WASHINGTON STATE DEPARTMENT OF ECOLOGY

Chemical Contamination, Acute Toxicity in Laboratory Tests, and Benthic Impacts in Sediments of Puget Sound

A summary of results of the joint 1997-1999 Ecology/NOAA survey

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General information and all data generated during this survey can be accessed from Ecology's Marine Sediment Monitoring website:

http://www.ecy.wa.gov/programs/eap/mar_sed/msm_intr.html

and the Sediment Quality Information System (SEDQUAL) website:

http://www.ecy.wa.gov/programs/tcp/smu/sedqualfirst.html

Chemical Contamination, Acute Toxicity in Laboratory Tests, and Benthic Impacts in Sediments of Puget Sound

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A summary of results of the joint 1997-1999 Ecology/NOAA survey

by

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October 2003

Waterbody Numbers

WA-01-0010	WA-14-0050	WA-PS-0010
WA-01-0020	WA-14-0110	WA-PS-0020
WA-01-0080	WA-14-0130	WA-PS-0030
WA-03-0020	WA-15-0010	WA-PS-0040
WA-06-0010	WA-15-0020	WA-PS-0040
WA-06-0020	WA-15-0030	WA-PS-0070
WA-07-0010	WA-15-0040	WA-PS-0090
WA-07-1005	WA-15-0050	WA-PS-0100
WA-07-1011	WA-15-0060	WA-PS-0220
WA-09-0010	WA-15-0080	WA-PS-0230
WA-10-0010	WA-15-0110	WA-PS-0240
WA-10-0030	WA-15-0120	WA-PS-0250
WA-13-0010	WA-15-0130	WA-PS-0270
WA-13-0020	WA-17-0010	WA-PS-0290
WA-14-0010	WA-17-0020	WA-PS-0300
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Acronyms and Abbreviations

AED –	atomic emission detector
B[a]P –	benzo[a]pyrene
BNA –	base/neutral/acid organic chemical analysis
CAS –	Columbia Analytical Services
CLIS –	Central Long Island Sound
CSL –	cleanup screening level
DCM –	dichloromethane
DMSO –	dimethylsulfoxide
EAP –	Environmental Assessment Program
EC50 –	50% effective concentration; concentrations of the extract that inhibited luminescence by 50%)
EMAP –	Environmental Monitoring and Assessment Program
ERL –	effects range low (Long et al., 1995)
ERM –	effects range median (Long et al., 1995)
HRGS –	human reporter gene system
LC50 –	lethal concentration for 50% of test animals
MEL –	Manchester Environmental Laboratory
MSD –	minimum significant difference
NOAA –	National Oceanic and Atmospheric Administration
NS&T –	National Status and Trends Program
PAH –	polynuclear aromatic hydrocarbon
PCB –	polychlorinated biphenyl
PSAMP –	Puget Sound Ambient Monitoring Program
SDI –	Swartz's Dominance Index
SDS –	sodium dodecyl sulfate
SEDQUAL –	Sediment Quality Information System Database
SQS –	sediment quality standard
SQT –	Sediment Quality Triad
SQG –	Sediment Quality Guideline
UPL –	upper prediction limit

Abstract

From 1997-1999, surficial sediments were collected from 300 randomly chosen locations throughout Puget Sound as part of a joint monitoring program conducted by the Washington State Department of Ecology and the National Oceanic and Atmospheric Administration. The study was designed to provide information on the severity, spatial patterns, and spatial extent of contamination, toxicity, and degraded benthos and to identify the relationships among these measures of sediment quality. Analyses were performed to quantify concentrations of numerous potentially toxic chemicals, responses in laboratory toxicity tests, and the structure of benthic infauna communities in sediments. Results for the 2363 km^2 survey area are summarized in this report.

Degraded conditions, as indicated with a combination of relative high chemical concentrations, statistically significant responses in one or more tests of toxicity, and adversely altered benthos, occurred in samples that represented about 1% of the total area. These conditions invariably occurred in samples collected within urbanized bays and industrial waterways, especially near the urban centers of Everett, Seattle, Tacoma, and Bremerton, where degraded conditions had been reported in previous studies. Sediments with high quality (as indicated by no elevated chemical concentrations, no significant responses in the toxicity tests, and the presence of abundant and diverse infauna and or pollution sensitive taxa) occurred in samples that represented a majority, 68%, of the total study area. Sediments in which results of the three kinds of analyses were not in agreement were classified as intermediate in quality and represented about 31% of the total area. This relatively large area with intermediate sediment quality is suggested as in most need of continued surveillance because of the heterogeneity and transitional nature of the sediments.

Sediment quality is also compared between six Puget Sound regions, and to estuaries nationwide. Relative to many other estuaries and marine bays along the U.S. coastline, Puget Sound sediments were ranked among the least contaminated and toxic.

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Executive Summary

This study was designed to provide information on the severity, spatial patterns, and spatial extent of contamination, toxicity, and degraded benthos and the relationships among these measures of sediment quality in the Puget Sound region. Analyses of sediments were performed to quantify the concentrations of a broad range of potentially toxic chemicals and a number of physical variables that can influence their relative biological availability. Four laboratory toxicity tests were performed to determine the relative degree of response among samples. The structure and composition of benthic infauna communities were determined as indicative of impacts among resident biota. Sediment was collected at 300 randomly chosen locations in Puget Sound sampled during 1997-1999. The 300 sampling locations were determined to cover a total survey area of 2363 km^2. Samples of surficial sediments were collected throughout the greater Puget Sound area. The study area extended from the U.S./Canada border, south through the central basin of Puget Sound, to the inlets of southern Puget Sound and Hood Canal. This area was divided into 6 sediment monitoring regions defined by their geographic locations and hydrogeological features, including the Strait of Georgia, Whidbey basin, Admiralty Inlet, Central Sound, South Sound, and Hood Canal. Sampling strata, defined by their geological and anthropogenic features, included deep basins, passages, rural bays, urban bays, and industrial harbors. During the three years, 300 samples were collected and analyzed, progressing from north to south, throughout this study area.

The study was performed as part of a joint research program of the Washington State Department of Ecology (Ecology) and the National Oceanic and Atmospheric Administration (NOAA). The results of the study were reported in detailed technical reports prepared for each of the three phases of the study (Long et al., 1999a, 2000a, and 2002). The purpose of this report is to summarize the information on the geographic patterns and spatial extent of degraded sediment quality over the entire study area developed during the three-year program.

A probabilistic, stratified-random sampling design was used to avoid biases in the selection of sampling locations and to allow estimations of the spatial extent of degraded and non-degraded conditions. Polygonal strata were designated based upon physiographic features and relative uniformity in bathymetry and sedimentological features. Sampling locations were selected randomly by a computer program within each stratum. Usually, three samples were collected in each stratum. Composited, homogenized sediment samples were collected at each sampling station and distributed to different laboratories for analyses of over 150 chemical and physical variables, for performance of four laboratory toxicity tests, and for identification and enumeration of benthic infauna captured on 1.0 mm sieves. Standardized methods, quality assurance, and quality control methods adopted by both Ecology and NOAA were applied in this survey to ensure acquisition of highest quality data.

Results of the chemical, toxicity, and benthic analyses were evaluated separately, using statistically-derived benchmarks (i.e., numerical “critical values”), to identify the spatial extent and spatial patterns in categories of relative sediment quality. Also, they were evaluated together in Sediment Quality Triad analyses to form a weight of evidence with which to compare and rank the overall degree of degradation in sediment quality among stations, strata, and regions.

The Triad analyses allowed us to identify the degree of concordance (agreement) among the three kinds of information that was developed.

To evaluate the chemistry data, concentrations were compared to sediment quality standards established for Washington State and informal guidelines derived for NOAA. Among the 300 samples collected, there were 184 (61% of the total) in which one or more chemical concentrations exceeded either a state standard or a NOAA guideline value. These 184 samples represented a total area of about 1260 km^2, equivalent to 53% of the total survey area. This overall estimate of chemical contamination was reduced to 70 samples, representing 144 km^2 (6% of total survey area) when the data were excluded for four relatively non-toxic, yet ubiquitous, chemicals: nickel, benzoic acid, phenol, 4-methyl phenol. Furthermore, the spatial extent of chemical contamination estimated relative to only NOAA's guideline values was much smaller, equivalent to only 1.3% of the total survey area. Complex mixtures of toxicants occurred in the contaminated samples, often consisting of organic compounds, including benzoic acid, phenol, 4-methyl phenol, polynuclear aromatic hydrocarbons, and polychlorinated biphenyls. Some samples also had elevated concentrations of potentially toxic trace elements including mercury, copper, and zinc. The degree of chemical contamination generally was higher in the Strait of Georgia, Whidbey Basin, Central Sound, and South Sound regions of the study area, notably highest in the industrialized, maritime harbors. The least contaminated samples generally were collected in the Hood Canal and Admiralty Inlet regions. Throughout the entire study area, the deep basins and rural bays farthest from sources were least contaminated.

The toxicity of the sediments was determined in a battery of four tests intended to provide information on three phases of sediments; solid-phase (bulk) sediments, pore waters, and organic solvent extracts. Tests were performed for survival among marine amphipods exposed to solid phase sediments, sea urchin egg fertilization in exposures to pore waters, microbial bioluminescence activity in tests of solvent extracts, and cytochrome P-450 HRGS activity in another assay of the solvent extracts. Significant responses as determined in the four laboratory tests were not widespread; generally being restricted in scope to industrialized bays and harbors. Only one sample was classified as highly toxic in the amphipod survival test of whole sediments. This sampling station represented about 0.04% of the total survey area. Samples in which results of the sea urchin fertilization test in 100% pore waters were highly significant represented 4% of the area. In the microbial bioluminescence assay of organic solvent extracts, eight samples had highly significant responses and they represented about 0.4% of the study area. Cytochrome P-450 induction was highest in samples that represented about 3% of the total area; whereas responses above background levels occurred in samples that represented 25% of the area.

The area in which responses in one or more of four laboratory tests exceeded the critical values (144 samples, representing 642 km^2 or 27% of the total area) was less than the area classified as chemically contaminated with one or more substances (184 samples, representing 1260 km^2 or 53% of the area). Much of the area in which toxicity test results were significant was attributable to significant responses in the HRGS assay, a test of an organic solvent extract; thus, not a test of the bioavailability of sediment-sorbed toxicants. There was relatively good agreement between responses in the urchin fertilization test and HRGS test. There were 69 samples in which only a toxicity test response was recorded, but no chemical contamination was apparent, representing 22% of the study area. The lack of concordance in these 69 sediments suggested that toxicity was in response either to unmeasured chemicals or chemicals for which there are no guidelines or criteria. There were 13 samples in which the sediments were contaminated, but not toxic, representing about 4% of the area. The toxicants in these sediments were apparently not bioavailable or sufficiently elevated in concentration to cause responses in either the laboratory tests or in the resident benthos. Only four (<1% of the study area) samples were classified as having degraded benthos, but were not contaminated or toxic. The benthos was apparently degraded as a result of factors other than chemical contamination.

Despite the lack of concordance among elements of the triad in some samples, there was agreement among these measures in the majority of samples. Sediments from 175 of the 300 sampling stations indicated concordance among the elements of the triad in classification of quality; that is, indicative of either high quality or degraded conditions. Together, they represented 69% of the total study area.

The presence and abundance of benthic infaunal taxa was summarized with nine calculated indices. In most cases, lowest index values (i.e., indicative of the lowest diversity and abundance or lowest counts of pollution-sensitive taxa) occurred in samples collected in industrial harbors and urban bays. No critical numerical values are available thus far for Puget Sound with which to classify benthic communities as degraded or stressed. Thus, the benthic data were analyzed qualitatively in subjective analyses of the weight of evidence formed with the triad of measures. An index of dominance and the abundance of arthropods, echinoderms, and miscellaneous taxa appeared to be most in concordance with overall indices of sediment quality, whereas total abundance, numbers of taxa and abundance of annelids and molluscs were least affected.

The weight-of-evidence from the three complimentary kinds of information suggested that, overall, sediment quality was good throughout most of the 2363 km^2 survey area. Degraded conditions (high chemical concentrations relative to effects-based critical values, highly significant response in one or more laboratory tests, and adversely altered benthic community structure) occurred in 37 samples that represented about 23 km^2, or 1.0% of the total study area. These sediments, in which there was a high degree of concordance among measures of sediment quality, invariably occurred in samples collected within urbanized bays and industrial waterways of the central Puget Sound region nearest the urban centers of Everett, Seattle, Tacoma, and Bremerton. Degraded sediment quality and high incidences of adverse biological effects had been recorded in these areas in previous studies. Any two elements of the triad were highly significant in 40 samples; thus, constituting intermediate/degraded conditions that represented about 4% of the total survey area. Another 85 samples (representing 27% of the study area) were of intermediate/high quality as indicated by only one of the elements of the triad. The 125 samples in which intermediate and non-concordant sediment quality (i.e., one or two elements of the triad indicating degraded conditions) was recorded underscores the transitional and heterogeneous nature of sediment quality in a fairly large proportion (31%) of Puget Sound. Sediments with intermediate or transitional conditions may be most in need of future surveillance to ensure that sediment quality does not deteriorate further in those areas. Sediments with high quality (as indicated by no significant responses in the four laboratory tests, no contamination relative to the values that were used, and supporting abundant and diverse infauna) occurred in 138 samples, representing the majority (i.e., 68%) of the total study area. These high quality conditions were most apparent throughout the study area in the rural bays, deep basins and passages and in the Strait of Georgia, Whidbey Basin, Admiralty Inlet, and Hood Canal regions adjacent to least populated areas farthest from toxicant sources.

Comparisons between results of the present study with those in which comparable methods were applied elsewhere in U.S. estuaries indicated that the percentages of samples and/or study areas with either chemical contamination or acute toxicity were relatively low in Puget Sound. Surficial sediments of Puget Sound, as classified in the present study, ranked among the least degraded relative to those from many other estuarine regions. Conditions, in the industrialized harbors and urban bays of Puget Sound, however, were roughly equivalent to those in similar areas of other estuaries and marine bays.

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Introduction

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 (National Research Council, 1989). Therefore, 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. Whereas this sedimentation process tends to rid the water column of toxicants, their concentrations in sediments can increase to the point that they eventually represent a potential toxicological threat to the resident benthic biota and predators that may depend on this resource as their food (Burton, 1992).

Toxic chemicals occur in a wide range of concentrations in surficial (recently deposited) sediments of Puget Sound (Llansó et al., 1998a). 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 1978-1990, 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, 1984b). In sediments from the industrial waterways of Commencement Bay, low amphipod survival was coincidental with low amphipod abundance in the benthic samples 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). Histopathological 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, 1984; Becker et al., 1987).

The incidence and spatial patterns in sediment contamination, sediment toxicity, benthic impacts, and histopathological disorders in demersal fishes were quantified in additional surveys of Commencement Bay (Tetra Tech, 1985), Elliott Bay/lower Duwamish River (PTI, 1988), Everett Harbor (PTI 1989), Sinclair Inlet (Tetra-Tech, 1988), and 13 small bays (Crecelius et al., 1989). Studies of invertebrate communities conducted in central Puget Sound indicated significant losses of benthic resources in some areas with high chemical concentrations (Malins et al., 1982; Kisker, 1986; Chapman et al., 1984a, b; Llansó et al., 1998a, b). Colonization rates by epifaunal invertebrates were slowest and resulted in the lowest numbers of taxa in contaminated harbors and waterways as compared to rural bays (Schoener, 1983).

Analysis of the SEDQUAL database developed by Ecology and consisting of chemical information from 8523 sediment samples collected throughout the greater Puget Sound region indicated that violations of Washington State standards occurred frequently. Among the 8523 samples, violations of the Sediment Quality Standards (SQS) occurred in 2319 samples (27%) and violations of Cleanup Screening Levels (CSL) occurred in 1565 samples (18%). The violations involved all 47 substances for which the state standards were developed. The chemical makeup of toxicant mixtures in sediments has varied from place to place in Puget Sound, mostly in relation to the nature of local sources. Such mixtures have included numerous polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), phthalate esthers, trace metals (including arsenic, copper, mercury, lead), phenols, chlorinated butadienes and hexachlorobenzenes.

Although contaminant levels in some regions of Puget Sound have been well characterized with data from many previous studies, considerably less information has been generated for other regions of the system. None of the historical data were collected with methods that allowed estimates to be made of the surficial (i.e., spatial) extent of degradation. Often, studies were performed in the vicinity of specific point sources, dredged channels, or other focused areas; thus, precluding analyses of the data to determine the size and spatial dimensions of the degraded areas for the entire system.

Objectives

To objectively evaluate the relative quality of sediments throughout the Puget Sound estuary system, data were needed that had been developed with consistent methods applied area-wide and during the same time frame. To estimate the spatial extent or area of degradation, a probabilistic sampling design was necessary to ensure a lack of bias in selections of sampling sites and to allow weighting of results to spatial dimensions of the study area. The survey described in this report was jointly funded and conducted by Ecology and NOAA, following methods previously used by both agencies in sediment quality assessments (Llansó et al., 1998a, b; Long et al., 1996; Long, 2000a, b).

Specific objectives of the Puget Sound survey were:

1. Determine the incidence and severity of toxicity and chemical contamination of sediments;

2. Identify spatial patterns and gradients in sediment toxicity and chemical concentrations as defined with the selected methods;

3. Estimate the spatial extent of toxicity and chemical contamination, as defined with the selected methods, in surficial sediments as percentages of the total survey area;

4. Describe the composition, abundance and diversity of benthic infaunal assemblages at each sampling location;

5. Determine the degree of concordance, or agreement, among the elements of the sediment quality triad in classification of sediment quality;

6. Determine the spatial patterns and extent of degraded conditions based upon a weight of evidence formed with the triad of measures; and

7. Compare the quality of sediment from six sediment monitoring regions and five strata types measured in Puget Sound.

Because the area was too large to evaluate in a single sampling season, the project was extended over three sampling phases. Sediments were sampled in the northern part of the study area during 1997 (Long et al., 1999a), the central area in 1998 (Long et al., 2000a), and the southern part, Hood Canal, and Commencement Bay in 1999 (Long et al., 2002). The same sampling and analytical methods were used in all three years; thus, ensuring that the data were comparable. The purpose of this report is to combine and summarize the data acquired during the three phases of the survey to identify the overall patterns and extent of degraded sediment quality as measured in the triad of analyses.

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Methods

To ensure that highest quality data were produced, a combination of standardized methods previously used by Ecology in the Puget Sound Ambient Monitoring Program (PSAMP) and by NOAA in the National Status and Trends (NS&T) Program was used in this survey (Long and Dzinbal, 1999). The sampling design, toxicity tests, and data analyses used in this survey were applied by NOAA in comparable surveys of sediment quality conducted elsewhere in the U.S. (Long et al., 1996; Long, 2000a, b). Sets of standardized methods for sample collections, chemical analyses, and benthic analyses in Puget Sound were previously described in the Puget Sound Estuary Program protocols (PSEP, 1986, 1987, 1996a, b, c). To ensure that the data were comparable throughout the study area, the same methods were used in all three phases of the survey. Details of these methods were provided in the individual technical reports (Long et al., 1999a, 2000a, 2002) and briefly summarized below.

Sampling Design and Sample Collections

A stratified-random sampling design was used in this survey. It was similar to those used in surveys of sediment quality conducted nationwide by NOAA as part of the NS&T Program (Long et al., 1996) and by U.S. EPA as a part of the Environmental Monitoring and Assessment Program (EMAP; Paul et al., 1992). This approach combined the strengths of a stratified design with the random-probabilistic selection of sampling locations within the boundaries of each stratum. Because the sampling locations were chosen randomly and without bias, data generated within each stratum were attributable to the size of the stratum. Therefore, this approach allowed us to estimate the spatial extent of toxicity with a quantifiable degree of confidence (Heimbuch et al., 1995). Strata boundaries were established to coincide with the dimensions of major basins, bays, inlets, waterways, etc. in which hydrographic, bathymetric and sedimentological conditions were expected to be relatively homogeneous. Sediment quality data in Ecology's SEDQUAL database were reviewed to assist in establishing strata boundaries.

The sample collections progressed from the northern strata, to the central strata, and finally to the southern strata (Figure 1) during the three sampling phases. In the analyses of the data for this report, the study area was sub-divided and realigned to better conform to the Puget Sound subregions defined by the Puget Sound Ambient Monitoring Program (PSWQAT, 2002). This realignment resulted in six regions for which results were summarized: Strait of Georgia, Whidbey Basin, Admiralty Inlet, Central Sound, South Sound, and Hood Canal (Figure 2).

The Strait of Georgia region ranges from the U.S./Canada border southward through Bellingham Bay, Samish Bay, Padilla Bay to the vicinity of Anacortes. It encompasses an area of 429 km^2. The Whidbey Basin region (345 km^2) included the strata east of Whidbey Island from the Skagit River delta to Port Gardner Bay and Everett Harbor. Admiralty Inlet and the Port Townsend area were included in the Admiralty Inlet region (186 km^2). The Central Sound region (690 km^2) was largest, extending from the southern tip of Whidbey Island, through the central basin of Puget Sound to the northern entrance of the Tacoma Narrows. The Central Sound region included the most urbanized bays, including Elliott Bay adjoining Seattle, Sinclair Inlet adjoining Bremerton, Commencement Bay adjoining Tacoma, and the passages and inlets West of

Bainbridge Island. The South Sound region (397 km^2) extended from the southern entrance of the Tacoma Narrows to the heads of the many inlets of southern Puget Sound. The Tacoma Narrows itself and a small area East of Budd Inlet were excluded from the survey area because these areas were known to not have soft sedimentary deposits and large boulders were present. The Hood Canal region (316 km^2) included the length of Hood Canal and three small adjoining bays; Dabob Bay, Port Gamble Bay, and Port Ludlow.

Large strata were established in the areas distant from toxicant sources where toxicant concentrations were either known or expected to be uniformly low (e.g., Admiralty Inlet, Puget Sound central basin), resulting in the least intense sampling effort. In contrast, relatively small strata were established in urban bays and industrial harbors nearer suspected sources in which conditions were expected to be heterogeneous or transitional (e.g., inner Elliott Bay, Commencement Bay waterways, Port of Olympia). Dimensions, locations and shapes of each stratum are outlined in Figures 3-7. In most cases, three samples were collected within each stratum at coordinates randomly selected with a NOAA computer program. Four samples were collected in a few strata that were expected to be more heterogeneous. The survey area encompassed a total area of 2363 km^2. All samples were collected in water depths of 2 m or more (mean lower low water), the operating limit of the sampling vessel.

A total of 300 samples were collected in the survey, distributed among 97 strata as shown in Figures 3-7. Sample numbers 101-105, 206-210, and 311-315 were field duplicates only for chemical analyses. Sediments were collected at each designated station with multiple deployments of a double 0.1m^2 vanVeen grab. Sufficient amounts of surficial material (upper 2-3 cm) were removed with a scoop to form a homogenized, composited sample for both chemical analyses and four toxicity tests. Benthic infauna samples were collected separately at the same location and same time with a single deployment of the 0.1 m^2 sampler. All infaunal samples were rinsed gently through nested 1.0 and 0.5 mm screens and the organisms retained on each screen were kept separate.

Sediments were collected during June of each year from the research vessel Kittiwake. Each station was sampled only once. Differential Global Positioning System (DGPS) was used to accurately position the vessel at the station coordinates. Recommended procedures (PSEP, 1986, 1987, 1996a, b) for collection of samples, decontamination of equipment, sample handling, chain of custody documentation, and re-screening of benthic samples were followed.

Chemical Analyses

Chemical analyses were performed for up to 171 chemical and physical variables, including trace elements (including potentially toxic metals), polynuclear aromatic hydrocarbons (PAHs), chlorinated pesticides, phenols, phthalate esters, polychlorinated biphenyls (PCBs), other organic toxicants, total organic carbon, and grain size. Protocols were used that satisfied requirements of both NOAA (Lauenstein and Cantillo, 1993) and Ecology (PSEP, 1987, 1995, 1996a, b, c).

Analyses were performed for 133 substances that are routinely quantified by the NS&T Program, plus 24 additional compounds either required by Ecology to ensure comparability with previous PSAMP and enforcement studies or automatically quantified during analyses for the required compounds. Analytical procedures provided performance (i.e., recovery efficiencies, detection limits) equivalent to those of both the NS&T Program and the PSEP Protocols. Information was reported on recovery of spiked blanks, analytical precision with standard reference materials, and duplicate analyses of every 20th sample with the exception of grain size analyses, all chemical analyses were performed by Ecology's Manchester Environmental Laboratory (MEL). Grain size analyses were contracted out under their supervision.

