as a percent of dilution control response @ 15 min	Statistical significance (p value <0.05, t-test)
San Juan Islands			
1, East Sound	94	111	
17, Cowlitz Bay	103	112	
25, Shoal Bay	118	110	
33, Blind Bay	116	116	
57, Lopez Sound, Hunter and Mud Bay	121	136	
65, Deer Harbor	98	111	
89, Mackaye Harbor and Outer Bay	56	57	
97, Roche Harbor	101	119	
105, Telegraph Bay	114	114	
129, West Sound, Massacre Bay	107	122	
153, Lopez Sound, Hunter and Mud Bay	106	114	
161, Griffin and North Bay	75	68	
193, East Sound	93	89	
217, Lopez Sound, Hunter and Mud Bay	119	128	
225, Prevost Harbor, Stuart Island	119	113	
233, Lopez Sound, Hunter and Mud Bay	102	115	
257, Echo Bay	108	117	
297, Westcott Bay	105	96	
305, Mackaye Harbor and Outer Bay	51	52	**
313, East Sound	58	59	**
337, Lopez Sound, Hunter and Mud Bay	104	100	
345, Echo and Fossil Bay	105	92	
369, Lopez Sound, Hunter and Mud Bay	108	101	
377, Griffin and North Bay	91	99	
409, East Sound	106	96	
421, Strawberry Bay	101	99	

Station, location	Mean light output in test samples @ 15 min	Mean response as a percent of dilution control response @ 15 min	Statistical significance (p value <0.05, t-test)
425, West of Waldron Island and North Cowlitz Bay	100	96	
433, Squaw Bay and Indian Cove	105	100	
441, East Sound	82	97	
465, Lopez Sound, Hunter and Mud Bay	105	100	
Eastern Strait of Juan de Fuca			
41, Port Angeles	104	108	
73, Port Angeles	107	111	
113, Discovery Bay	97	105	
137, Port Angeles	98	99	
177, Discovery Bay	105	113	
201, Port Angeles	90	103	
275, Discovery Bay	24	26	
289, Sequim Bay	83	89	
353, Port Angeles	114	113	
361, Discovery Bay	94	102	
363, Discovery Bay	107	109	
385, Port Angeles	77	89	
417, Dungeness Bay	111	109	
449, Port Angeles (inner harbor)	106	108	
481, Port Angeles	101	102	
521, Discovery Bay	114	102	
545, Dungeness Bay	71	78	**
577, Port Angeles	86	107	
609, Port Angeles	105	107	
649, Discovery Bay	116	102	
673, Port Angeles	84	107	
705, Port Angeles	104	110	
777, Discovery Bay	123	101	
801, Sequim Bay	113	101	

Station, location	Mean light output in test samples @ 15 min	Mean response as a percent of dilution control response @ 15 min	Statistical significance (p value <0.05, t-test)
1033, Discovery Bay	118	102	
1161, Discovery Bay	106	103	
1193, Discovery Bay	112	103	
1289, Sequim Bay	116	100	
1313, Sequim Bay	62	58	**
1387, Discovery Bay	118	100	
Admiralty Inlet			
51, Port Townsend	118	119	
83, South Port Townsend	103	112	
106, South Port Townsend	Not Analyzed		
107, South Port Townsend	Not Analyzed		
108, South Port Townsend	Not Analyzed		
109, Port Townsend	Not Analyzed		
110, Port Townsend	Not Analyzed		
111, Port Townsend	Not Analyzed		
112, Useless Bay	Not Analyzed		
115, Port Townsend	104	116	
116, Useless Bay	Not Analyzed		
117, Useless Bay	Not Analyzed		
119, Useless Bay	28	34	
211, South Port Townsend	106	109	
331, South Port Townsend	117	118	
395, Port Townsend	113	107	
459, Port Townsend	107	99	
491, Port Townsend	123	109	
523, Port Townsend	93	100	
527, Useless Bay	95	99	
587, South Port Townsend	130	111	
651, Port Townsend	101	99	
681, Port Townsend	78	81	*
715, Port Townsend	106	97	

Station, location	Mean light output in test samples @ 15 min	Mean response as a percent of dilution control response @ 15 min	Statistical significance (p value <0.05, t-test)
747, Port Townsend	125	112	
875, Oak Bay	90	106	
1139, Mutiny Bay	67	79	
1295, Useless Bay	90	107	
1355, Oak Bay	30	29	
2123, Oak Bay	107	105	

* Mean response significantly less than controls (p<0.05).
** Mean response significantly less than controls (p<0.05) and < 80% of control.

Table 17. Estimated incidence and spatial extent of toxicity in the 2002-2003 PSAMP Sediment Component study area. The number and percent of stations and the size (km^2) and percent of the total study area are shown for significant responses. The shaded area = total number of stations and total area sampled.

Critical Value Exceeded	Incidence		Spatial Extent	
	No. (%) of stations		km^2	(%) of total study area
San Juan Islands	**30**	**(100.0)**	**80.7**	**(100.0)**
Amphipod survival	1	(3.3)	2.7	(3.3)
Echinoderm embryo (72 hr)	9	(30.0)	24.2	(30.0)
Urchin fertilization (100% pore water)	1	(3.3)	2.7	(3.3)
Microtox®	2	(6.7)	5.4	(6.7)
Total for any one test	10	(33.3)	26.9	(33.3)
Eastern Strait of Juan de Fuca	**30**	**(100.0)**	**61.8**	**(100.0)**
Amphipod survival	0	(0.0)	0.0	(0.0)
Echinoderm embryo (72 hr)	12	(40.0)	31.2	(50.5)
Urchin fertilization (100% pore water)	5	(16.7)	13.7	(22.2)
Microtox®	2	(6.7)	5.5	(8.9)
Total for any one test	14	(46.7)	36.7	(59.4)
Admiralty Inlet	**30**	**(100.0)**	**69.2**	**(100.0)**
Amphipod survival	0	(0.0)	0.0	(0.0)
Echinoderm embryo (72 hr)[1]	4	(13.3)	8.5	(12.3)
Urchin fertilization (100% pore water)	2	(6.7)	7.7	(11.1)
Microtox®[1]	0	(0.0)	0.0	(0.0)
Total for any one test	6	(20.0)	16.2	(23.4)
Total Study Area	**90**	**(100.0)**	**211.7**	**(100.0)**
Amphipod survival	1	(1.1)	2.7	(1.3)
Echinoderm embryo (72 hr)[2]	25	(27.8)	63.9	(30.2)
Urchin fertilization (100% pore water)	8	(16.3)	24.1	(11.4)
Microtox®[2]	4	(4.4)	10.9	(5.1)
Total for any one test	30	(33.3)	79.8	(37.7)

[1] Echinoderm embryo and Microtox® tests performed at 21 stations.
[2] Echinoderm embryo and Microtox® tests performed at 81 stations.

Table 18. Total abundance, major taxa abundance, and major taxa percent of total abundance calculated for the 2002-2003 PSAMP Sediment Component regional monitoring stations.

Station	Total abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Echino-dermata	Echinodermata % of total abundance	Mollusca	Mollusca % of total abundance	Misc. taxa	Misc. taxa % of total abundance
San Juan Islands											
1	307	153	49.84	4	1.30	0	0.00	150	48.86	0	0.00
17	891	451	50.62	106	11.90	11	1.23	296	33.22	27	3.03
25	446	216	48.43	27	6.05	35	7.85	161	36.10	7	1.57
33	1088	782	71.88	241	22.15	0	0.00	64	5.88	1	0.09
57	571	274	47.99	11	1.93	1	0.18	281	49.21	4	0.70
65	764	700	91.62	6	0.79	0	0.00	58	7.59	0	0.00
89	141	94	66.67	13	9.22	0	0.00	32	22.70	2	1.42
97	783	478	61.05	64	8.17	1	0.13	218	27.84	22	2.81
105	703	436	62.02	65	9.25	14	1.99	164	23.33	24	3.41
129	885	784	88.59	11	1.24	0	0.00	89	10.06	1	0.11
153	638	147	23.04	7	1.10	0	0.00	481	75.39	3	0.47
161	650	320	49.23	67	10.31	6	0.92	232	35.69	25	3.85
193	27	26	96.30	1	3.70	0	0.00	0	0.00	0	0.00
217	689	531	77.07	5	0.73	2	0.29	147	21.34	4	0.58
225	471	306	64.97	90	19.11	2	0.42	69	14.65	4	0.85
233	725	286	39.45	335	46.21	0	0.00	103	14.21	1	0.14
257	956	402	42.05	38	3.97	3	0.31	489	51.15	24	2.51
297	390	269	68.97	49	12.56	0	0.00	72	18.46	0	0.00
305	52	35	67.31	10	19.23	0	0.00	7	13.46	0	0.00
313	79	78	98.73	1	1.27	0	0.00	0	0.00	0	0.00
337	726	274	37.74	1	0.14	0	0.00	451	62.12	0	0.00
345	1079	294	27.25	128	11.86	2	0.19	643	59.59	12	1.11
369	130	62	47.69	22	16.92	0	0.00	46	35.38	0	0.00
377	652	237	36.35	127	19.48	0	0.00	281	43.10	7	1.07
409	588	254	43.20	2	0.34	0	0.00	332	56.46	0	0.00
421	1557	917	58.90	461	29.61	1	0.06	162	10.40	16	1.03

Station	Total abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Echino-dermata	Echinodermata % of total abundance	Mollusca	Mollusca % of total abundance	Misc. taxa	Misc. taxa % of total abundance
425	686	231	33.67	70	10.20	3	0.44	365	53.21	17	2.48
433	885	219	24.75	14	1.58	1	0.11	647	73.11	4	0.45
441	57	39	68.42	6	10.53	0	0.00	9	15.79	3	5.26
465	972	721	74.18	52	5.35	12	1.23	186	19.14	1	0.10
Mean	**619.60**	**333.87**	**57.26**	**67.80**	**9.87**	**3.13**	**0.51**	**207.83**	**31.25**	**6.97**	**1.10**
Median	**669.00**	**274.00**	**54.76**	**24.50**	**8.70**	**0.00**	**0.00**	**161.50**	**25.59**	**3.00**	**0.53**
Min	**27**	**26**	**23.04**	**1**	**0.14**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**
Max	**1557**	**917**	**98.73**	**461**	**46.21**	**35**	**7.85**	**647**	**75.39**	**27**	**5.26**
Range	**1530**	**891**	**75.69**	**460**	**46.07**	**35**	**7.85**	**647**	**75.39**	**27**	**5.26**
Strait of Juan de Fuca											
41	392	335	85.46	17	4.34	0	0.00	39	9.95	1	0.26
73	371	302	81.40	50	13.48	0	0.00	16	4.31	3	0.81
113	833	339	40.70	26	3.12	0	0.00	457	54.86	11	1.32
137	570	421	73.86	95	16.67	3	0.53	47	8.25	4	0.70
177	667	382	57.27	18	2.70	0	0.00	259	38.83	8	1.20
201	466	292	62.66	99	21.24	0	0.00	73	15.67	2	0.43
275	16	13	81.25	2	12.50	0	0.00	1	6.25	0	0.00
289	651	500	76.80	39	5.99	0	0.00	109	16.74	3	0.46
353	527	200	37.95	99	18.79	0	0.00	227	43.07	1	0.19
361	244	106	43.44	2	0.82	0	0.00	133	54.51	3	1.23
363	148	97	65.54	17	11.49	0	0.00	34	22.97	0	0.00
385	581	469	80.72	14	2.41	0	0.00	91	15.66	7	1.20
417	1104	682	61.78	77	6.97	2	0.18	341	30.89	2	0.18
449	1058	433	40.93	167	15.78	0	0.00	444	41.97	14	1.32
481	791	366	46.27	123	15.55	0	0.00	299	37.80	3	0.38
521	187	80	42.78	53	28.34	0	0.00	54	28.88	0	0.00
545	1398	675	48.28	478	34.19	14	1.00	224	16.02	7	0.50
577	718	244	33.98	225	31.34	2	0.28	245	34.12	2	0.28
609	1100	556	50.55	142	12.91	2	0.18	385	35.00	15	1.36

Station	Total abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Echino-dermata	Echinodermata % of total abundance	Mollusca	Mollusca % of total abundance	Misc. taxa	Misc. taxa % of total abundance
649	155	123	79.35	3	1.94	0	0.00	29	18.71	0	0.00
673	345	131	37.97	81	23.48	0	0.00	132	38.26	1	0.29
705	1006	528	52.49	10	0.99	0	0.00	467	46.42	1	0.10
777	236	105	44.49	0	0.00	0	0.00	129	54.66	2	0.85
801	173	130	75.14	39	22.54	0	0.00	3	1.73	1	0.58
1033	224	95	42.41	5	2.23	0	0.00	124	55.36	0	0.00
1161	143	93	65.03	4	2.80	0	0.00	46	32.17	0	0.00
1193	343	265	77.26	8	2.33	0	0.00	69	20.12	1	0.29
1289	49	47	95.92	1	2.04	0	0.00	1	2.04	0	0.00
1313	223	162	72.65	18	8.07	0	0.00	43	19.28	0	0.00
1387	761	471	61.89	83	10.91	18	2.37	156	20.50	33	4.34
Mean	**516.00**	**288.07**	**60.54**	**66.50**	**11.20**	**1.37**	**0.15**	**155.90**	**27.50**	**4.17**	**0.61**
Median	**429.00**	**278.50**	**61.83**	**32.50**	**9.49**	**0.00**	**0.00**	**116.50**	**25.92**	**2.00**	**0.34**
Min	**16**	**13**	**33.98**	**0**	**0.00**	**0**	**0.00**	**1**	**1.73**	**0**	**0.00**
Max	**1398**	**682**	**95.92**	**478**	**34.19**	**18**	**2.37**	**467**	**55.36**	**33**	**4.34**
Range	**1382**	**669**	**61.94**	**478**	**34.19**	**18**	**2.37**	**466**	**53.62**	**33**	**4.34**
Admiralty Inlet											
51	563	216	38.37	31	5.51	2	0.36	301	53.46	13	2.31
83	1080	596	55.19	43	3.98	24	2.22	380	35.19	37	3.43
106	309	149	48.22	53	17.15	8	2.59	95	30.74	4	1.29
107	584	292	50.00	66	11.30	3	0.51	218	37.33	5	0.86
108	708	99	13.98	73	10.31	421	59.46	106	14.97	9	1.27
109	705	333	47.23	182	25.82	3	0.43	161	22.84	26	3.69
110	414	100	24.15	67	16.18	17	4.11	224	54.11	6	1.45
111	807	479	59.36	42	5.20	7	0.87	268	33.21	11	1.36
112	2370	758	31.98	1352	57.05	26	1.10	133	5.61	101	4.26
115	609	110	18.06	29	4.76	1	0.16	462	75.86	7	1.15
116	554	95	17.15	197	35.56	3	0.54	254	45.85	5	0.90
117	227	78	34.36	60	26.43	0	0.00	84	37.00	5	2.20
119	1177	787	66.86	74	6.29	125	10.62	88	7.48	103	8.75

Station	Total abundance	Annelida	Annelida % of total abundance	Arthropoda	Arthropoda % of total abundance	Echino-dermata	Echinodermata % of total abundance	Mollusca	Mollusca % of total abundance	Misc. taxa	Misc. taxa % of total abundance
211	320	59	18.44	19	5.94	54	16.88	187	58.44	1	0.31
331	781	117	14.98	23	2.94	339	43.41	297	38.03	5	0.64
395	906	482	53.20	36	3.97	0	0.00	370	40.84	18	1.99
459	937	295	31.48	43	4.59	69	7.36	497	53.04	33	3.52
491	1054	211	20.02	64	6.07	314	29.79	459	43.55	6	0.57
523	756	487	64.42	71	9.39	1	0.13	166	21.96	31	4.10
527	1350	295	21.85	835	61.85	1	0.07	197	14.59	22	1.63
587	1103	116	10.52	70	6.35	407	36.90	507	45.97	3	0.27
651	739	221	29.91	102	13.80	0	0.00	403	54.53	13	1.76
681	343	178	51.90	68	19.83	1	0.29	95	27.70	1	0.29
715	839	163	19.43	36	4.29	225	26.82	411	48.99	4	0.48
747	496	299	60.28	43	8.67	20	4.03	124	25.00	10	2.02
875	1250	189	15.12	506	40.48	12	0.96	539	43.12	4	0.32
1139	414	92	22.22	82	19.81	13	3.14	197	47.58	30	7.25
1295	590	140	23.73	145	24.58	6	1.02	271	45.93	28	4.75
1355	1253	691	55.15	70	5.59	3	0.24	478	38.15	11	0.88
2123	1421	536	37.72	463	32.58	10	0.70	389	27.38	23	1.62
Mean	**821.97**	**288.77**	**35.18**	**164.83**	**16.54**	**70.50**	**8.49**	**278.70**	**37.61**	**19.17**	**2.18**
Median	**747.50**	**213.50**	**31.73**	**67.50**	**9.85**	**9.00**	**0.99**	**261.00**	**38.09**	**10.50**	**1.53**
Min	**227**	**59**	**10.52**	**19**	**2.94**	**0**	**0.00**	**84**	**5.61**	**1**	**0.27**
Max	**2370**	**787**	**66.86**	**1352**	**61.85**	**421**	**59.46**	**539**	**75.86**	**103**	**8.75**
Range	**2143**	**728**	**56.35**	**1333**	**58.91**	**421**	**59.46**	**455**	**70.25**	**102**	**8.48**

Table 19. Total abundance, taxa richness, Pielou's evenness, and Swartz's Dominance Index calculated for the 2002-2003 PSAMP Sediment Component regional monitoring stations.

Station	Location	Total abundance	Taxa richness	Pielou's evenness (J')	Swartz's Dominance Index
San Juan Islands					
1	East Sound	307	26	0.61	4
17	Cowlitz Bay	891	120	0.78	25
25	Shoal Bay	446	58	0.81	16
33	Blind Bay	1088	47	0.66	7
57	Lopez Sound, Hunter and Mud Bay	571	45	0.60	4
65	Deer Harbor	764	35	0.58	4
89	Mackaye Harbor and Outer Bay	141	33	0.82	11
97	Roche Harbor	783	117	0.82	29
105	Telegraph Bay	703	149	0.86	41
129	West Sound, Massacre Bay	885	38	0.59	4
153	Lopez Sound, Hunter and Mud Bay	638	49	0.47	4
161	Griffin and North Bay	650	127	0.83	31
193	East Sound	27	2	0.23	1
217	Lopez Sound, Hunter and Mud Bay	689	53	0.45	3
225	Prevost Harbor, Stuart Island	471	61	0.78	14
233	Lopez Sound, Hunter and Mud Bay	725	32	0.72	7
257	Echo Bay	956	135	0.75	29
297	Westcott Bay	390	42	0.71	9
305	Mackaye Harbor and Outer Bay	52	6	0.81	3
313	East Sound	79	2	0.10	1
337	Lopez Sound, Hunter and Mud Bay	726	21	0.53	3
345	Echo and Fossil Bay	1079	77	0.67	12
369	Lopez Sound, Hunter and Mud Bay	130	19	0.81	6
377	Griffin and North Bay	652	45	0.66	6
409	East Sound	588	32	0.60	4
421	Strawberry Bay	1557	66	0.64	8
425	West of Waldron Island and North Cowlitz Bay	686	88	0.69	12
433	Squaw Bay and Indian Cove	885	68	0.47	5
441	East Sound	57	7	0.57	2
465	Lopez Sound, Hunter and Mud Bay	972	58	0.51	5
	Mean	**619.60**	**55.27**	**0.64**	**10.33**
	Median	**669.00**	**46.00**	**0.66**	**6.00**
	Minimum	**27**	**2**	**0.10**	**1**
	Maximum	**1557**	**149**	**0.86**	**41**
	Range	**1530**	**147**	**0.76**	**40**
Strait of Juan de Fuca					
41	Port Angeles	392	60	0.75	12
73	Port Angeles	371	64	0.80	15
113	Discovery Bay	833	93	0.73	14

Station	Location	Total abundance	Taxa richness	Pielou's evenness (J')	Swartz's Dominance Index
137	Port Angeles	570	94	0.82	23
177	Discovery Bay	667	85	0.77	17
201	Port Angeles	466	72	0.79	16
275	Discovery Bay	16	4	0.59	1
289	Sequim Bay	651	63	0.72	14
353	Port Angeles	527	92	0.74	19
361	Discovery Bay	244	35	0.61	5
363	Discovery Bay	148	11	0.75	4
385	Port Angeles	581	62	0.61	9
417	Dungeness Bay	1104	107	0.69	14
449	Port Angeles (inner harbor)	1058	102	0.71	19
481	Port Angeles	791	125	0.76	27
521	Discovery Bay	187	13	0.77	4
545	Dungeness Bay	1398	92	0.65	10
577	Port Angeles	718	89	0.76	17
609	Port Angeles	1100	137	0.73	26
649	Discovery Bay	155	30	0.86	11
673	Port Angeles	345	84	0.83	28
705	Port Angeles	1006	62	0.63	6
777	Discovery Bay	236	23	0.68	4
801	Sequim Bay	173	10	0.57	3
1033	Discovery Bay	224	30	0.65	7
1161	Discovery Bay	143	14	0.70	4
1193	Discovery Bay	343	46	0.77	12
1289	Sequim Bay	49	6	0.55	2
1313	Sequim Bay	223	23	0.69	5
1387	Discovery Bay	761	116	0.82	28
	Mean	**516.00**	**61.47**	**0.72**	**12.53**
	Median	**429.00**	**62.50**	**0.73**	**12.00**
	Minimum	**16**	**4**	**0.55**	**1**
	Maximum	**1398**	**137**	**0.86**	**28**
	Range	**1382**	**133**	**0.30**	**27**
Admiralty Inlet					
51	Port Townsend	563	87	0.78	21
83	Port Townsend, South	1080	131	0.81	30
106	Port Townsend, South	309	64	0.85	21
107	Port Townsend, South	584	85	0.82	24
108	Port Townsend, South	708	47	0.51	5
109	Port Townsend	705	134	0.83	34
110	Port Townsend	414	71	0.79	19
111	Port Townsend	807	111	0.77	23
112	Useless Bay	2370	195	0.54	19
115	Port Townsend	609	58	0.59	7
116	Useless Bay	554	53	0.71	8

Station	Location	Total abundance	Taxa richness	Pielou's evenness (J')	Swartz's Dominance Index
117	Useless Bay	227	49	0.81	15
119	Useless Bay	1177	199	0.83	46
211	Port Townsend, South	320	42	0.70	10
331	Port Townsend, South	781	41	0.56	4
395	Port Townsend	906	117	0.74	25
459	Port Townsend	937	99	0.75	21
491	Port Townsend	1054	68	0.60	6
523	Port Townsend	756	88	0.60	14
527	Useless Bay	1350	93	0.70	15
587	Port Townsend, South	1103	46	0.62	6
651	Port Townsend	739	119	0.72	20
681	Port Townsend	343	53	0.81	12
715	Port Townsend	839	53	0.56	4
747	Port Townsend	496	84	0.84	23
875	Oak Bay	1250	68	0.66	9
1139	Mutiny Bay	414	74	0.73	14
1295	Useless Bay	590	71	0.71	13
1355	Oak Bay	1253	75	0.65	8
2123	Oak Bay	1421	102	0.64	9
	Mean	**821.97**	**85.90**	**0.71**	**16.17**
	Median	**747.50**	**74.50**	**0.71**	**14.50**
	Minimum	**227**	**41**	**0.51**	**4**
	Maximum	**2370**	**199**	**0.85**	**46**
	Range	**2143**	**158**	**0.34**	**42**

Table 20. Estimated incidence and spatial extent of degraded sediments in the 2002-2003 PSAMP Monitoring Regions, as measured with the Sediment Quality Triad Index.