Analyses for grain size were performed using a sieve-pipette method according to the PSEP Protocols (PSEP, 1986). Total organic carbon analyses also followed PSEP Protocols (PSEP, 1986) and involved drying sediment material, pretreatment and subsequent oxidation of the dried sediment, and determination of CO_2 by infra-red spectroscopy.

To maintain compatibility with previous PSAMP metals data, EPA Methods 3050/6010 were used for the determination of metals in sediment. Method 3050 is a strong acid (aqua regia) digestion that has been used for the last several years by Ecology for the characterization of sediments for trace metal contamination and was the recommended technique for digestion of sediments in the recently revised PSEP protocols (PSEP, 1996b). This digestion does not yield geologic (total) recoveries for most analytes including silicon, iron, aluminum and manganese. It does, however, recover quantitatively most anthropogenic metals contamination and deposition. For comparison with NOAA's national database, metals analyses also were performed with a total (hydrofluoric acid-based) digestion (EPA method 3052) on portions of the same samples. Determinations of metals concentrations for both sets of extracts were made by ICP, ICP-MS, or GFAA, depending upon the appropriateness of the technique for each analyte.

Mercury concentrations were determined with U.S. EPA Method 245.5 by cold vapor atomic absorption (CVAA). The method consists of a strong acid sediment digestion, followed by reduction of ionic mercury to Hg0, and analysis of mercury by cold vapor atomic absorption as recommended by the PSEP Protocols (PSEP, 1996b). Butyl tins in sediments were analyzed by methods that consisted of solvent extraction of sediment, derivitization of the extract with the Grignard reagent hexylmagnesium bromide, cleanup with silica and alumina, and analysis by Atomic Emission Detector (AED) (Manchester Environmental Laboratory, 1997).

Analyses for semi-volatile compounds and PAHs followed methods of U.S. EPA Method 846 8270, as recommended in PSEP (1996c), using capillary column, GC/MS techniques. The list of compounds normally quantified for Puget Sound was extended by the inclusion of additional PAH compounds to match the analyte list for NOAA. U.S. EPA Method 8081 for chlorinated pesticides and PCB was used for the analysis of these compounds, using GC methods with dual dissimilar column confirmation and electron capture detectors. The concentrations of 20 target PCB congeners were determined following procedures outlined by NOAA (Lauenstein and Cantillo, 1993).

Laboratory Toxicity Tests

Multiple toxicity tests were performed on aliquots (portions) of each sample to provide a weight of evidence. Tests were selected for which there were widely accepted protocols that would represent the toxicological conditions within different phases (partitions) of the sediments. The tests included those for amphipod survival in solid-phase sediments, sea urchin fertilization success in pore waters, and both microbial bioluminescence activity and cytochrome P450

HRGS induction in portions of an organic solvent extract. Test endpoints, therefore, ranged from survival to rate of physiological activity. Either the tests were initiated (amphipod survival) or the sample extractions were performed (all others) within 10 days of the sample collection dates.

Amphipod Survival Tests of Solid Phase Sediments

Amphipod tests, using the taxa *Ampelisca abdita*, followed the procedures detailed in ASTM (1993) which are equivalent to those of PSEP (1995). The amphipod tests are the most widely and frequently used assays in sediment evaluations performed in North America. These tests provided wide ranges in responses among samples, strong statistical associations with elevated toxicant levels, little sensitivity to natural factors, strong correlations with losses of benthic resources, and small within-sample variability (Long et al., 1990, 1996, 2001).

In these tests, amphipods were exposed to test and negative control solid phase (or bulk) sediments for 10 days with 5 replicates of 20 animals each under static conditions using filtered seawater. The numbers of survivors were counted after the ten-day exposures. Aliquots of 200 mL of test or control sediments were placed in one-liter test chambers, and covered with approximately 600 ml of filtered seawater (28-30 ppt).

Amphipod survival tests were conducted by Science Applications International Corporation (SAIC) in Narragansett, R.I. (1997-1998), and then by ToxScan, Inc. in Watsonville, CA (1999), under a sub-contract with SAIC. Amphipods were collected from tidal flats in the Pettaquamscutt (Narrow) River, a small estuary adjoining Narragansett Bay, RI. Control sediments were from a Central Long Island Sound (CLIS) location and tested with each batch of test samples. These sediments had been tested repeatedly with the amphipod survival test and other assays and found to be non-toxic (amphipod survival has exceeded 90% in 85% of the tests). Positive controls (sodium dodecyl sulfate, SDS) were tested in water-only exposures to document the sensitivity of each batch of test organisms, resulting in LC50 values (lethal concentration for 50% of the test animals). Ammonia concentrations were determined in both pore waters (day 0 of the tests) and overlying waters (days 2 and 8 of the tests). Concentrations of the un-ionized form of ammonia were calculated, based upon measures of total ammonia, and concurrent measures of pH, salinity and temperature.

Sea urchin Fertilization Tests of Pore Waters

Sea urchin fertilization tests of pore waters followed protocols of the U.S. Geological Survey (Carr and Chapman, 1995; Carr et al., 1996a, b; Carr, 1998) using gametes of the purple urchin *Strongylocentrotus purpuratus*. Tests of sea urchin fertilization have been used in assessments of ambient water and wastewater effluents and in previous NS&T Program surveys of sediment toxicity (Long et al., 1996; Turgeon et al., 1998). Test results have shown wide ranges in responses among test samples, excellent within-sample homogeneity, and strong associations with the concentrations of toxicants in the sediments (Long et al., 1990; Carr et al., 1996b). This test combines the features of testing sediment pore waters (the phase of sediments in which dissolved toxicants are highly bioavailable) and exposures to early life stages of invertebrates (sperm cells) which often are more sensitive to toxicants than adult forms.

Pore water was extracted by the U.S.G.S. laboratory (Corpus Christi, TX) from sediments with a pressurized squeeze extraction device. Then, porewater samples were centrifuged to remove particulate matter, and the supernatant was retained and frozen (Carr and Chapman, 1995). Adult *S. purpuratus* obtained from Marinus Corporation, Long Beach, CA, were induced to spawn by injecting potassium chloride into the coelomic cavity. To determine urchin fertilization success, 50 µl of appropriately diluted sperm were added to each porewater test vial, and incubated at 20±2°C for 30 minutes. One ml of a well mixed dilute egg suspension was added to each vial, and incubated an additional 30 minutes at 20± 2°C. Buffered formalin was added to stop the test. Fertilization membranes were counted, and fertilization percentages calculated for each replicate test. Each of the pore water samples was tested in a dilution series of 100%, 50%, and 25% of the salinity-adjusted sample with 5 replicates per treatment. Dilutions were made with clean, filtered (0.45 µm), Port Aransas, Texas, laboratory seawater. A dilution series test with SDS was included as a positive control. Pore water from sediments collected in Redfish Bay, Texas were used as negative controls.

Microbial Bioluminescence (Microtox™) Tests of Organic Solvent Extracts

Microbial bioluminescence (Microtox™) tests were performed with protocols initially developed for Puget Sound (Schiewe et al., 1985; PSEP 1995; Johnson and Long, 1998) to determine inhibition of light production. This is a test of the relative toxicity of extracts of the sediments prepared with an organic solvent, and, therefore, it is immune to the effects of environmental factors, such as grain size, ammonia and organic carbon that can influence outcomes of other types of sediment tests. Organic toxicants, regardless of their bioavailability in nature, are extracted with the organic solvent. Therefore, this test is considered as indicative of the potential toxicity of mixtures of substances bound to the sediment matrices (Long et al., 1996). Results of these tests frequently show strong correlations with the concentrations of mixtures of organic compounds. The tests were performed by the U.S.G.S. laboratory in Columbia, MO, on extracts prepared by Columbia Analytical Services (CAS) in Kelso, WA.

All tests were run on portions of the extracts prepared for the cytochrome P-450 HRGS assays (described below), using three replicates of each extract. The amount of light lost per sample was assumed to be proportional to the toxicity of that test sample. A suspension of luminescent bacteria, *Vibrio fischeri* (Azur Environmental, Inc.) was exposed to a dilution series (four concentrations) of each sample to determine percent decrease in bioluminescence activity relative to the reagent blank. Light loss was expressed as a gamma value and defined as the ratio of light lost to light remaining. The mean concentrations of the extract that inhibited luminescence by 50% (with 95% confidence intervals) after a 5-min exposure period, the EC50 value, were determined and expressed as mg equivalent sediment wet weight. Thus, relative toxicity of samples increased as mean EC50's decreased. Tests of extracts of sediments from the Redfish Bay, TX, site used in the urchin tests also were used as negative controls in the Microtox™ tests.

Cytochrome P450 HRGS Assays of Organic Solvent Extracts

Cytochrome P-450 assays of the light produced by luciferase in a human reporter gene system (HRGS) of cultured human liver cells was conducted on organic solvent extracts, following standard protocols (Anderson et al., 1995, 1996; APHA, 1998; ASTM, 1999; EPA 2000). This assay is responsive to the presence of mixed-function oxygenase inducers such as dioxins, furans, high molecular weight PAHs, and coplanar PCBs in tissues and sediments (Anderson et al., 1995; 1999a; 1999b, Jones and Anderson 1999). Therefore, it provides an estimate of the presence of contaminants bound to sediment that could produce chronic and/or carcinogenic effects in benthic biota and/or demersal fishes that feed in sediments. Columbia Analytical Services, Inc. in Vista, CA performed these tests with solvent extracts prepared by their laboratory in Kelso, WA.

Approximately 20 g of sediment from each station were extracted using EPA method 3550 to produce 1 ml of dichloromethane (DCM)/extract. Extracts were exchanged into dimethylsulfoxide (DMSO) to produce a sufficient amount of sample for triplicate tests. Small portions (up to 20 µl) were applied to approximately one million human liver cells contained in three replicate wells with 2 ml of culture medium. After 16 hours of incubation (exposure), the cells were washed, then lysed, and the solution centrifuged. The supernatant was then placed into a 96-well plate with a buffer solution, and on the addition of luciferin the light produced by each replicate was measured with a luminometer. Solvent blanks and the reference toxicants (2, 3, 7, 8 - dioxin and benzo[a]pyrene) were tested with each batch of samples. Responses were compared to that of the solvent blank to produce fold induction (times background) values. Data were then converted to µg of benzo[a]pyrene equivalents per gram (µgB[a]P/g) of sediment, based on the observation that 60 fold induction is produced by 1 µg of B[a]P/ml. The HRGS assays also were performed on an extract of the Redfish Bay, TX, negative control previously used in the urchin fertilization tests.

Benthic Community Analyses

Methods for sorting of major taxonomic groups, identification to taxa level (when possible), and sample documentation followed those described for Puget Sound benthic studies (PSEP, 1987; Dutch et al., 1998). A single 0.1 m^2 benthic sample was collected at each station and sieved with stacked 1.0 mm and 0.5 mm sieves in the field. Material retained on the two sieves was bagged separately and preserved with formalin. Samples were then transported to the Ecology benthic laboratory. After a minimum fixation period of 24 hours, the samples were washed to remove the formalin, transferred to 70% ethanol, and stained with rose bengal. Data are reported here only for material retained on the 1.0 mm sieves.

All macroinfaunal invertebrates and fragments were removed and 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 QA/QC procedures consisted of resorting 20% 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.

Upon completion of sorting and sorting QA/QC, the majority of the taxonomic work was contracted to recognized, regional specialists. When possible, at least two scientific references were used for the identification of each taxa. A maximum of three representative organisms of each taxa or taxon were removed and retained in a voucher collection. 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 Summaries, Displays, and Statistical Analyses

The data from this survey were summarized in tables, displayed on regional base maps, and subjected to a variety of statistical analyses. The same methods were used consistently during each of the three years to ensure comparability of results. These methods were selected to both satisfy the objectives established for the study and to allow comparisons of results with those generated in estuarine sediment quality surveys conducted nationwide by NOAA and U.S. EPA. It is important to note that the data analyses in this study did not necessarily comply with those that Ecology must use in enforcement and regulatory programs that involve contaminated sediments. It should be noted also that numerical "critical values" as used in the NS&T Program (Long et al., 1996) and EMAP estuarine surveys (Paul et al., 1992; Schimmel et al., 1994) were applied to the data from the chemical analyses and toxicity tests as aids in their interpretation.

Incidence, Spatial Patterns and Spatial Extent of Sediment Contamination

Three sets of chemical concentrations were used as critical values in the analyses of these data. The Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSL) were developed specifically for Puget Sound and are included in the Washington State Sediment Management Standards (Washington Dept. of Ecology, 1995). The Effects Range Low (ERL) and Effects Range Median (ERM) values were developed by Long et al. (1995) for NOAA with a national sediment quality database. Trace metals concentrations determined with partial digestions were compared to the SQS and CSL values, whereas those determined with total digestions were compared to the ERL and ERM values.

To identify possible spatial gradients or other patterns in chemical contamination among the 300 sampling locations, maps were prepared in which symbols were used to depict where numerical guidelines and/or criteria were exceeded. An open circle at a sampling location was used to indicate that none of the chemical concentrations exceeded either of these sets of values in the sample from that location. A darkened quadrant of a circle indicates that either an ERM, or an SQS, or a CSL value was exceeded. Because benzoic acid, 4-methylphenol, and phenol were so ubiquitous in the 300 samples, especially in those from the northern stations, they were treated separately in these figures. Stations with symbols darkened in two or more quadrants were viewed as more contaminated than stations in which no guidelines were exceeded or the chemical concentrations exceeded only one set of values. Concentrations were higher if they exceeded the CSL values in addition to the lower SQS values.

Estimates of the spatial extent of chemical contamination were determined with cumulative distribution functions in which the chemistry data from each station were compared to selected critical values (see below) weighted to the dimensions (km^2) of the sampling stratum in which the samples were collected and weighted (Schimmel et al., 1994). The size of each stratum (km^2) was determined with an electronic planimeter applied to navigation charts, upon which the boundaries of each stratum were outlined. Estimates of the spatial extent of contamination were calculated for each of the six regions outlined in Figures 2, and for the entire survey area.

In addition, calculations of the spatial extent of contamination were made for 5 strata, defined by their geologic and anthropogenic features including harbors, urban bays, rural bays, basins, and passages. In these analyses, strata were grouped into one of these five categories according to the following features:

- Harbor strata: semi-enclosed embayments, terminal inlets-head of bay/estuary, shallow, maritime activity-commercial vessel traffic, and/or ports, and/or shipyards, adjacent to urban /industrial centers, high numbers of point and /or nonpoint sources of discharge, frequently dredged, and presence of docks, breakwaters, and jetties;

- Urban strata: semi-enclosed embayment, sometimes head of bay/estuary, includes outer harbors, shallow to mid depth, adjacent to urban/industrial centers, lower numbers of point and/or nonpoint source discharge, and may or may not be dredged;

- Rural strata: includes semi-enclosed embayments and terminal inlets, as well as larger inlets, shallow to deep, not adjacent to urban/industrial centers or maritime activity, adjacent land mass is largely undeveloped, lightly populated, lowest numbers of point and/or nonpoint source discharges, and frequently used as reverence locations;

- Basin strata: deep, associated with a sill, may or may not be adjacent to urban/industrial centers, and lowest numbers of point and/or nonpoint source discharge (although some receive treated effluent form municipal point source outfalls);

- Passage strata: bounded by two shorelines and open at both ends (i.e., not a terminal bay), often deep, not associated with a sill, not adjacent to urban/industrial areas, and lowest numbers of point and/or nonpoint source discharge.

As indices of concentrations of chemical mixtures, mean ERM quotients (Long and MacDonald, 1998; Long et al., 2000c) and analogous mean SQS and CSL quotients were calculated. Mean ERM quotients were calculated as the mean of the quotients derived by dividing the chemical concentrations in the samples by their respective ERM values. The greater the mean ERM quotient, the greater the overall contamination of the sample as determined by the mixtures of 25 substances. Mean ERM quotient values of 1.5 or greater were independently determined to be highly predictive of acute toxicity in amphipod survival tests (Long et al., 2000c). Mean SQS and CSL quotients were determined using the same procedure, using all of the SQS and CSL values. In all of these analyses, the concentrations of nickel were not included. The reliability of the ERM value for nickel was reported as uniquely low (Long et al., 1995) and no state standards for nickel have been developed.

Toxicity Tests of Amphipod Survival

Mean percent amphipod survival in each sample was compared to that in the CLIS control using a one-way, unpaired t-test assuming unequal variance. Results were not transformed because examination of data from previous tests has shown that results of tests performed with *A. abdita* met the requirements for normality. When mean survival was not significantly different from that of the control (i.e., alpha $\geq$0.05), the sample was classified as “non-toxic” in this test. Samples were classified as "significantly toxic" in samples in which mean survival was significantly less than that in the performance control (i.e., alpha < 0.05). In addition, samples in which survival was significantly less than controls and less than 80% of mean survival in the CLIS controls were regarded as "highly toxic". The 80% criterion was based upon iterative statistical power curves created from an extensive database for tests with *A. abdita* (Thursby et al., 1997). Their analyses showed that the power to detect a 20% difference from the control is approximately 90%. The minimum significant difference (i.e., "MSD" of <80% of control response) was used as the critical value in calculations of the spatial extent of toxicity nationwide by NOAA (Long et al., 1996; Long, 2000a, b; Turgeon et al., 1998).

Toxicity Tests of Sea Urchin Fertilization

For the sea urchin fertilization tests, statistical comparisons among treatments were made using ANOVA, followed by Dunnett's one-tailed t-test on the arcsine square root transformed data with the aid of SAS (SAS, 1989). Prior to statistical analyses, the transformed data sets were screened for outliers, using a Bonferroni-type adjustment when necessary (Moser and Stevens, 1992). After omitting outliers but prior to further analyses, the transformed data sets were tested for normality and for homogeneity of variance using SAS/LAB Software (SAS, 1992). Statistical comparisons were made with mean results from the Redfish Bay controls. Samples in which mean percent fertilization was not different from that in equivalent porewater concentrations for the Redfish Bay controls were classified as "non-toxic". Samples in which fertilization success was significantly different from that in the controls were classified as "significantly toxic".

In addition to the Dunnett's one-tailed t-tests, data from field-collected samples were treated with an analysis similar to the MSD analysis used in the amphipod tests. Power analyses of the sea urchin fertilization data have shown MSDs of 15.5% for alpha <0.05 and 19% for alpha <0.01. However, to be consistent with the statistical methods used in previous surveys (Long et al., 1996; Long, 2000a, b), estimates of the spatial extent of toxicity were based upon the same critical value used in the amphipod tests (i.e., samples were classified as "highly toxic" when fertilization success was significantly different (i.e., alpha from >0.05) from that in controls and <80% of control response).

Microtox™ Tests of Microbial Bioluminescence

Microtox™ data were analyzed using the computer software package developed by Microbics Corporation (Azur Environmental Inc.) to determine concentrations of the extract that inhibited luminescence by 50% (i.e., the EC50). Statistical comparisons among treatments and Redfish Bay controls were made using ANOVA followed by Dunnett's one-tailed t-tests on the log transformed data with the aid of SAS (SAS, 1989). Concentrations tested were expressed as mg dry weight based on the percentage extract in the 1 ml exposure volume and the calculated dry weight of the extracted sediment. Samples with EC50's not significantly different (i.e., p>0.05) from that of the Redfish Bay controls were considered to be not toxic in this test. EC50's that were significantly different from controls (p<0.05) were considered as "significant ".

As described in the annual reports (Long et al., 1999a, 2000a, 2002), the Microtox test results in the Redfish Bay controls were highly unusual and required development of additional statistical tools for interpretation of the data. Therefore, three critical values were used to estimate the spatial extent of toxicity in these tests. First, a value of <80% of Redfish Bay controls was used; i.e., equivalent to the values used with the amphipod and urchin tests. Second and third, values of <0.51 mg/ml and <0.06 mg/ml calculated in the 1997 northern Puget Sound study were used, based upon the frequency distribution of Microtox™ data from NOAA's surveys nationwide (Long et al., 1999a).

Power analyses equivalent to those conducted with the amphipod and sea urchin test results have not been performed with the Microtox and HRGS data. No other statistically derived, critical values have been previously developed for either of these tests. The responses of the Microtox tests to the Redfish Bay (TX) negative control in the Puget Sound studies resulted in very high EC50 values, much higher than in previous surveys. This outcome had the effect of classifying an inordinate percentage of samples as different from controls in comparison tests. Therefore, two critical values were derived for both of these tests, based on prediction limits, specifically for application to the survey results for Puget Sound.

For the Microtox test results, data from previous NOAA surveys performed nationwide (n=1013) were compiled, including those from northern Puget Sound. An EC50 value of <0.06 mg/ml was derived as the 90% lower prediction limit (LPL) of the entire database. The probability that a future observation from this data distribution would be more toxic (i.e., an EC50 <0.06 mg/ml) would be 90%. Such an outcome was considered in this study to represent an extreme response in this test. An EC50 value of <0.51 mg/ml was derived as the 80% LPL of the database after removal of the lowest (most toxic) 10% of the data to eliminate the influence of outliers on the data distribution. Survey samples with EC50 values of < 0.51 mg/ml were considered in this study to represent a significant response, i.e., functionally equivalent to such classifications with the amphipod survival and urchin fertilization tests.

Cytochrome P450 HRGS Toxicity Tests

Microsoft Excel 5.0 was used to determine the mean HRGS response in each sample. Two values were derived with statistical procedures during the first year of the study to serve as critical values in the interpretation of the results: >11.1 µg/g and >37.1 µg/g B[a]p equivalents (Long et al., 1999a). The value 11.1 µg/g was determined as the 80% upper prediction limit (UPL) in the NOAA national database following elimination of data above the 90th percentile of response. A response greater than 11.1 ug/g was considered in this study as both the upper limit of the background response and a "significant" response. The value 37.1 µg/g was calculated as the 90% UPL of the entire NOAA database and was considered to represent a very high response. Both values agree well with the lower 99% confidence interval (11 ug/g) and upper 99% confidence interval (32 ug/g) among 1109 samples determined later with an expanded national database (Dr. Jack Anderson, CAS, Vista CA.). Calculations of the spatial extent of toxicity were made using both values. It should be noted that samples with HRGS assay results >11.1 ug/g were considered to be greater than those that represent background conditions and, therefore, functionally equivalent to the critical values used to interpret the invertebrate toxicity tests, i.e., <80% of controls. However, there is no strong evidence that values between 11.1 (background) and 37.1 ug B[a]P/g are associated with acute toxicity. Because the compounds detected by this assay (dioxins, furans, coplanar PCBs, PAHs) partition slowly from sediments to pore water, concentrations above 37.1 ug/g are likely required to produce significant toxicity in benthic species. Fairey et al. 1996 reported degraded benthic communities in San Diego Bay at all stations where the B[a]P equivalents were 60 ug/g and higher.

Incidence and Severity, Spatial Patterns and Gradients, and Spatial Extent of Sediment Toxicity

The incidence of toxicity in each test was determined by dividing the numbers of samples in which the results were considered to be significant by the total number of samples tested. In the amphipod and urchin tests, mean percent survival and mean percent fertilization, respectively, less than 80% of that in controls were considered as significant. Mean EC50's <0.51 mg/ml were considered as significant in the Microtox tests and responses >11.1 ug/g B[a]p equivalents in the HRGS assays were considered as significant and carried forward in subsequent "triad" analyses. Severity of the responses was determined by examining the range in responses for each of the tests and identifying those samples with the highest and lowest responses. Spatial patterns in toxicity test responses were illustrated on base maps of each major region, using different symbols to represent significant and non-significant results.

The same approach used to calculate the spatial extent of contamination (described above) was used to calculate the spatial extent of toxicity. Estimates of the spatial extent of toxicity were determined with cumulative distribution functions in which the toxicity test results from each station were weighted to the dimensions (km^2) of the sampling stratum in which the samples were collected (Schimmel et al., 1994). Estimates of the spatial extent of toxicity were calculated for each of the regions outlined in Figure 2 and for the entire survey area. In addition, calculations of the spatial extent of toxicity were made for strata classified as harbors, urban bays, rural bays, basins, or passages as defined above.

Benthic Community Abundance and Diversity

No multi-metric indices of benthic infauna integrity, available for other regions of the U.S. (Van Dolah et al., 1999), have been developed for Puget Sound. Such indices must be tailored to the infaunal assemblages of each biogeographic area; therefore, application of indices from other regions to Puget Sound infaunal assemblages is not warranted. Therefore, nine benthic infaunal indices were calculated to summarize the raw data and characterize the infaunal invertebrate assemblages. Indices were based upon all countable taxa, excluding colonial and epifaunal forms. Four indices were calculated that represented total abundance (total identifiable animals present), taxa richness (total numbers of taxa present), Pielou's evenness (J'), and Swartz's dominance index (SDI, the numbers of taxa present that represented 75% of the total abundance). In addition, total counts of annelids, arthropods, molluscs, echinoderms, and miscellaneous taxa were calculated. Spatial patterns in selected indices were illustrated on base maps, using symbols to represent three different percentiles in the data distributions for each of the four selected indices. In three out of four (i.e. not total abundance) cases, relatively high index values indicated good benthic conditions. However total organism abundance was very high in some samples because of the presence of pollution tolerant taxa.

There are no numerical criteria for the benthic indices consistently calculated with Puget Sound data. The sediment quality standards provide methods for comparing the relative abundance of crustaceans, molluscs, and polychaetes between study sites and reference areas (Chapter 173-204

WAC). Ranges in a variety of benthic indices were calculated for Puget Sound reference areas (Striplin and Weston, 1999). Neither document provides guidance, however, on a species-level basis for judging the relative condition of the benthos. The data from this survey, therefore, were interpreted qualitatively and descriptively using both best professional judgment based upon considerable local experience and the approaches identified in both documents. To aid in visual identification of spatial patterns in the benthic diversity and abundance, base maps were prepared in which each station is shown with symbols for each benthic index. On these figures, each station is depicted as falling within upper, middle or lower quartiles of the distribution of the data for each index from the 300 samples. This approach does not provide any judgment value as to whether the benthic community was 'degraded' or 'stressed' or not; it was used to depict relatively high, relatively low, and intermediate benthic index values.

Sediment Quality Triad Analyses

Information from the chemical analyses, toxicity tests, and benthic infaunal analyses constitute the Sediment Quality Triad (SQT, Long and Chapman, 1985). SQT data were used together in this study to form a weight of evidence with which to classify the relative quality of the sediments, following the approach of Chapman (1996).

Results from the toxicity testing, chemical analyses, and benthic community analyses for all stations are summarized in Appendix A. Included in this compilation are the chemicals measured at concentrations above the critical values (i.e., either Washington state standards, or NOAA guidelines or both), bioassay results indicative of a significant response, and benthic infaunal indices generated for each station. Both best professional judgment and methods outlined in Chapter 173-204 WAC and Striplin and Weston (1999) were used to evaluate the condition of the infaunal assemblages, using multiple individual indices.

The data were examined to determine which samples had any chemical concentrations that exceeded one or more of the Washington state standards or NOAA guidelines. The toxicity test results were examined to determine in which samples the responses were statistically significant as defined above. The benthic data were examined subjectively to determine which samples did not support a diverse and abundant infauna community or in which it was composed primarily of pollution-tolerant taxa. Following classification of the chemical, toxicity, and benthic data, the spatial extent of sediment quality was summed for each of four categories that represented four combinations of chemical/toxicity/benthic results. High quality sediments were those in which no chemical concentrations exceeded any of the standards or guidelines, significant responses were not apparent in any of the toxicity tests, and the benthos included relatively large numbers of organisms and taxa, including pollution-sensitive taxa. Sediments with a significant result in one element of the triad 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 a Washington state standard or NOAA guideline, a significant outcome in at least one of the toxicity tests, and either a relatively depauperate benthos or one with an abundance of pollution tolerant taxa (or both). Estimates of the spatial extent of the four sediment quality categories based upon the triad of analyses followed the same procedures as applied separately to the chemistry data and the toxicity data alone.

Results

Incidence and Spatial Extent of Chemical Contamination

The spatial extent of chemical contamination relative to the critical values (state standards, NOAA guidelines) was summarized for the entire survey area (2363.3 km^2), for each of the six sampling regions (Table 1), and for each of five stratum types (Table 2). The data were summarized as the number and percentages of samples that exceeded the critical values (i.e., incidence of spatial contamination), the spatial area that these samples represented (as km^2), and as the percentages of the total area of each region or stratum type or total survey area (i.e., extent of spatial contamination).

The spatial extent of chemical contamination relative to the ERM values was similar (2.1%, 1.9%, 1.4%, and 0.9%) in four of the regions (Strait of Georgia, Central Sound, South Sound, Hood Canal, respectively). The percentage of area affected was lowest (0.2% and 0.0%) in the Whidbey Basin and Admiralty Inlet, respectively, as estimated with the ERM values. Overall, there were 39 samples in which one or more chemical concentrations exceeded an ERM value. These 39 samples represented an area of 31 km^2, or about 1.3% of the total survey area.

The degree of chemical contamination showed a larger range among the six regions when compared to the state SQS and CSL values. Relative to the state SQS values, contamination was most widespread in the Strait of Georgia, Whidbey Basin, Admiralty Inlet, and Central Sound regions (77%, 58%, 68%, 79% of those areas, respectively) than in the South Sound and Hood Canal regions (14% and 0.5% of those areas, respectively). Because the CSL values are higher than the respective SQS values, the spatial extent of contamination relative to the CSL levels was lower than when gauged to the SQS values. Nevertheless, the pattern among the regions was the same using either set of values.

The differences in the estimates of the spatial extent of chemical contamination relative to the ERMs and to the SQS/CSL values are attributable to differences in the numbers and kinds of chemicals for which these sets of values were derived. Notably, numerous samples had concentrations of three organic compounds (benzoic acid, phenol, and 4-methyl phenol) that were elevated relative to the state standards. ERMs were not derived for these substances, therefore, their presence could not be accounted for with those values. When the spatial extent of contamination was re-calculated after excluding these substances, the estimates were reduced considerably in the four regions (Strait of Georgia, Whidbey Basin, Admiralty Inlet, and Central Sound) in which they were highest (Table 1). For example, after excluding the data for these substances, the percentage of the Strait of Georgia area with concentrations that exceeded the SQS values was reduced from 77% to 10%. In all cases, the areas estimated to be contaminated when data for these substances were excluded ranged from 0.0% (Admiralty Inlet) to 10% (Strait of Georgia) relative to the SQS values. Based upon these data (i.e., SQS and CSL values with the three ubiquitous substances omitted), the areal extent of chemical contamination was highest in four regions (Strait of Georgia, Whidbey Basin, Central Sound, South Sound) and lowest in the two other regions (Admiralty Inlet and Hood Canal).

The spatial extent of contamination was estimated also using any one of the values (i.e., an ERM, SQS, or SQS/CSL) as the critical values. The results showed the same regional pattern as with the SQS and CSL values alone, especially with data for the three ubiquitous substances omitted. That is, the percentages of areas affected ranged from 5% to 10% in four regions (Strait of Georgia, Whidbey Basin, Central Sound, South Sound). The absolute areas affected were remarkably similar among these four regions (44, 31, 32, and 33km^2, respectively). In contrast, the areas affected ranged from 0.0% in Admiralty Inlet to 1.4% in Hood Canal. Among the 300 samples tested, there were 184 (61% of the total) in which one or more chemical concentrations exceeded one or more respective sediment quality values (i.e., an ERM, or SQS). These 184 samples represented a total area of about 1259 km^2, equivalent to 53% of the total survey area. This overall estimate of chemical contamination was reduced to 70 samples, representing 144 km^2 (6% of total survey area) with the data for the three ubiquitous chemicals excluded.

Most (177) of the 300 samples were collected in areas that were classified as either deep basins, passages, or rural bays (Table 2). The basin, passage, and rural strata combined represented a large majority (91%) of the total survey area and were expected to be least contaminated because of the effects of greater distances from sources and greater potential for dilution of toxicant concentrations. The remaining samples were collected in either industrial harbors or urbanized bays which, together, represented about 9% of the survey area. Sediments from these two strata types were expected to be the most contaminated due to their proximity to sources. A large majority of the samples (30 of 39) in which one or more chemical concentrations exceeded an ERM value were collected in one of the strata classified as an industrial harbor. These 30 samples represented 13% of the area classified as industrial harbor. Samples that were contaminated at levels greater than any one of the ERMs represented about 3% of both the urban bay and rural bay areas. None of the ERMs were exceeded in samples collected in either the deep basins or passages.

The largest percentages of samples in which one or more chemical concentrations exceeded either the SQS values (70%) or CSL values (59%) were collected in the industrial harbors (Table 2). However, because these strata generally were among the smallest, these samples represented only 23% and 18%, respectively, of the areas classified as harbors (i.e., the lowest percentages among the five categories). The spatial extent of contamination greater than the SQS and CSL values, calculated as percentages of the areas sampled, was greatest in the passages, followed by the basins and urban bays. That is, samples in which one or more of the SQS values or CSL values was exceeded represented 68% and 63%, respectively, of the area classified as passages. The spatial extent of contamination was consistently relatively low in the rural bays as compared to the urban bays, basins, and passages.

When the data for the relatively ubiquitous substances (benzoic acid, 4-methylphenol, and phenol) were excluded, the pattern changed. When these three chemicals were excluded from the calculations, the relatively high degrees of contamination by other substances in the industrial harbors (21% of area relative to the SQS values) and urban bays (16% of area) became more apparent. The relatively low degree of contamination by other substances (as compared to the SQS's) in the deep basins (0.5% of area) and rural bays (7% of area), and the intermediate degree in the passages (9% of area), also was apparent in these final calculations.

In summary, based upon these data and the three combined sets of critical values, the percentages of areas affected by chemical contamination (excluding estimates influenced by three ubiquitous substances) were greatest in the urban bays and industrial harbors, especially in the central, southern, and northern regions of Puget Sound. The percentages of the areas affected were consistently lower throughout the passages and rural bays, and lowest in the deep basins of the study area, particularly in Hood Canal and Admiralty Inlet.

Spatial Patterns in Chemical Contamination

As indicated in the estimates of the spatial extent of chemical contamination (Table 1), the concentrations of benzoic acid, and/or 4-methylphenol, and/or phenol were elevated relative to Washington state standards in most of the samples collected in the northern stations (Figure 8**.** The concentrations of these substances exceeded the respective SQS values in many samples collected throughout the area from the U.S./Canada border to Possession Sound (Appendix A). However, there were no readily apparent gradients or other patterns in the violations of the standards.

The sample collected at station 9 in the southern Strait of Georgia west of Blaine had high chemical concentrations in all four categories, including a mercury concentration that exceeded both the ERM and CSL values (Figure 8). Samples from three other stations (38 in Samish Bay, 64 in Skagit Bay, 85 in Possession Sound) had at least one phthalate concentration that exceeded a state SQS value. However, in all three cases chemical concentrations were below all or most guideline values in other samples from surrounding stations. Similarly, chemical concentrations exceeded one or more SQSs in two categories in a sample from an industrial waterway of Bellingham Bay, but other samples collected nearby were not as contaminated. One sample collected off March Point had relatively high chemical concentrations, but, again, there were no readily apparent gradients in concentrations as identified with this approach.

Samples from clusters of stations in northern Bellingham Bay, Port Susan, and mid-channel between Guemes Island and March Point appeared to be among the least contaminated, i.e., none of the concentrations exceeded the NOAA guidelines or state standards (Figure 8). However, in each case samples collected from other nearby stations had elevated concentrations of either benzoic acid/4-methylephenol/phenol or other substances.

All nine samples from inner Everett Harbor had elevated concentrations in at least one category and frequently in two to four categories. The concentrations of one or more PAHs exceeded their respective ERM values in all Everett Harbor samples except the one from station 91. In addition, the concentrations of arsenic, lead, copper, and zinc in the sample from station 94 exceeded their respective ERM values. The copper concentration in the sample from station 94 also exceeded the state CSL value. These elevated concentrations decreased remarkably in Port Gardner Bay.

In addition to the obvious gradient in chemical concentrations in the Everett Harbor/Port Gardner Bay area, there were several others in the central region (Figures 9 & 10). Concentrations of mercury were relatively high in all samples (stations 160 -165) collected in Sinclair Inlet, exceeding the ERM and/or CSL values in all samples (Figure 9). These high concentrations dropped considerably eastward beyond the mouth of the inlet. Similarly, two of the samples collected in Dyes Inlet were contaminated with mercury (the concentration exceeded the CSL value) and concentrations diminished eastward out of this bay.

Spatial gradients in contamination were readily apparent in both Elliott Bay and Commencement Bay (Figure 10). In Elliott Bay the samples collected in the lower Duwamish waterways and along the Seattle waterfront had the highest concentrations of mixtures of chemicals, often exceeding the guidelines in two to four categories in most samples. In the lower Duwamish River strata, mixtures of PAHs, PCBs, phthalates, phenols, and arsenic exceeded one or more sets of sediment quality values. Relatively high chemical concentrations continued northward along the Seattle waterfront. Concentrations of mixtures of PAHs, phenols, and mercury in many samples collected along the Seattle waterfront exceeded respective SQS, CSL, and/or ERM values. These relatively high concentrations eventually decreased westward into the deeper central and outer reaches of the bay and, again, into the central basin. However, mercury concentrations remained relatively high in some samples from the deeper mid-bay stations. Most of the samples collected in the Puget Sound central basin were not contaminated relative to the NOAA guidelines or state standards, excluding those for the three ubiquitous substances, which were commonly elevated (Figure 9).

In Commencement Bay, the spatial gradient was much more distinct than that observed in Elliott Bay. Samples from the industrial waterways were contaminated, whereas those from the deep central and outer reaches of the bay were not (Figure 10). Thus, relatively high chemical concentrations did not extend as far into the bay as in Elliott Bay. All three samples from the Thea Foss Waterway were contaminated in either two or three categories. Another sample from the Middle Waterway was contaminated in three categories. These samples had elevated concentrations of numerous chemicals, including many PAHs, several trace metals, phenols, PCBs, and phthalates. Concentrations of PCBs, hexachlorobenzene, and phenol were elevated in the Hylebos Waterway. Among the waterways sampled at Tacoma, the sediments collected in the Blair Waterway were the least contaminated.

The majority of samples (i.e., 79%) collected in the southern region were not contaminated (Figure 11). That is, none of the sediment quality values were exceeded in these samples. Scattered among these un-contaminated samples were nine stations in which the sediment samples had one or more chemical concentrations that exceeded one or more sets of guidelines or criteria. One sample each from Hale Passage, Nisqually Reach, Henderson Inlet, and Budd Inlet had elevated concentrations of only phenol, and/or benzoic acid, and/or 4-methyl phenol. Concentrations of other chemicals exceeded the respective ERM, SQS, and/or CSL values in one or more samples each from southern Pickering Passage, Totten Inlet, Budd Inlet, and Port of Olympia.

Much like the samples from the southern region, most samples collected in Hood Canal and near Port Townsend were not highly contaminated (Figure 12). Of the 27 samples analyzed from these areas, only 8 had elevated chemical concentrations. Five of the six samples collected near Port Townsend had relatively high concentrations of 4-methylphenol, but no other chemicals. Low molecular weight PAHs were elevated in one sample from Port Ludlow and another sample from Port Gamble. Another sample from Port Gamble had a high concentration of silver. Chemical concentrations were less than the guidelines and criteria throughout Hood Canal and adjoining Dabob Bay and Quilcene Bay.

In summary, most of the samples from Admiralty Inlet, the central basin, Port Madison, Colvos Passage, the Bainbridge Island basin, and Quartermaster Harbor were not contaminated relative to three sets of guidelines and standards. Therefore it was apparent that the central basin and other waterways near relatively undeveloped lands either had not received major inputs of contaminants or were not depositional areas in which these chemicals were retained in sediments in high concentrations. In contrast, contaminant concentrations generally were highest in Everett Harbor, Sinclair Inlet, lower Duwamish waterways, inner Elliott Bay, and the Thea Foss and Hylebos waterways at Tacoma; all of which are areas nearest known sources.

Incidence and Spatial Extent of Toxicity

There were very few consistent patterns in the spatial extent of toxicity among the six regions of the study area, reflective of the generally low degree of toxicity in the four different tests (Table 3). Results of the amphipod survival tests were highly significant in only one sample (collected in Port Washington Narrows where it represented <0.1% of that region). The spatial extent of highly significant responses in the sea urchin tests of 100% pore water was greatest in Hood Canal as both absolute area (39 km^2) and percentage of the regional area (12%). However, none of the samples from Hood Canal had a highly significant response in tests of 50% porewater concentrations and the spatial extent estimates were greatest in the Strait of Georgia (2.6% of the area) and South Sound (1.1% of the area). In the Microtox tests, the samples with mean EC50's <80% of controls represented the largest proportion of the Strait of Georgia region (100%), followed by the Whidbey Basin region (96% of area), and South Sound (84% of area). The percentages of areas affected were lowest (31-49%) in the Central Sound, Hood Canal, and Admiralty Inlet regions. Based on the more realistic critical value of <0.51 mg/L, the areas affected ranged from 0.0% in Admiralty Inlet and Hood Canal to 2.0% in the Strait of Georgia. There were no samples in the entire survey area in which Microtox results fell below the more severe critical value of < 0.06mg/L.

In the HRGS assays, there was a total of 134 samples in which the outcome was greater than 11.1 ug/g, indicative of responses above background levels. The samples in which results were greater than 11.1 ug/g represented 45% of the respective areas in the Central Sound and South Sound regions, followed by the Hood Canal region (25% of that area). The regions with the smallest areas affected were Admiralty Inlet, Strait of Georgia, and Whidbey Basin (0 – 3% of respective areas). There were considerably fewer samples (48 in the entire survey) in which HRGS assay results exceeded the upper critical value of 37.1 ug/g, 40 of which were collected in the Central Sound region. Notably, none of the results of this test exceeded 37.1 ug/g in the samples from Admiralty Inlet and the Strait of Georgia and there was only one such outcome in Hood Canal.

There were no samples in which the critical values for all four tests indicated significant results. In contrast, there were 144 samples in which any one of the tests indicated a significant result. These 144 samples represented about 27% of the total survey area. The largest percentages of areas affected in any one of the tests were in the South Sound and Central Sound regions (46% and 45% of those areas, respectively), followed by the Hood Canal region (25% of that area). The smallest percentages were apparent in the Admiralty Inlet, Whidbey Basin, and Strait of Georgia regions (0 – 9% of areas). It should be noted that these estimates would be much smaller if the more severe critical values for the Microtox tests (i.e., <0.06 mg/ml) and HRGS assays (i.e., >37.1 ug/g) had been used.

Toxicity generally was most pervasive in the industrial harbor strata as compared to the urban bays, passages, basins, and rural bays (Table 4). Mean EC50's in the Microtox tests were <0.51 mg/ml in 12% of the samples from the harbor stratum (representing 3% of the area) and 2% of the urban bay stations (7% of the area). In contrast, none of the EC50's for the samples from the passages, basins, or rural bays were that low.

HRGS assay results exceeded 11.1 ug/g in 54 of the harbor samples, representing 91% of the area and exceeded 37.1 ug/g in 36 samples that represented 36% of the area. In both cases, these were the highest percentages of areas affected among the five stratum types. The percentage of area affected in any of the four tests performed (91% of the area) was highest in the harbor stratum type, as compared to a range of 4% to 52% in the other stratum types (lowest in passage stratum; 4% of total study area). Test results were significant in all three tests, excluding those performed with the amphipods, in 6 samples that represented 1.2% of the area as compared to 0% in all other stratum types. However, results of the urchin fertilization tests of 100% pore water were significant in 19 harbor samples that represented 6% of the area, a somewhat lower percentage than in rural bays (12%) and urban bays (8%). Also, the area affected (3%) in samples with Microtox EC50s <0.51 mg/L was somewhat lower in harbors than in the urban bays (6%).

The percentages of areas affected in the tests often were second highest in the urban bays and lowest in the basin, passage, or rural bay stratum types. An exception, however, the area affected in the urchin fertilization tests in 100% pore waters, was highest in the rural bays, where 9 samples represented about 12% of that area.

In summary, the data combined from all four tests indicated that highly significant responses were not pervasive in this study of Puget Sound. None of the samples had highly significant responses in all four tests. Percent amphipod survival was significantly reduced in only one sample. Excluding the amphipod survival tests, there were only six samples in which responses in all three of the remaining tests were highly significant, four from Whidbey Basin (Everett Harbor), and one each from the Central Sound (Thea Foss Waterway) and South Sound (Port of Olympia – Inner Budd Inlet) regions. All six of these samples were collected in the industrial harbor stratum type and represented only 0.8 km^2, or 0.03% of the total survey area. The area represented by 144 samples in which any one of the four tests indicated a significant response constituted only 642 km^2 (27% of the total survey area). Significant responses were most frequent in the HRGS and Microtox tests. Both are tests of organic solvent extracts, performed either with a cultured bacteria or cell line, therefore, not a toxicity test indicative of bioavailable chemicals. HRGS results most frequently were significant in the Central Sound, South Sound, and Hood Canal regions. Responses in the HRGS test greater than 37.1 ug/g were observed only in 48 of the 300 samples; the majority of which were collected in the industrial harbors of the Central Sound and South Sound regions. Sediment quality, based upon data from these four tests, was highest in the rural bays, deep basins, and passages, particularly in the Whidbey Basin, Hood Canal, and Admiralty Inlet regions.

Spatial Patterns in Toxicity

To identify possible spatial patterns, such as gradients, in toxicity among the individual sampling stations, results of each of the four tests were plotted on base maps, using symbols to depict either a significant or non-significant response. A white circle at a sampling location indicates a lack of significant response in all four tests. A black wedge in any of the four quadrants of the circle indicates a significant response as defined in the methods section and figure legends (Figures 13-17).

As indicated by the estimates of the spatial extent of toxicity, the majority of samples (156/300) failed to induce significant responses in any of the four tests (Table 3); thus, indicating relatively good concordance in identifying samples as not toxic. This lack of toxicity was very apparent in most samples (78 of 100) from the Strait of Georgia and Whidbey Basin regions, notably excluding those from Everett Harbor (Figure 13). Non-toxic conditions were observed in most of the samples from the southern Strait of Georgia, Samish Bay, Port Susan, and in the bays and basins east of Whidbey Island. The exceptions were the 9 samples from Everett Harbor in which two or three significant responses were recorded and 13 samples collected from scattered locations in which only one (never two or more) tests indicated a significant response. The samples from Everett Harbor were among the most toxic in the overall Puget Sound survey. All 9 of these samples indicated a significant response in either two or three of the tests, always including the urchin fertilization and HRGS tests. The Microtox tests also were significant in four of the Everett Harbor samples. High toxicity in this area diminished into Port Gardner Bay and southward into the region of the central basin off Edmonds. Test results were significant in any one of the tests in 13 samples from scattered locations including: Blaine Harbor, Bellingham Bay, Padilla Bay, March Point/Fidalgo Bay, Skagit Bay, and Port Gardner Bay. As indicated by the numbers of tests showing toxic responses, there were no readily apparent gradients of high to low toxicity among these sampling locations.

In contrast, farther South in the central Puget Sound region, many more samples (95 of 128) indicated significant responses in one or more tests (Figures 14, 15). Several spatial gradients were apparent in the results, all of them associated with urban bays and/or industrial harbors. A significant response in one test (usually the HRGS test) was recorded for all samples collected in inner Liberty Bay, Sinclair Inlet, and 4 of 6 stations in Dyes Inlet, and diminished gradually eastward into Port Washington Narrows toward the central basin. All three samples from Eagle Harbor on Bainbridge Island induced a significant HRGS response along with two from the central basin collected near the mouth of this bay.

Amphipod survival was highly significant (i.e., <80% of control survival) in one sample collected in the entire study. This sample was collected in a small cove adjoining the outer reach of Dyes Inlet (Figure 14). The response in the HRGS test was significant in this sample also.

The majority of samples collected in the two largest urban bays of Puget Sound, Elliott and Commencement Bays, showed significant responses in at least one of the tests (Figure 15). Collectively, among the 58 samples tested from both bays, there were only three in which all the toxicity test results were negative. Significant responses were observed in the HRGS and/or urchin tests in samples from the lower Duwamish River, off the Seattle waterfront and into central and outer Elliott Bay. One sample collected off Duwamish Head and two collected off

Magnolia were non-toxic in all tests, perhaps, indicating a slight loss in the degree of toxicity test responses westward toward the central basin. A similar situation was apparent in much of Commencement Bay and its adjoining industrial waterways. As indicated in the HRGS tests and occasionally the Microtox and/or urchin tests, significant responses were widespread in this urbanized bay. The sample collected in the inner most station in Thea Foss Waterway induced significant responses in three of the tests. The HRGS response in this sample was the highest observed in the entire study. The degree of response diminished somewhat northward into the outer reaches of Commencement Bay and, again, into the basin waters surrounding Vashon Island (Figure 14).

Significant responses occurred in samples from scattered locations in the inlets and basins of Southern Puget Sound and in two industrialized harbors, Budd Inlet and Shelton Harbor (Figure 16). Significant responses were apparent in all three samples from Port of Olympia. The sample from the inner-most station induced significant responses in three of the tests. The HRGS response was significant also in the three samples from outer Budd Inlet. All six samples from the Oakland Bay/Shelton Harbor area had significant HRGS responses. Samples from Nisqually Reach, Carr Inlet, Case Inlet, and Pickering Passage were among the least toxic in the southern basin.