Sediment Quality Triad Index Category	Incidence		Spatial extent	
	No. (%) of stations		km^2 (%) of study area	
San Juan Islands	**30**	**(100.0)**	**80.7**	**(100.0)**
High[1]	**9**	**(30.0)**	**24.2**	**(30.0)**
Intermediate/high[2]	**11**	**(36.7)**	**29.6**	**(36.7)**
Chemistry	1	(3.3)	2.7	(3.3)
Toxicity	0	(0.0)	0.0	(0.0)
Infaunal	10	(33.3)	26.9	(33.3)
Intermediate/degraded[3]	**10**	**(33.3)**	**26.9**	**(33.3)**
Chemistry/toxicity	0	(0.0)	0.0	(0.0)
Chemistry/infaunal	0	(0.0)	0.0	(0.0)
Infaunal/toxicity	10	(33.3)	26.9	(33.3)
Degraded[4]	**0**	**(0.0)**	**0.0**	**(0.0)**
Eastern Strait of Juan de Fuca	**30**	**(100.0)**	**61.8**	**(100.0)**
High[1]	**12**	**(40.0)**	**17.6**	**(28.5)**
Intermediate/high[2]	**7**	**(23.3)**	**14.1**	**(22.8)**
Chemistry	1	(3.3)	0.9	(1.5)
Toxicity	3	(10.0)	6.6	(10.7)
Infaunal	3	(10.0)	6.6	(10.7)
Intermediate/degraded[3]	**11**	**(36.7)**	**30.1**	**(48.7)**
Chemistry/toxicity	0	(0.0)	0.0	(0.0)
Chemistry/infaunal	0	(0.0)	0.0	(0.0)
Infaunal/toxicity	11	(36.7)	30.1	(48.7)
Degraded[4]	**0**	**(0.0)**	**0.0**	**(0.0)**
Admiralty Inlet	**30**	**(100.0)**	**69.2**	**(100.0)**
High[1]	**22**	**(73.3)**	**47.7**	**(68.9)**
Intermediate/high[2]	**7**	**(23.3)**	**17.7**	**(25.6)**
Chemistry	0	(0.0)	0	(0.0)
Toxicity	5	(16.7)	12.3	(17.8)
Infaunal	2	(6.7)	5.4	(7.8)
Intermediate/degraded[3]	**1**	**(3.3)**	**3.8**	**(5.5)**
Chemistry/toxicity	0	(0.0)	0.0	(0.0)
Chemistry/infaunal	0	(0.0)	0.0	(0.0)
Infaunal/toxicity	1	(3.3)	3.8	(5.5)
Degraded[4]	**0**	**(0.0)**	**0.0**	**(0.0)**

[1] No parameters
[2] One parameter (chemistry, toxicity, or benthos)
[3] Two parameters (chemistry, toxicity, and/or benthos)
[4] Three parameters (chemistry, toxicity, and benthos)

Table 21. Percent incidence and spatial extent of chemical contamination among eight monitoring regions of Puget Sound surveyed by the PSAMP.

Monitoring Region	Year(s) sampled	Percent of samples	Percent of area
		> SQS	> SQS
San Juan Islands	2002-03	3.3	3.3
Eastern Strait of Juan de Fuca	2002-03	3.3	1.4
Admiralty Inlet	2002-03	0.0	0.0
Strait of Georgia	1997	14.8	10.1
Whidbey Basin	1997	12.8	9.0
Central Puget Sound	1998	31.3	3.5
South Puget Sound	1999	4.8	1.5
Hood Canal	1999	4.8	0.5
Hood Canal	2004	0.0	0.0

Table 22. Percentages of sediment samples in which one or more sediment quality guidelines (SQGs) were exceeded and the spatial area that they represented in Puget Sound, other estuarine regions, and national databases.

Location, Database, and Standards or Guideline Used*	Numbers of samples exceeding at least one SQG value*		As percentage of study area		Source of Data
	Ratio	Percent	km^2	Percent	
Present Study					
• exceeded at least one ERM value	0/90	0.0	0.0	0.0	This report
• exceeded at least one SQS value	2/90	2.2	3.6	1.7	This report
PSAMP/NOAA survey of Puget Sound					
• exceeded at least one ERM value	39/300	13.0	30.7	1.3	NOAA/PSAMP 1997-99
• exceeded at least one SQS value[1]	57/300	19.0	106.0	4.5	NOAA/PSAMP 1997-99
[1]benzyl alcohol, benzoic acid, phenol, 2-methylphenol, and 4-methylphenol excluded from calculations					
Washington State Outer Coast, 1999					
• exceeded at least one ERM value	0/41	0.0	0.0	0.0	Washington Dept. of Ecology, 2004
• exceeded at least one SQS value	0/41	0.0	0.0	0.0	Washington Dept. of Ecology, 2004
National Inventories					
EPA 1996 National Sediment Quality Inventory					EPA, 1997
• exceeded two or more SQGs or were toxic	5460/21,000	26.0			
U.S. NOAA/EMAP database for estuaries					Long et al., 1998
• exceeded at least one ERM value	291/1068	27.2			
• exceeded at least one PEL value	385/1068	36.0			
Field validation database for metals criteria	46/77	59.7			Hansen et al., 1996
Regional Inventories: Estuaries					
Puget Sound SEDQUAL database					
• exceeded at least one sediment quality standard (i.e., SQS)	2319/8523	27.2			SEDQUAL database
NOAA survey of Biscayne Bay, FL	33/226	14.6	3.5	0.7	Long et al., 1999c

Location, Database, and Standards or Guideline Used*	Numbers of samples exceeding at least one SQG value*		As percentage of study area		Source of Data
	Ratio	Percent	km^2	Percent	
NOAA/EMAP database for North Carolina estuaries	44/175	25.1	1855.4	21±5	Hyland et al., 2000
EMAP - Louisiana estuaries				5±5	EPA/EMAP website
EMAP - Mississippi estuaries				0.0	EPA/EMAP website
EMAP - Alabama estuaries				29±30	EPA/EMAP website
EMAP - Florida panhandle estuaries				4.0	EPA/EMAP website
Mid-Atlantic Integrated Assessment estuaries				6.0	EPA/EMAP website
Southern California Bight shelf survey (1994)	51/261	19.5	3520.0	12.3	SCCWRP website
Southern California Bight shelf, bays, harbors survey (1998)	78/290	26.9		14.7	SCCWRP website
San Francisco Estuary Institute RMP data (1993-2000)					Bruce Thompson, SFEI
• exceeded at least one ERM value (all chemicals considered)	381/397	96.0			
• exceeded at least one ERM value (excluding nickel)	20/397	5.0			
Regional Inventories: Industrial harbors					
New York/New Jersey Harbor R-EMAP survey; 1993/94			250.5	50	Darvene Adams, EPA Region 2
New York/New Jersey Harbor R-EMAP survey; 1998			235.5	47	Darvene Adams, EPA Region 2
California BPTCP database for harbors and bays	406/568	71.4			Russell Fairey, CalState, Moss Ldg
Pearl Harbor, U.S. Navy survey	176/219	80.4			Jeff Grovhoug, U.S. Navy, San Diego
Industrialized Sydney Harbor, Australia	77/103	74.8			Stephanie McCready, PhD Thesis
United Kingdom ports and harbors, England and Scotland	38/86	44.2			CEFAS lab, Burnham-on-Crouch
Dutch ports and harbors, The Netherlands	133/280	47.5			RIKZ lab, The Hague

* Unless indicated as otherwise, all data were calculated as incidence of samples in which one or more ERM values were exceeded.

Table 23. Percent incidence and spatial extent of toxicity in tests of sea urchin fertilization in three concentrations (100%, 50%, 25%) of sediment pore water from eight Puget Sound monitoring regions.

Monitoring Region	Year(s) sampled	Percent Incidence of Toxicity to Sea Urchins			Percent of Area Toxic to Sea Urchins		
		100%	50%	25%	100%	50%	25%
San Juan Islands	2002-03	3	0	0	3	0	0
Eastern Strait of Juan de Fuca	2002-03	17	3	0	22	5.2	0
Admiralty Inlet	2002-03	7	3	0	11	5.5	0
Puget Sound all	1997-99	11	5	4	4	0.7	0.6
Strait of Georgia	1997	8	3	2	5	3	1
Whidbey Basin	1997	26	13	13	6	0.1	1
Central Puget Sound	1998	8	3	2	1	0.2	1
South Puget Sound	1999	10	7	7	3	1	1
Hood Canal	1999	14	0	0	12	0	0
Hood Canal	2004	17	13	7	18	15	8

Table 24. Incidence and spatial extent of four categories of relative sediment quality compared among eight Puget Sound monitoring regions based on the Sediment Quality Triad.

Monitoring regions	Year(s) sampled	Percent incidence of stations in each category				Spatial extent (percent of study area)			
		High	Intermediate/ high	Intermediate/ degraded	Degraded	High	Intermediate/ high	Intermediate/ degraded	Degraded
San Juan Islands[1]	2002-03	30.0	36.7	33.3	0.0	30.0	36.7	33.3	0.0
Eastern Strait of Juan de Fuca[1]	2002-03	40.0	23.3	36.7	0.0	28.5	22.8	48.7	0.0
Admiralty Inlet[1]	2002-03	73.3	23.3	3.3	0.0	68.9	25.5	5.5	0.0
PSAMP/NOAA survey[2]	1997-99	46.0	28.3	13.3	12.3	68.4	26.6	4.1	1.0
Strait of Georgia	1997	70.5	24.6	4.9	0.0	80.5	18.0	1.5	0.0
Whidbey Basin	1997	61.5	12.8	5.1	20.5	81.9	15.1	2.8	0.2
Central Puget Sound	1998	23.4	37.5	19.5	19.5	54.2	41.4	2.2	2.3
South Puget Sound	1999	50.0	31.0	16.7	2.4	53.7	31.7	14.5	0.1
Hood Canal	1999	61.9	19.0	9.5	9.5	74.5	23.7	1.0	0.9
Hood Canal[3]	2004	23.3	60.0	16.7	0.0	21.9	60.4	17.7	0.0

[1] Calculations based on removal of 5 chemicals, inclusion of 4 toxicity tests (Amphipod 10-day, Sea urchin fertilization, Microtox® porewater, Echinoderm larval survival/development) conducted in 2002-03.
[2] Calculations based on removal of 5 chemicals, inclusion of 4 toxicity tests (Amphipod 10-day, Sea urchin fertilization, Microtox® organic solvent extract, Cytochrome P-450 RGS) conducted in 1999-97.
[3] Calculations based on removal of 5 chemicals, inclusion of 1 toxicity test (Sea urchin fertilization) conducted in 2004.

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Appendices

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Appendix A. Navigation Report for the 2002-2003 PSAMP Sediment Component Sampling Stations.

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
San Juan Islands												
1, East Sound	7-Jun-02	48 38.7510	122 52.0940	1	48 38.7513	122 52.0941	1159	0.4	19.0	0.4	-18.6	2.0/1.1
				2	48 38.7509	122 52.0944	1209	0.4	19.0	0.5	-18.5	2.0/1.1
				3	48 38.7508	122 52.0946	1221	0.6	19.0	0.6	-18.4	1.9/1.1
				4	48 38.7507	122 52.0943	1232	0.7	19.0	0.6	-18.4	2.9/1.9
				5	48 38.7516	122 52.0944	1242	1.1	19.0	0.7	-18.3	2.4/1.7
				6	48 38.7515	122 52.0953	1249	1.6	19.0	0.7	-18.3	3.0/2.2
17, Cowlitz Bay	6-Jun-02	48 41.5706	123 04.1164	1	48 41.5706	123 04.1156	1013	1.1	11.0	0.4	-10.6	2.4/1.3
				2	48 41.5712	123 04.1169	1030	1.2	11.0	0.4	-10.6	1.8/1.0
				3	48 41.5700	123 04.1156	1046	1.5	11.0	0.5	-10.5	1.8/0.9
				4	48 41.5699	123 04.1150	1103	2.1	11.0	0.5	-10.5	2.0/1.0
				5	48 41.5701	123 04.1166	1121	0.8	11.0	0.6	-10.4	2.2/1.1
				6	48 41.5696	123 04.1168	1136	1.9	11.0	0.6	-10.4	1.9/1.0
25, Shoal Bay	5-Jun-02	48 34.0270	122 52.8127	1	48 34.0263	122 52.8118	1055	1.5	6.7	0.9	-5.8	1.8/1.0
				2	48 34.0274	122 52.8126	1108	0.6	7.0	0.9	-6.1	2.0/1.0
				3	48 34.0270	122 52.8123	1120	0.4	7.0	0.9	-6.1	2.2/1.1
				4	48 34.0274	122 52.8131	1132	0.8	7.0	1.0	-6.0	2.1/1.1
33, Blind Bay	5-Jun-02	48 34.8137	122 56.5204	1	48 34.8142	122 56.5205	0930	0.9	4.5	0.6	-3.9	2.2/1.3
				2	48 34.8135	122 56.5196	0939	1.1	4.5	0.7	-3.8	1.7/1.0
				3	48 34.8143	122 56.5194	0949	1.5	4.5	0.7	-3.8	1.6/0.9
				4	48 34.8142	122 56.5188	1002	2.1	4.5	0.7	-3.8	1.9/1.1
				5	48 34.8136	122 56.5198	1012	1.0	4.5	0.7	-3.8	2.5/1.3
57, Lopez Sound,	3-Jun-02	48 30.0260	122 50.7253	1	48 30.0263	122 50.7247	1454	0.8	12.0	0.8	-11.2	2.3/1.2
				2	48 30.0257	122 50.7252	1509	0.8	12.0	0.8	-11.2	1.9/1.0

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
Hunter and Mud Bay				3	48 30.0265	122 50.7263	1520	0.8	12.0	0.8	-11.2	1.8/0.9
				4	48 30.0259	122 50.7252	1531	0.7	12.0	0.7	-11.3	1.7/0.9
65, Deer Harbor	7-Jun-02	48 37.2600	123 00.3040	1	48 37.2594	123 00.3038	1649	0.9	11.5	1.8	-9.7	2.9/1.6
				2	48 37.2606	123 00.3034	1703	1.3	11.5	1.8	-9.7	2.9/1.6
				3	48 37.2595	123 00.3034	1717	1.3	11.5	1.8	-9.7	2.6/1.5
				4	48 37.2593	123 00.3039	1739	1.3	11.5	1.8	-9.7	2.3/1.6
				5	48 37.2596	123 00.3039	1749	0.7	11.5	1.8	-9.7	2.5/1.7
				6	48 37.2599	123 00.3044	1758	0.5	11.5	1.7	-9.8	2.6/1.7
89, Mackaye Hbr. & Outer Bay	4-Jun-02	48 26.5980	122 52.2870	1	48 26.5976	122 52.2873	1213	0.7	9.0	1.2	-7.8	2.0/1.0
				2	48 26.5985	122 52.2873	1227	1.0	9.0	1.2	-7.8	2.0/1.0
				3	48 26.5976	122 52.2864	1238	0.9	9.0	1.2	-7.8	2.0/1.1
				4	48 26.5987	122 52.2869	1248	1.4	9.0	1.2	-7.8	2.8/1.9
				5	48 26.5976	122 52.2875	1258	0.9	9.0	1.2	-7.8	2.9/2.1
97, Roche Harbor	8-Jun-02	48 37.1310	123 09.9160	1	48 37.1313	123 09.9161	1054	0.6	12.0	-0.1	-12.1	2.1/1.1
				2	48 37.1314	123 09.9172	1109	1.9	12.0	-0.1	-12.1	2.1/1.1
				3	48 37.1314	123 09.9157	1120	0.9	12.0	0.0	-12.0	2.1/1.2
				4	48 37.1308	123 09.9165	1131	0.6	12.0	0.0	-12.0	2.1/1.2
105, Telegraph Bay	4-Jun-02	48 26.3920	122 48.4060	1	48 26.3920	122 48.4044	1412	2.0	22.0	1.1	-20.9	1.9/1.0
				2	48 26.3921	122 48.4060	1423	0.1	22.0	1.1	-20.9	2.0/1.0
				3	48 26.3920	122 48.4053	1445	0.9	22.0	1.0	-21.0	2.3/1.1
				4	48 26.3922	122 48.4059	1456	0.3	22.0	1.0	-21.0	2.2/1.2
				5	48 26.3923	122 48.4062	1506	0.5	22.0	1.0	-21.0	1.8/1.0
129, West Sound Massacre Bay	7-Jun-02	48 38.1506	122 59.0473	1	48 38.1502	122 59.0470	1425	0.7	15.0	1.3	-13.7	2.4/1.1
				2	48 38.1512	122 59.0477	1437	1.1	15.0	1.3	-13.7	2.3/1.1
				3	48 38.1502	122 59.0466	1448	1.0	15.0	1.4	-13.6	2.0/1.0
				4	48 38.1505	122 59.0473	1459	0.2	15.0	1.4	-13.6	1.8/1.0
				5	48 38.1503	122 59.0477	1510	0.7	15.2	1.5	-13.7	1.7/0.9
				6	48 38.1518	122 59.0466	1522	2.3	15.3	1.5	-13.8	1.9/1.1
				7	48 38.1506	122 59.0465	1531	0.9	15.5	1.6	-13.9	1.9/1.1

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
				8	48 38.1504	122 59.0474	1540	0.5	15.5	1.6	-13.9	1.7/0.9
				9	48 38.1500	122 59.0457	1549	2.3	15.5	1.7	-13.8	1.6/0.9
153, Lopez Sound, Hunter and Mud Bay	3-Jun-02	48 29.2000	122 50.4934	1	48 29.2006	122 50.4929	1341	1.3	21.0	1.1	-19.9	1.8/0.9
				2	48 29.2006	122 50.4922	1353	1.8	21.0	1.1	-19.9	1.7/0.9
				3	48 29.1997	122 50.4930	1409	0.7	21.0	1.0	-20.0	1.8/1.0
				4	48 29.2000	122 50.4937	1422	0.4	21.0	1.0	-20.0	2.0/1.0
161, Griffin and North Bay	4-Jun-02	48 29.4820	123 00.0690	1	48 29.4812	123 00.0683	0928	1.8	35.5	1.0	-34.5	1.8/1.0
				2	48 29.4820	123 00.0708	1001	1.8	36.0	1.0	-35.0	1.7/0.9
				3	48 29.4817	123 00.0692	1018	0.7	35.0	1.1	-33.9	2.4/1.2
				4	48 29.4826	123 00.0689	1036	0.9	35.2	1.1	-34.1	1.7/1.0
				5	48 29.4822	123 00.0690	1046	0.3	35.2	1.1	-34.1	1.7/1.0
193, East Sound	7-Jun-02	48 40.9190	122 53.5063	1	48 40.9186	122 53.5065	1015	0.8	19.0	0.1	-18.9	1.8/1.0
				2	48 40.9192	122 53.5069	1035	0.7	19.0	0.1	-18.9	1.9/1.0
				3	48 40.9191	122 53.5069	1049	0.7	19.0	0.1	-18.9	2.0/1.0
				4	48 40.9195	122 53.5062	1103	0.8	19.2	0.2	-19.0	2.2/1.1
				5	48 40.9194	122 53.5062	1113	0.7	19.2	0.2	-19.0	2.2/1.1
				6	48 40.9193	122 53.5070	1124	1.0	19.2	0.3	-18.9	2.2/1.1
217, Lopez Sound, Hunter and Mud Bay	3-Jun-02	48 31.4884	122 51.4649	1	48 31.4881	122 51.4649	1605	0.6	11.5	0.6	-10.9	1.6/0.9
				2	48 31.4881	122 51.4665	1620	2.0	11.5	0.6	-10.9	1.9/1.0
				3	48 31.4881	122 51.4652	1634	0.7	11.5	0.6	-10.9	4.0/1.9
				4	48 31.4887	122 51.4649	1648	0.5	11.5	0.6	-10.9	2.7/1.5
225, Prevost Harbor Stuart Island	8-Jun-02	48 40.8074	123 11.8364	1	48 40.8084	123 11.8373	1301	2.0	9.5	0.5	-9.0	4.4/2.7
				2	48 40.8075	123 11.8366	1318	0.3	9.5	0.6	-8.9	3.6/2.2
				3	48 40.8072	123 11.8361	1328	0.5	9.5	0.7	-8.8	1.6/0.9
				4	48 40.8072	123 11.8365	1339	0.3	9.5	0.8	-8.7	1.7/1.0
				5	48 40.8074	123 11.8366	1349	0.3	9.5	0.9	-8.6	1.8/1.0
233, Lopez Sound, Hunter and	3-Jun-02	48 29.5395	122 49.0247	1	48 29.5394	122 49.0243	1111	0.5	3.0	1.3	-1.7	2.0/1.0
				2	48 29.5391	122 49.0246	1120	0.7	3.0	1.3	-1.7	2.0/1.1
				3	48 29.5390	122 49.0242	1131	1.2	3.0	1.3	-1.7	2.1/1.1