The majority of samples (21 of 27, 78%) from Hood Canal and Port Townsend area indicated non-significant responses in all four tests (Figure 17). The exceptions were samples from Port Ludlow, Port Gamble, Dabob Bay, and the southern reach of Hood Canal, all of which had significant responses in the HRGS test and three of which also had significant responses in the urchin test.

In summary, the least toxic conditions were observed in southern Strait of Georgia/outer Boundary Bay, Cherry Pt, outer Bellingham Bay, Guemes Channel, Samish and Padilla Bays, Whidbey Basin/Saratoga Passage, the northern reach of the Puget Sound central basin, Port Gardner Bay, Case and Carr inlets, Port Townsend Bay, Quilcene Bay, and portions of Hood Canal. The samples that indicated the most significant responses were those from inner Everett Harbor, inner Sinclair Inlet, lower Duwamish River, inner Elliott Bay, Thea Foss Waterway, Port of Olympia, and Dabob Bay.

Spatial Distribution of Benthic Indices

Mean and median values for the nine indices were calculated for each of the six sampling regions (Table 5) and stratum types (Table 6) to contrast the ranges in values between the two sets of geographic categories. The data indicated a great amount of heterogeneity (high standard deviations) in the benthic indices within each region and each stratum type. Standard deviations often approached, equaled, or exceeded mean values. However, there were a few consistent patterns in mean and median values for these data. In nearly all cases, the highest means and medians in the indices were apparent in samples from either the Strait of Georgia or Admiralty Inlet. The median indices of total abundance, numbers of taxa, evenness, dominance, and median abundance of arthropods, echinoderms, and molluscs were highest in one or the other of these two regions. In contrast, the lowest mean and median values for most indices occurred in samples from Whidbey Basin and South Sound. Significantly, the abundance of all organisms, the numbers of species, and the abundance of arthropods (often relatively sensitive to stressors such as toxic chemicals) were very low in these samples. Ratios between the highest and lowest medians were 2.1 (numbers of taxa), 3.4 (SDI), 8.2 (arthropod abundance), and 20.5 (echinoderm abundance).

The patterns in mean and median values in the benthic indices among the different stratum types were less clear (Table 6). Total abundance generally was higher in samples from the harbors and urban bays than elsewhere and lowest in samples from the basins. High total abundance probably was attributable, in large part, to the presence of numerous annelids, which were most abundant in harbors and urban bays and least abundant in the basins. Generally, the numbers of taxa were highest in samples from the urban bays and passages and lowest in rural bays. Indices of evenness and dominance were highest in the passages and basins, lowest in the harbors. Reflective of the high total abundance of infauna in the samples from urban bay sites, the abundance of annelids, arthropods, molluscs, and echinoderms were relatively high in the same samples. In contrast, the abundance of annelids, molluscs, and echinoderms were very low in samples from the basins. The ratios between highest and lowest medians were 1.4 (numbers of taxa), 2.6 (SDI), 1.7 (arthropod abundance), and 8.5 (echinoderm abundance). Thus, these data suggest that there were greater ranges in benthic index values between the regions than between the stratum types. They also indicated a more consistent pattern among regions (with highest values often in Admiralty Inlet or Strait of Georgia) than among stratum types.

Indices of total abundance of identifiable taxa, total numbers of taxa, Pielou's Evenness (J') index, and Swartz's Dominance Index were selected to represent the spatial patterns in the benthic data. Experience has shown that these indices usually decrease as stresses increase; however, in some cases they will increase from sandy sediments in which there is little food available to sediments high in silts and clays and elevated organic carbon content in which there is much more food. In such fine-grained sediments that are highly contaminated with toxicants, all measures of benthic diversity and abundance ultimately are expected to eventually decrease. In some cases these indices can decrease precipitously as taxa and individuals are no longer capable of tolerating the stressful conditions.

A comparison of the benthic infaunal indices among the northern Puget Sound stations indicated a wide range in values from those in the upper 75% quartile to those in the lower 25% quartile (Figure 18). Most of the samples collected in the southern Strait of Georgia had indices of diversity and abundance in the middle quartiles. In contrast, a number of samples from nearby stations in the mouth of Boundary Bay, Drayton Harbor at Blaine, and inner Bellingham Bay had benthic index values that were within the lower quartile. The infauna at three stations in Bellingham Bay had three indices in the lower 25% quartile, indicating relatively low numbers of taxa, evenness, and numbers of dominant taxa. With some exceptions, typical of the spatial heterogeneity in benthic indices, the measures of diversity and abundance tended to increase southward from Bellingham Bay toward Samish Bay and Padilla Bay. Generally, the benthic infauna was relatively abundant and diverse in the vicinity of March Point and Anacortes. Farther south, conditions were heterogeneous with many samples collected in Oak Harbor, Possession Sound and Saratoga Passage (east of Whidbey Island) indicating relatively low abundance and diversity. Similar benthic conditions were apparent also in Port Susan with one station indicating low values in three indices. The indices of total abundance, taxa richness, and dominance were low in three samples from inner Everett Harbor and all four indices were low in a fourth sample from the harbor. The benthic conditions gradually improved southward into Port Gardner Bay.

Benthic indices indicated heterogeneity and equally wide ranges in response in the central Puget Sound stations (Figure 19). Benthic diversity and abundance were relatively low in some of the samples from inner Sinclair Inlet, inner Liberty Bay and inner Dyes Inlet and tended to increase eastward into the Bainbridge basin, Rich Passage, and the flats surrounding Blake Island. There were two samples from Sinclair Inlet in which three indices were in the lower 25% percentile of the data distributions. Benthic index values were heterogeneous and patchy in Colvos Passage and East Passage surrounding Vashon Island.

In the Duwamish Waterways, many of the samples had relatively low evenness and dominance indices, but high or intermediate indices of total abundance and numbers of taxa (Figure 20). Benthic indices tended to increase somewhat from the Duwamish into Elliott Bay, but this was not a clear and consistent pattern. There was little uniformity among indices at any given station and there was no clear spatial pattern in benthic indices in Elliott Bay. Equally non-uniform and heterogeneous conditions were apparent in Commencement Bay where many samples had benthic indices in the intermediate ranges.

In the inlets and basins of southern Puget Sound, the benthic indices were depressed in most of the samples from Port of Olympia and outer Budd Inlet (Figure 21). All four indices were in the lower 25% quartiles in samples from three Port of Olympia stations. Benthic samples from most other southern Puget Sound inlets (Henderson, Eld, Totten, and Hammersley) also had relatively low indices of abundance and diversity. These indices were somewhat higher in samples from Case and Carr inlets and from the Nisqually Reach; however, some samples from these areas also had relatively low benthic indices.

Benthic indices were as variable and heterogeneous in the Hood Canal region as in the other regions (Figure 22). Eight samples collected from Dabob Bay to the terminus of Hood Canal were low in taxa numbers and total abundance, and one (Lynch Cove), was low in all four indices. Indices measured from the three stations in northern Hood Canal, three station in Quilcene Bay, and two stations in Port Ludlow, had relatively high values. All three stations in Port Gamble indicated low evenness and/or dominance values, and one station in Port Ludlow had mid or low values for all four indices. All samples collected near Port Townsend, however, had benthic indices in the upper or intermediate quartiles, indicative of relatively high diversity and abundance.

In summary, most of the nine indices of benthic abundance and diversity generally were highest in samples from the Strait of Georgia and Admiralty Inlet. Individual samples with relatively high benthic index values were collected in Padilla Bay, eastern Guemes Channel near March Point, Port Madison, the entrance to Sinclair Inlet, the flats surrounding Blake Island, Port Townsend Bay, and a few scattered locations elsewhere. The nine benthic index values generally were lowest in the Whidbey Basin, Central Sound and South Sound regions, occasionally, but not consistently in the urbanized bays, including Bellingham Bay, Everett inner harbor, inner Sinclair Inlet, the lower Duwamish River waterways, Port of Olympia, several other South Sound inlets, and outer Hood Canal.

Sediment Quality Triad Analysis: Spatial Extent of Degraded Conditions

By combining the results of the chemical, toxicity, and benthic analyses, a weight of evidence index was generated to classify the overall quality of the sediment samples. Equal weight was given to the data from each element of the triad of measures. Samples were classified as *high quality* (i.e., least degraded) when none of the chemical concentrations exceeded the critical values, none of the results of toxicity testing were significant, and the benthic indices indicated that the infaunal assemblages were diverse and abundant and/or supported sensitive species. In contrast, samples were classified as *degraded* when chemical concentrations exceeded one or more sediment quality values, significant results were observed in at least one toxicity test, and the benthic indices indicated that the infauna was depauperate (i.e., low abundance and numbers of taxa) and/or was dominated by pollution-tolerant species. Samples of intermediate quality were classified as either *intermediate/high* or *intermediate/degraded* when one or two elements, respectively, of the triad exceeded critical values. These triad indices were summarized for the stations grouped both by the six regions and the five stratum types defined above, excluding the data for nickel, benzoic acid, phenol, and 4-methyl phenol. Therefore, the results reported in this report differ somewhat from a previous analysis of these data in which the concentrations of the three organic compounds (but, still excluding nickel) were considered in the triad evaluations (Puget Sound Water Quality Action Team, 2002).

Sediment Quality in Total Study Area

Of the 300 samples analyzed, most (138) were classified as being of high quality (Table 7). These 138 samples comprised 46% of the total number of samples, but represented over 68% of the total survey area, thereby indicating that many of them were collected in relatively large strata. There were 37 samples classified as degraded with the triad of measures. Because many of them were collected in relatively small strata, they represented only 23 km^2 or about 1% of the area surveyed. The percentage of the survey area that the samples represented declined markedly as the quality of sediments decreased among the four categories; i.e., from 68% (high) to 27% (intermediate/high) to 4% (intermediate/degraded) to 1% (degraded).

Toxicity test results contributed the most to classification of samples in the intermediate/high category, indicating significant responses in at least one test in 68 samples that represented about 22% of the total survey area (Table 7). Elevated chemical concentrations contributed 13 samples (representing 4% of the area) to this classification whereas relatively low benthic indices contributed only 4 samples that represented less than 1% of the area. In the intermediate/degraded classification, the combinations of elevated chemical concentrations/significant toxicity and poor infauna/significant toxicity contributed 19 and 20 samples respectively. These 39 samples, together, represented 4% of the total survey area.

Sediment Quality Triad by Region

The majority (26 of 37; 70%) of the samples classified as having degraded sediment quality were collected in the Central Sound region, where they represented about 19 km^2 or 3% of that area (Table 7). The eight samples from the Whidbey Basin (including Everett Harbor) with these characteristics represented <1% of that area. Samples from one or two stations each with these characteristics were collected in the Hood Canal and South Sound regions respectively, in both cases representing less than 1% of those areas. No degraded samples were found in the Strait of Georgia or the Admiralty Inlet regions.

The majority (25 of 40, 63%) of samples with intermediate/degraded (i.e., two elements of the triad indicative of degraded) conditions also were from the Central Sound region (Table 7). All of these 24 samples had either elevated chemical concentrations and significant toxicity (14 samples) or poor infauna and significant toxicity (11 samples). Eight samples from the South Sound region had equivalent intermediate/degraded conditions, where they represented 63 km^2 or about 16% of that area. Seven other samples with two of the triad measures indicating degraded conditions were collected in the Strait of Georgia (3), Whidbey Basin (2), and Hood Canal (2) where they represented about 1-3% of those respective areas. In nearly all cases, the sample classifications were as a result of either the chemistry/toxicity data or the infauna/toxicity data.

Based upon these measures of sediment quality and the samples that were collected in this survey, the highest quality sediments were collected in the Admiralty Inlet region; all nine samples collected there were classified as high quality. Following Admiralty Inlet in sediment quality, were the Strait of Georgia region and the Hood Canal region (98% of respective areas classified as either high quality or intermediate/high quality). Samples from the Strait of Georgia were classified as intermediate/high quality primarily because of elevated chemistry or significant toxicity, whereas those from Hood Canal had either significant toxicity or depressed infauna.

Sediment Quality Triad by Stratum Type

Spatial extent data were then summarized for each of the 5 previously defined strata (Table 8). The largest percentage of samples (30 of 37, 81%) with degraded sediment quality (i.e., significant results in all three triad elements) came from the industrial harbor stratum type (Table 8). These 30 samples represented about 15% of the area classified as industrial harbors. Only 5 samples from urban bays and 2 samples from rural bays had characteristics of lowest sediment quality. Those samples represented about 7% and 0.4%, respectively, of the areas encompassed in each stratum type. None of the samples collected in strata categorized as basins and passages were classified as highly degraded.

Half of the samples (20 of 40, 51%) classified as intermediate/degraded in quality were, also, collected in strata identified as industrial harbors (Table 8). Therefore, the spatial extent of these intermediate/degraded conditions was highest (encompassing 74% of area) in the urban harbor stratum. The percentages of area represented by such conditions were much less in the urban bays (12%), rural bays (<4%), passages (<1%), and basins (0%). The classification of samples in this category was consistently attributable to combinations of high chemistry/ toxicity and poor infauna/toxicity. One sample from a rural bay was classified in this category based upon a combination of high chemistry and poor infauna.

Among the 85 samples classified as intermediate/high quality, many were collected in urban bays (29), rural bays (23), and basins (17), where they represented about 43%, 33%, and 32% of those respective stratum types (Table 8). A total of 57 samples (67% of 85 total) in this classification from these three stratum types were attributable to significant toxicity. Intermediate/high quality conditions encompassed considerably smaller percentages of the harbor strata (<4%) and the passage strata (<12%) areas.

The spatial extent of highest quality conditions was greatest (88% of the area) in the passage stratum type, followed by the basins (68%) and rural bays (63%) (Table 8). These conditions were least pervasive in the urban bays (39% of area) and industrial harbors (7% of area). Only 4 samples (<3%) of the 138 samples classified as high quality were collected in the harbors and 17 (12%) were collected in the urban bays.

In summary, the triad of analyses confirmed the observations made with the individual measures of sediment quality that degraded conditions were most pervasive, i.e., encompassed the largest percentages of areas, within the industrial harbors and urban bays, particularly in the Central Sound. There were 37 samples classified as degraded based upon concordant information from the triad of analyses, but they represented an area of only 23 km^2, or 1% of the total survey area. Intermediate sediment quality (either one or two elements of the triad with significant results) also was most pervasive (78% of area) in the harbors, followed by the urban bays (55% of area), especially in the South Sound (52% of area) and Central Sound (43% of area). Highest sediment quality was most apparent in the deep basins, passages, and rural bays, particularly in the Strait of Georgia, Admiralty Inlet, and Whidbey Basin. The 223 samples that were classified as having highest quality or only slightly degraded quality, together, constituted a large majority (95%) of the total survey area.

Sediment Quality Triad Analysis: Spatial Patterns

Results of the triad of analyses were summarized on the base maps for each station to identify any spatial patterns in relative sediment quality (Figures 23-27). Shaded symbols were used to depict the presence of high quality, intermediate/high quality, intermediate/degraded quality, or degraded quality sediments. These analyses were performed excluding the information for nickel, benzoic acid, phenol, and 4-methyl phenol. Detailed chemical, toxicity, and benthic data described for the degraded stations in each region are compiled in Appendix A.

There were eight sampling stations in the northern region, all in Everett Harbor, in which degraded conditions were apparent in the sediments with all three elements of the sediment quality triad (Figure 23, Appendix A). Results in two of the triad elements were significant in the ninth of nine sampling stations in the harbor. Concentrations of PAHs, PCBs, phenols, benzoic acid, copper and other trace metals were elevated in some or all nine samples. The mean ERM quotient for sample number 86 was very high (1.77) and those for the remaining samples were moderately high (0.3 to 0.9). Total organic carbon concentrations were relatively high in these samples (range: 4.5% to 9.9%), which could inhibit or preclude the bioavailability of these potentially toxic substances. However, significant responses were apparent in one or more toxicity tests in all nine samples. Results of the urchin fertilization tests were highly significant in all nine samples with fertilization success in 100% pore water ranging from <10% in five samples to 68% in the sample from the harbor entrance. Results of the cytochrome P450 HRGS assays were significant in all nine samples with enzyme induction ranging from 26 ug/g in the sample from station 89 to >100 ug/g in three samples. In exploratory analyses of selected samples, relatively high concentrations of dioxins and furans (TEQ 110 pg/g) were discovered in the sample (#86) from the innermost station and were major contributors to the HRGS induction. In some samples, only four taxa of infauna were found and as few as 1-3 taxa were dominant in four samples. Taxa numbers were low in all samples. The benthic infauna was dominated in many samples by opportunists such as Capitella capitata, Prionospio lighti, and Macoma carlottensis. Crustaceans and echinoderms generally were absent in these samples. Indices of diversity and abundance generally improved from the head of the harbor to its entrance (Appendix A).

Samples with intermediate/degraded conditions (i.e., two of the triad elements were significant) were collected at two stations each in inner Bellingham Bay and in the vicinity of Anacortes/March Point/Padilla Bay, and at one station in Port Gardner Bay (Figure 23, Appendix A). Samples in which degraded conditions were not apparent (i.e., high quality) or were observed in only one element of the triad (i.e., intermediate/high quality) were scattered throughout much of this region.

In the central region, the triad analyses indicated that the degraded conditions occurred in samples from inner Sinclair Inlet, inner Dyes Inlet, lower Duwamish waterways, inner Elliott Bay, and the Hylebos and Thea Foss waterways (Figures 24, 25 and Appendix A). All six samples from Sinclair Inlet had mercury concentrations that exceeded the ERM and/or SQS/CSL values. The concentrations of benzoic acid exceeded both the SQS and CSL values in all six samples. Mean ERM quotients ranged from 0.3 to 0.6, indicating slightly elevated concentrations of chemical mixtures. HRGS responses were moderately elevated in all six samples, ranging from 28 to 65 ug/g, urchin fertilization was significantly depressed in one sample. Benthic infauna indices differed considerably among the six stations. The numbers of taxa at each station were relatively high (range: 21-53); however, the numbers of dominants were low (range: 2-7). At some stations, the relatively sensitive arthropods and echinoderms were either absent or rare, but at other stations they were abundant. Dominants at most stations included pollution tolerant taxa, including Aphelochaeta spp, Nephtys cornuta and Prionospio pinnata.

Samples from two stations in inner Dyes Inlet were classified as degraded (Figure 24). The SQS values for benzoic acid and benzyl alcohol were exceeded in both samples and the CSL value for mercury was exceeded in one of them. The HRGS responses (28 and 30 ug/g) were elevated in both samples. Both samples had only 4 dominant taxa and, although arthropods and echinoderms were abundant, several pollution tolerant taxa, including Aphelochaeta spp also were abundant (Appendix A).

Eleven samples from Elliott Bay/lower Duwamish River were classified as degraded in the triad analyses (Figure 25, Appendix A). Mixtures of PAHs, PCBs, 4-methylphenol, and other organic compounds were elevated above critical values in all or most samples along with mercury and arsenic in a few samples. Mean ERM quotients were high (range: 0.4 to 3.9), indicative of the presence of mixtures of substances in relatively high concentrations. Responses in the HRGS assays were uniformly high (range: 47 – 153 ug/g) in these eleven samples and percent urchin fertilization was significantly depressed in many of them. In the benthic samples from these stations, the numbers of taxa identified often were high (>40) and total abundance, while variable, often was very high (400 to 1600 animals). However, the numbers of dominant taxa often were very low (≤5) and the arthropods and echinoderms were either present in low numbers or absent. The echinoderms were consistently absent in the most contaminated samples from inner Elliott Bay and the lower Duwamish River channels. Usually the pollution tolerant taxa Aphelochaeta sp., Axinopsida serricata or Euphilomedes spp. were dominant.

Seven stations in the industrial waterways at Tacoma were classified as degraded in these analyses (Figure 25). Among these seven stations, the sample from near the shoreline of inner Thea Foss waterway (#294) was remarkably different from the others. The mean ERM quotient was 4.3 in this sample, the highest value observed in the study. Concentrations of numerous PAHs were elevated above NOAA guideline and/or state criteria levels and were accompanied by high concentrations of lead, mercury, phenols, phthalates, and PCBs. The response in the HRGS assay (1995 ug/g) was the highest observed in the study. Responses in the sea urchin (29% fertilization) and Microtox (0.3 mg/ml) tests were significant. The numbers of infaunal taxa and organisms, while not remarkably depressed, included no echinoderms and only 36 arthropods. Pollution tolerant molluscs were abundant. The other two samples from Thea Foss Waterway were contaminated with mixtures of PAHs above ERM and SQS values and induced high responses in the HRGS assays (356 – 529 ug/g). Sediments at these two locations supported infaunal assemblages low in evenness (0.4 – 0.6), low in dominant taxa (3 – 8), mostly the pollution tolerant Aphelochaeta spp. and Axinopsida serricata. The sample from station 299 (Middle Waterway) was highly contaminated (mean ERM quotient: 1.1) with mixtures of many PAHs along with arsenic, copper, and mercury. The HRGS response was elevated (120 ug/g). The benthic sample was similar to those from the Thea Foss Waterway, i.e., low indices of evenness and dominance and dominated by Aphelochaeta spp. The sediments from three stations in the Hylebos Waterway also were contaminated (PCBs, hexachlorobenzene), induced high responses in the HRGS assays (73 – 176 ug/g), and supported benthic assemblages with low indices of evenness, dominance and dominated by pollution tolerant animals (i.e., Aphelochaeta spp and Axinopsida serricata).

In the central region, the degraded conditions observed in these industrial harbors and urbanized bays gradually improved seaward into the central basin (Figures 24, 25). Most stations in the middle of Elliott Bay indicated impairment in two elements of the triad (usually elevated chemistry and HRGS response), while most in the central basin, Bainbridge basin, and outer Commencement Bay indicated impairment in only one parameter or in none. Intermediate/ degraded conditions were apparent in samples from Tacoma Narrows and five other locations scattered throughout the central region. High and Intermediate/High quality conditions were apparent throughout much of the central basin, Port Madison, Liberty Bay, the flats surrounding Blake Island, and the entrance to Sinclair Inlet.

In the southern region, one of the three samples from the Port of Olympia had degraded quality and the other two were intermediate/degraded based upon the triad of analyses (Figure 26). Sediments from station 243 were contaminated with a phthalate ester and benzoic acid and the responses were highly significant in the sea urchin, Microtox, and HRGS tests. No infaunal organisms were observed in the benthic sample from this location – one of only two such benthic samples in the study. No infauna was found at station 242 – the other station in the study that was azoic. At the third of the Port of Olympia stations, the sediments supported only 123 organisms belonging to 18 taxa, most of which were pollution-tolerant polychaetes. Samples from two other locations in Port of Olympia, as well as three samples from Shelton Harbor, had intermediate/degraded quality. Elsewhere in the southern region, most samples indicated high quality or intermediate/high quality conditions.

High and intermediate/high quality conditions, roughly comparable to those in much of the southern region, were also apparent in much of Hood Canal and vicinity (Figure 27). The exceptions were samples from Port Gamble and Port Ludlow, where degraded and intermediate/degraded conditions, respectively, were observed in two samples each. In Port Gamble, one station had elevated concentrations of PAHs, while the other had a high concentration of silver. Both had significant responses in the HRGS assay and the urchin fertilization test was significant in one of them. The abundance of the benthic infauna was very high in both stations; however, the infauna was dominated almost exclusively by Aphelochaeta spp. The relatively poor conditions in both Port Gamble and Port Ludlow improved remarkably seaward of these bays in the mouth of Hood Canal and Admiralty Inlet (Figures 24, 27).

Mean and median benthic indices were compared among the sampling stations that were grouped into each of the four categories of triad results to help identify which indices, if any, were most often indicative of degraded conditions (Table 9). Average indices of evenness and dominance were lowest in the degraded sediments and highest in the sediments with high quality. Both indices were intermediate in the two intermediate classifications. Differences in evenness and dominance among these classifications largely were a function of differences in abundance and numbers of taxa of arthropods, echinoderms, and miscellaneous taxa – all of which were most abundant in high quality sediments and least abundant in degraded sediments. In contrast, the numbers of annelids was highest in the degraded sediments and lowest in the high quality sediments, whereas the abundance of molluscs did not differ remarkably among the four categories.

In summary, based upon this review of the triad of data, areas with the highest sediment quality included much of Admiralty Inlet, Port Gardner Bay, Port Madison, the entrance to Sinclair Inlet, the flats surrounding Blake Island, and Hood Canal; and parts of Carr Inlet, Case Inlet, and Nisqually Reach. The sediments in these areas did not have chemical concentrations that exceeded effects-based guidelines or criteria, did not induce significant responses in any of the four toxicity tests, and supported a taxa-rich and abundant infauna, often including many arthropods, echinoderms and other sensitive taxa. Based upon these data, the areas with poorest sediment quality included the inner Everett Harbor, inner Sinclair Inlet, Dyes Inlet, the lower Duwamish River waterways, inner (eastern) Elliott Bay, the Thea Foss and Hylebos waterways at Tacoma, Port of Olympia, and Port Gamble. Sediments with the poorest sediment quality were contaminated with mixtures of chemicals, the composition of which differed among sampling locations.

The toxicological significance of the chemical mixtures was indicated by significant responses in one or more laboratory toxicity tests. In turn, the ecological relevance of the toxicity tests was confirmed by indices of benthic community composition. Sediments of poor quality supported infauna assemblages that were low in numbers of taxa and indices of evenness and dominance, frequently because the annelids were dominant and the arthropods, echinoderms, and miscellaneous taxa were relatively low in numbers of species and abundance. In an extreme condition, sediments from two locations in Olympia were azoic.

Discussion

In the three-year study summarized in this report, analyses were conducted on 300 sediment samples collected to represent conditions throughout much of Puget Sound. Samples were collected in regions distant from sources of toxicants, in the deep basins, in the mouths of rivers, and in industrialized harbors. The stratified-random, probabilistic sampling design was similar to those used in estuarine sediment quality assessments conducted elsewhere in the U.S. by NOAA (Long et al., 1996) and U.S. EPA (Paul et al., 1992). Thus, the study design was intended to provide an objective, unbiased representation of the relative quality of sediments throughout this large complex region. In addition, the study design allowed us to estimate the spatial (or aerial) extent of degraded sediment quality and to compare results from the study with those obtained in equivalent surveys previously conducted elsewhere in the U.S.

Degree of Chemical Contamination

In the PSAMP/NOAA survey, there were 39 samples in which one or more of the 25 ERM values were exceeded and 62 samples in which one or more of the 47 SQS values were exceeded (Table 10). These samples represented 13% and 21% of the 300 samples, respectively, and 1.3% and 5.9% of the total survey area, respectively. To provide perspective to these data, similar information was compiled from several nationwide inventories and many regional, estuarine surveys conducted along all three coastlines of the U.S. Nearly all of these studies reported the percentages of samples in which sediment quality guidelines (usually ERMs) were exceeded by one or more chemicals. Most also reported the areas affected and the percentages of total areas studied. Sampling and analytical methods comparable to those used in the present study were applied in most of the others; however, differences in methods could account for some proportion of apparent differences among regions and data inventories.

U.S. EPA (1997) compiled the largest sediment quality database currently available as a part of a national inventory of sediment contamination. 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 toxic in an acute 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 methods were the same. Among the 1068 samples, 27% and 36% exceeded at least one ERM or PEL (Probable Effect Level, MacDonald et al., 1996) value, respectively.

In Ecology's SEDQUAL database, largely populated with data from samples (i.e., excluding PSAMP/NOAA samples) collected during enforcement or other regulatory actions in urbanized bays of Puget Sound, 27% of 8523 samples had at least one chemical concentration that exceeded an SQS value. In surveys conducted either by NOAA or EMAP in marine and estuarine regions, 1.2% 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 harbor, California bays and harbors, and Pearl Harbor (Hawaii), the sampling designs focused upon urbanized and industrialized areas known or suspected to be contaminated. In two surveys of the NY/NJ harbor, the estimates of the spatial extent of chemical contamination were very similar, 50% in 1993 and 47% in 1998. 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.

The incidence and/or spatial extent of chemical contamination in the present Puget Sound study was roughly comparable with that reported for several other regions, including Biscayne Bay (FL), Southern California continental shelf, and the estuaries of Louisiana, the Florida panhandle, and the mid-Atlantic states. The percentage of samples with an SQS exceeded in the present survey (21%) was slightly lower than that reported in the SEDQUAL database (27%) for Puget Sound. Relative to results of the present study, the incidence of contamination above ERM values was lower in Tampa Bay (FL) and the spatial extent was lower in the estuaries of Mississippi. In contrast, the degree of chemical contamination (either expressed as percentages of samples or percentages of areas) was much greater in other regions. These regions included the estuaries of North Carolina, and Alabama; and the bays and harbors of Southern California, Pearl Harbor, and NY/NJ. The incidence of contamination in samples compiled in all national – scale inventories (26-60%) exceeded that in the present study (13% for ERMs, 21% for SQSs) by factors of two to four.

These comparisons suggest that chemical contamination of Puget Sound surficial sediments wasn't as widespread or as frequent as in many other regions, including those surveyed as a part of large-scale inventories. However, chemical contamination in Puget Sound exceeded that observed in several other estuarine areas.

Laboratory Tests of Toxicity

Results of the toxicity tests differed considerably as a function of the type of test and the numerical critical values used to interpret the outcomes. Only one sample was classified as highly toxic (mean percent survival <80% of controls) in the test of mortality in juvenile amphipods, the least sensitive test. In the Microtox test, microbial bioluminescence activity was less than 80% of controls in 237 of the samples; however, the mean EC50 was less than the more realistic critical value of 0.51 mg/ml in only 8 of these samples. HRGS results were greater than the critical value of 11.1 ug/g in 134 samples, indicating responses greater than in reference sediments. However, there were only 48 samples in which the HRGS assay response was greater than 37.1 ug/g. Results of urchin fertilization tests were highly significant in 32 samples of 100% pore water. Thus, if the survey had been conducted using only one toxicity test, the overall outcome of the survey would have been dictated entirely by results of the specific test that was selected.

There were 144 samples in which one or more of the laboratory tests indicated a significant result (Table 11). Therefore, there were 156 samples in which there was agreement, or concordance, in classification of the sediments as non-toxic. These 156 samples represented a large majority of the study area (73%). In four of the six possible combinations of two toxicity tests, there was complete concordance on the absence of toxicity in all 300 samples. There were no samples in which all four tests indicated outcomes that exceeded the respective critical values.

There was one sample in which the responses in both the Microtox and HRGS tests were significant (representing 0.05% of the area). Eighteen samples had significant responses in both the sea urchin and HRGS tests representing good concordance in representing 2% of the area). Six samples were highly toxic in all but the amphipod tests (<1% of the total study area).

To put the results of the toxicity tests in the Puget Sound study into perspective, they are compared to results of surveys conducted elsewhere in the U.S. using similar or the same methods. All surveys followed a stratified-random sampling design, all tested surficial sediments (upper 2-3 cm.), most used the same test taxa, and all treated the data the same way, using the same critical values. In the amphipod and sea urchin tests, sites were scored as "toxic" in calculations of the spatial extent of toxicity when outcomes were less than 80% of controls (Long et al., 1996; Long, 2000a, b). With two exceptions, the same critical value was used with Microtox results. In the Delaware Bay and Puget Sound studies, a critical value of <0.51 mg sediment/ml was used because of unusual results in the negative controls (Long et al., 1999). In all studies in which HRGS assays were performed, the same critical values (>11.1 ug/g and 37.1 ug/g) used in the Puget Sound study were applied.

Results of the amphipod survival tests in the present study are compared to those developed for other estuarine regions of the U.S. (Table 12). Results were combined together from individual surveys performed by NOAA in estuarine regions as summarized previously (Long et al., 1996; Long, 2000a, b). The methods used in other NOAA surveys were the same as those used in the Puget Sound study, using *A. abdita*, except in the California bays, where *Rhepoxynius abronius* was the test taxa. Highly significant results (survival <80% of controls) were most pervasive in the estuaries of the northeastern U.S. and several bays in southern California where highly toxic samples represented 38% and 35% of the areas, respectively. Toxicity occurred least frequently in the opposite regions of the U.S., i.e., the southeastern estuaries and Puget Sound, covering 3% and 0.04% of those regions, respectively. The cumulative average calculated by Long (2000b) on results developed through the 1997 field season (i.e., including Puget Sound data only from 1997) was 5.9% of the total area. The estuarine studies conducted as a part of the EMAP reported amphipod survival results with *A. abdita* for several estuarine provinces. They included the Louisianian province along the Gulf of Mexico (Summers et al., 1993; Macauley et al., 1994), the Virginian province in the northeast (Schimmel et al., 1994; Strobel et al., 1995), the Carolinian province in the southeast (Hyland et al., 2000), and offshore southern California (Bay, 1996). Results of these studies showed the spatial extent of toxicity covered 0% to 10% of these estuarine study areas and a cumulative average of about 7% for the combined total area. The one sample in which a highly significant result was recorded in the Puget Sound study represented less than 0.1% of the study area, considerably less than observed in all except one other region that was surveyed by either NOAA or EMAP.

Results of the sea urchin fertilization tests with 100% porewater concentrations in Puget Sound are compared to those of the same or equivalent tests in 21 other estuaries and bays in the U.S. studied by NOAA (Table 13). Porewater tests were not conducted in the EMAP surveys. Except in California and Puget Sound, tests were performed for fertilization success with the urchin *Arbacia punctulata*. Experiments conducted during the 1997 Puget Sound survey showed that *A. punctulata* and *S. purpuratus* were similar in sensitivity to six different toxicants (Long et al., 1999); thus, results among study areas based upon fertilization success in the two taxa should be comparable. The percentages of study areas affected in these tests ranged from 0% (Leadenwah

Creek, SC) to 98% (San Pedro Bay, CA). The embryological development test used in the San Pedro Bay and other California studies was extremely sensitive, indicating a response in many samples to the presence of ammonia. Excluding results of embryological development tests in California surveys, the range in responses was 0% to 84% (Tampa Bay, FL). The 32 Puget Sound stations that were classified as highly toxic in the urchin fertilization tests represented about 4% of the total survey area, the fourth lowest percentage among the 22 areas. The combined, cumulative average for spatial extent of toxicity in these tests for surveys conducted through 1995 was about 43%. As data were acquired and added to the database from surveys conducted in 1996 and 1997, the cumulative average decreased to 39% and 25%, respectively. The estimate for Puget Sound (4%) was considerably lower than all three of these averages.

Results of Microtox tests of organic solvent extracts ranged from 0.1% of area affected (Tampa Bay, FL) to 100% of area affected (two other Florida bays) (Table 14). Microtox tests were not performed in EMAP surveys or in NOAA surveys in California. Thus, the largest areas affected and percentages of totals were in bays and estuaries of the southeast and northeast. The lowest percentages of areas affected were recorded in the studies of Puget Sound (0.4%) and Tampa Bay (0.1%). The outcome for Puget Sound, using the standard critical value of <80% control response (1629 km^2, 69%, Tables 4, 5) would have ranked Puget Sound considerably higher. However, this outcome was biased by the unusual response in the Redfish Bay control in this test.

HRGS assays have been performed with 1110 sediment samples from14 marine and estuarine survey areas by NOAA (Table 15). Mean HRGS response in these surveys ranged from 5.1 ug/g in the 2002 survey of Chesapeake Bay to 57 ug/g in Delaware Bay, comparable to the results in the three years of the Puget Sound survey (range: 11.1 to 52.8 ug/g). The high standard deviation and upper confidence interval in the southern Puget Sound data probably were attributable to the elevated responses in samples from the Thea Foss waterway at Tacoma. Otherwise, the distribution of results in Puget Sound was not remarkably different from those calculated for other areas. Responses greater than 37.1 ug/g have been recorded in 132 samples, 48 of them in the Puget Sound sediments. One-half of the 74 samples in which responses were greater than 60 ug/g came from the Puget Sound surveys. The percentages of survey areas affected by results >37.1 ug/g ranged from 0% to 29% and averaged about 5% among all areas. In Puget Sound, the 48 samples with results >37.1 represented about 2.8% of the survey area, ranging from 0.04% to 5.0% among the three years. These comparisons suggest that the responses in these tests in the Puget Sound surveys were somewhat higher than observed in some other survey areas, but not the highest.

Forming a Weight of Evidence with the Triad of Analyses

Among the 300 samples tested, there were 175 samples in which there was complete concordance in results among the three elements of the triad. That is, there was either at least one chemical concentration that exceeded an ERM or SQS value, at least one significant outcome in the toxicity tests, and the benthos was judged to be degraded (37 samples) or, in contrast, none of the three was observed in 138 samples. It was hypothesized that in the former 37 samples that pollution-induced degradation to biological resources (i.e., infaunal benthos) had occurred in these sediments as outlined by Chapman (1996). In contrast, there was no evidence of pollution-induced degradation in the latter 138 samples. Together, these 175 samples represented about 69% of the total survey area.

There was concordance between combinations of two of the triad elements in another 40 samples, resulting in a total of 215 samples in which concordance was reasonably good to excellent (i.e., either in 2 out of 3 or all elements of the triad). Together these 215 samples (72% of the 300) represented about 74% of the total survey area. Non-concordance was represented in the 85 samples classified in the Intermediate/High Quality category, representing about 27% of the survey area. These samples could be viewed as representing false negative outcomes. No toxicity or no benthic impacts were observed when predicted by relatively high chemistry (13 samples), perhaps because the chemicals were not biologically available for uptake. No contamination or benthic impacts were observed in 68 samples in which there was a significant response in one or more toxicity tests, possibly because the tests were more sensitive than the benthos to un-measured substances or to chemicals not accounted for with numerical guidelines or criteria. The infauna appeared to be degraded in 4 uncontaminated and non-toxic sediment samples, possibly responding to un-measured natural factors that did not cause toxicity.

Estuarine sediment quality in the studies conducted under the auspices of the EMAP often computed the spatial extent of degraded conditions in estuaries and rivers categorized according to their size (Hyland et al., 2000; Paul et al., 1992). In contrast, similar summations were done in the Puget Sound study according to geographic location (e.g., northern, southern, etc.) and strata type (e.g., rural bay, harbor, etc.). As expected, these analyses indicated that the quality of sediments was degraded most frequently in urban bays and industrial harbors, particularly nearest the metropolitan centers of Everett, Seattle, Tacoma, and Bremerton. Toxicant-induced biological effects have been recorded in these urbanized bays and harbors of Puget Sound for many years. Adverse effects have included acute and sublethal toxicity in laboratory tests of sediments and sea surface microlayers, reduced epifaunal colonization rates, and histopathological disorders in demersal fishes (Long, 1982; Long et al., 1985; Malins et al., 1984). Sediment toxicity tests conducted during the 1980's indicated effects in tests of mortality among amphipods, respiration rates in fish, metabolic activity in bacteria, and mutagenicity in fish cells (Long et al., 1985). Reduced abundance of resident amphipods in the benthos of Commencement Bay was observed in samples that were most contaminated and most toxic in amphipod survival tests (Swartz et al., 1982). Our analyses presented in this report of the data collected during the PSAMP/NOAA survey indicated that degraded sediments were most frequently found in the same urban bays and industrial harbors of Puget Sound. Therefore, results of the PSAMP/NOAA survey confirmed that degraded sediment quality previously reported was still apparent in the same areas of Puget Sound. Significantly, the results of this survey now provide a quantification of the magnitude or spatial extent of these problem areas.

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Conclusions

The weight of evidence from the triad of analyses showed that sediments in one percent of the Puget Sound study area, equivalent to 23 km^2, were degraded by the presence of chemical toxicants. Degraded conditions were most frequently observed in the urban bays and industrialized harbors of the Whidbey Basin (Everett) and the Central Sound region, which included embayments adjacent to Seattle, Tacoma, and Bremerton. Sediments with intermediate quality were distributed over 724 km^2, or about 31 percent of the area. These samples were classified as intermediate in quality because a mixture of results was recorded; that is, the agreement in results observed in the degraded and high quality sediments was not recorded. The majority of the area studied (about 68%, or 1616 km^2) was determined to have high quality sediments as indicated by low chemical concentrations, absence of toxicity, and presence of abundant and diverse infaunal communities. Much of the area classified as deep passages, deep basins, and rural bays had the highest quality sediments.

Sediments from 175 of the 300 sampling stations indicated concordance among the elements of the triad in classification of quality; that is, indicative of either high quality or degraded conditions. There were only four samples in which the degraded condition of the benthos could not be explained with the results of matching chemistry or toxicity analyses of the samples.

There were 85 samples (representing 27% of the area) in which only one of the elements of the triad indicated degraded conditions. In contrast, there were only 40 samples (representing 4% of the area) in which two of the elements indicated degraded conditions, indicative of the general lack of concordance among the elements of the triad in these samples. Those in which a significant response was recorded in one or more of four laboratory tests were much greater (642 km^2 or 27% of the total area) than the area classified as chemically contaminated (144 km^2 or 6% of the total area, excluding data for nickel and three organic compounds). It should be noted, however, that the outcome of this comparison was a function of the statistical criteria used to interpret the toxicity tests and chemical analyses. The results could have differed considerably if other criteria had been applied to the data.

Significant responses above background levels (>11.1 ug B[aP/g) were most widespread in a test of the presence of certain organic compounds in the sediments, affecting 586 km^2 or 25% of the total area. However, highly significant responses (>37.1 ug B[a]P/g) in this test affected only 3% of the survey area. In the least sensitive test, highly significant mortality in benthic amphipods was recorded in only one sample, representing 0.04% of the area.

The benthic infaunal communities collected in the survey ranged widely in the numbers of species, numbers of individuals, and in several calculated indices of diversity. The composition of the benthos differed considerably among sampling locations, reflecting the diversity of habitats in Puget Sound. Some taxonomic groups increased remarkably in numbers of species and abundance with increasing chemical contamination and toxicity, whereas others declined along the same gradients. There were two samples in which no benthic organisms were found.

The sediments sampled during this study were contaminated above guideline or criteria values with mixtures of trace metals, PAHs, chlorinated substances, and miscellaneous chemicals. High concentrations of benzoic acid, 4-methylphenol, phenol and other miscellaneous substances were most widespread with concentrations exceeding state SQS values in 174 samples, representing about 53% of the survey area. Otherwise, it was apparent from these data that the contamination of surficial Puget Sound sediments was not dominated by any single class of substances. The study design did not include any attempts to determine which chemicals or other factors caused or significantly contributed to toxicity or benthic impacts. Laboratory experiments and confirmatory bioassays would be necessary to assign causality.

Although the weight of evidence suggests that the large majority of the Puget Sound study area had relatively high quality surficial sediments and the area classified as degraded was relatively small (1% of the area), there was a sizeable area (31%) classified as intermediate in quality. Future attention and surveillance should focus upon these areas with intermediate quality to ensure that conditions there improve and do not deteriorate further.

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Figures and Tables

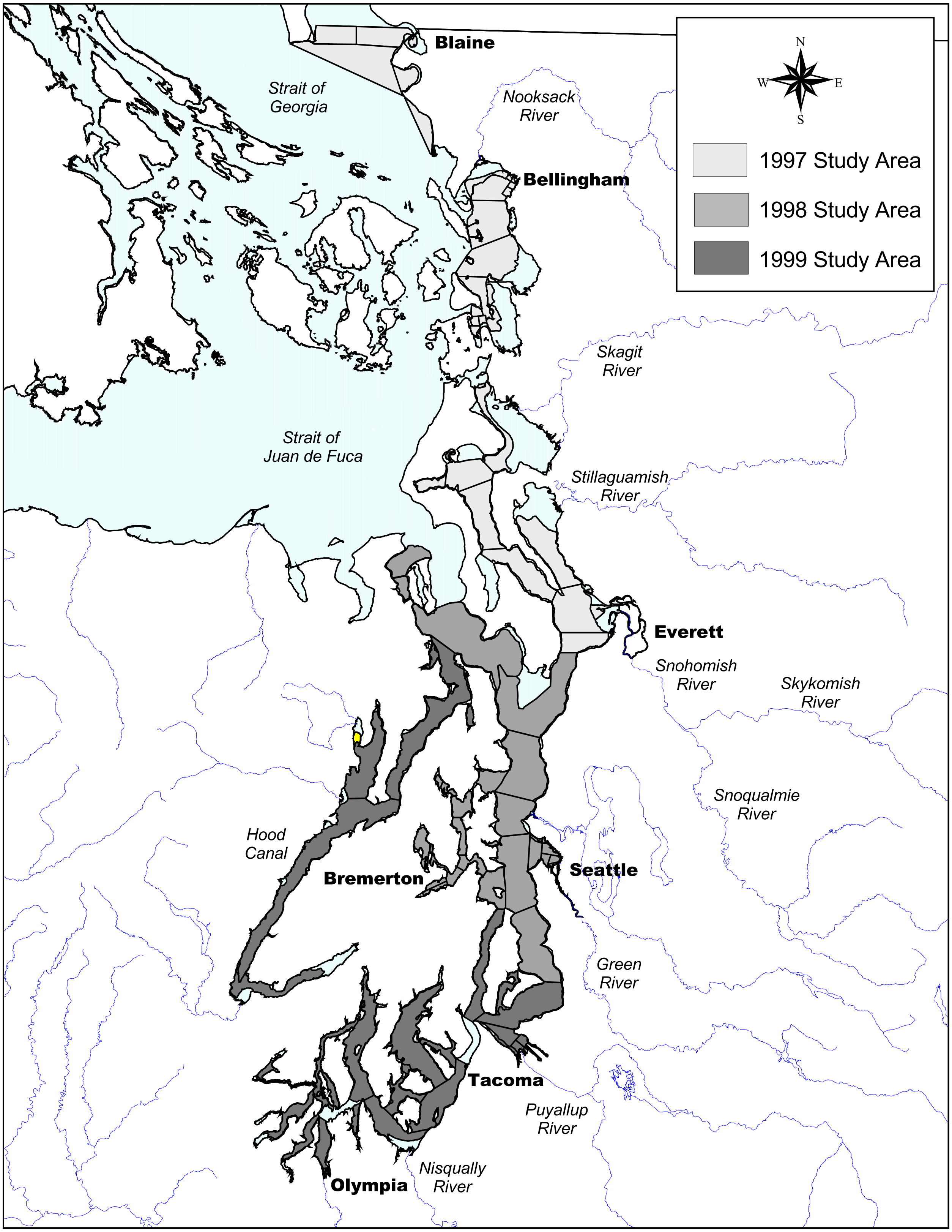

Figure 1. Map of the Puget Sound study area for the PSAMP/NOAA bioeffects survey. The areas sampled during 1997-1999 are outlined.

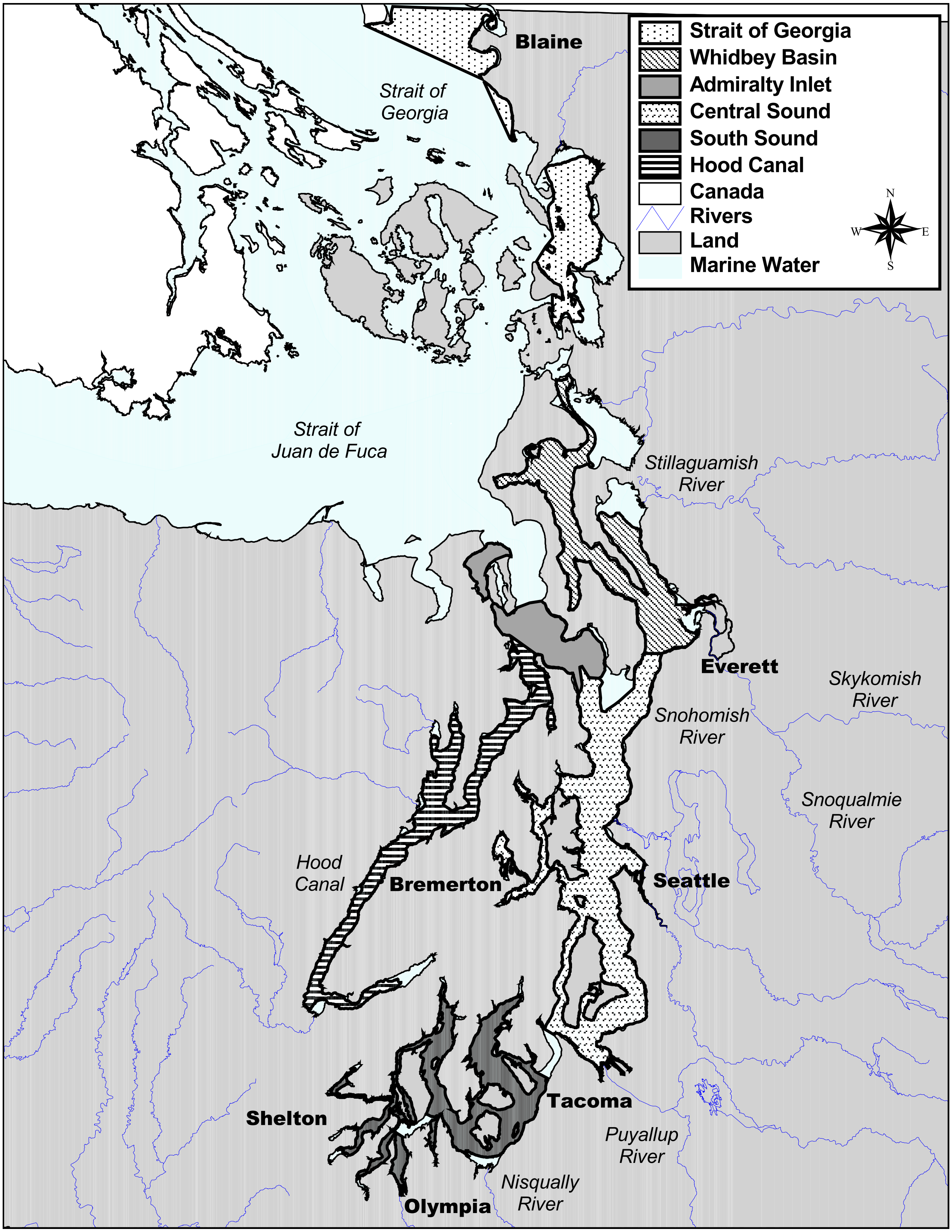

Figure 2. Map of the six PSAMP sediment monitoring regions.