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
Mud Bay				4	48 29.5393	122 49.0240	1143	0.9	3.0	1.3	-1.7	2.1/1.2
				5	48 29.5398	122 49.0251	1155	0.7	3.0	1.3	-1.7	2.3/1.2
				6	48 29.5397	122 49.0241	1203	0.8	3.0	1.3	-1.7	2.3/1.2
				7	48 29.5394	122 49.0244	1218	0.5	3.0	1.3	-1.7	2.3/1.2
257, Echo Bay	6-Jun-02	48 45.5333	122 53.1437	1	48 45.5339	122 53.1432	1306	1.2	41.0	1.0	-40.0	4.9/2.9
				2	48 45.5332	122 53.1434	1320	0.3	40.5	1.1	-39.4	4.4/2.6
				3	48 45.5319	122 53.1429	1334	2.6	40.5	1.1	-39.4	3.6/2.1
				4	48 45.5337	122 53.1431	1348	1.1	41.0	1.2	-39.8	1.7/1.0
				5	48 45.5335	122 53.1443	1402	0.8	41.0	1.3	-39.7	1.9/1.0
				6	48 45.5331	122 53.1445	1414	1.1	41.0	1.4	-39.6	1.9/1.0
297, Westcott Bay	10-Jun-03	48 35.8103	123 09.2143	1	48 35.8100	123 09.2140	1009	0.6	6.5	0.5	-6.0	1.1
				2	48 35.8110	123 09.2139	1020	1.5	6.4	0.5	-5.9	1.1
				3	48 35.8100	123 09.2154	1031	1.3	6.5	0.6	-5.9	1.1
				4	48 35.8096	123 09.2149	1041	1.5	6.5	0.6	-5.9	1.1
305, Mackaye Hbr. And Outer Bay	9-Jun-03	48 26.0992	122 52.3867	1	48 26.0991	122 52.3862	1144	0.7	5.0	1.3	-3.7	1.4
				2	48 26.0990	122 52.3854	1154	1.7	5.0	1.3	-3.7	1.7
				3	48 26.0999	122 52.3868	1201	1.2	5.0	1.3	-3.7	1.7
				4	48 26.0995	122 52.3857	1209	1.4	5.0	1.4	-3.6	1.7
				5	48 26.0986	122 52.3864	1215	1.1	5.0	1.4	-3.6	1.7
				6	48 26.0993	122 52.3864	1223	0.5	5.0	1.4	-3.6	1.5
				7	48 26.0988	122 52.3872	1230	1.0	5.0	1.4	-3.6	1.5
313, East Sound	11-Jun-03	48 39.4411	122 54.0847	1	48 39.4412	122 54.0849	0944	0.1	25.8	-0.1	-25.9	1.0
				2	48 39.4412	122 54.0825	0959	2.6	25.9	-0.1	-26.0	1.0
				3	48 39.4408	122 54.0858	1010	1.4	25.8	0.0	-25.8	1.1
				4	48 39.4412	122 54.0856	1026	1.0	25.9	0.0	-25.9	1.1
				5	48 39.4410	122 54.0865	1038	2.0	26.0	0.1	-25.9	1.1
				6	48 39.4412	122 54.0848	1048	0.1	26.0	0.1	-25.9	1.1
337, Lopez Sound and	12-Jun-03	48 31.7864	122 50.8920	1	48 31.7858	122 50.8931	1302	1.7	24.1	0.7	-23.4	1.2
				2	48 31.7857	122 50.8914	1316	1.4	24.2	0.8	-23.4	1.2

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
Mud Bay				3	48 31.7865	122 50.8927	1327	0.8	24.5	0.9	-23.6	1.5
				4	48 31.7875	122 50.8906	1344	2.6	24.8	1.1	-23.7	1.2
				5	48 31.7866	122 50.8933	1355	1.6	24.9	1.2	-23.7	1.1
345, Echo and Fossil Bay	10-Jun-03	48 45.8040	122 53.7360	1	48 45.8044	122 53.7366	1649	1.1	10.4	1.7	-8.7	0.9
				2	48 45.8043	122 53.7354	1717	0.8	10.4	1.8	-8.6	1.2
				3	48 45.8045	122 53.7376	1739	2.2	10.4	1.8	-8.6	1.9
				4	48 45.8041	122 53.7365	1749	0.7	10.4	1.8	-8.6	1.9
				5	48 45.8043	122 53.7364	1758	0.8	10.5	1.8	-8.7	1.3
369, Lopez Sound, Hunter and Mud Bay	12-Jun-03	48 27.7781	122 51.3958	1	48 27.7783	122 51.3947	0957	1.5	3.5	-0.4	-3.9	1.1
				2	48 27.7786	122 51.3954	1011	1.1	3.6	-0.4	-4.0	1.1
				3	48 27.7775	122 51.3957	1021	1.1	3.6	-0.4	-4.0	1.1
				4	48 27.7785	122 51.3951	1029	1.1	3.6	-0.3	-3.9	1.1
				5	48 27.7785	122 51.3952	1039	1.1	3.8	-0.3	-4.1	1.1
377, Griffin and North Bay	9-Jun-03	48 30.9265	123 00.6066	1	48 30.9262	123 00.6062	0915	0.7	10.0	0.7	-9.3	1.0
				2	48 30.9266	123 00.6062	0928	0.6	10.0	0.8	-9.2	1.0
				3	48 30.9266	123 00.6074	0939	1.1	10.0	0.8	-9.2	1.0
				4	48 30.9269	123 00.6070	0950	0.8	10.0	0.8	-9.2	1.0
				5	48 30.9267	123 00.6079	0959	1.6	10.0	0.8	-9.2	1.0
				6	48 30.9261	123 00.6074	1011	1.4	10.0	0.9	-9.1	1.1
409, East Sound	11-Jun-03	48 38.5210	122 51.9050	1	48 38.5206	122 51.9057	1332	1.1	23.0	1.2	-21.8	1.4
				2	48 38.5217	122 51.9047	1345	1.2	22.8	1.3	-21.5	1.3
				3	48 38.5204	122 51.9050	1402	1.3	23.0	1.5	-21.5	1.1
				4	48 38.5209	122 51.9038	1410	1.5	22.8	1.5	-21.3	1.1
				5	48 38.5217	122 51.9035	1418	2.2	22.8	1.6	-21.2	1.4
				6	48 38.5217	122 51.9035	1432	2.3	23.4	1.7	-21.7	1.6
421, Strawberry Bay	9-Jun-03	48 33.7150	122 43.2870	1	48 33.7149	122 43.2867	1447	0.5	5.0	1.4	-3.6	1.6
				2	48 33.7146	122 43.2869	1458	0.7	5.0	1.4	-3.6	1.9
				3	48 33.7142	122 43.2879	1508	1.6	5.0	1.4	-3.6	1.9
				4	48 33.7142	122 43.2873	1516	1.5	5.0	1.3	-3.7	1.9

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
				5	48 33.7150	122 43.2869	1527	0.2	5.0	1.3	-3.7	1.3
				6	48 33.7153	122 43.2859	1537	1.4	5.0	1.3	-3.7	1.5
425, West of Waldron Island, and North of Cowlitz Bay	10-Jun-03	48 41.4962	123 03.0692	1	48 41.4966	123 03.0701	1206	1.2	14.0	1.0	-13.0	1.7
				2	48 41.4959	123 03.0697	1218	0.8	14.0	1.1	-12.9	1.6
				3	48 41.4963	123 03.0674	1228	2.3	14.0	1.2	-12.8	1.0
				4	48 41.4958	123 03.0674	1239	2.2	14.1	1.2	-12.9	1.2
				5	48 41.4962	123 03.0690	1250	0.4	14.3	1.3	-13.0	1.2
433, Squaw Bay and Indian Cove	11-Jun-03	48 33.2805	122 55.9648	1	48 33.2802	122 55.9645	1533	0.7	18.7	1.9	-16.8	1.5
				2	48 33.2815	122 55.9640	1545	2.0	18.6	1.9	-16.7	1.5
				3	48 33.2806	122 55.9634	1551	1.7	18.8	1.9	-16.9	1.6
				4	48 33.2806	122 55.9667	1559	2.4	18.7	1.9	-16.8	1.6
				5	48 33.2803	122 55.9658	1606	1.3	18.8	2.0	-16.8	1.5
441, East Sound	11-Jun-03	48 40.5899	122 53.8860	1	48 40.5903	122 53.8871	1113	1.3	25.5	0.2	-25.3	1.3
				2	48 40.5903	122 53.8866	1126	0.8	25.5	0.3	-25.2	1.3
				3	48 40.5890	122 53.8862	1146	1.7	25.7	0.5	-25.2	1.7
				4	48 40.5901	122 53.8865	1157	0.7	25.8	0.5	-25.3	1.6
				5	48 40.5890	122 53.8861	1210	1.8	25.8	0.6	-25.2	1.6
465, Lopez Sound, Hunter and Mud Bay	12-Jun-03	48 30.4066	122 51.3407	1	48 30.4072	122 51.3409	1107	1.2	9.4	-0.1	-9.5	1.2
				2	48 30.4064	122 51.3395	1116	1.4	9.4	-0.1	-9.5	1.3
				3	48 30.4066	122 51.3409	1126	0.4	9.4	0.0	-9.4	1.3
				4	48 30.4071	122 51.3408	1136	1.0	9.5	0.0	-9.5	1.8
				5	48 30.4067	122 51.3397	1147	1.2	9.5	0.1	-9.4	1.7
Eastern Strait of Juan De Fuca												
41, Port Angeles	10-Jun-02	48 07.7454	123 25.8393	1	48 07.7451	123 25.8396	1658	0.7	23.0	2.1	-20.9	2.9/1.7
				2	48 07.7448	123 25.8398	1709	1..2	23.0	2.1	-20.9	2.6/1.5
				3	48 07.7441	123 25.8389	1720	2.2	23.0	2.1	-20.9	1.9/1.2
				4	48 07.7463	123 25.8394	1731	1.8	23.0	2.1	-20.9	2.4/1.6
73, Port	10-	48	123	1	48 07.4968	123 25.1411	1603	1.2	16.0	2.0	-14.0	4.1/1.9

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
Angeles	Jun-02	07.4973	25.1418	2	48 07.4979	123 25.1410	1615	1.4	16.0	2.0	-14.0	2.8/1.5
				3	48 07.4964	123 25.1428	1626	2.0	16.0	2.1	-13.9	2.7/1.4
113, Discovery Bay	12-Jun-02	48 02.3774	122 51.8711	1	48 02.3776	122 51.8696	1704	1.9	35.0	1.8	-33.2	2.6/1.5
				2	48 02.3774	122 51.8706	1717	1.5	35.0	1.9	-33.1	2.3/1.5
				3	48 02.3776	122 51.8699	1726	1.5	35.2	2.0	-33.2	2.5/1.6
				4	48 02.3776	122 51.8701	1734	1..2	35.2	2.1	-33.1	2.6/1.7
				5	48 02.3777	122 51.8716	1744	0.7	35.0	2.1	-32.9	2.6/1.7
137, Port Angeles	10-Jun-02	48 07.3420	123 25.3440	1	48 07.3414	123 25.3441	1319	0.8	10.0	0.9	-9.1	1.7/0.9
				2	48 07.3416	123 25.3433	1328	1.1	10.1	1.0	-9.1	1.7/0.9
				3	48 07.3418	123 25.3443	1337	0.6	10.2	1.1	-9.1	1.8/1.0
				4	48 07.3425	123 25.3437	1347	0.9	10.2	1.2	-9.0	1.9/1.0
				5	48 07.3424	123 25.3441	1354	0.8	10.5	1.2	-9.3	2.3/1.1
177, Discovery Bay	12-Jun-02	48 03.8916	122 55.1741	1	48 03.8904	122 55.1742	1004	2.1	32.0	-0.6	-32.6	1.7/1.0
				2	48 03.8920	122 55.1740	1016	0.7	32.0	-0.7	-32.7	1.8/1.0
				3	48 03.8915	122 55.1750	1025	0.9	32.0	-0.7	-32.7	1.9/1.0
				4	48 03.8911	122 55.1745	1036	1.1	32.0	-0.7	-32.7	2.0/1.1
201, Port Angeles	10-Jun-02	48 07.4450	123 24.4900	1	48 07.4451	123 24.4899	1159	0.3	11.5	0.3	-11.2	2.0/1.0
				2	48 07.4441	123 24.4901	1208	1.7	11.5	0.4	-11.1	2.0/1.1
				3	48 07.4448	123 24.4892	1217	1.1	11.5	0.4	-11.1	3.0/1.8
				4	48 07.4455	123 24.4896	1227	1.0	11.6	0.5	-11.1	2.8/2.0
				5	48 07.4452	123 24.4902	1235	0.5	11.7	0.6	-11.1	2.9/2.1
275, Discovery Bay	12-Jun-02	48 00.2748	122 50.5701	1	48 00.2745	122 50.5691	1605	1.4	24.0	1.3	-22.7	2.8/1.5
				2	48 00.2745	122 50.5702	1623	0.5	24.1	1.4	-22.7	2.9/1.6
				3	48 00.2748	122 50.5698	1634	0.3	24.1	1.5	-22.6	2.9/1.6
289, Sequim Bay	11-Jun-02	48 03.4981	123 02.0108	1	48 03.4981	123 02.0101	1759	0.9	32.0	2.4	-29.6	2.5/1.7
				2	48 03.4978	123 02.0104	1810	0.7	32.0	2.4	-29.6	2.4/1.6
				3	48 03.4982	123 02.0105	1821	0.6	32.0	2.4	-29.6	2.0/1.1
321, Port Angeles (site	10-Jun-02	48 07.5847	123 24.1657	1	48 07.5854	123 24.1664	1439	1.4	18.2	1.6	-16.6	1.9/1.0
				2	48 07.5850	123 24.1662	1448	0.8	18.2	1.6	-16.6	1.9/1.0

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
rejected)				3	48 07.5847	123 24.1663	1457	0.7	18.4	1.7	-16.7	1.8/1.0
				4	48 07.5852	123 24.1657	1506	0.9	18.5	1.7	-16.8	1.7/0.9
				5	48 07.5849	123 24.1658	1513	0.5	18.5	1.8	-16.7	2.0/1.1
				6	48 07.5841	123 24.1647	1522	1.7	18.6	1.8	-16.8	1.9/1.1
				7	48 07.5844	123 24.1639	1530	2.3	18.5	1.9	-16.6	1.7/0.9
				8	48 07.5840	123 24.1651	1540	1.3	18.5	1.9	-16.6	1.7/1.0
353, Port Angeles	11-Jun-02	48 07.6421	123 22.9492	1	48 07.6424	123 22.9496	0952	0.7	16.5	-0.6	-17.1	2.4/1.2
				2	48 07.6422	123 22.9484	1001	0.9	16.5	-0.6	-17.1	1.7/1.0
				3	48 07.6419	123 22.9495	1014	0.6	16.7	-0.6	-17.3	1.8/1.0
				4	48 07.6416	123 22.9487	1021	1.1	16.7	-0.6	-17.3	1.8/1.0
				5	48 07.6419	123 22.9494	1029	0.3	16.7	-0.5	-17.2	1.9/1.0
				6	48 07.6418	123 22.9486	1037	0.7	16.7	-0.5	-17.2	2.0/1.0
361, Discovery Bay	20-Jun-03	48 04.2722	122 53.2889	1	48 04.2719	122 53.2901	1020	1.5	52.1	1.3	-50.8	1.1
				2	48 04.2721	122 53.2893	1036	0.4	52.1	1.2	-50.9	1.3
				3	48 04.2718	122 53.2895	1053	0.9	51.9	1.1	-50.8	1.1
363, Discovery Bay	19-Jun-03	48 01.6474	122 50.2635	1	48 01.6482	122 50.2621	1403	2.2	34.4	-0.2	-34.6	0.8
				2	48 01.6473	122 50.2626	1417	1.1	34.4	-0.2	-34.6	1.2
				3	48 01.6475	122 50.2640	1435	0.5	34.4	-0.2	-34.6	1.9
385, Port Angeles	11-Jun-02	48 08.4031	123 25.2302	1	48 08.4029	123 25.2292	0847	1.3	12.0	-0.5	-12.5	1.9/1.0
				2	48 08.4032	123 25.2292	0858	1.2	11.7	-0.6	-12.3	1.9/1.0
				3	48 08.4021	123 25.2291	0905	2.3	12.2	-0.6	-12.8	1.8/1.0
				4	48 08.4024	123 25.2290	0914	1.9	12.0	-0.6	-12.6	2.0/1.1
				5	48 08.4029	123 25.2305	0923	0.5	12.0	-0.6	-12.6	1.6/0.9
417, Dungeness Bay	17-Jun-03	48 10.8585	123 05.7736	1	48 10.8569	123 05.7740	1153	2.9	76.0	-0.7	-76.7	1.5
				2	48 10.8577	123 05.7732	1206	1.4	76.0	-0.7	-76.7	1.3
				3	48 10.8584	123 05.7758	1219	2.4	76.0	-0.7	-76.7	1.2
				4	48 10.8584	123 05.7750	1232	1.8	76.0	-0.7	-76.7	1.2
				5	48 10.8595	123 05.7738	1250	1.8	76.0	-0.7	-76.7	1.2
449, Port	16-	48	123	1	48 07.2847	123 24.4176	1403	0.9	10.0	0.4	-9.6	0.8

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
Angeles (inner harbor)	Jun-03	07.2850	24.4180	2	48 07.2858	123 24.4170	1413	1.8	10.1	0.5	-9.6	0.8
				3	48 07.2850	123 24.4175	1425	0.7	10.1	0.6	-9.5	1.2
				4	48 07.2842	123 24.4173	1437	1.7	10.2	0.7	-9.5	1.8
				5	48 07.2852	123 24.4177	1449	0.6	10.4	0.9	-9.5	1.9
				6	48 07.2850	123 24.4188	1459	0.8	10.5	1.0	-9.5	1.3
				7	48 07.2851	123 24.4179	1508	0.2	10.7	1.1	-9.6	1.5
481, Port Angeles	11-Jun-02	48 07.8231	123 23.6379	1	48 07.8231	123 23.6391	1104	1.3	22.2	-0.4	-22.6	2.1/1.2
				2	48 07.8229	123 23.6382	1123	0.3	22.5	-0.3	-22.8	2.3/1.2
				3	48 07.8228	123 23.6375	1130	0.8	22.5	-0.2	-22.7	2.3/1.2
				4	48 07.8227	123 23.6377	1137	0.8	22.5	-0.2	-22.7	2.3/1.2
				5	48 07.8227	123 23.6389	1145	1.4	22.6	-0.1	-22.7	3.5/1.9
				6	48 07.8229	123 23.6366	1154	1.7	22.7	-0.1	-22.8	2.0/1.0
521, Discovery Bay	19-Jun-03	48 01.3747	122 50.7863	1	48 01.3748	122 50.7845	1252	2.1	41.1	0.0	-41.1	1.2
				2	48 01.3741	122 50.7850	1322	2.0	41.2	-0.1	-41.3	1.1
				3	48 01.3742	122 50.7845	1337	2.1	41.2	-0.1	-41.3	1.0
545, Dungeness Bay	17-Jun-03	48 08.8498	123 04.8635	1	48 08.8503	123 04.8653	0906	2.4	10.2	0.5	-9.7	1.0
				2	48 08.8497	123 04.8633	0915	0.5	10.1	0.4	-9.7	1.0
				3	48 08.8493	123 04.8625	0926	1.6	10.0	0.3	-9.7	1.0
				4	48 08.8500	123 04.8638	0934	0.5	10.0	0.2	-9.8	1.0
				5	48 08.8500	123 04.8615	0941	2.4	9.9	0.1	-9.8	1.1
				6	48 08.8499	123 04.8632	0948	0.5	9.8	0.0	-9.8	1.1
				7	48 08.8497	123 04.8635	0958	0.2	9.6	0.0	-9.6	1.1
				8	48 08.8501	123 04.8628	1007	1.0	9.5	-0.1	-9.6	1.1
				9	48 08.8487	123 04.8642	1016	2.1	9.4	-0.2	-9.6	1.1
				10	48 08.8495	123 04.8615	1025	2.5	9.3	-0.3	-9.6	1.1
577, Port Angeles	16-Jun-03	48 07.2056	123 23.9108	1	48 07.2055	123 23.9107	1155	0.3	9.0	-0.6	-9.6	1.5
				2	48 07.2054	123 23.9113	1205	0.9	9.0	-0.5	-9.5	1.0
				3	48 07.2053	123 23.9108	1213	0.6	9.0	-0.5	-9.5	1.2
				4	48 07.2057	123 23.9117	1222	1.2	9.1	-0.4	-9.5	1.2

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
				5	48 07.2054	123 23.9108	1230	0.3	9.2	-0.4	-9.6	1.2
				6	48 07.2054	123 23.9110	1242	0.5	9.3	-0.3	-9.6	1.2
				7	48 07.2049	123 23.9114	1249	1.5	9.3	-0.3	-9.6	1.2
				8	48 07.2052	123 23.9108	1259	0.7	9.4	-0.2	-9.6	1.2
609, Port Angeles	16-Jun-03	48 08.0266	123 23.7416	1	48 08.0271	123 23.7399	1542	2.1	35.2	1.4	-33.8	1.6
				2	48 08.0267	123 23.7420	1554	0.6	35.2	1.5	-33.7	1.2
				3	48 08.0262	123 23.7421	1603	1.1	35.3	1.6	-33.7	1.5
				4	48 08.0273	123 23.7415	1613	1.3	35.4	1.7	-33.7	1.6
				5	48 08.0260	123 23.7420	1622	1.2	35.5	1.8	-33.7	1.6
				6	48 08.0266	123 23.7415	1631	0.1	35.8	1.8	-34.0	1.6
				7	48 08.0261	123 23.7412	1642	1.0	35.8	1.9	-33.9	1.6
649, Discovery Bay	17-Jun-03	48 04.1202	122 54.7599	1	48 04.1203	122 54.7599	1536	0.2	48.9	0.4	-48.5	1.6
				2	48 04.1202	122 54.7602	1550	0.5	49.1	0.5	-48.6	1.2
				3	48 04.1199	122 54.7595	1605	0.6	49.2	0.7	-48.5	1.6
				4	48 04.1198	122 54.7597	1617	0.6	49.4	0.8	-48.6	1.6
673, Port Angeles	16-Jun-03	48 07.6452	123 22.1603	1	48 07.6456	123 22.1594	1006	1.2	17.7	-0.7	-18.4	1.1
				2	48 07.6450	123 22.1602	1015	0.5	17.7	-0.8	-18.5	1.1
				3	48 07.6445	123 22.1606	1026	1.2	17.6	-0.8	-18.4	1.1
				4	48 07.6452	123 22.1587	1036	1.8	17.5	-0.8	-18.3	1.1
				5	48 07.6446	123 22.1601	1043	0.9	17.5	-0.8	-18.3	1.0
				6	48 07.6444	123 22.1607	1051	1.4	17.5	-0.8	-18.3	1.5
				7	48 07.6457	123 22.1594	1059	1.3	17.5	-0.8	-18.3	1.3
				8	48 07.6459	123 22.1594	1110	1.8	17.5	-0.8	-18.3	1.3
				9	48 07.6459	123 22.1594	1119	1.8	17.5	-0.8	-18.3	1.4
				10	48 07.6455	123 22.1597	1125	0.8	17.5	-0.7	-18.2	1.7
705, Port Angeles	16-Jun-03	48 08.2442	123 24.6563	1	48 08.2443	123 24.6557	1701	0.7	49.8	2.1	-47.7	1.5
				2	48 08.2443	123 24.6574	1714	1.4	49.8	2.1	-47.7	1.9
				3	48 08.2445	123 24.6570	1726	1.2	49.8	2.1	-47.7	1.0
				4	48 08.2447	123 24.6567	1736	1.0	50.0	2.3	-47.7	1.0