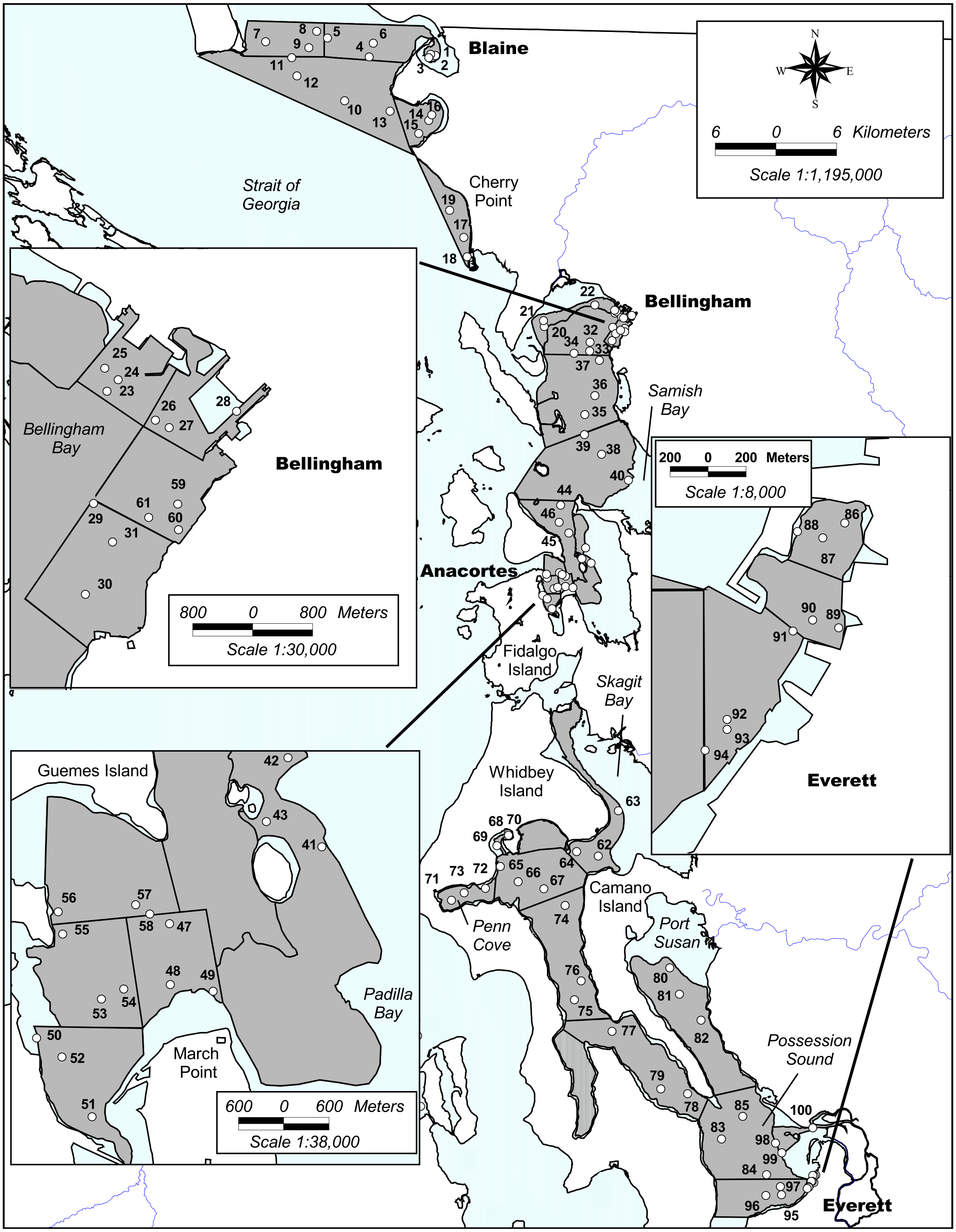

Figure 3. Strait of Georgia and Whidbey Basin sampling stations for the PSAMP/NOAA bioeffects survey, Boundary Bay to Everett. Stations are identified by sample numbers.

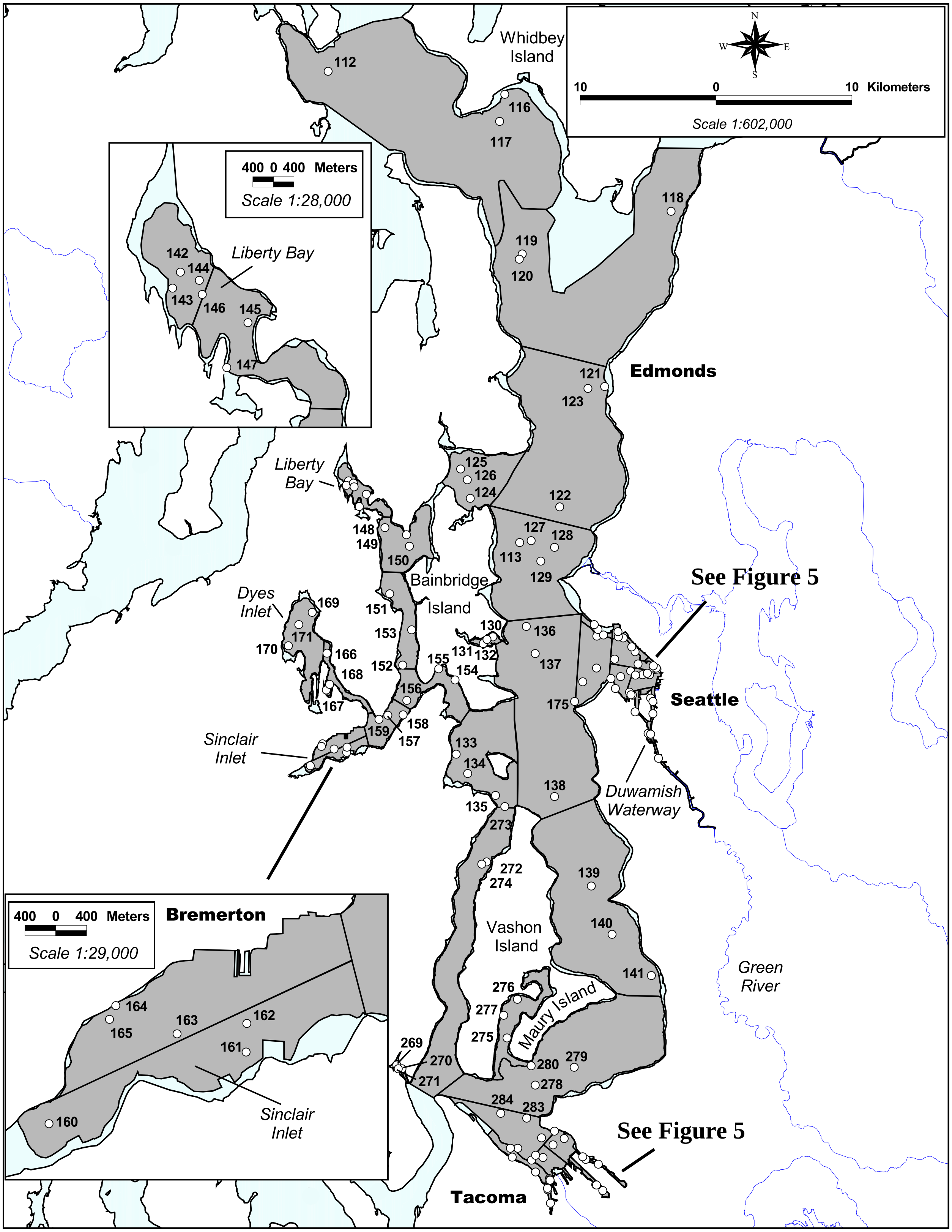

Figure 4. Central Puget Sound sampling stations for the PSAMP/NOAA bioeffects survey, Admiralty Inlet, Possession Sound to Commencement Bay. Stations are identified by sample numbers.

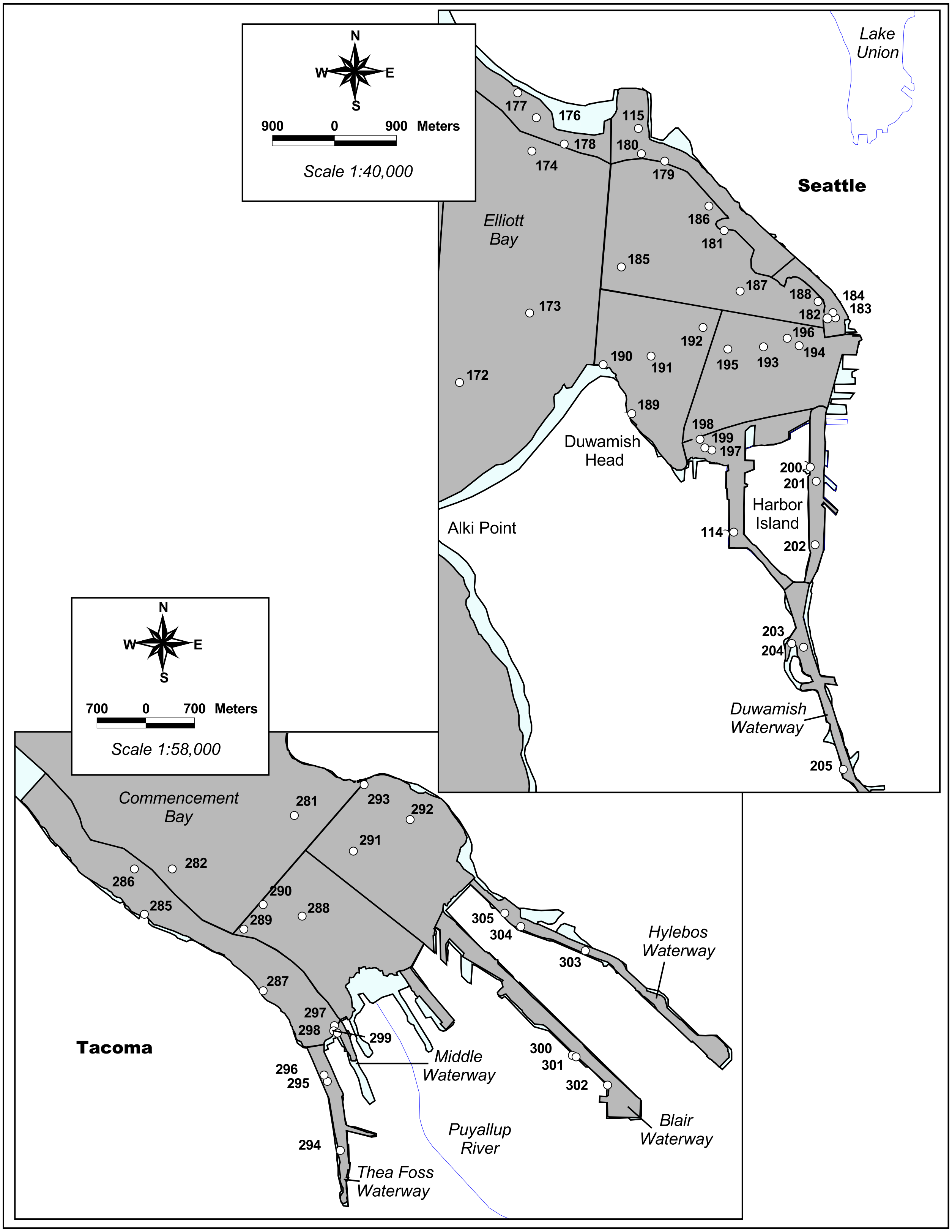

Figure 5. Central Puget Sound sampling stations for the PSAMP/NOAA bioeffects survey, Elliott Bay and Commencement Bay. Stations are identified by sample numbers.

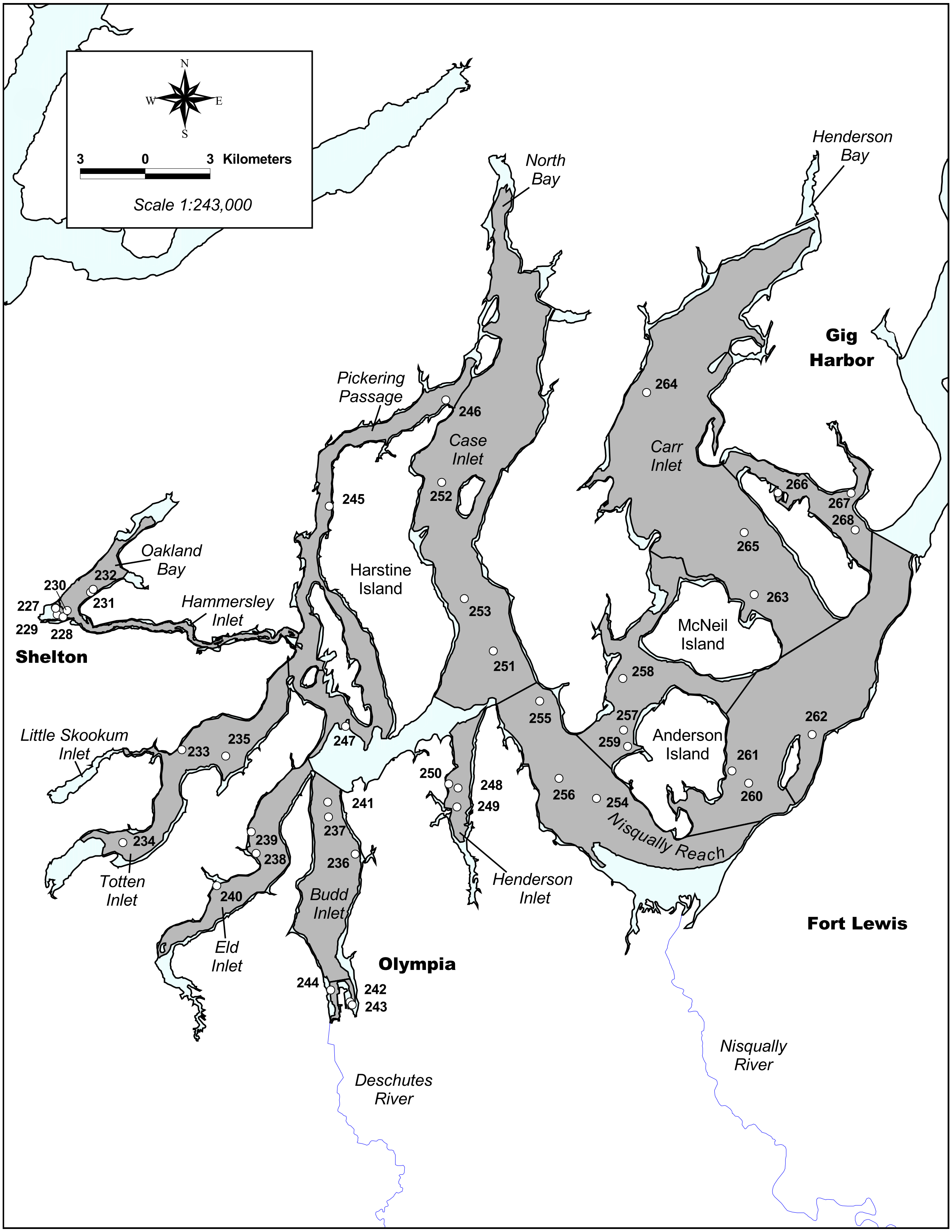

Figure 6. South Puget Sound sampling stations for the PSAMP/NOAA bioeffects survey, Tacoma Narrows to Shelton Harbor Stations are identified by sample numbers.

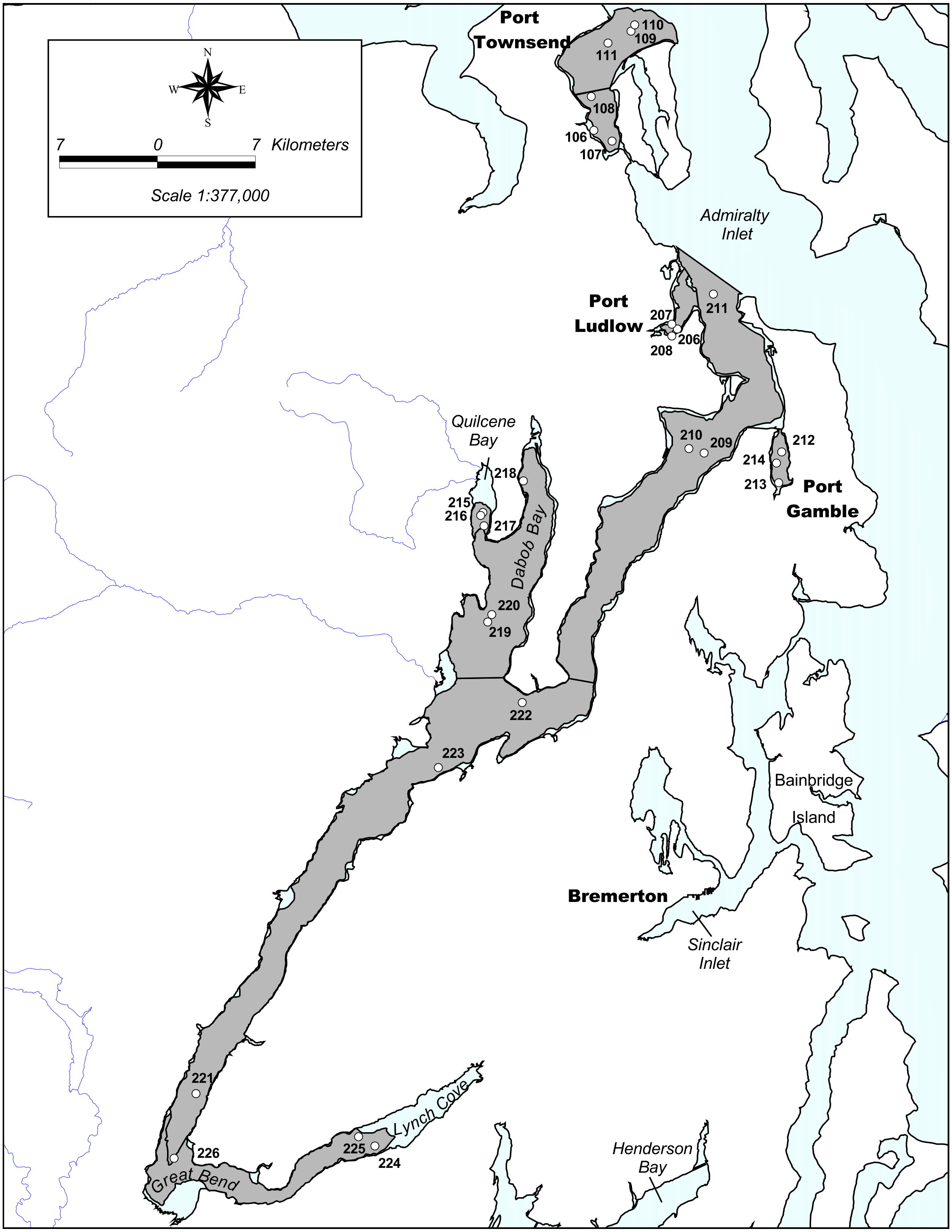

Figure 7. Hood Canal and Port Townsend sampling stations for the PSAMP/NOAA bioeffects survey, Port Townsend to Lynch Cove. Stations are identified by sample numbers.

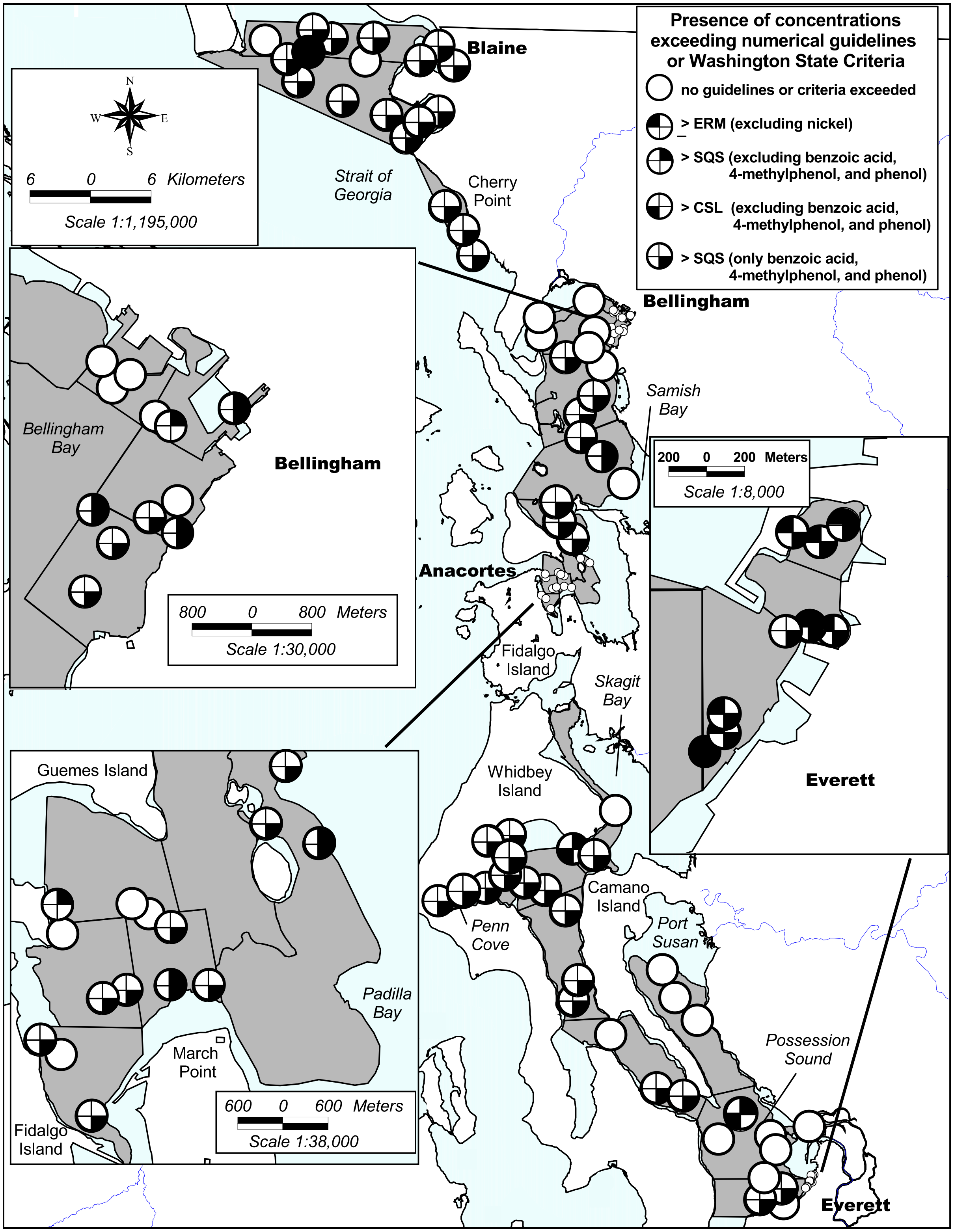

Figure 8. Summary of spatial patterns of chemical contamination for northern Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Boundary Bay to Possession Sound.