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
				5	48 08.2450	123 24.6554	1752	1.9	49.9	2.3	-47.6	1.0
777, Discovery Bay	20-Jun-03	48 02.8978	122 52.1207	1	48 02.8979	122 52.1206	0919	0.1	53.2	1.4	-51.8	1.0
				2	48 02.8974	122 52.1213	1932	0.9	53.3	1.4	-51.9	1.1
				3	48 02.8976	122 52.1205	1948	0.5	53.3	1.4	-51.9	1.1
801, Sequim Bay	18-Jun-03	48 03.4808	123 00.6674	1	48 03.4811	123 00.6674	0938	0.6	27.3	0.9	-26.4	1.1
				2	48 03.4807	123 00.6677	1005	0.3	27.2	0.7	-26.5	1.1
				3	48 03.4810	123 00.6670	1017	0.6	27.2	0.6	-26.6	1.1
1033, Discovery Bay	19-Jun-03	48 03.5923	122 54.0814	1	48 03.5936	122 54.0822	0855	2.5	49.8	1.5	-48.3	1.7
				2	48 03.5923	122 54.0809	0908	0.5	49.8	1.4	-48.4	1.0
				3	48 03.5918	122 54.0806	0921	1.3	49.8	1.4	-48.4	1.1
				4	48 03.5923	122 54.0822	0934	0.9	49.8	1.3	-48.5	1.1
1161, Discovery Bay	19-Jun-03	48 02.9323	122 51.5272	1	48 02.9316	122 51.5270	1538	1.4	49.9	0.1	-49.8	1.5
				2	48 02.9322	122 51.5262	1550	1.3	49.9	0.1	-49.8	1.5
				3	48 02.9322	122 51.5275	1601	0.4	50.0	0.2	-49.8	1.6
				4	48 02.9323	122 51.5265	1616	0.8	50.0	0.3	-49.7	1.6
1193, Discovery Bay	17-Jun-03	48 05.6004	122 53.5356	1	48 05.5997	122 53.5364	1427	1.6	50.4	-0.2	-50.6	1.2
				2	48 05.6008	122 53.5357	1441	0.8	50.8	-0.1	-50.9	1.9
				3	48 05.6006	122 53.5361	1453	0.9	50.9	0.0	-50.9	1.3
				4	48 05.6011	122 53.5358	1507	1.3	50.9	0.1	-50.8	1.5
1289, Sequim Bay	18-Jun-03	48 04.0055	123 00.7996	1	48 04.0062	123 00.7978	1049	2.4	25.1	0.3	-24.8	1.3
				2	48 04.0061	123 00.7994	1105	1.4	24.9	0.2	-24.7	1.2
				3	48 04.0051	123 00.7993	1116	0.7	24.9	0.1	-24.8	1.7
1387, Discovery Bay	19-Jun-03	48 00.5363	122 51.1615	1	48 00.5365	122 51.1617	1046	0.5	21.9	0.8	-21.1	1.3
				2	48 00.5365	122 51.1625	1058	1.3	21.9	0.7	-21.2	1.2
				3	48 00.5363	122 51.1609	1114	0.8	21.8	0.6	-21.2	1.6
				4	48 00.5361	122 51.1601	1121	1.7	21.8	0.5	-21.3	1.6
				5	48 00.5357	122 51.1614	1132	1.1	21.8	0.5	-21.3	1.6
				6	48 00.5363	122 51.1619	1140	0.6	21.7	0.4	-21.3	1.5

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
Admiralty Inlet												
51, Port Townsend	13-Jun-02	48 05.2215	122 44.7987	1	48 05.2210	122 44.7989	1618	0.8	20.4	0.8	-19.6	2.9/1.6
				2	48 05.2210	122 44.7988	1634	0.7	20.5	0.9	-19.6	2.9/1.6
				3	48 05.2218	122 44.7977	1646	1.4	20.6	1.1	-19.5	2.9/1.6
				4	48 05.2211	122 44.7989	1658	0.7	21.0	1.2	-19.8	2.6/1..5
				5	48 05.2209	122 44.7974	1711	2.0	21.0	1.3	-19.7	2.2/1.5
83, South Port Townsend	13-Jun-02	48 02.1590	122 44.4200	1	48 02.1582	122 44.4194	1040	1.5	14.5	-0.4	-14.9	2.1/1.1
				2	48 02.1584	122 44.4194	1057	1.4	14.5	-0.5	-15.0	2.1/1.2
				3	48 02.1586	122 44.4199	1106	0.6	14.4	-0.6	-15.0	2.1/1.2
				4	48 02.1593	122 44.4193	1126	1.0	14.3	-0.7	-15.0	2.3/1.2
				5	48 02.1588	122 44.4202	1135	0.3	14.2	-0.8	-15.0	2.2/1.2
106, South Port Townsend	30-Jun-98	48 02.8158	122 45.8275	1	48 02.8153	122 45.8271	0911	1.0	13.3	1.5	11.8	0.9/1.2
				2	48 02.8159	122 45.8274	0925	0.3	13.3	1.5	11.8	0.9/1.2
				3	48 02.8151	122 45.8276	0935	1.3	13.3	1.5	11.8	0.9/1.2
107, South Port Townsend	30-Jun-98	48 02.4110	122 44.6098	1	48 02.4102	122 44.6112	1011	2.1	20.9	1.5	19.4	1.8/1.0
				2	48 02.4118	122 44.6108	1025	1.9	20.9	1.4	19.5	1.8/1.0
				3	48 02.4108	122 44.6093	1033	0.7	20.8	1.4	19.4	1.7/0.9
108, South Port Townsend	30-Jun-98	48 04.1880	122 45.9190	1	48 04.1881	122 45.9197	1829	1.0	26.0	1.3	24.7	1.9/1.1
				2	48 04.1879	122 45.9182	1840	1.0	26.0	1.4	24.6	1.8/1.0
				3	48 04.1890	122 45.9209	1849	3.0	26.0	1.4	24.6	1.8/1.0
109, Port Townsend	29-Jun-98	48 06.6500	122 43.7263	1	48 06.6493	122 43.7254	1525	1.5	33.8	0.3	33.5	4.0/2.3
				2	48 06.6498	122 43.7252	1538	1.3	34.0	0.3	33.7	1.8/1.0
				3	48 06.6504	122 43.7273	1548	1.5	34.2	0.4	33.8	1.9/1.0
				4	48 06.6500	122 43.7253	1600	1.4	34.4	0.4	34.0	2.0/1.1
				5	48 06.6497	122 43.7278	1608	2.0	34.4	0.5	33.9	2.0/1.1
110, Port Townsend	29-Jun-98	48 06.9000	122 43.4421	1	48 06.9001	122 43.4414	1339	1.7	13.2	0.2	13.0	2.3/1.1
				2	48 06.9006	122 43.4396	1426	3.3	12.8	0.2	12.6	2.3/1.1
				3	48 06.8994	122 43.4417	1437	1.2	13.2	0.2	13.0	2.3/1.1

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
				4	48 06.9005	122 43.4418	1446	0.9	12.9	0.2	12.7	2.2/1.1
111, Port Townsend	29-Jun-98	48 06.1757	122 45.0001	1	48 06.1756	122 45.0007	1234	0.8	15.3	0.5	14.8	1.7/0.9
				2	48 06.1759	122 44.9986	1245	1.8	15.3	0.4	14.9	1.7/0.9
				3	48 06.1770	122 45.0006	1254	2.4	15.2	0.4	14.8	1.7/0.9
112, Useless Bay	30-Jun-98	47 58.8918	122 30.2032	1	47 58.8913	122 30.2027	1533	1.2	26.0	0.7	25.3	1.8/1.0
				2	47 58.8923	122 30.2023	1548	1.5	25.0	0.6	24.4	1.8/1.0
				3	47 58.8915	122 30.2028	1557	0.4	26.0	0.6	25.4	1.9/1.0
115, Port Townsend	13-Jun-02	48 04.4482	122 45.2599	1	48 04.4482	122 45.2599	1431	0.1	28.5	-0.2	-28.7	1.8/1.0
				2	48 04.4477	122 45.2600	1447	0.9	28.5	-0.1	-28.6	1.7/0.9
				3	48 04.4484	122 45.2612	1456	1.7	28.7	0.0	-28.7	1.7/0.9
				4	48 04.4485	122 45.2600	1507	0.5	28.7	0.1	-28.6	1.9/1.1
116, Useless Bay	30-Jun-98	47 57.8047	122 30.4741	1	47 57.8045	122 30.4770	1440	3.5	61.0	0.8	60.2	2.2/1.1
				2	47 57.8035	122 30.4776	1453	4.9	62.0	0.8	61.2	2.1/1.2
				3	47 57.8055	122 30.4679	1509	7.7	67.0	0.7	66.3	2.1/1.3
117, Useless Bay	30-Jun-98	47 59.6239	122 40.6870	1	47 59.6249	122 40.6872	1142	1.7	45.0	1.4	43.6	1.6/0.9
				2	47 59.6238	122 40.6853	1200	2.2	46.0	1.3	44.7	1.6/1.1
				3	47 59.6241	122 40.6864	1212	0.9	46.0	1.3	44.7	1.9/1.1
				4	47 59.6233	122 40.6878	1230	1.4	45.0	1.2	43.8	1.8/1.0
119, Useless Bay	17-Jun-02	47 56.7074	122 28.2875	1	47 56.7076	122 28.2861	0932	1.9	90.0	2.1	-88	1.6/1.0
				2	47 56.7076	122 28.2868	0958	0.9	90.0	2.2	-88	1.8/1.0
				3	47 56.7081	122 28.2869	1039	1.4	90.0	2.1	-88	2.1/1.2
				4	47 56.7074	122 28.2874	1054	0.5	90.0	2.1	-88	2.1/1.2
				5	47 56.7076	122 28.2870	1103	0.8	90.0	2.0	-88	2.3/1.2
				6	47 56.7069	122 28.2863	1113	1.8	90.0	2.0	-88	2..2/1.2
171, Mutiny Bay (station rejected)	19-Jun-02	47 58.6452	122 34.1391	1	47 58.6440	122 34.1398	0934	2.1	46.0	1.2	-45	1.7/1.0
				2	47 58.6449	122 34.1390	0947	0.4	46.0	1.3	-45	1.8/1.0
				3	47 58.6449	122 34.1393	1004	0.5	46.0	1.4	-45	2.0/1.0
				4	47 58.6442	122 34.1375	1019	2.1	47.0	1.5	-46	2.1/1.1

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		Latitude	Longitude		Latitude	Longitude						
211, South Port Townsend	13-Jun-02	48 03.4246	122 44.6134	1	48 03.4249	122 44.6127	1303	1.0	17.5	-0.8	-18.3	3.3/2.1
				2	48 03.4243	122 44.6137	1323	0.6	17.5	-0.7	-18.2	1.7/1.0
				3	48 03.4248	122 44.6124	1337	1.3	17.7	-0.6	-18.3	2.2/1.1
				4	48 03.4240	122 44.6132	1347	0.8	17.7	-0.6	-18.3	2.3/1.1
331, South Port Townsend	14-Jun-02	48 02.4730	122 45.0292	1	48 02.4724	122 45.0297	1129	1.4	24.0	-0.4	-24.4	2.2/1.2
				2	48 02.4722	122 45.0292	1146	1.4	23.9	-0.5	-24.4	2.0/1.0
				3	48 02.4730	122 45.0287	1156	0.5	23.9	-0.5	-24.4	2.0/1.1
				4	48 02.4733	122 45.0291	1207	0.9	23.7	-0.6	-24.3	2.8/1.9
				5	48 02.4731	122 45.0286	1218	0.9	23.6	-0.7	-24.3	2.9/2.1
395, Port Townsend	14-Jun-02	48 05.5786	122 44.6818	1	48 05.5794	122 44.6811	0950	1.5	31.0	0.6	-30.4	1.7/1.0
				2	48 05.5783	122 44.6807	1004	1.5	31.0	0.5	-30.5	1.7/1.0
				3	48 05.5782	122 44.6816	1015	0.7	30.8	0.4	-30.4	1.9/1.0
				4	48 05.5781	122 44.6816	1027	0.8	30.8	0.2	-30.6	2.0/1.1
				5	48 05.5791	122 44.6819	1040	0.8	30.8	0.1	-30.7	2.1/1.1
419, Useless Bay (station rejected)	19-Jun-02	47 56.6455	122 32.6554	1	47 56.6470	122 32.6560	1533	2.4	105.0	1.8	-103	2.8/1.5
459, Port Townsend	5-Jun-03	48 05.2694	122 45.4769	1	48 05.2696	122 45.4772	1602	0.6	23.5	0.0	-23.5	1.5
				2	48 05.2693	122 45.4764	1612	0.5	23.6	0.0	-23.6	1.6
				3	48 05.2694	122 45.4755	1624	1.5	23.7	0.1	-23.6	1.6
				4	48 05.2695	122 45.4770	1642	0.4	24.0	0.2	-23.8	1.4
				5	48 05.2699	122 45.4777	1656	1.4	23.9	0.3	-23.6	1.6
483, Useless Bay (station rejected)	19-Jun-02	47 58.8112	122 39.6266	1	47 58.8105	122 39.6277	1214	1.6	68.0	2.1	-66	4.4/2.8
				2	47 58.8102	122 39.6264	1226	1.8	68.0	2.1	-66	4.0/2.5
				3	47 58.8111	122 39.6262	1309	0.6	68.0	2.1	-66	2.1/1.1
				4	47 58.8111	122 39.6260	1320	0.8	68.0	2.1	-66	2.3/1.1
				5	47 58.8111	122 39.6260	1330	0.7	68.0	2.1	-66	2.4/1.1
				6	47 58.8110	122 39.6256	1341	1.2	68.0	2.1	-66	2.3/1.1
				7	47 58.8112	122 39.6277	1354	1.4	68.0	2.1	-66	2.2/1.1

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		Latitude	Longitude		Latitude	Longitude						
				8	47 58.8110	122 39.6260	1410	0.9	68.0	2.1	-66	1.8/1.0
				9	47 58.8115	122 39.6266	1423	0.6	68.0	2.0	-66	1.7/0.9
				10	47 58.8112	122 39.6265	1440	0.1	68.0	2.0	-66	1.9/1.1
491, Port Townsend	5-Jun-03	48 04.3346	122 46.8563	1	48 04.3342	122 46.8558	1253	0.8	19.0	-0.2	-19.2	1.0
				2	48 04.3349	122 46.8563	1312	0.7	20.0	-0.3	-20.3	1.2
				3	48 04.3340	122 46.8566	1327	1.1	19.0	-0.3	-19.3	1.2
				4	48 04.3344	122 46.8569	1337	0.7	18.9	-0.3	-19.2	1.2
523, Port Townsend	6-Jun-03	48 06.9799	122 43.0808	1	48 06.9805	122 43.0808	1312	1.0	12.9	0.2	-12.7	1.2
				2	48 06.9799	122 43.0809	1320	0.2	12.8	0.1	-12.7	1.2
				3	48 06.9799	122 43.0813	1332	0.8	12.7	0.1	-12.6	1.2
				4	48 06.9801	122 43.0800	1344	1.0	12.6	0.0	-12.6	1..2
				5	48 06.9802	122 43.0801	1354	1.0	12.7	0.0	-12.7	1.3
527, Useless Bay	6-Jun-03	47 56.1890	122 26.9130	1	47 56.1889	122 26.9128	1013	0.4	8.9	2.1	-6.8	1.0
				2	47 56.1881	122 26.9128	1027	1.3	9.0	2.0	-7.0	1.1
				3	47 56.1889	122 26.9140	1038	1.2	9.3	2.0	-7.3	1.2
				4	47 56.1896	122 26.9138	1051	1.4	9.0	1.9	-7.1	1.1
				5	47 56.1888	122 26.9126	1101	0.7	8.8	1.8	-7.0	1.1
				6	47 56.1895	122 26.9143	1114	1.6	9.0	1.7	-7.3	1.1
				7	47 56.1886	122 26.9120	1123	1.6	8.3	1.7	-6.6	1.4
547, Useless Bay (station rejected)	19-Jun-02	47 55.9170	122 33.4997	1	47 55.9166	122 33.5231	1555	28.0	51.0	1.7	-49	2.9/1.6
587, South Port Townsend	5-Jun-03	48 03.4958	122 45.2128	1	48 03.4958	122 45.2131	1413	0.4	27.4	-0.4	-27.8	1.2
				2	48 03.4955	122 45.2128	1426	0.4	27.4	-0.4	-27.8	1.0
				3	48 03.4956	122 45.2135	1437	0.8	27.4	-0.4	-27.8	1.0
				4	48 03.4958	122 45.2119	1458	1.0	27.5	-0.3	-27.8	0.8
651, Port Townsend	6-Jun-03	48 06.5440	122 44.5558	1	48 06.5455	122 44.5572	1427	1.9	18.5	-0.1	-18.6	1.0
				2	48 06.5440	122 44.5552	1434	0.7	18.7	-0.1	-18.8	1.0

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
				3	48 06.5433	122 44.5546	1443	1.6	18.6	-0.1	-18.7	0.8
				4	48 06.5435	122 44.5557	1451	0.9	18.7	-0.1	-18.8	0.8
				5	48 06.5435	122 44.5555	1459	1.0	18.7	-0.2	-18.9	0.8
				6	48 06.5426	122 44.5555	1508	2.2	18.5	-0.1	-18.6	1.2
				7	48 06.5438	122 44.5561	1517	0.5	18.7	-0.1	-18.8	1.3
675, Useless Bay	19-Jun-02	47 54.1719	122 31.0174	1	47 54.1740	122 31.0185	1631	3.7	19.2	1.5	-17.7	2.6/1.5
				2	47 54.1717	122 31.0164	1642	1.6	19.2	1.4	-17.8	1.9/1.2
681, Port Townsend	5-Jun-03	48 05.9750	122 47.0515	1	48 05.9744	122 47.0506	0926	1.5	5.5	1.4	-4.1	1.0
				2	48 05.9748	122 47.0515	0944	0.3	5.4	1.3	-4.1	1.0
				3	48 05.9751	122 47.0509	0952	0.7	5.2	1.2	-4.0	1.0
				4	48 05.9750	122 47.0507	1003	1.1	5.1	1.2	-3.9	1.0
				5	48 05.9751	122 47.0522	1016	1.0	5.0	1.0	-4.0	1.0
				6	48 05.9754	122 47.0508	1028	1.1	5.0	1.0	-4.0	1.1
715, Port Townsend	6-Jun-03	48 05.6269	122 46.6067	1	48 05.6271	122 46.6061	1541	0.9	18.8	-0.1	-18.9	1.3
				2	48 05.6271	122 46.6058	1553	1.2	18.6	-0.1	-18.7	1.5
				3	48 05.6270	122 46.6075	1601	0.9	18.7	-0.1	-18.8	1.5
				4	48 05.6274	122 46.6074	1616	1.4	18.8	0.0	-18.8	1.6
747, Port Townsend	5-Jun-03	48 05.6246	122 47.4551	1	48 05.6245	122 47.4545	1102	0.8	9.7	0.7	-9.0	1.1
				2	48 05.6242	122 47.4547	1116	0.6	9.6	0.5	-9.1	1.1
				3	48 05.6247	122 47.4539	1126	1.4	9.8	0.5	-9.3	1.4
				4	48 05.6245	122 47.4552	1136	0.2	9.6	0.4	-9.2	1.3
875, Oak Bay	24-Jun-02	48 00.2633	122 42.8116	1	48 00.2645	122 42.8111	1224	2.2	24.0	-0.6	-24.6	1.7/1.0
				2	48 00.2632	122 42.8108	1238	1.1	24.0	-0.5	-24.5	1.7/1.0
				3	48 00.2626	122 42.8110	1248	1.5	24.2	-0.4	-24.6	2.1/1.1
				4	48 00.2631	122 42.8123	1258	1.0	24.2	-0.2	-24.4	2.3/1.1
1139, Mutiny Bay	24-Jun-02	47 59.3849	122 33.2954	1	47 59.3849	122 33.2954	1102	0.1	27.2	-0.9	-28.1	2.0/1.0
				2	47 59.3850	122 33.2943	1112	1.2	27.2	-0.9	-28.1	2.0/1.0
				3	47 59.3853	122 33.2949	1120	1.4	27.5	-0.9	-28.4	1.9/1.1

Station, Location	Date	Station Target NAD 1983 Degrees, Decimal Minutes		Deploy-ment	DGPS Trimble NT300D (2-m. accuracy) NAD 1983, Decimal Minutes		GPS Time	Dist. to Target m.	Meter Wheel Depth m.	Predicted Tide (m.): Nearest Station	Predicted Mudline Depth, m. (MLLW)	GPS Status PDOP/ HDOP
		Latitude	Longitude		Latitude	Longitude						
				4	47 59.3850	122 33.2962	1130	0.8	27.5	-0.8	-28.3	2.8/2.0
1295, Useless Bay	24-Jun-02	47 58.9045	122 29.6020	1	47 58.9045	122 29.6022	1629	0.3	57.7	2.5	-55	2.3/1.5
				2	47 58.9051	122 29.6014	1642	1.5	57.9	2.7	-55	2.5/1.7
				3	47 58.9050	122 29.6001	1655	2.5	58.0	2.8	-55	2.6/1.7
				4	47 58.9044	122 29.6016	1709	0.5	58.0	2.9	-55	2.5/1.7
				5	47 58.9044	122 29.6021	1722	0.4	58.2	3.0	-55	2.4/1.6
1313, Sequim Bay	18-Jun-03	48 03.3715	123 01.4341	1	48 03.3721	123 01.4344	1148	1.2	26.2	-0.1	-26.3	1.5
				2	48 03.3712	123 01.4326	1204	1.8	26.0	-0.2	-26.2	1.0
				3	48 03.3711	123 01.4331	1219	1.0	25.9	-0.3	-26.2	1.2
				4	48 03.3705	123 01.4339	1238	1.8	25.8	-0.4	-26.2	1.2
1355, Oak Bay	24-Jun-02	48 01.0280	122 42.3760	1	48 01.0285	122 42.3755	1421	1.2	4.7	0.8	-3.9	1.9/1.1
				2	48 01.0279	122 42.3767	1430	0.9	5.0	1.0	-4.0	1.7/0.9
				3	48 01.0280	122 42.3760	1440	0.1	5.1	1.1	-4.0	1.6/0.9
				4	48 01.0282	122 42.3753	1449	1.1	5.2	1.2	-4.0	1.7/1.0
1827, Mutiny Bay (station rejected)	24-Jun-02	47 58.6681	122 33.1678	1	47 58.6684	122 33.1678	1041	0.8	21.0	-0.8	-21.8	2.2/1.2
				2	47 58.6856	122 33.2416	1048	1.8	25.7	-0.8	-26.5	2.1/1.2
2123, Oak Bay	24-Jun-02	47 59.3317	122 41.9666	1	47 59.3320	122 41.9672	1327	1.0	24.5	0.1	-24.4	2.3/1.1
				2	47 59.3314	122 41.9674	1336	1.0	24.5	0.2	-24.3	2.1/1.1
				3	47 59.3321	122 41.9665	1346	0.8	25.0	0.3	-24.7	1.8/1.0
				4	47 59.3316	122 41.9661	1354	0.8	25.2	0.4	-24.8	1.8/0.9

Appendix B. Toxicity Reports

Appendix B-1. Toxicity Report Review and Summary

Appendix B-2. Toxicity of marine sediments from the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet regions to *Eohaustorius estuarius*, *Dendraster excentricus,* and *Vibrio fischeri* – Final reports and appendices from BC Research Inc.

Appendix B-3. Toxicity of marine sediments from the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet regions to *Strongylocentrotus purpuratus* –
Final reports and appendices from U.S. Geological Survey.

Appendix B-1, B-2, and B-3 are available only electronically, on the web and on a compact disk.

Appendix B - Tables 1-8. Reference Toxicant Control Data

Appendix B. Table 1. Mean reference toxicant EC50s and 95% confidence intervals for 2002 96-hour solid phase sediment amphipod survival test with *Eohaustorius estuarius* compared to means and intervals of previous studies.

Date	Organism Batch	Mean EC50 (95% CL) (mg Cd /L)	2 SD range of previous tests (mg Cd /L)	Mean & SD of previous tests (mg Cd/L)
June 12, 2002	SE 020608	6.46 (N/A)	0.22 – 9.72	4.97 ± 2.37
June 22, 2002	SE 020616	10.98 (8.60, 14.40)	0.59 – 9.64	5.11±2.26
June 29, 2002	SE 020616	12.75 (9.40, 19.37)	0.13 – 10.91	5.52±2.70

Appendix B. Table 2. Mean reference toxicant EC50s and 95% confidence intervals for the 2003 96-hour solid phase amphipod survival test with *Eohaustorius estuarius* compared to means and intervals of previous studies.

Date	Organism Batch	Mean EC50 (95% CL) (mg Cd /L)	2 SD Range of previous tests (mg Cd /L)	Mean & SD of previous tests (mg Cd/L)
June 14, 2003	SE030611	8.15 (5.76 – 12.60)	0.46 – 12.37	5.96 ± 3.21
June 20, 2003	SE030611	11.50 (6.88 – 15.52)	0 – 12.31	6.11 ± 3.10
June 25, 2003	SE030619	10.63 (7.72 – 16.29)	0 – 12.87	6.42 ± 3.23
June 27, 2003	SE030619	11.50 (6.88 – 15.52)	0.18 – 13.12	6.65 ± 3.23

Appendix B. Table 3. Mean reference toxicant EC50s and 95% confidence intervals for the 2002 echinoderm embryo test with *Dendraster excentricus* compared to means and intervals of previous studies, based on the percent abnormality endpoint, based on the percent abnormality endpoint.

Date	Organism Batch	Mean EC50 (95% CL) (mg Cd/L)	2 SD range of previous tests (mg Cd/L)	Mean & SD of previous tests (mg Cd/L)
June 11, 2002	MA 020605	12.55 (10.63, 14.64)	3.67 – 4.37	4.02 ± 0.18 *
June 14, 2002	MA 020605	9.42 (7.96, 11.07)	0 – 13.92	5.88±4.02
June 24, 2002	MR 020620	6.40 (N/A)	0 – 13.92	6.61±3.65
June 28, 2002	MR 020627	6.17 (N/A)	0 – 13.16	6.57±3.30

Appendix B. Table 4. Mean reference toxicant EC50s and 95% confidence intervals for the 2002 echinoderm embryo test with *Dendraster excentricus* compared to means and intervals of previous studies, based on the combined mortality/abnormality endpoint.

Date	Organism Batch	Mean EC50 (95% CL) (mg Cd/L)	2 SD range of previous tests (mg Cd/L)	Mean & SD of previous tests (mg Cd/L)
June 11, 2002	MA 020605	11.37 (10.76, 11.93)	N/A	N/A
June 14, 2002	MA 020605	11.35 (N/A)	N/A	N/A
June 24, 2002	MR 020620	6.82 (6.69, 6.94))	11.34-11.38	11.36±0.01
June 28, 2002	MR 020627	5.94 (N/A)	5.30-13.86	9.58±2.14

Appendix B. Table 5. Mean reference toxicant EC50s and 95% confidence intervals for the 2003 echinoderm embryo test with *Dendraster excentricus* compared to means and intervals of previous studies, based on the percent abnormality endpoint.

Date	Organism Batch	Mean EC50 (95% CL) (mg Cd/L)	2 SD Range of previous tests (mg Cd/L)	Mean & SD of previous tests (mg Cd/L)
June 13, 2003	MR030612	8.18 (7.88, 8.45)	0.42-12.58	6.50 ± 3.04
June 17, 2003	MR030617	3.43 (2.92, 3.91)	1.04 – 12.40	6.72 ± 2.84
June 19, 2003	MR030617	6.85 (6.60, 7.09)	0.29 – 12.06	6.18 ± 2.94
June 24, 2003	MR030624	4.86 (3.15, 6.38)	0.70 – 11.79	6.25 ± 2.77
July 2, 2003	MR030702	4.71 (3.71, 5.77)	0.71 – 11.48	6.09 ± 2.69

Appendix B. Table 6. Mean reference toxicant EC50s and 95% confidence intervals for the 2003 echinoderm embryo test with *Dendraster excentricus* compared to means and intervals of previous studies, based on the combined mortality/abnormality endpoint.

Date	Organism Batch	Mean EC50 (95% CL) (mg Cd/L)	2 SD Range of previous tests (mg Cd/L)	Mean & SD of previous tests (mg Cd/L)
June 13, 2003	MR030612	8.00 (7.60, 8.32)	3.48 – 13.52	8.50 ± 2.51
June 17, 2003	MR030617	3.28 (2.44, 3.96)	3.85 – 12.94	8.40 ± 2.27
June 19, 2003	MR030617	6.97 (6.68, 7.25)	1.41 – 12.97	7.19 ± 2.89
June 24, 2003	MR030624	4.09 (2.73, 5.28)	1.77 – 12.54	7.16 ± 2.69
July 2, 2003	MR030702	3.07 (0.97, 5.07)	1.11 – 12.24	6.67 ± 2.78

Appendix B. Table 7. Mean reference toxicant EC50s and 95% confidence intervals for the 2002 microbial bioluminescence (Microtox®) test of pore water compared to means and intervals of previous studies.

Date	EC50 (95% CL) (mg/L phenol)	2 SD Range of previous tests (mg/L phenol)	Mean & SD of previous tests (mg/L phenol)
June 10, 2002-	19.26 (17.58, 21.09)	15.63 – 23.38	19.51±1.94
June 16, 2002	18.21 (15.86-20.91)	15.66 – 23.39	19.52±1.93

Appendix B. Table 8. Mean reference toxicant EC50s and 95% confidence intervals for the 2003 microbial bioluminescence (Microtox®) test of pore water compared to intervals of previous studies.

Date	Reagent Lot #	Mean EC50 (95% CL) (mg/L phenol)	2 SD range of previous tests (mg/L phenol)	Mean & SD of previous tests (mg/L phenol)
June 10, 2003	2L6026	18.10 (16.65-19.67)	15.92-24.73	20.33±2.20
June 23, 2003	2L6026	16.58 (15.44-17.79)	15.68-24.70	20.19 ± 2.26
June 25, 2003	3A2111	20.08 (17.62-22.89)	15.19-24.70	19.94±2.38

Appendix C. NOAA Sediment Quality Guidelines and Washington State Sediment Management Standards.

Chemical	NOAA Guidelines			Washington State Sediment Management Standards		
	ERL[1]	ERM[1]	Unit[1]	SQS[2]	CSL[2]	Unit[2]
Trace metals						
Arsenic	8.2	70	PPM Dry Weight	57	93	PPM Dry Weight
Cadmium	1.2	9.6	PPM Dry Weight	5.1	6.7	PPM Dry Weight
Chromium	81	370	PPM Dry Weight	260	270	PPM Dry Weight
Copper	34	270	PPM Dry Weight	390	390	PPM Dry Weight
Lead	46.7	218	PPM Dry Weight	450	530	PPM Dry Weight
Mercury	0.15	0.71	PPM Dry Weight	0.41	0.59	PPM Dry Weight
Nickel	20.9	51.6	PPM Dry Weight	NA	NA	PPM Dry Weight
Silver	1	3.7	PPM Dry Weight	6.1	6.1	PPM Dry Weight
Zinc	150	410	PPM Dry Weight	410	960	PPM Dry Weight
Organic Chemicals						
LPAH						
2-Methylnaphthalene	70	670	PPB dry weight	38	64	PPM Organic Carbon
Acenaphthene	16	500	PPB dry weight	16	57	PPM Organic Carbon
Acenaphthylene	44	640	PPB dry weight	66	66	PPM Organic Carbon
Anthracene	85.3	1100	PPB dry weight	220	1200	PPM Organic Carbon
Fluorene	19	540	PPB dry weight	23	79	PPM Organic Carbon
Naphthalene	160	2100	PPB dry weight	99	170	PPM Organic Carbon
Phenanthrene	240	1500	PPB dry weight	100	480	PPM Organic Carbon
Sum of LPAHs:						
Sum of 6 LPAH (Ch. 173-204 WAC)	NA	NA		370	780	PPM Organic Carbon
Sum of 7 LPAH (Long et al., 1995)	552	3160	PPB dry weight	NA	NA	
HPAH						
Benzo(a)anthracene	261	1600	PPB dry weight	110	270	PPM Organic Carbon
Benzo(a)pyrene	430	1600	PPB dry weight	99	210	PPM Organic Carbon
Benzo(g,h,I)perylene	NA	NA		31	78	PPM Organic Carbon
Chrysene	384	2800	PPB dry weight	110	460	PPM Organic Carbon
Dibenzo(a,h)anthracene	63.4	260	PPB dry weight	12	33	PPM Organic Carbon
Fluoranthene	600	5100	PPB dry weight	160	1200	PPM Organic Carbon

Chemical	NOAA Guidelines			Washington State Sediment Management Standards		
	ERL[1]	ERM[1]	Unit[1]	SQS[2]	CSL[2]	Unit[2]
Indeno(1,2,3-c,d)pyrene	NA	NA		34	88	PPM Organic Carbon
Pyrene	665	2600	PPB dry weight	1000	1400	PPM Organic Carbon
Total Benzofluoranthenes	NA	NA		230	450	PPM Organic Carbon
Sum of HPAHs:						
Sum of 9 HPAH (Ch. 173-204 WAC)	NA	NA		960	5300	PPM Organic Carbon
Sum of 6 HPAH (Long et al., 1995)	1700	9600	PPB dry weight	NA	NA	
Sum of 13 PAHs	4022	44792	PPB dry weight	NA	NA	
Phenols						
2,4-Dimethylphenol	NA	NA		29	29	PPB Dry Weight
2-Methylphenol	NA	NA		63	63	PPB Dry Weight
4-Methylphenol	NA	NA		670	670	PPB Dry Weight
Pentachlorophenol	NA	NA		360	690	PPB Dry Weight
Phenol	NA	NA		420	1200	PPB Dry Weight
Phthalate Esters						
Bis (2-Ethylhexyl) Phthalate	NA	NA		47	78	PPM Organic Carbon
Butylbenzylphthalate	NA	NA		4.9	64	PPM Organic Carbon
Diethylphthalate	NA	NA		61	110	PPM Organic Carbon
Dimethylphthalate	NA	NA		53	53	PPM Organic Carbon
Di-N-Butyl Phthalate	NA	NA		220	1700	PPM Organic Carbon
Di-N-Octyl Phthalate	NA	NA		58	4500	PPM Organic Carbon
Chlorinated Pesticide and PCBs						
4,4'-DDE	2.2	27	PPB dry weight	NA	NA	
Total DDT	1.58	46.1	PPB dry weight	NA	NA	
Total PCB:						
Total Aroclors (Ch. 173-204 WAC)	NA	NA		12	65	PPM Organic Carbon
Total congeners (Long et al., 1995):	22.7	180	PPB dry weight	NA	NA	
Miscellaneous Chemicals						
1,2-Dichlorobenzene	NA	NA		2.3	2.3	PPM Organic Carbon
1,2,4-Trichlorobenzene	NA	NA		0.81	1.8	PPM Organic Carbon
1,4-Dichlorobenzene	NA	NA		3.1	9	PPM Organic Carbon
Benzoic Acid	NA	NA		650	650	PPB Dry Weight
Benzyl Alcohol	NA	NA		57	73	PPB Dry Weight

Chemical	NOAA Guidelines			Washington State Sediment Management Standards		
	ERL[1]	ERM[1]	Unit[1]	SQS[2]	CSL[2]	Unit[2]
Dibenzofuran	NA	NA		15	58	PPM Organic Carbon
Hexachlorobenzene	NA	NA		0.38	2.3	PPM Organic Carbon
Hexachlorobutadiene	NA	NA		3.9	6.2	PPM Organic Carbon
N-Nitrosodiphenylamine	NA	NA		11	11	PPM Organic Carbon

[1] Long, Edward R., Donald D. Macdonald, Sherri L. Smith, and Fred D. Calder. 1995. Incidence of adverse biological effect with ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1): 81-97.

[2] Washington State Sediment Management Standard Chapter 173-204, Amended December 1995.

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Appendix D. Field notes for the 2002-2003 PSAMP Sediment Component Sampling Stations.

Station, location	Strata type	Depth (m)	Grab pene-tration (cm)	Overlying Sediment Color	Underlying Sediment Color	Compo-sition	Odor	Presence of		Sediment/ water interface salinity (ppt)	Sediment temper-ature (c°)	Redox potential depth (cm)	Sheen
								shell hash	wood				
San Juan Islands													
1, East Sound	Rural	19	17	Olive	NR	Silt/Clay	None	No	NR	31	11	None	No
17, Cowlitz Bay	Rural	11	13	Brown	NR	Sand with Fines	None	No	NR	31	11	Mixed	No
25, Shoal Bay	Rural	7	17	Olive	Gray	Silt/Clay	None	Yes	NR	31	12	3	No
33, Blind Bay	Rural	4	9	Olive	Gray Brown	Silt/Clay	None	Yes	NR	31	12	3	No
57, Lopez Sound, Hunter and Mud Bay	Rural	12	17	Olive	Gray	Silt/Clay	None	No	NR	32	12	4	No
65, Deer Harbor	Rural	12	16	Olive	NR	mixed	None	No	NR	30	11.5	None	No
89, Mackaye Hbr. & Outer Bay	Rural	9	7	Gray brown	Gray	Sand	None	No	NR	31	11.5	None	No
97, Roche Harbor	Rural	12	16	Gray	NR	Sand with Fines	None	No	NR	29	11	None	No
105, Telegraph Bay	Rural	22	7	Gray	Gray Brown	Mixed	None	No	NR	30	12	None	No
129, West Sound, Massacre Bay	Rural	15	17	Olive	NR	Silt/Clay	None	No	NR	32	12	None	No

Station, location	Strata type	Depth (m)	Grab penetration (cm)	Overlying Sediment Color	Underlying Sediment Color	Composition	Odor	Presence of		Sediment/ water interface salinity (ppt)	Sediment temperature (c°)	Redox potential depth (cm)	Sheen
								shell hash	wood				
153, Lopez Sound, Hunter and Mud Bay	Rural	21	15	Olive	Gray	Silt/Clay	None	No	NR	32	12	1.5	No
161, Griffin and North Bay	Rural	36	9	Gray Brown	Gray	Sand	None	Yes	NR	32	11	None	No
193, East Sound	Rural	19	17	Olive	NR	Silt/Clay	Moderate H_2S	No	NR	30	11	None	No
217, Lopez Sound, Hunter and Mud Bay	Rural	12	16	Olive	Olive Gray	Silt/Clay	None	No	NR	31	12	4	No
225, Prevost Harbor, Stuart Island	Rural	10	16	Olive	NR	Sand with Fines	None	No	NR	24	12	None	No
233, Lopez Sound, Hunter and Mud Bay	Rural	3	7	Gray	NR	Sand	Slight H_2S	Yes	NR	32	12	None	No
257, Echo Bay	Rural	41	13	Brown	NR	Sand with Fines	None	Yes	Yes	30	11	None	No
297, Westcott Bay	Rural	6	13	Olive	gray	Silt/Clay	None	No	NR	30	12.5	NR	No
305, Mackaye Harbor and Outer Bay	Rural	5	10	Brown	Gray	Sand with Fines	Moderate H_2S	No	NR	10	12	NR	No
313, East Sound	Rural	26	17	Olive	Black	Silt/Clay	Strong H_2s	Yes	Yes	30	12	NR	No
337, Lopez Sound, Hunter and Mud Bay	Rural	24	17	Olive	Gray	Silt/Clay	None	No	No	32	11	None	No
345, Echo and Fossil Bay	Rural	10	17	Olive	Gray Brown	Silt/Clay	None	No	No	27	12	NR	No

Station, location	Strata type	Depth (m)	Grab pene-tration (cm)	Overlying Sediment Color	Underlying Sediment Color	Compo-sition	Odor	Presence of shell hash	Presence of wood	Sediment/ water interface salinity (ppt)	Sediment temper-ature (c°)	Redox potential depth (cm)	Sheen
369, Lopez Sound, Hunter and Mud Bay	Rural	4	16	Olive	Gray	Silt/Clay	Slight H_2S	No	No	30	12	NR	No
377, Griffin and North Bay	Rural	10	9	Olive	Olive	Sand with Fines	None	No	No	30	11	3	No
409, East Sound	Rural	23	15	Olive	Gray	Gravel with Fines	Slight H_2S	Yes	Yes	30	12	NR	No
421, Strawberry Bay	Rural	5	10	Olive	Black	Silt/Clay	Slight H_2S	No	No	30	11	2	No
425, West of Wadron Island, and North Cowlitz Bay	Rural	14	15	Olive	Brown	Sand with Fines	None	No	No	29	11	NR	No
433, Squaw Bay and Indian Cove	Rural	19	13	Brown	Brown	Sand with Fines	None	No	No	30	10.5	NR	No
441, East Sound	Rural	26	17	Olive	Black	Silt/Clay	Slight H_2S	No	No	30	12	NR	No
465, Lopez Sound, Hunter and Mud Bay	Rural	9	14	Olive	Gray	Silt/Clay	None	No	No	30	11.5	NR	No
Strait of Juan de Fuca													
41, Port Angeles	Urban	23	9	Olive	Black	Silt/Clay	None	No	Yes	32	13	NR	No
73, Port Angeles	Harbor	16	10	Gray brown	Gray	Silt/Clay	None	No	NR	32	13	NR	No
113, Discovery Bay	Rural	35	7	Gray	Gray	Sand with fines	None	No	NR	32	14	None	No
137, Port Angeles	Harbor	10	7	Brown	Gray	Sand with	None	No	NR	33	13	None	No

Station, location	Strata type	Depth (m)	Grab pene-tration (cm)	Overlying Sediment Color	Underlying Sediment Color	Compo-sition	Odor	Presence of		Sediment/ water interface salinity (ppt)	Sediment temper-ature (c°)	Redox potential depth (cm)	Sheen
								shell hash	wood				
						fines							
177, Discovery Bay	Rural	32	10	Brown	Gray	Sand with fines	None	No	NR	32	14	None	No
201, Port Angeles	Harbor	12	7	Gray brown	Gray	Coarse Sand/ Gravel	None	Yes	NR	32	13	None	No
275, Discovery Bay	Rural	24	17	Olive	Black	Silt/Clay	Strong H_2S	No	NR	32	14	1	No
289, Sequim Bay	Rural	32	12	Gray	Gray	Sand with fines	Moderate H_2S	No	Yes	32	14	None	No
353, Port Angeles	Urban	16	7	Brown	Gray	Sand with fines	None	No	NR	32	13	None	No
361, Discovery Bay	Rural	52	15	Olive	Olive	Silt/Clay	None	Yes	No	32	10	NR	No
363, Discovery Bay	Rural	34	17	Olive	Olive	Silt/Clay	Slight H_2S	Yes	No	32	10	NR	No
385, Port Angeles	Urban	12	8	Gray	Gray	Sand	None	No	Yes	32	12	None	No
417, Dungenes Bay	Rural	76	12	Brown	Brown	Sand with fines	None	No	No	33	8	None	No
449, Port Angeles (inner harbor)	Harbor	10	9	Brown	Brown	Mixed	None	Yes	Yes	34	9	None	No
481, Port Angeles	Urban	22	8	Brown	Gray	Sand with fines	None	No	NR	32	12	None	No
521, Discovery Bay	Rural	41	17	Olive	Olive	Silt/Clay	Moderate H_2S	No	No	33	11	NR	No

Station, location	Strata type	Depth (m)	Grab pene-tration (cm)	Overlying Sediment Color	Underlying Sediment Color	Compo-sition	Odor	Presence of		Sediment/ water interface salinity (ppt)	Sediment temper-ature (c°)	Redox potential depth (cm)	Sheen
								shell hash	wood				
545, Dungenes Bay	Rural	10	6.5	Brown	Brown	Sand and Cobble	None	No	No	32	10	None	No
577, Port Angeles	Urban	9	9	Brown	Brown	Sand with fines	None	Yes	Yes	34	9	None	No
609, Port Angeles	Urban	35	11	Brown	Brown	Sand with fines	None	Yes	Yes	34	8		No
649, Discovery Bay	Rural	49	17	Olive	Gray	Silt/Clay	None	Yes	No	32	10	None	No
673, Port Angeles	Urban	18	7	Brown	Brown	Sand	None	Yes	No	34	8	None	No
705, Port Angeles	Urban	50	14.5	Brown	Brown	Sand with fines	None	No	No	34	8	None	No
777, Discovery Bay	Rural	53	17	Olive	Gray	Silt/Clay	None	Yes	No	33	10	NR	No
801, Sequim Bay	Rural	27	17	Olive	Olive	Silt/Clay	Moderate H_2S	No	No	32	11	None	No
1033, Discovery Bay	Rural	50	13	Olive	Gray	Silt/Clay	None	No	No	33	9	NR	No
1161, Discovery Bay	Rural	50	17	Olive	Gray	Silt/Clay	None	No	No	33	9	NR	No
1193, Discovery Bay	Rural	50	14	Olive	Gray	Silt/Clay	None	Yes	No	32	9	None	No
1289, Sequim Bay	Rural	25	17	Olive	Olive	Silt/Clay	Moderate H_2S	No	No	32	11	None	No
1313, Sequim Bay	Rural	26	15.5	Olive	Olive	Silt/Clay	None	No	No	33	11	None	No
1387, Discovery Bay	Rural	22	11	Brown	Brown	Coarse Sand/	None	Yes	No	32	10	NR	No