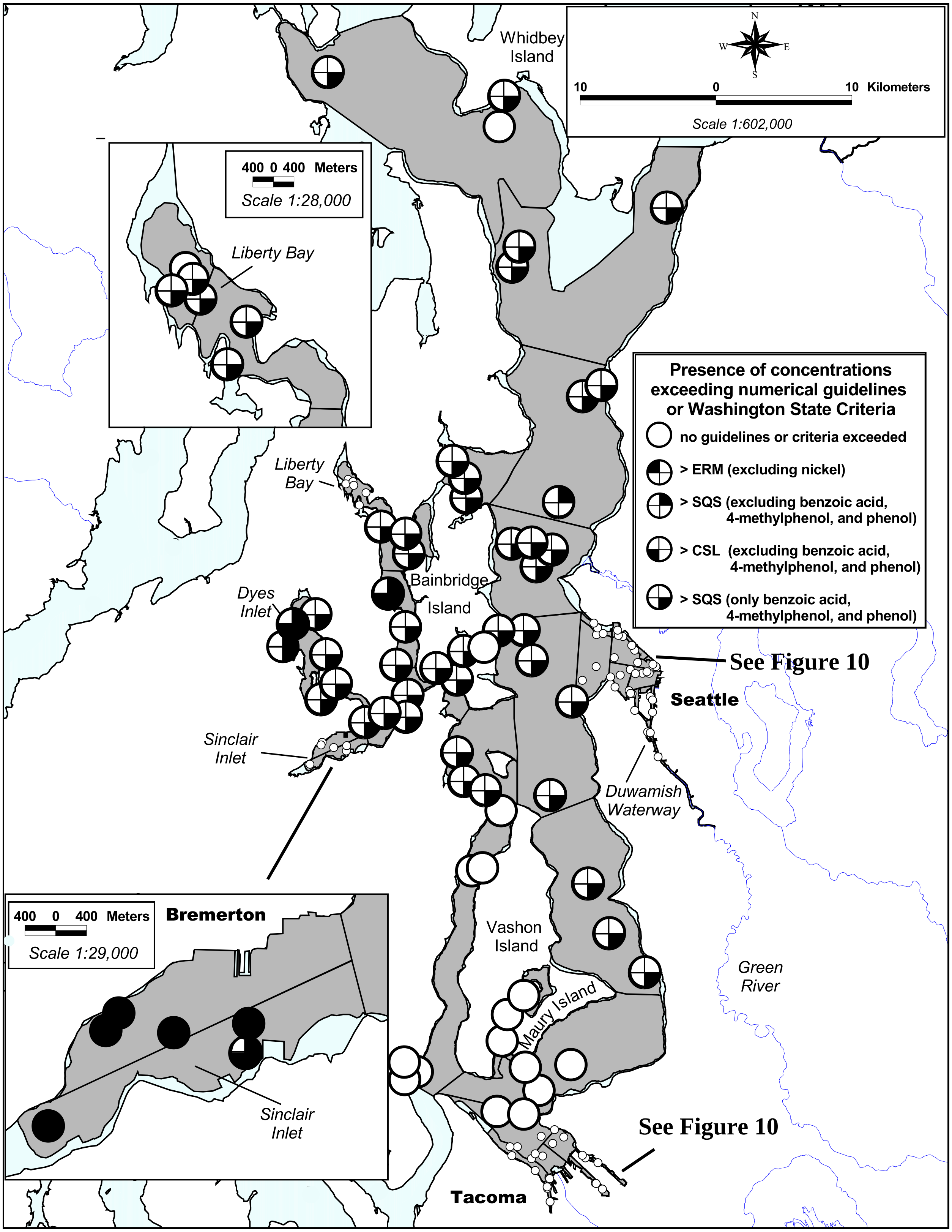

Figure 9. Summary of spatial patterns of chemical contamination for central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Possession Sound to Commencement Bay.

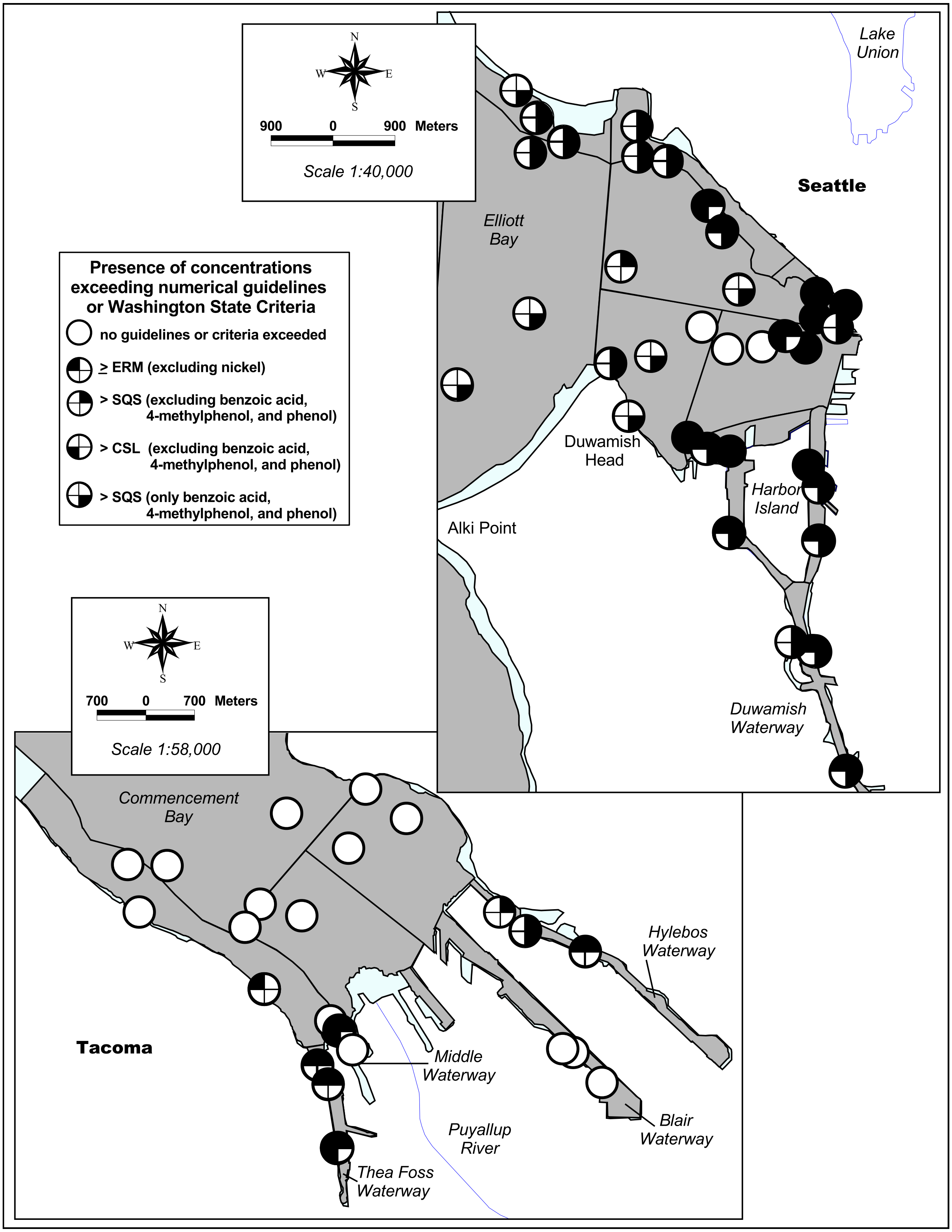

Figure 10. Summary of spatial patterns of chemical contamination for central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Elliott Bay and Commencement Bay.

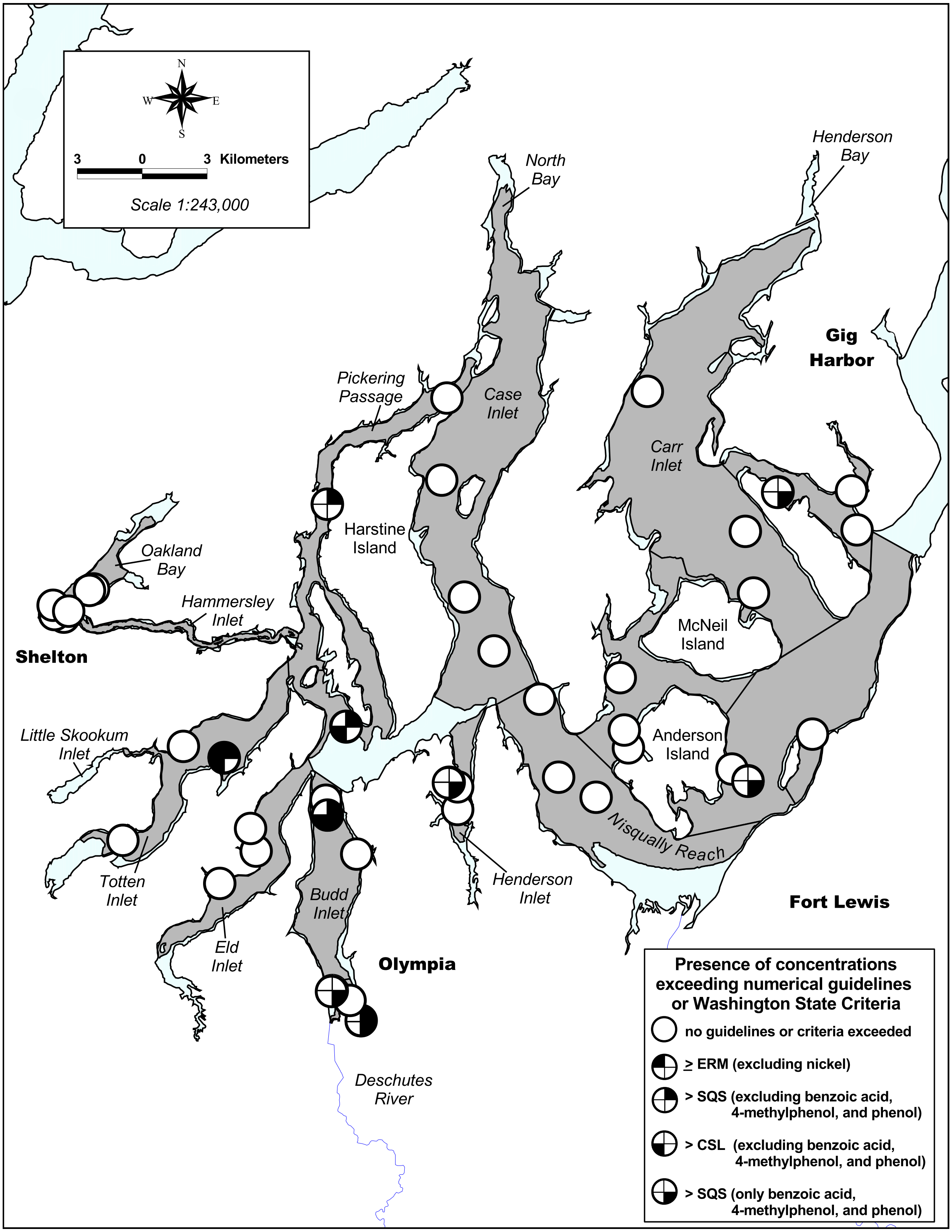

Figure 11. Summary of spatial patterns of chemical contamination for south Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Tacoma Narrows to Shelton Harbor.

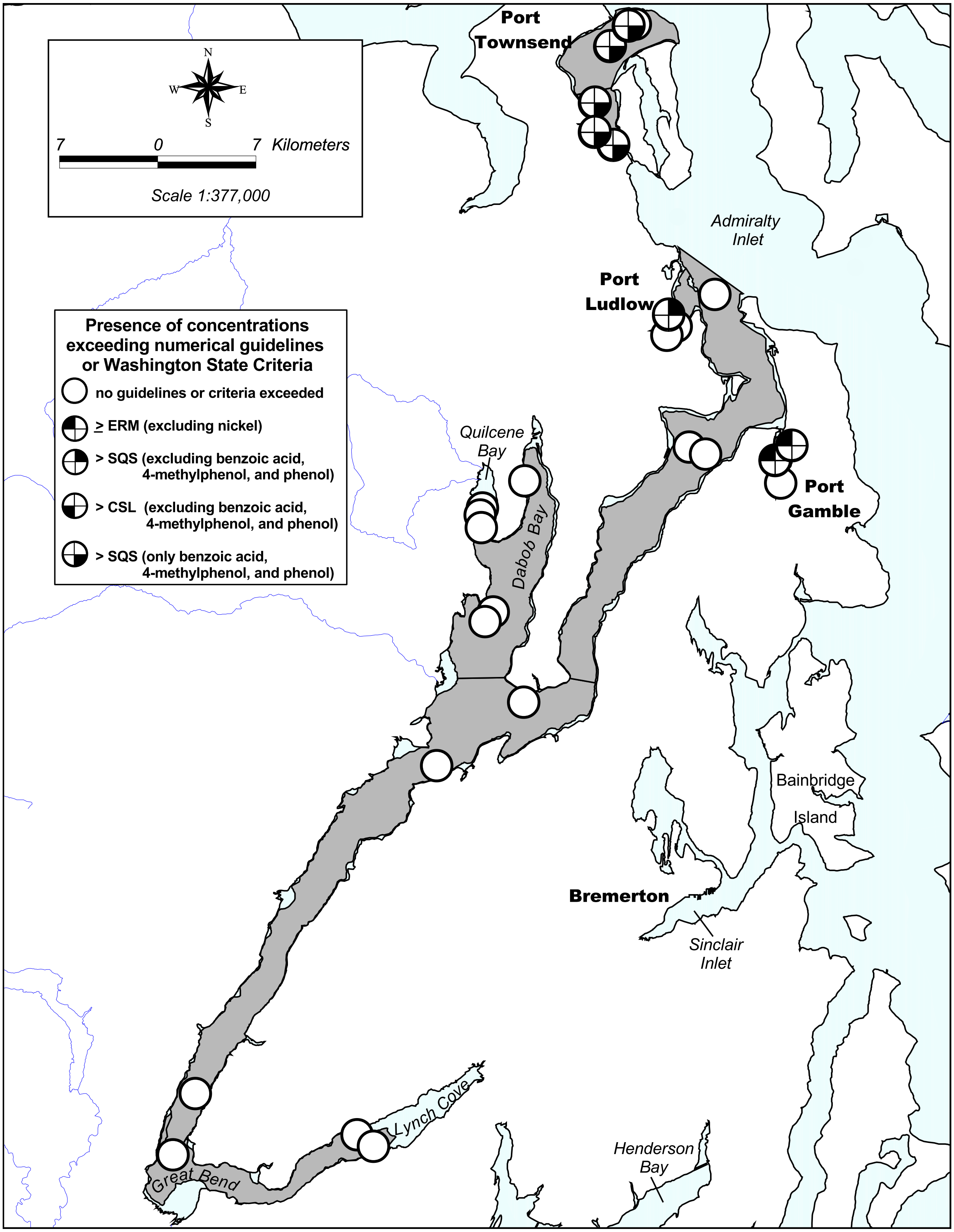

Figure 12. Summary of spatial patterns of chemical contamination for Hood Canal and Port Townsend sampling stations from the PSAMP/NOAA bioeffects survey, Port Townsend to Lynch Cove.

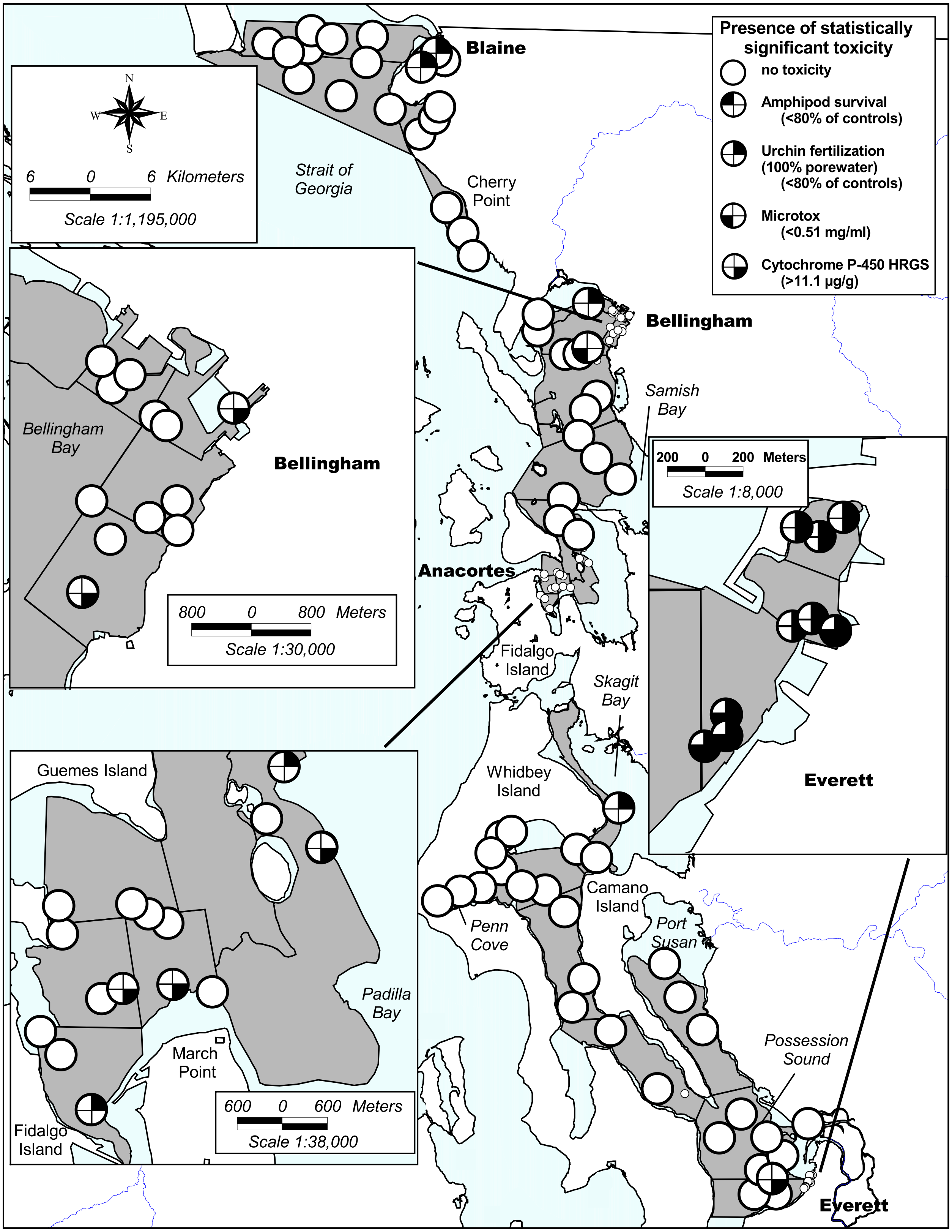

Figure 13. Summary of spatial patterns of toxicity for northern Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Boundary Bay to Everett.

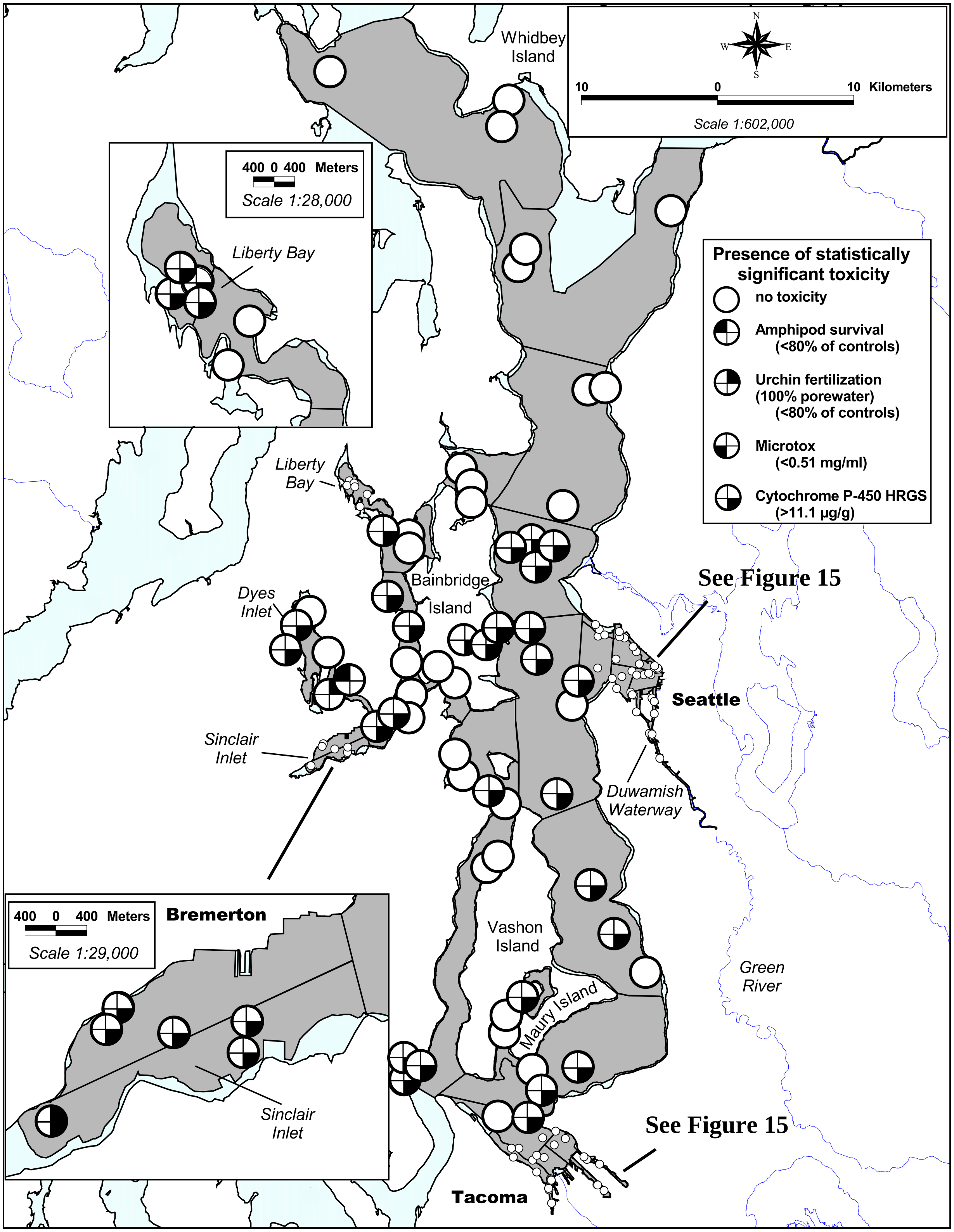

Figure 14. Summary of spatial patterns of toxicity for central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Admiralty Inlet, Possession Sound to Commencement Bay.

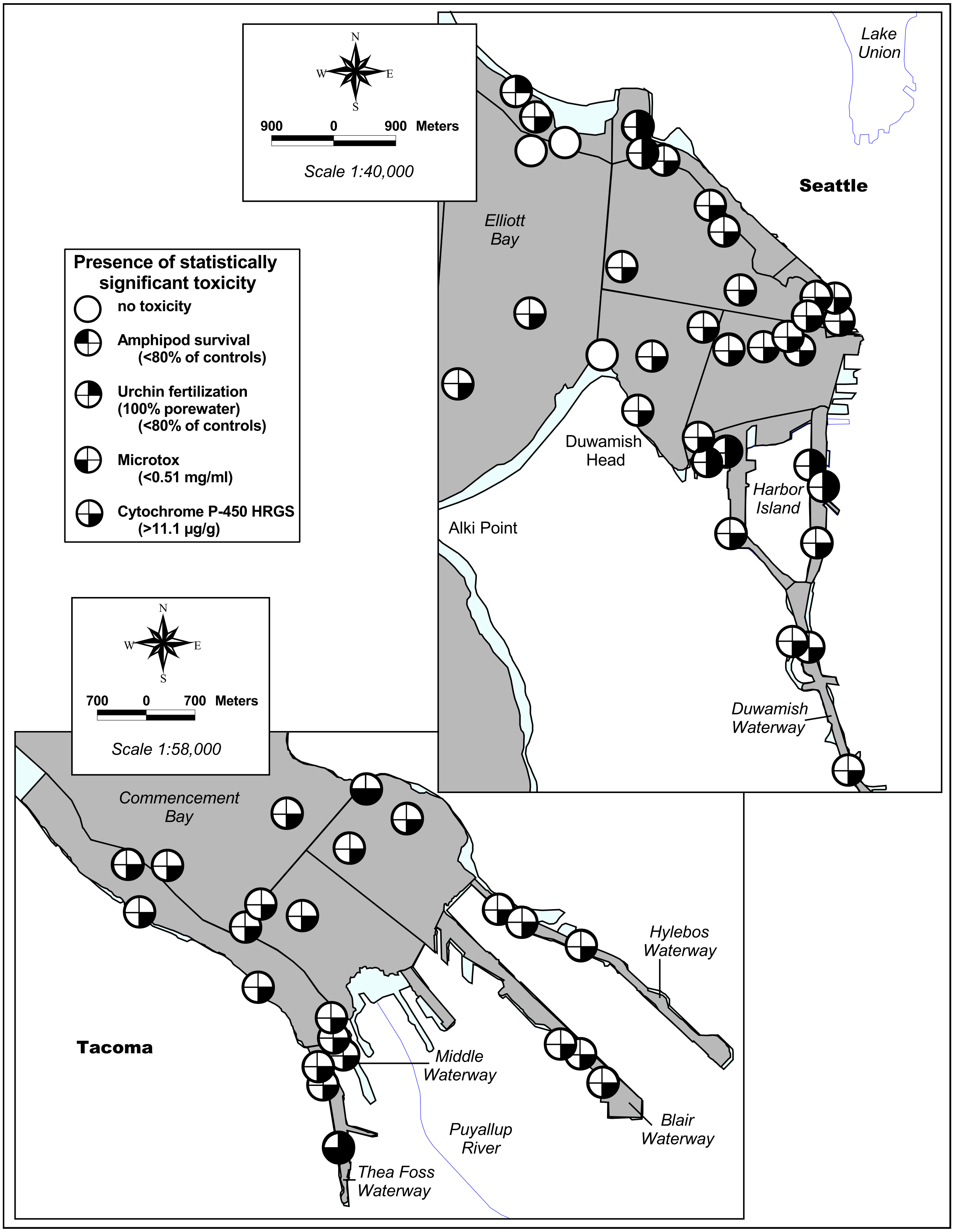

Figure 15. Summary of spatial patterns of toxicity for central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Elliott Bay and Commencement Bay.