Station, location	Strata type	Depth (m)	Grab pene-tration (cm)	Overlying Sediment Color	Underlying Sediment Color	Compo-sition	Odor	Presence of		Sediment/ water interface salinity (ppt)	Sediment temper-ature (c°)	Redox potential depth (cm)	Sheen
								shell hash	wood				
						Gravel							
Admiralty Inlet													
51, Port Townsend	Urban	20	15	Brown	NR	Silt/Clay	None	No	NR	31	13	None	No
83, South Port Townsend	Urban	14	15	Olive	NR	Sand with fines	None	Yes	NR	32	13	None	No
106, South Port Townsend	Urban	13	17	Gray	NR	Sand with fines	None	No	Yes	32	11.5	5	No
107, South Port Townsend	Urban	21	16	olive gray	NR	Silt/Clay	None	No	No	34	12	4	No
108, South Port Townsend	Urban	26	11	olive gray	NR	Silt/Clay	None	No	No	32	13	4.5	No
109, Port Townsend	Urban	34	7	Gray brown	NR	Sand	None	Yes	No	33	12	None	No
110, Port Townsend	Urban	13	11	Gray brown	NR	Sand	None	No	No	34	11	None	No
111, Port Townsend	Urban	15	12	Gray brown	NR	Sand with fines	None	No	No	32	12	None	No
112, Useless Bay	Passage	26	5	Gray brown	NR	Sand with fines	None	No	No	32	13	None	No
115, Port Townsend	Urban	28	17	Olive	Gray	Silt/Clay	None	No	NR	32	13	0.1	No
116, Useless Bay	Passage	63	13	Gray	NR	Sand	None	No	No	27	13	None	No
117, Useless Bay	Passage	46	7	Gray	NR	Sand	None	No	No	30	13	None	No

Station, location	Strata type	Depth (m)	Grab pene-tration (cm)	Overlying Sediment Color	Underlying Sediment Color	Compo-sition	Odor	Presence of		Sediment/ water interface salinity (ppt)	Sediment temper-ature (c°)	Redox potential depth (cm)	Sheen
								shell hash	wood				
119, Useless Bay	Passage	90	7	Gray	Gray	Mixed	None	Yes	NR	30	14	None	No
211, South Port Townsend	Urban	18	16	Olive	NR	Sand with fines	None	No	NR	32	13	None	No
331, South Port Townsend	Urban	24	17	Olive	Olive	Silt/Clay	None	No	NR	31	13	5	No
395, Port Townsend	Urban	31	8	Olive	Olive	Sand with fines	None	Yes	NR	32	13	None	No
459, Port Townsend	Urban	24	15.5	Olive	Gray	Sand with fines	None	No	No	32	11	None	No
491, Port Townsend	Urban	19	17	Olive	Gray	Silt/Clay	None	No	No	32	11	None	No
523, Port Townsend	Urban	13	7	Gray brown	Gray brown	Coarse Sand/ Gravel	None	No	No	30	11	None	No
527, Useless Bay	Passage	9	9	Brown	Gray brown	Sand with fines	Moderate organic decom-position	No	Yes	30	12	None	No
587, South Port Townsend	Urban	27	17	Olive	Gray	Silt/Clay	None	No	No	32	10	NR	No
651, Port Townsend	Urban	18	8	Gray brown	Gray brown	Sand	None	Yes	No	31	11.5	NR	No
681, Port Townsend	Urban	6	7	Brown	Gray	Sand	None	No	No	32	12	None	No
715, Port Townsend	Urban	19	17	Olive	Olive	Silt/Clay	None	No	No	32	12	None	No
747, Port Townsend	Urban	10	16	Brown	Gray	Sand with	None	No	No	32	11	None	No

Station, location	Strata type	Depth (m)	Grab pene-tration (cm)	Overlying Sediment Color	Underlying Sediment Color	Compo-sition	Odor	Presence of		Sediment/ water interface salinity (ppt)	Sediment temper-ature (c°)	Redox potential depth (cm)	Sheen
								shell hash	wood				
						fines							
875, Oak Bay	Passage	24	16	Olive	Brown	Silt/Clay	None	No	NR	30	14	5	No
1139, Mutiny Bay	Passage	27	10	Brown	NR	Sand	None	No	NR	30	14	None	No
1295, Useless Bay	Passage	58	10	Brown	NR	Sand	None	No	NR	31	13	None	No
1355, Oak Bay	Passage	5	7	Brown	NR	Sand	None	No	NR	30	14	None	No
2123, Oak Bay	Passage	24	9	Olive	Brown	Sand with fines	None	No	NR	30	14	None	No

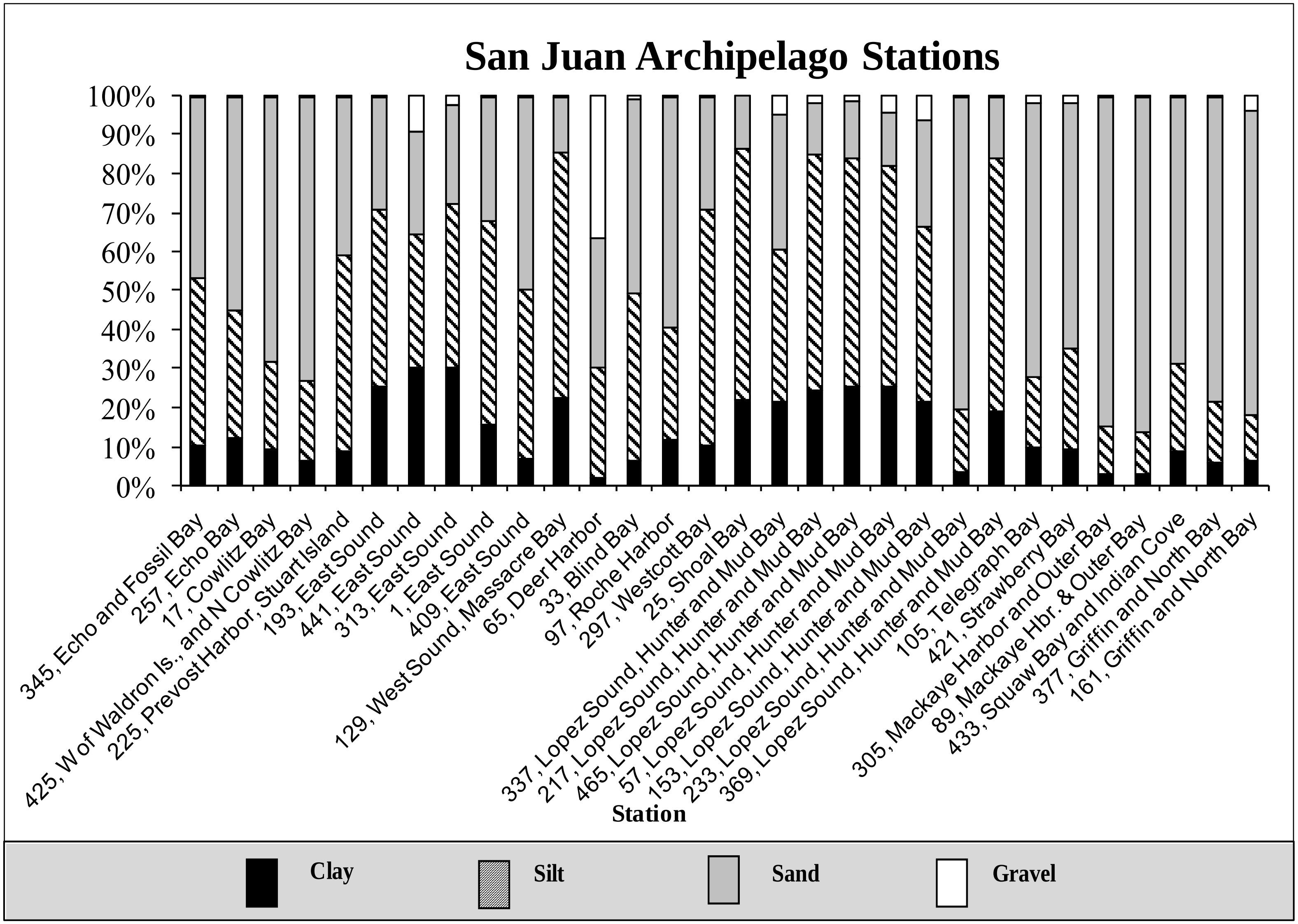
NR = Not recorded

Appendix E. Sediment Grain Size Distribution, Total Organic Carbon Values, and Chemical Concentrations and Quality Assurance information for all Stations

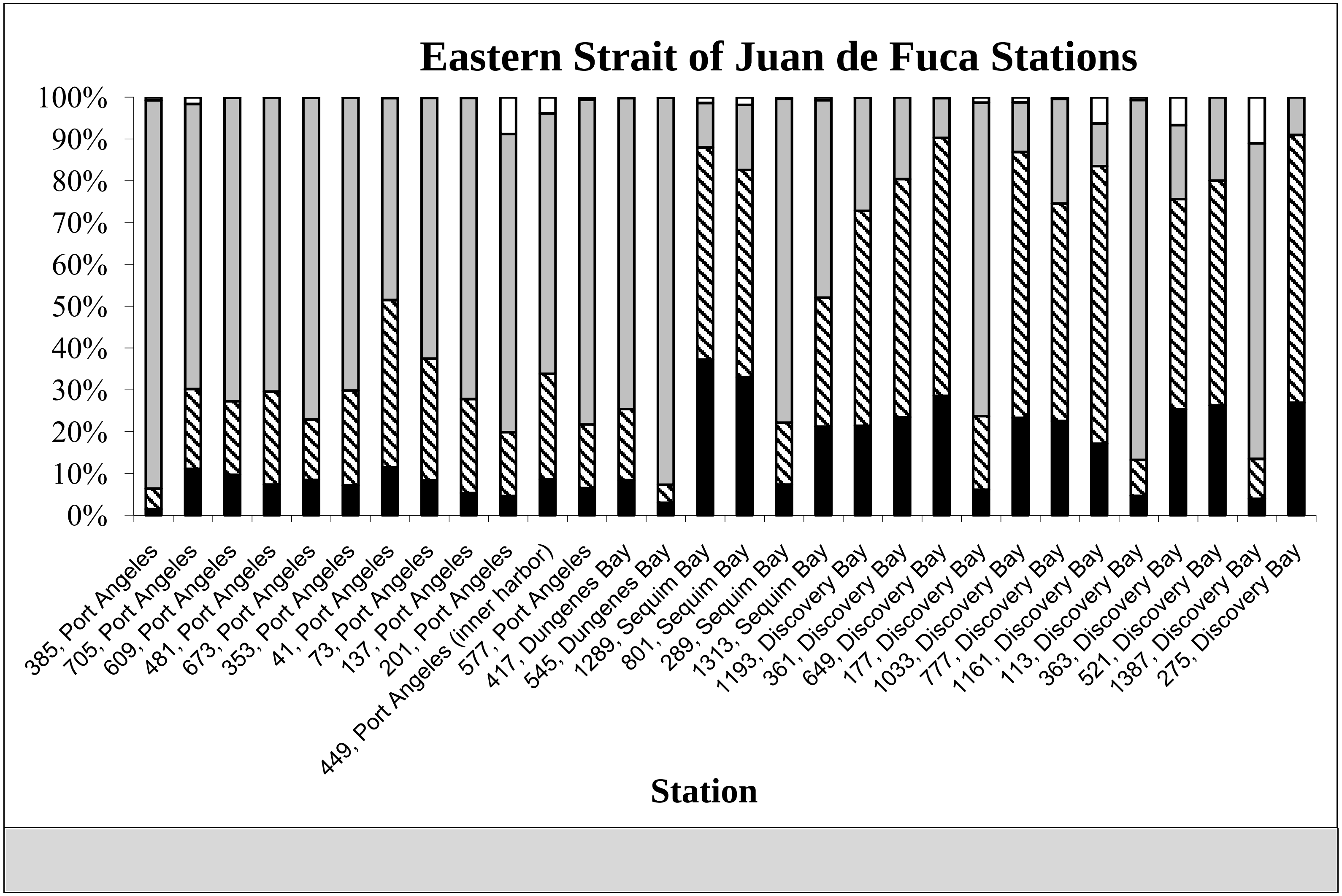
Appendix E-1. Chemistry Case Narratives – *Available only electronically, on the web and on a compact disk.*

Appendix E-2. Chemicals Excluded from Analyses – *Available only electronically, on the web and on a compact disk.*

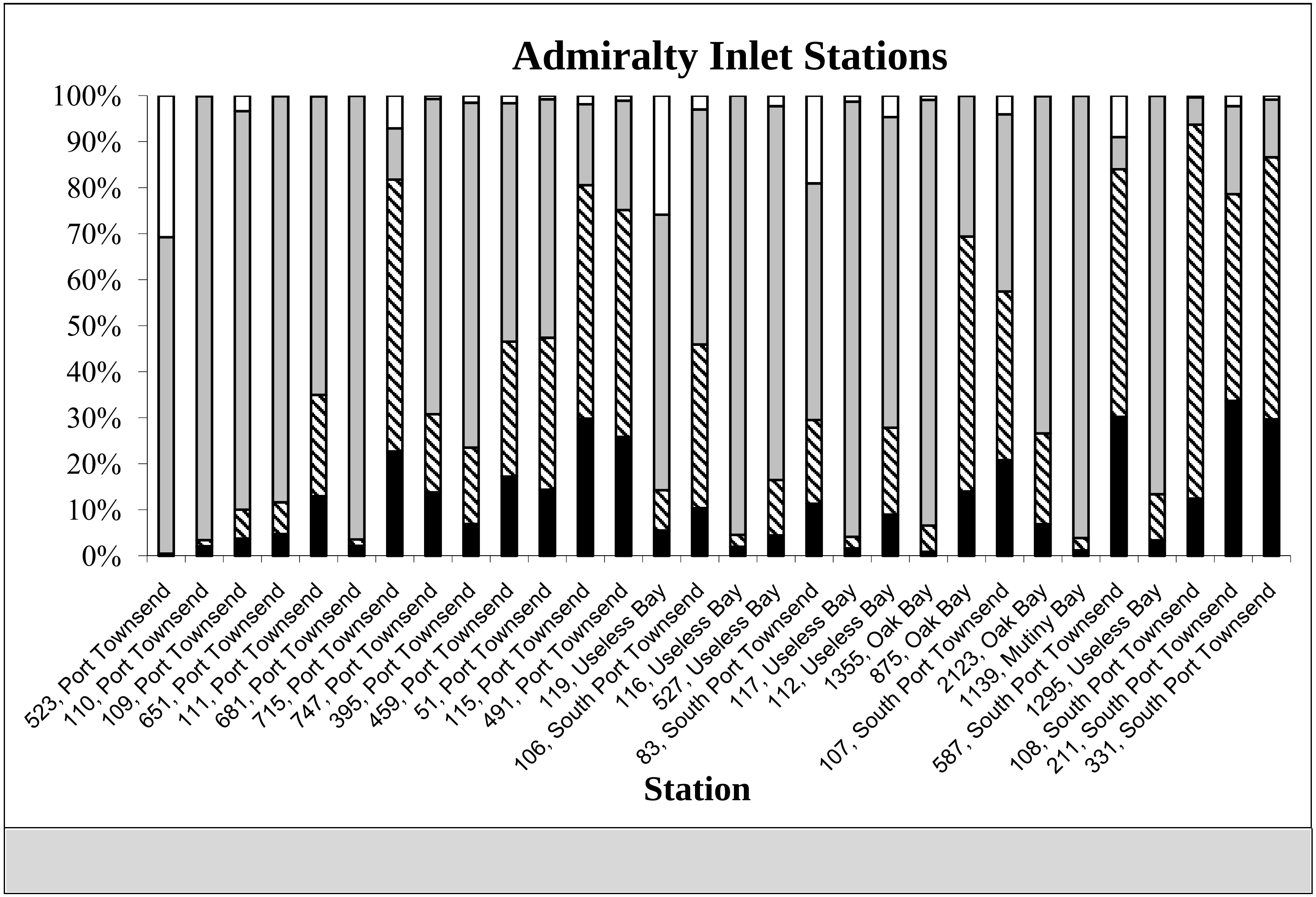
Appendix E - Figures



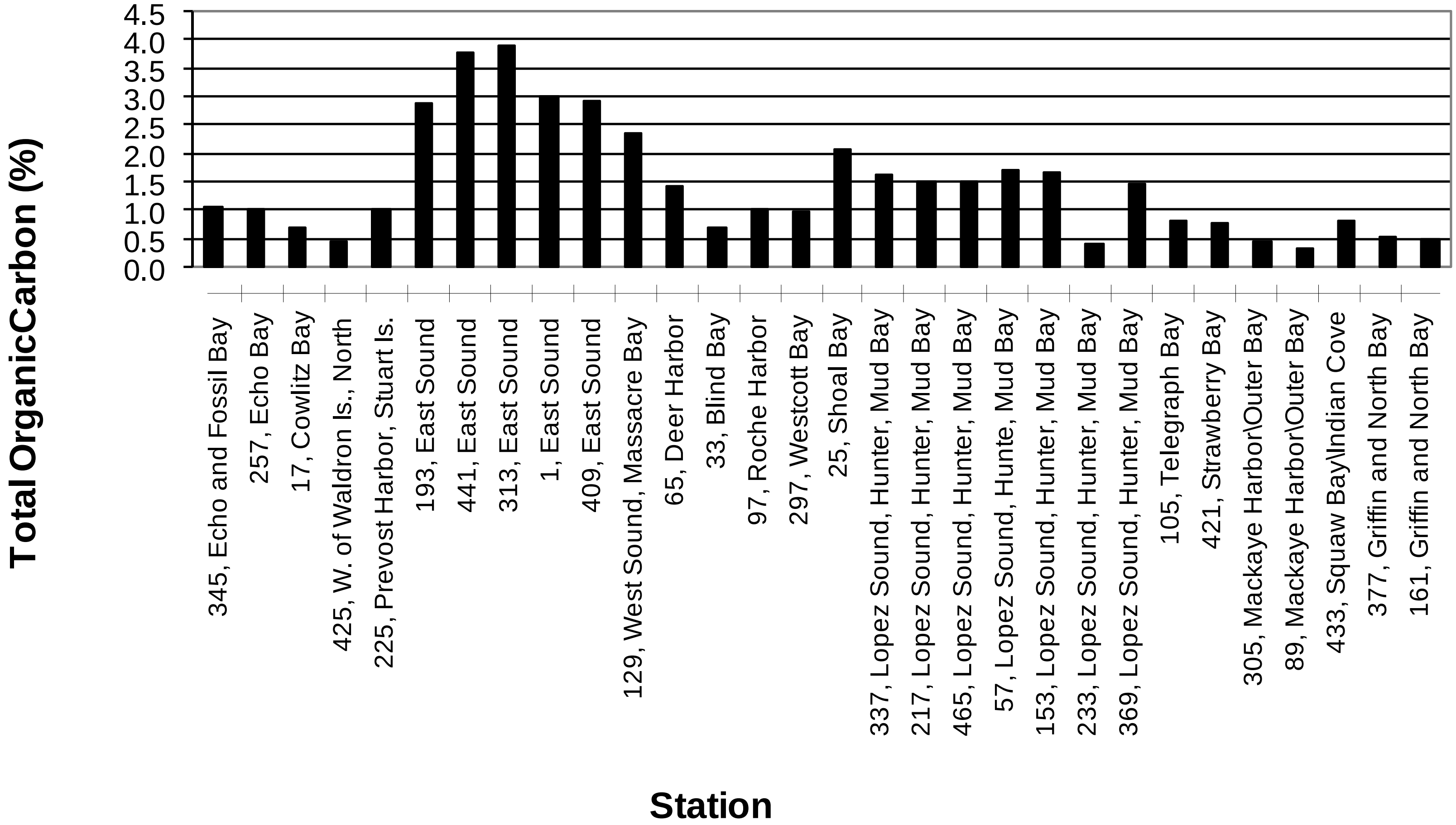
Appendix E. Figure 1. Grain size distribution of sediments collected from the San Juan Archipelago region for the 2002-2003 PSAMP Sediment Component sampling stations (grain size fractions in percent).



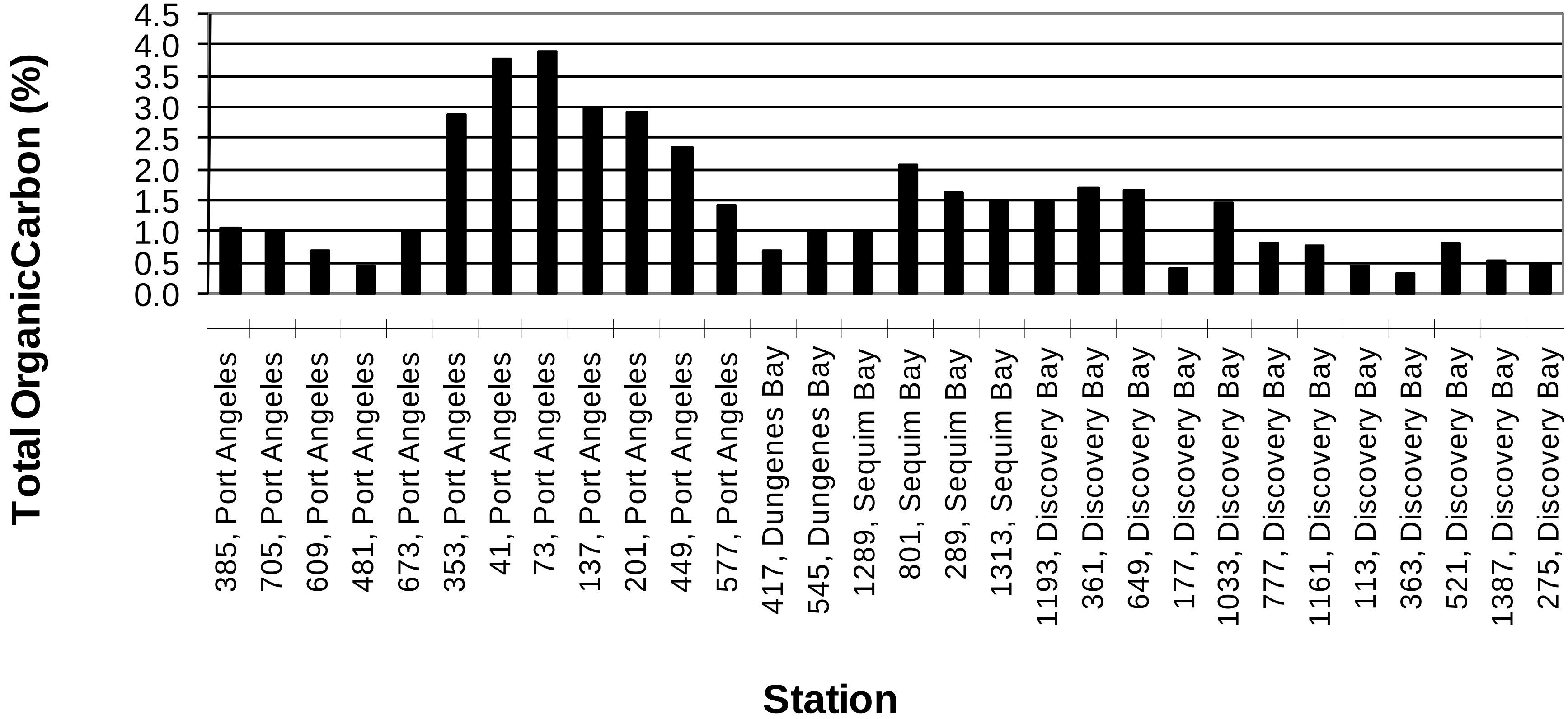
Appendix E. Figure 2. Grain size distribution of sediments collected from the eastern Strait of Juan de Fuca region for the 2002-2003 PSAMP Sediment Component sampling stations (grain size fractions in percent).



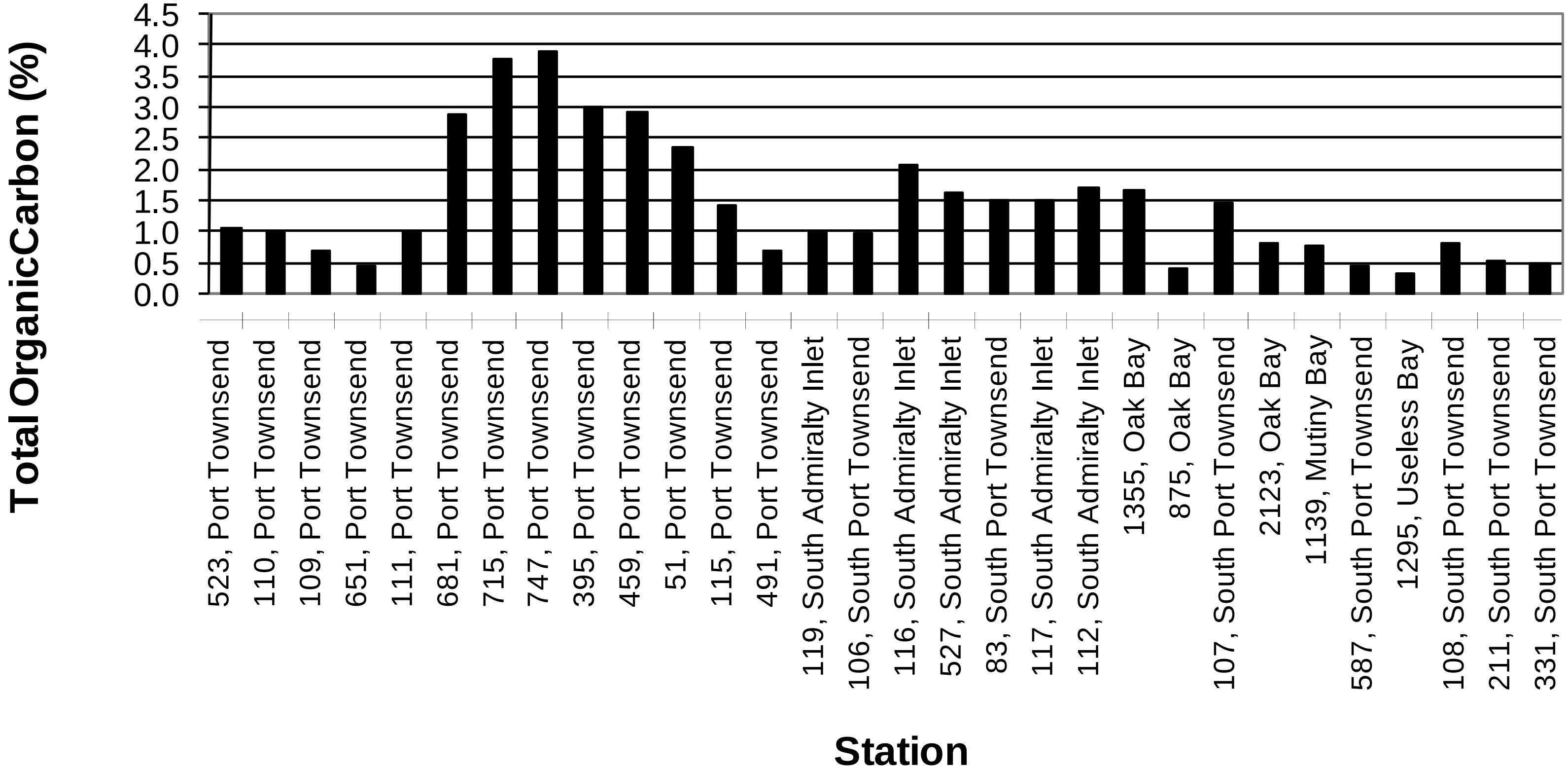
Appendix E.. Figure 3. Grain size distribution of sediments collected from the Admiralty Inlet region for the 2002-2003 PSAMP Sediment Component sampling stations (grain size fractions in percent).



Appendix E. Figure 4. Total organic carbon distribution in sediments collected from the San Juan Islands region for the 2002-2003 PSAMP Sediment Component sampling stations.



Appendix E. Figure 5. Total organic carbon distribution in sediments collected from the eastern Strait of Juan de Fuca region for the 2002-2003 PSAMP Sediment Component sampling stations.



Appendix E. Figure 6. Total organic carbon distribution in sediments collected from the Admiralty Inlet region for the 2002-2003 PSAMP Sediment Component sampling stations.

Appendix E. Figure 7. Chemical concentrations in the San Juan Islands.

Appendix E. Figure 8. Chemical concentrations in the eastern Strait of Juan de Fuca.

Appendix E. Figure 9. Chemical concentrations in Admiralty Inlet.

Appendix E. Figures 7-9 are available only electronically, on the web and on a compact disk.

Appendix E Tables

Appendix E. Table 1. Grain size distribution for the 2002-2003 Marine Sediment Program sampling stations (grain size in fractional percent).

Stratum, Location	% Solids	% Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	Total % Sand	% Silt	% Clay	% Fines (Silt+Clay)
		>2000 mm	2000-1000 mm	1000-500 mm	500-250 mm	250-125 mm	125-62.5 mm	2000-62.5 mm	62.5-3.9 mm	<3.9 mm	<62.5 mm
San Juan Islands											
1, East Sound	31.70	0.07	14.98	6.68	3.95	2.97	3.94	32.52	51.75	15.65	67.41
17, Cowlitz Bay	60.50	0.01	0.49	1.05	5.65	39.68	21.73	68.61	22.11	9.28	31.39
25, Shoal Bay	40.40	0.00	0.11	0.47	2.50	2.37	8.37	13.81	64.45	21.74	86.19
33, Blind Bay	63.80	1.32	0.49	1.92	10.65	23.42	13.21	49.67	42.87	6.13	49.00
57, Lopez Sound, Hunter and Mud Bay	40.70	4.83	0.15	0.39	1.39	2.20	9.36	13.48	56.61	25.07	81.69
65, Deer Harbor	62.90	36.75	8.45	9.52	6.84	3.36	5.07	33.25	28.33	1.67	30.01
89, Mackaye Hbr. & Outer Bay	74.90	0.05	1.88	11.29	25.96	32.11	15.36	86.60	10.69	2.66	13.35
97, Roche Harbor	54.00	0.08	1.09	2.25	7.22	15.07	33.88	59.50	28.90	11.52	40.42
105, Telegraph Bay	60.90	2.03	0.79	1.76	6.40	47.88	13.41	70.24	18.08	9.64	27.73
129, West Sound, Massacre Bay	33.40	0.89	0.18	4.87	4.74	2.05	1.98	13.82	63.22	22.07	85.29
153, Lopez Sound, Hunter and Mud Bay	46.00	6.42	0.40	1.07	3.64	7.39	15.11	27.60	44.51	21.47	65.98
161, Griffin and North Bay	68.70	4.32	0.64	1.23	9.65	49.74	16.63	77.89	11.43	6.36	17.79
193, East Sound	20.10	0.15	13.47	6.40	3.49	2.64	3.15	29.15	45.54	25.16	70.70
217, Lopez Sound, Hunter and Mud Bay	45.10	2.06	0.07	0.37	0.94	1.34	10.41	13.13	60.58	24.22	84.80
225, Prevost Harbor, Stuart Island	52.90	0.15	0.03	0.72	1.82	4.67	33.72	40.97	50.14	8.74	58.89
233, Lopez Sound, Hunter and Mud Bay	71.30	0.34	1.94	7.51	20.91	34.66	15.46	80.49	16.13	3.04	19.17
257, Echo Bay	50.50	0.69	0.14	1.45	4.47	11.85	36.88	54.80	32.41	12.11	44.51

Stratum, Location	% Solids	% Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	Total % Sand	% Silt	% Clay	% Fines (Silt+Clay)
		>2000 mm	2000-1000 mm	1000-500 mm	500-250 mm	250-125 mm	125-62.5 mm	2000-62.5 mm	62.5-3.9 mm	<3.9 mm	<62.5 mm
297, Westcott Bay	56.69	0.11	0.61	0.90	2.40	3.35	22.23	29.50	60.47	9.92	70.39
305, Mackaye Harbor and Outer Bay	57.84	0.93	0.82	4.60	16.92	24.31	37.27	83.92	12.24	2.92	15.15
313, East Sound	18.83	2.52	16.96	4.25	1.99	1.35	1.15	25.69	41.91	29.88	71.79
337, Lopez Sound, Hunter and Mud Bay	39.59	5.23	1.69	2.25	6.68	5.57	18.20	34.39	38.86	21.52	60.38
345, Echo and Fossil Bay	51.34	0.03	0.63	0.83	2.10	6.73	36.77	47.06	42.85	10.06	52.91
369, Lopez Sound, Hunter and Mud Bay	43.94	0.00	0.62	1.10	1.54	2.37	10.85	16.48	64.62	18.89	83.51
377, Griffin and North Bay	48.27	0.87	0.51	0.49	1.22	4.66	71.02	77.89	15.43	5.81	21.25
409, East Sound	35.83	0.62	14.66	8.24	8.47	8.93	9.28	49.57	43.28	6.53	49.81
421, Strawberry Bay	36.06	2.23	0.51	0.89	1.53	3.79	56.23	62.94	25.91	8.92	34.83
425, West of Wadron Island, and North Cowlitz Bay	64.77	0.03	0.10	0.93	18.80	25.44	28.23	73.51	20.45	6.02	26.46
433, Squaw Bay and Indian Cove	59.10	0.50	0.54	1.42	3.70	29.77	32.81	68.24	22.80	8.46	31.26
441, East Sound	19.86	9.65	18.43	3.37	1.81	1.35	1.10	26.05	34.15	30.15	64.30
465, Lopez Sound, Hunter and Mud Bay	38.75	1.81	0.86	0.56	1.08	1.86	10.06	14.43	58.69	25.08	83.76
Strait of Juan de Fuca											
41, Port Angeles	54.40	0.19	0.76	1.84	3.87	16.28	25.57	48.31	39.98	11.52	51.50
73, Port Angeles	61.40	0.17	0.98	1.73	13.09	27.94	18.61	62.35	29.12	8.36	37.48
113, Discovery Bay	70.80	0.69	2.41	9.76	26.24	32.49	15.18	86.07	8.55	4.69	13.24
137, Port Angeles	63.90	0.15	0.38	7.74	30.94	19.30	13.67	72.04	22.48	5.33	27.81
177, Discovery Bay	72.10	1.29	0.45	3.93	25.46	34.45	10.71	75.00	17.61	6.10	23.71
201, Port Angeles	66.60	8.80	8.79	11.57	18.45	18.85	13.69	71.35	15.21	4.64	19.85
275, Discovery Bay	19.50	0.00	0.74	1.93	2.75	1.83	1.76	9.01	64.07	26.92	90.99
289, Sequim Bay	58.50	0.33	1.24	1.82	14.25	49.26	10.94	77.51	14.81	7.34	22.16
353, Port Angeles	63.30	0.07	0.21	0.70	1.41	17.24	50.55	70.11	22.66	7.17	29.82
361, Discovery Bay	35.46	0.00	2.42	6.46	4.74	2.56	3.42	19.60	56.90	23.50	80.40

Stratum, Location	% Solids	% Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	Total % Sand	% Silt	% Clay	% Fines (Silt+Clay)
		>2000 mm	2000-1000 mm	1000-500 mm	500-250 mm	250-125 mm	125-62.5 mm	2000-62.5 mm	62.5-3.9 mm	<3.9 mm	<62.5 mm
363, Discovery Bay	25.16	6.67	11.17	3.24	1.43	0.94	0.92	17.70	50.26	25.37	75.63
385, Port Angeles	70.90	0.77	0.60	5.55	16.12	56.96	13.62	92.85	4.88	1.50	6.38
417, Dungeness Bay	64.09	0.20	0.52	0.58	1.55	31.03	40.68	74.35	17.04	8.40	25.44
449, Port Angeles (inner harbor)	63.17	3.87	4.15	9.78	20.42	15.24	12.71	62.29	25.22	8.61	33.83
481, Port Angeles	63.00	0.06	0.38	0.99	1.45	17.08	50.44	70.34	22.24	7.37	29.60
521, Discovery Bay	27.74	0.00	11.33	4.40	1.97	1.26	0.99	19.95	53.78	26.27	80.05
545, Dungeness Bay	70.22	0.10	1.40	10.00	36.69	40.45	4.07	92.60	4.30	3.00	7.30
577, Port Angeles	67.00	0.63	1.77	8.28	26.06	24.11	17.41	77.63	15.22	6.52	21.74
609, Port Angeles	62.02	0.13	0.86	0.98	1.28	25.04	44.40	72.57	17.60	9.70	27.31
649, Discovery Bay	41.82	0.21	0.75	1.22	1.67	1.48	4.39	9.50	61.72	28.57	90.28
673, Port Angeles	63.21	0.10	0.27	0.71	1.16	22.21	52.65	77.00	14.44	8.47	22.90
705, Port Angeles	62.35	1.64	0.63	0.64	1.87	26.86	38.18	68.17	19.08	11.11	30.19
777, Discovery Bay	32.39	0.38	3.11	10.27	5.56	3.13	2.95	25.03	52.05	22.54	74.59
801, Sequim Bay	26.00	1.85	3.58	2.30	1.61	2.25	5.81	15.56	49.56	33.03	82.59
1033, Discovery Bay	38.88	1.24	1.63	1.12	2.34	1.87	4.91	11.87	63.58	23.31	86.89
1161, Discovery Bay	25.29	6.29	3.85	3.36	1.32	0.74	0.91	10.18	66.40	17.13	83.53
1193, Discovery Bay	48.83	0.06	1.44	1.41	2.30	4.96	16.99	27.11	51.43	21.39	72.82
1289, Sequim Bay	20.57	1.36	3.42	2.58	1.49	1.02	2.16	10.66	50.72	37.26	87.98
1313, Sequim Bay	43.41	0.72	1.16	1.09	3.66	28.26	13.07	47.25	30.81	21.23	52.04
1387, Discovery Bay	66.04	11.02	11.47	18.85	25.57	15.88	3.73	75.50	9.56	3.93	13.49
Admiralty Inlet											
51, Port Townsend	50.90	0.81	0.52	1.44	3.12	11.18	35.58	51.82	33.00	14.37	47.37
83, South Port Townsend	59.45	19.08	6.45	11.24	11.89	15.61	6.24	51.43	18.19	11.31	29.49
106, South Port Townsend	47.07	3.01	0.49	0.54	4.46	25.89	19.69	51.08	35.52	10.39	45.91
107, South Port Townsend	42.25	4.07	1.85	2.64	4.90	17.10	12.01	38.50	36.66	20.78	57.44
108, South Port Townsend	35.38	0.39	0.52	0.37	0.87	1.07	3.09	5.92	81.26	12.44	93.70
109, Port Townsend	70.51	3.38	1.17	1.22	15.53	56.83	11.84	86.59	6.28	3.75	10.03
110, Port Townsend	74.93	0.13	0.31	12.25	54.72	27.12	2.05	96.46	1.33	2.08	3.41
111, Port Townsend	61.76	0.19	0.28	0.23	0.84	20.46	43.04	64.85	22.02	12.94	34.96

Stratum, Location	% Solids	% Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	Total % Sand	% Silt	% Clay	% Fines (Silt+Clay)
		>2000 mm	2000-1000 mm	1000-500 mm	500-250 mm	250-125 mm	125-62.5 mm	2000-62.5 mm	62.5-3.9 mm	<3.9 mm	<62.5 mm
112, Useless Bay	55.70	4.67	1.58	2.15	5.26	34.29	24.22	67.51	18.87	8.96	27.83
115, Port Townsend	35.20	1.86	3.88	2.08	1.72	4.93	5.00	17.61	50.70	29.83	80.53
116, Useless Bay	73.72	0.00	0.00	0.44	35.22	51.05	8.74	95.44	2.60	1.96	4.56
117, Useless Bay	71.72	1.32	6.12	8.38	19.13	47.21	13.69	94.53	2.52	1.62	4.14
119, Useless Bay	70.00	25.89	6.98	5.96	11.89	25.88	9.15	59.86	8.75	5.50	14.25
211, South Port Townsend	34.35	2.29	4.57	2.20	2.13	2.88	7.35	19.13	44.93	33.65	78.58
331, South Port Townsend	31.80	0.88	6.30	1.59	0.47	0.83	3.33	12.53	56.93	29.67	86.60
395, Port Townsend	66.00	1.55	0.32	0.81	2.25	39.28	32.31	74.96	16.55	6.94	23.49
459, Port Townsend	41.81	1.64	1.32	1.45	3.20	9.75	36.12	51.84	29.30	17.22	46.52
491, Port Townsend	41.64	1.09	1.25	1.35	5.46	7.41	8.30	23.77	49.28	25.86	75.15
523, Port Townsend	80.10	30.77	1.18	21.55	33.36	11.11	1.54	68.75	0.21	0.27	0.48
527, Useless Bay	48.99	2.30	2.08	3.40	3.18	22.72	49.85	81.23	12.02	4.45	16.47
587, South Port Townsend	34.04	9.00	2.91	1.36	0.45	0.55	1.72	7.00	53.82	30.18	84.01
651, Port Townsend	65.77	0.12	1.44	3.38	9.73	39.84	33.88	88.25	6.91	4.72	11.63
681, Port Townsend	72.01	0.05	0.29	2.23	55.41	36.50	1.98	96.42	1.35	2.18	3.53
715, Port Townsend	35.82	7.12	2.90	1.76	1.95	1.43	3.10	11.15	59.05	22.68	81.74
747, Port Townsend	55.34	0.73	1.18	2.50	29.97	32.00	2.86	68.50	16.98	13.78	30.77
875, Oak Bay	49.10	0.03	2.06	1.77	5.80	3.09	17.88	30.60	55.36	14.01	69.37
1139, Mutiny Bay	72.00	0.00	0.20	0.68	9.73	76.00	9.54	96.14	2.65	1.21	3.86
1295, Useless Bay	64.00	0.02	0.25	1.74	9.09	33.25	42.28	86.62	9.99	3.38	13.36
1355, Oak Bay	78.30	0.91	6.00	33.18	41.68	8.91	2.76	92.53	5.67	0.88	6.56
2123, Oak Bay	62.30	0.10	0.25	0.71	1.15	15.90	55.31	73.31	19.69	6.90	26.59

Appendix E. Table 2. Results of Total Organic Carbon analyses of sediments collected in the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet regions for the 2002-2003 PSAMP Sediment Component.

Station, location	Strata type	Percent Total Organic Carbon (and qualifier)							
		Field sample		Field duplicate		Lab duplicate		Lab triplicate	
San Juan Islands									
1, East Sound	Rural	2.99							
17, Cowlitz Bay	Rural	0.70							
25, Shoal Bay	Rural	2.08							
33, Blind Bay	Rural	0.70							
57, Lopez Sound, Hunter and Mud Bay	Rural	1.71							
65, Deer Harbor	Rural	1.42							
89, Mackaye Harbor and Outer Bay	Rural	0.33							
97, Roche Harbor	Rural	1.02							
105, Telegraph Bay	Rural	0.80							
129, West Sound, Massacre Bay	Rural	2.34							
153, Lopez Sound, Hunter and Mud Bay	Rural	1.65							
161, Griffin and North Bay	Rural	0.50							
193, East Sound	Rural	2.88							
217, Lopez Sound, Hunter and Mud Bay	Rural	1.52							
225, Prevost Harbor, Stuart Island	Rural	1.02							
233, Lopez Sound, Hunter and Mud Bay	Rural	0.40				0.39		0.41	
257, Echo Bay	Rural	1.02							
297, Westcott Bay	Rural	0.99							
305, Mackaye Harbor and Outer Bay	Rural	0.46							
313, East Sound	Rural	3.88							
337, Lopez Sound, Hunter and Mud Bay	Rural	1.61							
345, Echo and Fossil Bay	Rural	1.05							
369, Lopez Sound, Hunter and Mud Bay	Rural	1.45							
377, Griffin and North Bay	Rural	0.52							
409, East Sound	Rural	2.99				2.82		2.91	
421, Strawberry Bay	Rural	0.78							
425, West of Waldron Island, and North Cowlitz Bay	Rural	0.45							
433, Squaw Bay and Indian Cove	Rural	0.80							
441, East Sound	Rural	3.77							
465, Lopez Sound, Hunter and Mud Bay	Rural	1.52							
Eastern Strait of Juan de Fuca									
41, Port Angeles	Urban	1.89							
73, Port Angeles	Harbor	1.50				1.48		1.42	
113, Discovery Bay	Rural	0.65							
137, Port Angeles	Harbor	1.15		1.16					
177, Discovery Bay	Rural	0.47							
201, Port Angeles	Harbor	1.20							
275, Discovery Bay	Rural	3.65							
289, Sequim Bay	Rural	1.00							
353, Port Angeles	Urban	0.88							
361, Discovery Bay	Rural	2.07							
363, Discovery Bay	Rural	3.27							
385, Port Angeles	Urban	0.49							

Station, location	Strata type	Percent Total Organic Carbon (and qualifier)							
		Field sample		Field duplicate		Lab duplicate		Lab triplicate	
417, Dungeness Bay	Rural	0.51							
449, Port Angeles (inner harbor)	Harbor	1.80		1.84					
481, Port Angeles	Urban	0.86							
521, Discovery Bay	Rural	3.16							
545, Dungeness Bay	Rural	0.29							
577, Port Angeles	Urban	0.71		0.76					
609, Port Angeles	Urban	0.63							
649, Discovery Bay	Rural	1.56							
673, Port Angeles	Urban	0.57				0.53		0.57	
705, Port Angeles	Urban	0.89							
777, Discovery Bay	Rural	2.49				2.50		2.54	
801, Sequim Bay	Rural	2.43							
1033, Discovery Bay	Rural	1.79							
1161, Discovery Bay	Rural	2.8							
1193, Discovery Bay	Rural	1.26							
1289, Sequim Bay	Rural	2.79							
1313, Sequim Bay	Rural	1.87							
1387, Discovery Bay	Rural	0.62							
Admiralty Inlet									
51, Port Townsend	Urban	1.25							
83, South Port Townsend	Urban	1.85		2.17					
106, South Port Townsend	Urban	2.15							
107, South Port Townsend	Urban	2.13							
108, South Port Townsend	Urban	2.13							
109, Port Townsend	Urban	0.38							
110, Port Townsend	Urban	0.11							
111, Port Townsend	Urban	0.72				0.75		0.74	
112, Useless Bay	Passage	0.75							
115, Port Townsend	Urban	2.67							
116, Useless Bay	Passage	0.17							
117, Useless Bay	Passage	0.21							
119, Useless Bay	Passage	0.77							
211, South Port Townsend	Urban	2.97		2.96					
331, South Port Townsend	Urban	3.01							
395, Port Townsend	Urban	0.61							
459, Port Townsend	Urban	1.15							
491, Port Townsend	Urban	1.84							
523, Port Townsend	Urban	0.10	Undetected						
527, Useless Bay	Passage	1.41							
587, South Port Townsend	Urban	2.41							
651, Port Townsend	Urban	0.38							
681, Port Townsend	Urban	0.22		0.26		0.25		0.26	
715, Port Townsend	Urban	2.06							
747, Port Townsend	Urban	1.26							
875, Oak Bay	Passage	1.56							
1139, Mutiny Bay	Passage	0.22				0.22		0.23	
1295, Useless Bay	Passage	0.60							
1355, Oak Bay	Passage	0.30							
2123, Oak Bay	Passage	0.64							

Appendix E. Table 3. Results of metal and organic analyses from sediments collected in the San Juan Islands region for the 2002-2003 PSAMP Sediment Component. Not all chemicals were analyzed at all stations.

Appendix E. Table 4. Results of metal and organic analyses from sediments collected in the eastern Strait of Juan de Fuca region for the 2002-2003 PSAMP Sediment Component. Not all chemicals were analyzed at all stations.

Appendix E. Table 5. Results of metal and organic analyses from sediments collected in the Admiralty Inlet region for the 2002-2003 PSAMP Sediment Component. Not all chemicals were analyzed at all stations.

Appendix E. Tables 3-5 are available only electronically, on the web and on a compact disk.

Appendix E. Table 6. Summary statistics for metal and organic analyses from sediments collected in the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet regions for the 2002-2003 PSAMP Sediment Component. Not all chemicals were analyzed at all stations.

Chemical	Mean	Median	Minimum	Maximum	Range	N	No. of un-detected	No. of missing values
Priority Pollutant Metals (mg/kg dry weight)								
Arsenic	5.39	4.60	2.10	16.20	14.10	90	0	0
Cadmium	0.71	0.48	0.11	3.78	3.67	87	3	0
Chromium	29.75	27.00	9.36	58.60	49.24	90	0	0
Copper	16.94	15.10	4.57	42.30	37.74	90	0	0
Lead	8.26	7.39	2.28	17.40	15.12	90	0	0
Mercury	0.05	0.05	0.01	0.12	0.11	90	0	0
Nickel	26.71	26.50	7.75	89.50	81.75	90	0	0
Selenium	1.40	0.85	0.49	11.20	10.71	43	47	0
Silver	0.18	0.17	0.10	0.32	0.22	43	47	0
Zinc	57.10	56.30	19.50	104.00	84.50	90	0	0
Trace Elements								
Tin	0.86	0.74	0.22	3.63	3.41	90	0	0
Organics (ug/kg dry weight)								
Chlorinated Alkanes								
Hexachlorobutadiene						0	90	0
Chlorinated and Nitro-Substituted Phenols								
Pentachlorophenol						0	90	0
Chlorinated Aromatic Compounds								
1,2,4-Trichlorobenzene						0	90	0
1,2-Dichlorobenzene						0	90	0
1,3-Dichlorobenzene						0	90	0
1,4-Dichlorobenzene						0	90	0
2-Chloronaphthalene	14.00	14.00	14.00	14.00	0.00	1	80	9
Hexachlorobenzene (SW8081/8082)	1.38	0.21	0.10	8.30	8.20	7	74	9
Hexachlorobenzene (SW8270)						0	90	0
Chlorinated Pesticides								
2,4'-DDD	0.15	0.15	0.15	0.15	0.00	1	89	0
2,4'-DDE						0	90	0
2,4'-DDT						0	90	0
4,4'-DDD	0.51	0.38	0.13	2.45	2.32	19	71	0
4,4'-DDE	0.36	0.25	0.10	2.30	2.20	32	58	0
4,4'-DDT	1.30	0.66	0.44	4.20	3.76	5	85	0
Aldrin						0	90	0
Cis-Chlordane (Alpha-Chlordane)						0	90	0
Dieldrin						0	90	0
Endosulfan I						0	90	0
Endosulfan II						0	90	0
Endosulfan Sulfate						0	90	0
Endrin						0	90	0

Chemical	Mean	Median	Minimum	Maximum	Range	N	No. of un-detected	No. of missing values
Endrin Aldehyde						0	90	0
Endrin Ketone						0	90	0
Gamma-BHC (Lindane)						0	90	0
Heptachlor						0	90	0
Heptachlor Epoxide						0	90	0
Mirex						0	90	0
Oxychlordane						0	90	0
Toxaphene						0	90	0
Trans-Chlordane (Gamma)						0	90	0
Trans-Nonachlor						0	11	79
Polycyclic Aromatic Hydrocarbons								
LPAHs								
1,6,7-Trimethylnaphthalene	14.46	12.00	0.99	36.00	35.01	88	2	0
1-Methylnaphthalene	22.26	19.00	0.92	60.00	59.08	89	1	0
1-Methylphenanthrene	16.72	12.00	0.55	54.00	53.45	90	0	0
2,6-Dimethylnaphthalene	50.91	28.00	1.20	350.00	348.80	89	0	1
2-Methylnaphthalene	31.72	29.00	1.40	96.00	94.60	89	1	0
2-Methylphenanthrene	28.99	26.00	1.00	77.00	76.00	90	0	0
Acenaphthene	4.43	2.60	0.33	56.00	55.67	89	1	0
Acenaphthylene	8.75	4.30	0.05	51.00	50.95	88	2	0
Anthracene	13.07	7.50	0.97	120.00	119.03	89	1	0
Biphenyl	10.42	8.10	0.52	39.00	38.48	82	8	0
Dibenzothiophene	4.73	3.40	0.46	22.00	21.54	71	19	0
Fluorene	12.17	9.40	0.89	80.00	79.11	89	1	0
Naphthalene	48.29	25.75	1.70	360.00	358.30	88	2	0
Phenanthrene	70.31	52.50	2.60	370.00	367.40	90	0	0
Retene	42.88	28.00	1.90	660.00	658.10	89	1	0
HPAHs								
2-Methylfluoranthene	6.68	5.30	0.93	30.00	29.07	80	1	9
Benzo(a)anthracene	19.85	13.00	1.40	120.00	118.60	89	1	0
Benzo(a)pyrene	21.10	15.00	1.10	110.00	108.90	89	1	0
Benzo(b)fluoranthene	25.61	17.00	1.90	133.00	131.10	89	1	0
Benzo(e)pyrene	21.43	15.00	1.50	160.00	158.50	89	1	0
Benzo(g,h,i)perylene	21.11	16.00	1.40	81.00	79.60	89	1	0
Benzo(k)fluoranthene	23.38	17.00	0.59	140.00	139.41	89	1	0
Chrysene	26.34	19.00	2.10	141.50	139.40	89	1	0
Dibenzo(a,h)anthracene	4.85	3.80	0.48	21.00	20.52	84	6	0
Fluoranthene	106.30	46.00	1.30	4080.00	4078.70	90	0	0
Indeno(1,2,3-c,d)pyrene	15.62	11.00	0.80	69.50	68.70	89	1	0
Perylene	56.97	42.00	1.60	160.00	158.40	90	0	0
Pyrene	98.75	35.50	1.10	3980.00	3978.90	90	0	0
Carbazole	3.45	2.80	0.41	8.60	8.19	73	8	9
Miscellaneous Extractable Compounds								
Benzoic Acid	593.84	371.00	141.00	3070.00	2929.00	61	29	0

Chemical	Mean	Median	Minimum	Maximum	Range	N	No. of un-detected	No. of missing values
Benzyl Alcohol	94.65	85.50	23.00	212.00	189.00	10	80	0
Beta-coprostanol	236.67	304.00	76.00	330.00	254.00	3	78	9
Beta-Sitosterol	2505.73	1865.00	281.00	11800.00	11519.00	80	1	9
Cholesterol	3526.14	2390.00	35.00	36500.00	36465.00	81	0	9
p-Isopropyltoluene	33.18	19.00	5.05	184.00	178.95	27	54	9
Dibenzofuran	12.90	9.10	0.53	91.00	90.47	89	1	0
Organonitrogen Compounds								
Caffeine								
N-Nitrosodiphenylamine						0	90	0
Organotin, Butyl tin								
Dibutyltin Dichloride	2.48	1.70	1.00	8.30	7.30	19	49	22
Monobutyltin Trichloride	2.83	2.30	1.20	5.90	4.70	18	41	31
Tetrabutyltin	3.68	3.00	1.70	7.00	5.30	4	55	31
Tributyltin Chloride	2.42	1.70	0.49	8.40	7.91	24	44	22
Phenols								
2,4-Dimethylphenol	6.60	6.35	4.60	9.10	4.50	4	86	0
2-Methylphenol	12.03	2.20	1.20	48.00	46.80	7	83	0
4-Methylphenol	1450.40	380.00	8.70	27600.00	27591.30	59	31	0
Phenol	2018.99	1070.00	112.00	17600.00	17488.00	41	49	0
Phenol, 4-Nonyl-	15.00	15.00	15.00	15.00	0.00	1	89	0
Phthalate Esters								
Bis(2-Ethylhexyl) Phthalate	189.00	189.00	189.00	189.00	0.00	1	89	0
Butylbenzylphthalate	5.10	5.10	5.10	5.10	0.00	1	89	0
Diethylphthalate	25.33	22.00	15.00	39.00	24.00	3	87	0
Dimethylphthalate	32.60	16.00	13.00	92.00	79.00	5	85	0
Di-N-Butylphthalate	436.64	166.50	44.00	3100.00	3056.00	14	76	0
Di-N-Octyl Phthalate						0	90	0
Polychlorinated Biphenyls								
PCB Aroclors								
PCB Aroclor 1016						0	90	0
PCB Aroclor 1221						0	90	0
PCB Aroclor 1232						0	90	0
PCB Aroclor 1242						0	90	0
PCB Aroclor 1248						0	90	0
PCB Aroclor 1254	5.93	4.10	2.70	26.00	23.30	16	74	0
PCB Aroclor 1260	9.15	6.20	1.80	46.00	44.20	10	80	0
PCB Aroclor 1262						0	81	9
PCB Aroclor 1268						0	81	9
PCB Congeners								
PCB congener 8	0.16	0.16	0.16	0.16	0.00	1	88	1
PCB congener 18						0	90	0
PCB congener 28	0.17	0.16	0.11	0.26	0.15	12	78	0
PCB congener 44	0.23	0.17	0.11	0.59	0.48	6	84	0
PCB congener 52	0.31	0.22	0.14	1.20	1.06	10	80	0

Chemical	Mean	Median	Minimum	Maximum	Range	N	No. of un-detected	No. of missing values
PCB congener 66	0.16	0.16	0.11	0.21	0.10	10	80	0
PCB congener 77						0	90	0
PCB congener 101	0.36	0.21	0.12	2.30	2.18	32	58	0
PCB congener 105	0.29	0.15	0.10	1.40	1.30	11	79	0
PCB congener 110	0.31	0.27	0.12	0.61	0.49	18	63	9
PCB congener 118	0.37	0.31	0.10	1.50	1.40	29	61	0
PCB congener 126						0	90	0
PCB congener 128	0.24	0.26	0.10	0.36	0.26	3	87	0
PCB congener 138	0.44	0.25	0.11	2.40	2.29	33	57	0
PCB congener 153	0.47	0.26	0.13	3.30	3.17	40	50	0
PCB congener 169	1.20	1.20	1.20	1.20	0.00	1	80	9
PCB congener 170	0.58	0.42	0.11	2.20	2.09	8	82	0
PCB congener 180	0.65	0.20	0.11	4.90	4.79	17	73	0
PCB congener 187	0.45	0.24	0.10	2.50	2.40	11	79	0
PCB congener 195	0.91	0.91	0.91	0.91	0.00	1	89	0
PCB congener 206	1.80	1.80	1.80	1.80	0.00	1	89	0
PCB congener 209	0.20	0.23	0.12	0.25	0.13	3	86	1

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Appendix F. List of Benthic Infauna and Quality Assurance/Quality Control Data

Appendix F. Figure 1. Benthic infaunal index values in the San Juan Islands.

Appendix F. Figure 2. Benthic infaunal index values the eastern Strait of Juan de Fuca.

Appendix F. Figure 3. Benthic infaunal index values Admiralty Inlet.

Appendix F. Table 1. Benthic infaunal species identified for the 2002-2003 PSAMP Sediment Component

Appendix F. Figures 1-3 and Tables 1 are available only electronically, on the web and on a compact disk.

Appendix F. Table 2. Infauna sediment sample sorting QA/QC report for the 2002-2003 PSAMP Sediment Component.

Station	Sampling Location	Sampling Date	Sorted by	QA/QC Sorter	QA/QC Percent sorted	QA/QC Pass/Fail
1	East Sound	6/7/2002	SW	SA	25%	Pass
17	Cowlitz Bay	6/6/2002	SW	SA	25%	Pass
25	Shoal Bay	6/5/2002	SW	SA	25%	Pass
33	Blind Bay	6/5/2002	SW	SA	25%	Pass
41	Port Angeles	6/10/2002	SW	SA	25%	Pass
51	Port Townsend	6/13/2002	SW	SA	25%	Pass
57	Lopez Sound, Hunter and Mud Bay	6/3/2002	SW	SA	25%	Pass
65	Deer Harbor	6/7/2002	SW	SA	25%	Pass
73	Port Angeles	6/10/2002	SW	SA	25%	Pass
83	South Port Townsend	6/13/2002	SW	SA	25%	Pass
89	Mackaye Harbor and Outer Bay	6/4/2002	SW	SA	25%	Pass
97	Roche Harbor	6/8/2002	SW	SA	25%	Pass
105	Telegraph Bay	6/4/2002	SW	SA	25%	Pass
113	Discovery Bay	6/12/2002	SW	SA	25%	Pass
115	Port Townsend	6/13/2002	SW	SA	25%	Pass
119	South Admiralty Inlet	6/17/2002	SA	CR	25%	Pass
129	West Sound Massacre Bay	6/7/2002	SW	SA	25%	Pass
137	Port Angeles	6/10/2002	SW	SA	25%	Pass
153	Lopez Sound, Hunter and Mud Bay	6/3/2002	SW	SA	25%	Pass
161	Griffin and North Bay	6/4/2002	SW	SA	25%	Pass
177	Discovery Bay	6/12/2002	SW	SA	25%	Pass
193	East Sound	6/7/2002	SW	SA	25%	Pass
201	Port Angeles	6/10/2002	SW	SA	25%	Pass
211	South Port Townsend	6/13/2002	SW	SA	25%	Pass
217	Lopez Sound, Hunter and Mud Bay	6/3/2002	SW	SA	50%	Pass
225	Prevost Harbor Stuart Island	6/8/2002	SW	SA	50%	Pass
233	Lopez Sound, Hunter and Mud Bay	6/3/2002	SW	SA	100%	Fail/Resort
257	Echo Bay	6/6/2002	SW	SA	25%	Pass
275	Discovery Bay	6/12/2002	SW	SA	100%	Pass
289	Sequim Bay	6/11/2002	SW	SA	25%	Pass
331	South Port Townsend	6/14/2002	SW	SA	25%	Pass
353	Port Angeles	6/11/2002	SW	SA	100%	Pass
385	Port Angeles	6/11/2002	SW	SA	50%	Pass
395	Port Townsend	6/14/2002	SW	SA	50%	Pass
481	Port Angeles	6/11/2002	SW	SA	25%	Pass
875	Oak Bay	6/24/2002	VP	SA	100%	Pass
1139	Mutiny Bay	6/24/2002	VP	SA	100%	Pass
1295	Useless Bay	6/24/2002	SA	CR	100%	Pass
1355	Oak Bay	6/24/2002	SA	CR	25%	Pass
2123	Oak Bay	6/24/2002	SA	CR	50%	Pass
297	Westcott Bay	6/10/2003	MH	SA	100%	Pass
305	Mackaye Harbor and Outer Bay	6/9/2003	KJ	HRJ	25%	Pass

Station	Sampling Location	Sampling Date	Sorted by	QA/QC Sorter	QA/QC Percent sorted	QA/QC Pass/Fail
313	East Sound	6/11/2003	MH	SA	100%	Pass
337	Lopez Sound, Hunter and Mud Bay	6/12/2003	MH	SA	100%	Pass
345	Echo and Fossil Bay	6/10/2003	MH	SA	100%	Pass
361	Discovery Bay	6/20/2003	MH	SA	100%	Pass
363	Discovery Bay	6/19/2003	MH	SA	100%	Pass
369	Lopez Sound, Hunter & Mud Bay	6/12/2003	SS	KJ	25%	Pass
377	Griffin & North Bay	6/9/2003	SS	KJ	25%	Pass
409	East Sound	6/11/2003	TL	KJ	25%	Pass
417	Dungeness Bay	6/17/2003	TL	KJ	25%	Pass
421	Strawberry Bay	6/9/2003	SA	KW	25%	Pass
425	West of Waldron Island, North & Cowlitz Bay	6/10/2003	SS	KJ	25%	Pass
433	Squaw Bay & Indian Cove	6/11/2003	SS	KJ	25%	Pass
441	East Sound	6/11/2003	KJ	HRJ	25%	Pass
449	Port Angeles (inner harbor)	6/16/2003	SA	KW	25%	Pass
459	Port Townsend	6/5/2003	KJ	HRJ	25%	Pass
465	Lopez Sound, Hunter and Mud Bay	6/12/2003	SS	KJ	25%	Pass
491	Port Townsend	6/5/2003	SS	KJ	25%	Pass
521	Discovery Bay	6/19/2003	SS	KJ	25%	Pass
523	Port Townsend	6/6/2003	SA	KW	25%	Pass
527	South Admiralty Inlet	6/6/2003	TL	KJ	25%	Pass
545	Dungeness Bay	6/17/2003	KJ	HRJ	25%	Pass
577	Port Angeles	6/16/2003	TL	KJ	25%	Pass
587	South Port Townsend	6/5/2003	SS	KJ	25%	Pass
609	Port Angeles	6/16/2003	SS	KJ	25%	Pass
649	Discovery Bay	6/17/2003	TL	KJ	25%	Pass
651	Port Townsend	6/6/2003	SS	KJ	25%	Pass
673	Port Angeles	6/16/2003	SS	KJ	25%	Pass
681	Port Townsend	6/5/2003	SS	KJ	25%	Pass
705	Port Angeles	6/16/2003	SS	KJ	25%	Pass
715	Port Townsend	6/6/2003	TL	KJ	25%	Pass
747	Port Townsend	6/5/2003	TL	KJ	25%	Pass
777	Discovery Bay	6/20/2003	TL	KJ	25%	Pass
801	Sequim Bay	6/18/2003	MH	SA	100%	Pass
1033	Discovery Bay	6/19/2003	TL	KJ	25%	Pass
1161	Discovery Bay	6/19/2003	TL	KJ	25%	Pass
1193	Discovery Bay	6/17/2003	MH	SA	100%	Pass
1289	Sequim Bay	6/18/2003	KJ	HRJ	25%	Pass
1313	Sequim Bay	6/18/2003	MH	SA	100%	Pass
1387	Discovery Bay	6/19/2003	SA	KW	25%	Pass

Appendix F. Table 3. Infauna taxonomy QA/QC report for the 2002-2003 PSAMP Sediment Component.

Completed QA	2002 Crustacea	2002 Misc Taxa	2002 Echinodermata	2002 Annelida	2002 Mollusca
Primary Taxonomist	Renee Zane	Steve Hulsman	Steve Hulsman	Eugene Ruff	Susan Weeks
QA Taxonomist	Jeffery Cordell	Ron Shimek	N/A	N/A	Ron Shimek
Number of Bulk Samples QAed	2	1	1	2	2
Number of Vouchers QAed	27	3	0	0	10
Identifications confirmed	11	2	N/A	N/A	5
Identifications changed (includes species-level changes)	16	1	N/A	N/A	5
Species-level changes	8	0	N/A	N/A	2

Completed QA	2003 Crustacea	2003 Misc Taxa	2003 Echinodermata	2003 Annelida	2003 Mollusca
Primary Taxonomist	Renee Zane	Steve Hulsman	Steve Hulsman	Eugene Ruff	Susan Weeks
QA Taxonomist	Jeffery Cordell	John Ljubenkov	N/A	Kathy Welch	Allan Fukuyama
Number of Bulk Samples QAed	2	1	1	2	2
Number of Vouchers QAed	16	4	0	1	7
Identifications confirmed	12	4	N/A	1	7
Identifications changed (includes species-level changes)	4	0	N/A	0	0
Species-level changes	2	0	N/A	0	0

QAed – quality assured

Appendix G. Selected Results for Chemistry, Toxicity, and Benthic Infaunal Analyses for all 2002-2003 PSAMP Sediment Component Stations. (Weight-of-Evidence)

Appendix G is available only electronically, on the web and on a compact disk.