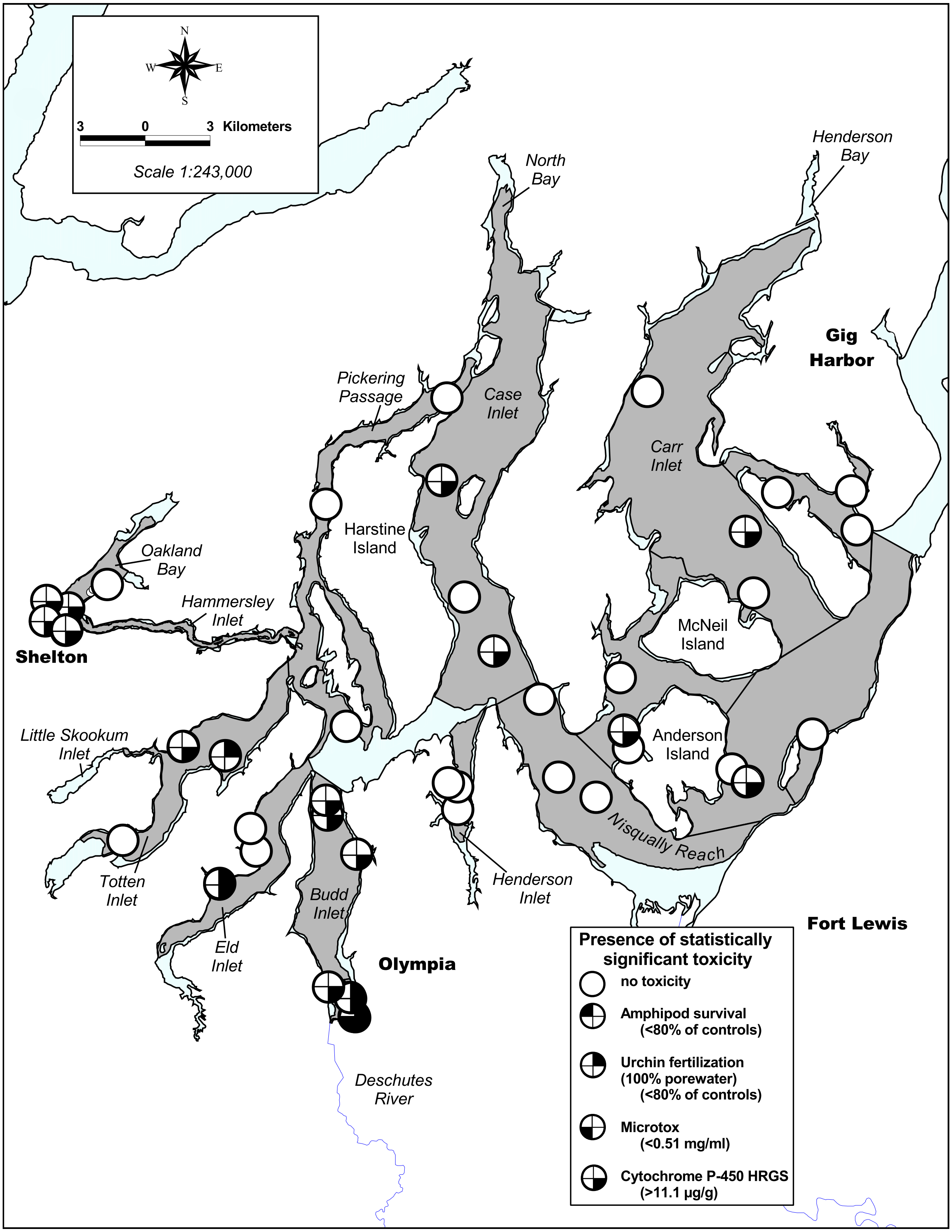

Figure 16. Summary of spatial patterns of toxicity for south Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Tacoma Narrows to Shelton Harbor.

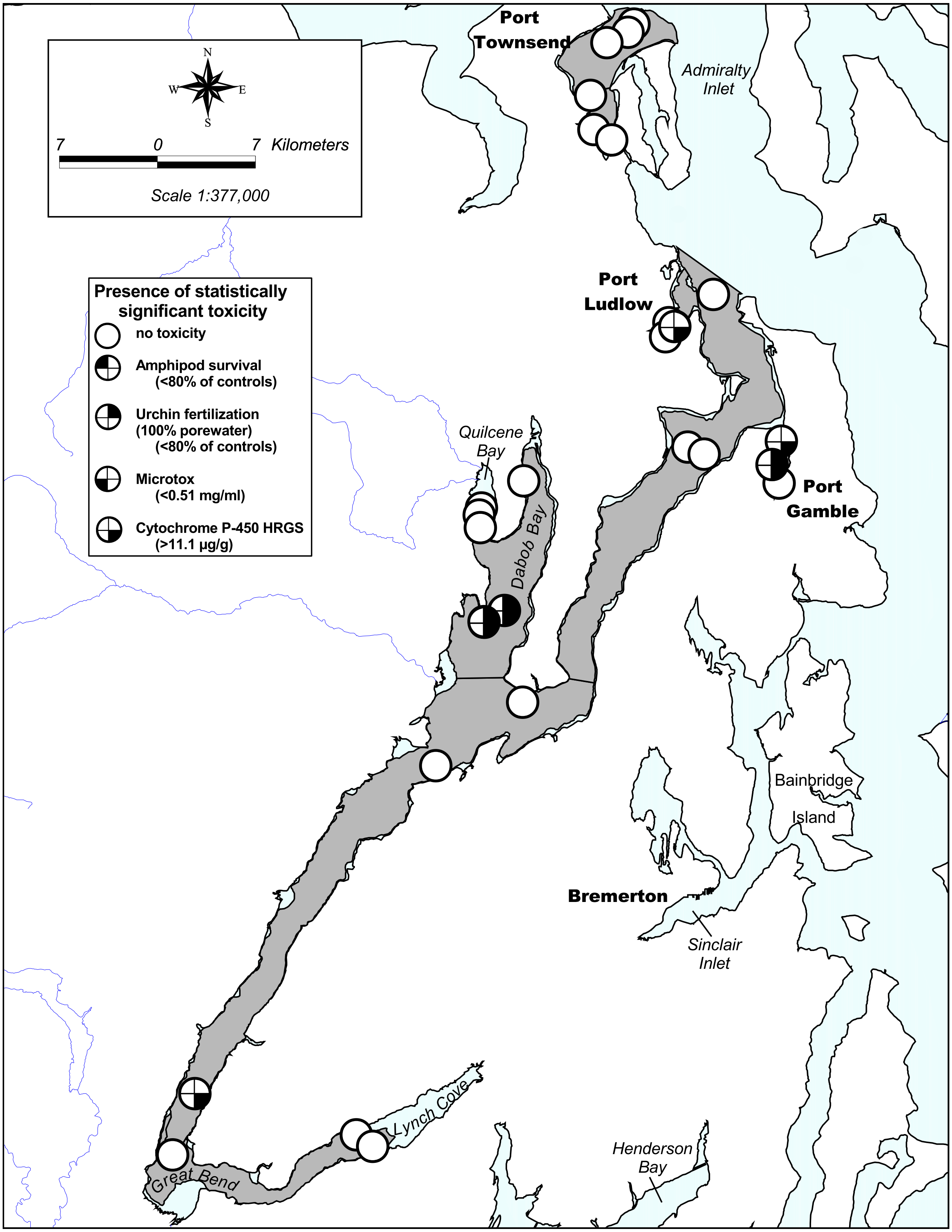

Figure 17. Summary of spatial patterns of toxicity for Hood Canal and Port Townsend sampling stations from the PSAMP/NOAA bioeffects survey, Port Townsend to Lynch Cove.

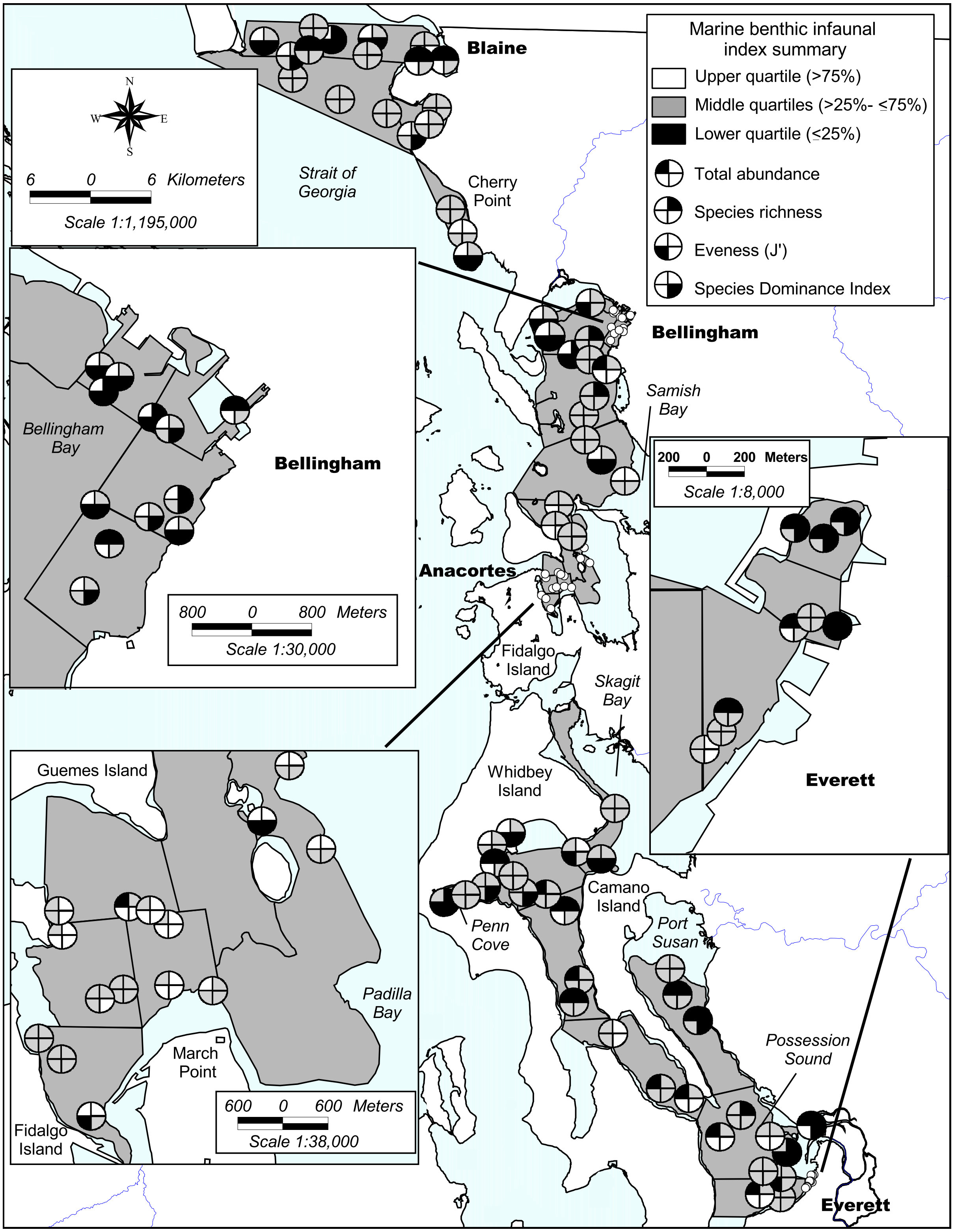

Figure 18. Summary of spatial patterns of benthic infaunal indices for northern Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Boundary Bay to Everett.

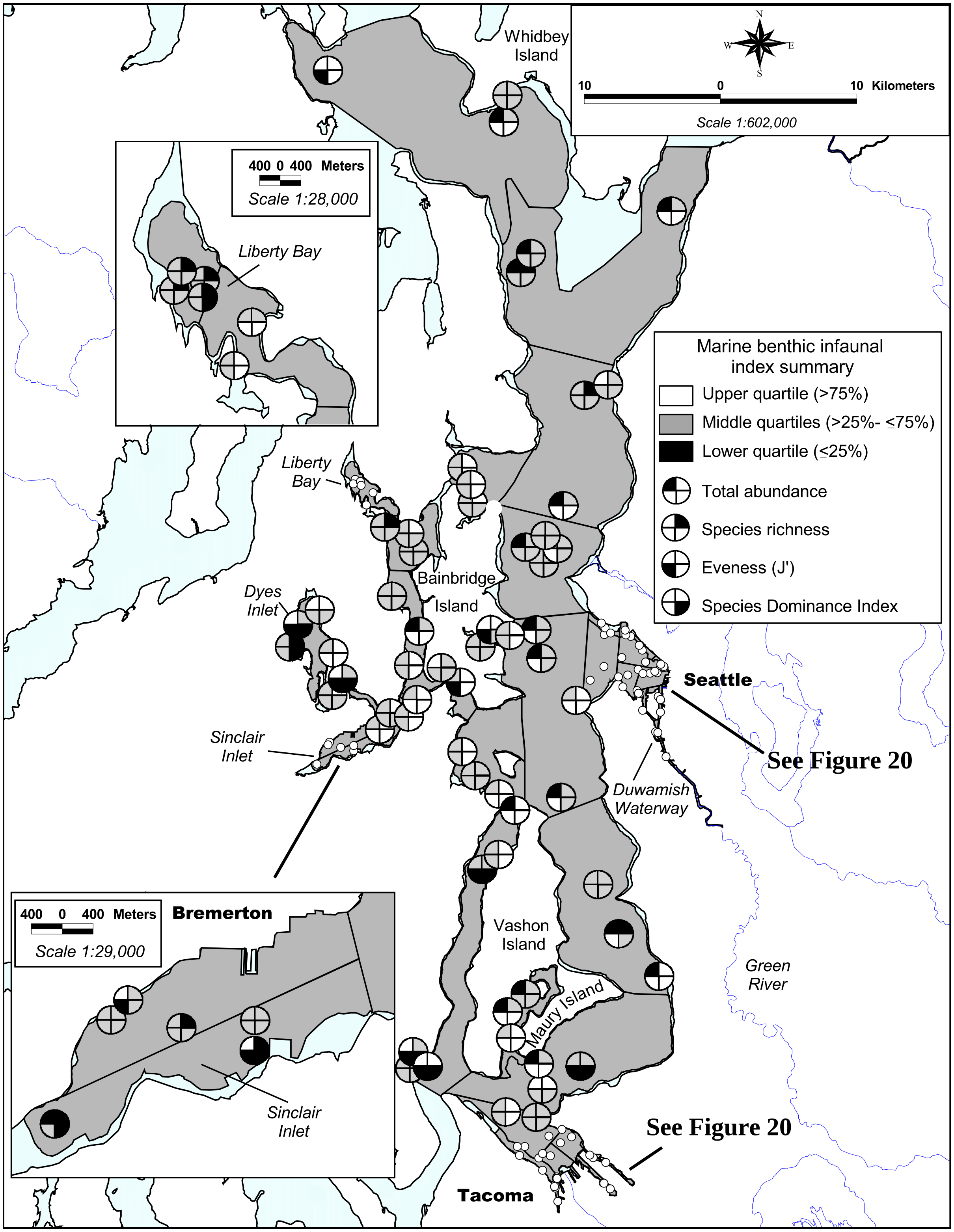

Figure 19. Summary of spatial patterns of benthic infaunal indices for central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey Admiralty Inlet, Possession Sound to Commencement Bay.

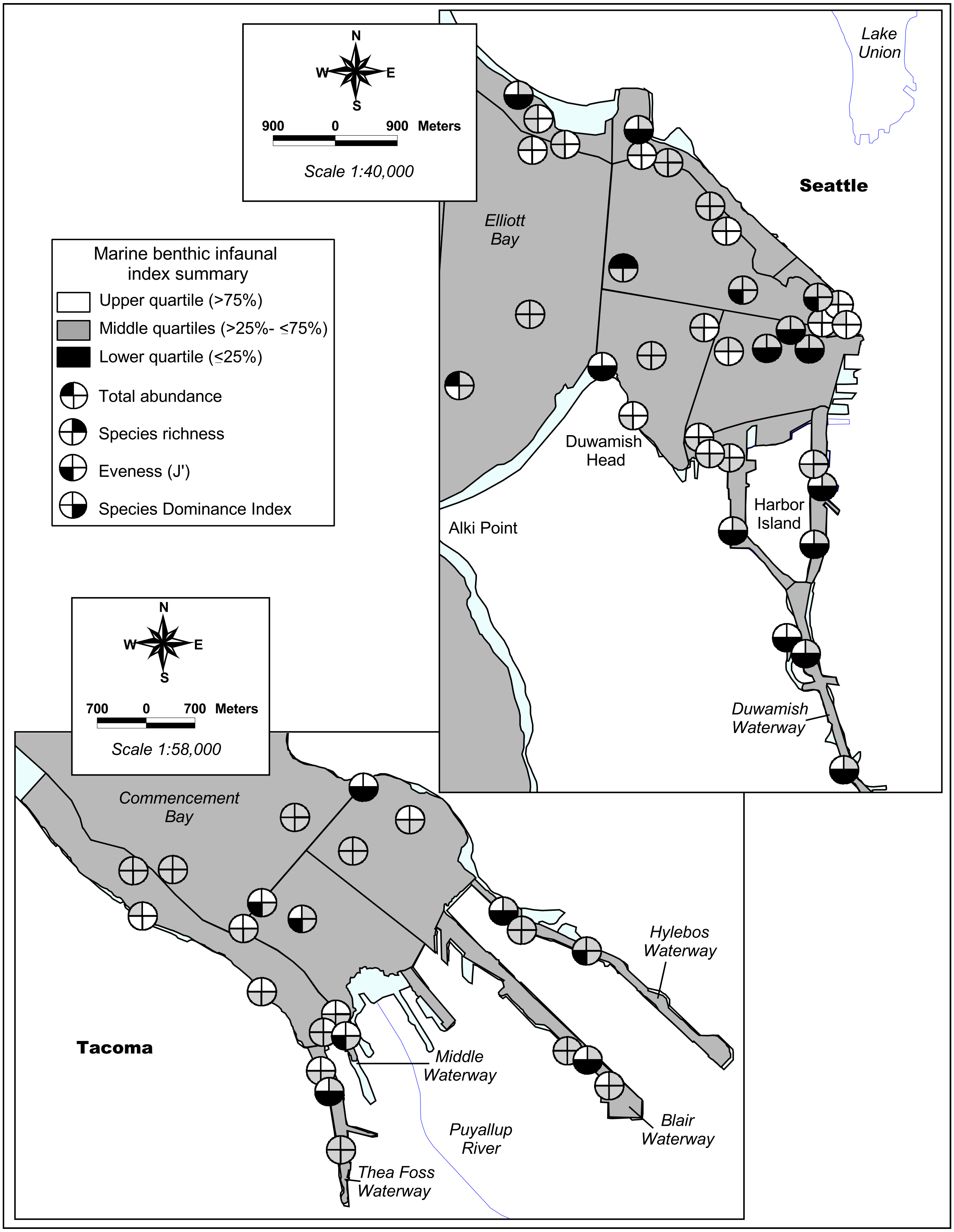

Figure 20. Summary of spatial patterns of benthic infaunal indices central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Elliott Bay and Commencement Bay.

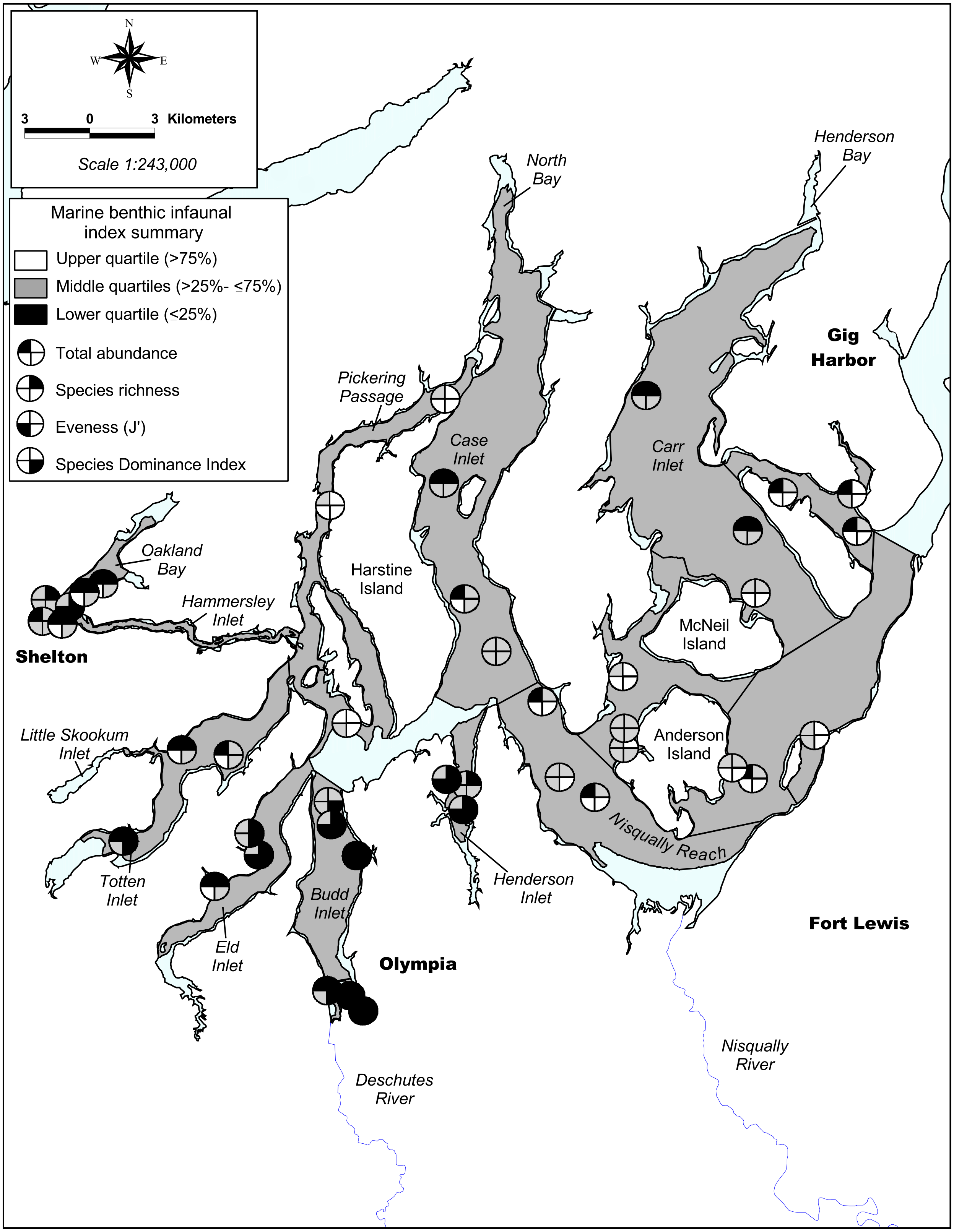

Figure 21. Summary of spatial patterns of benthic infaunal indices for south Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Tacoma Narrows to Shelton Harbor.

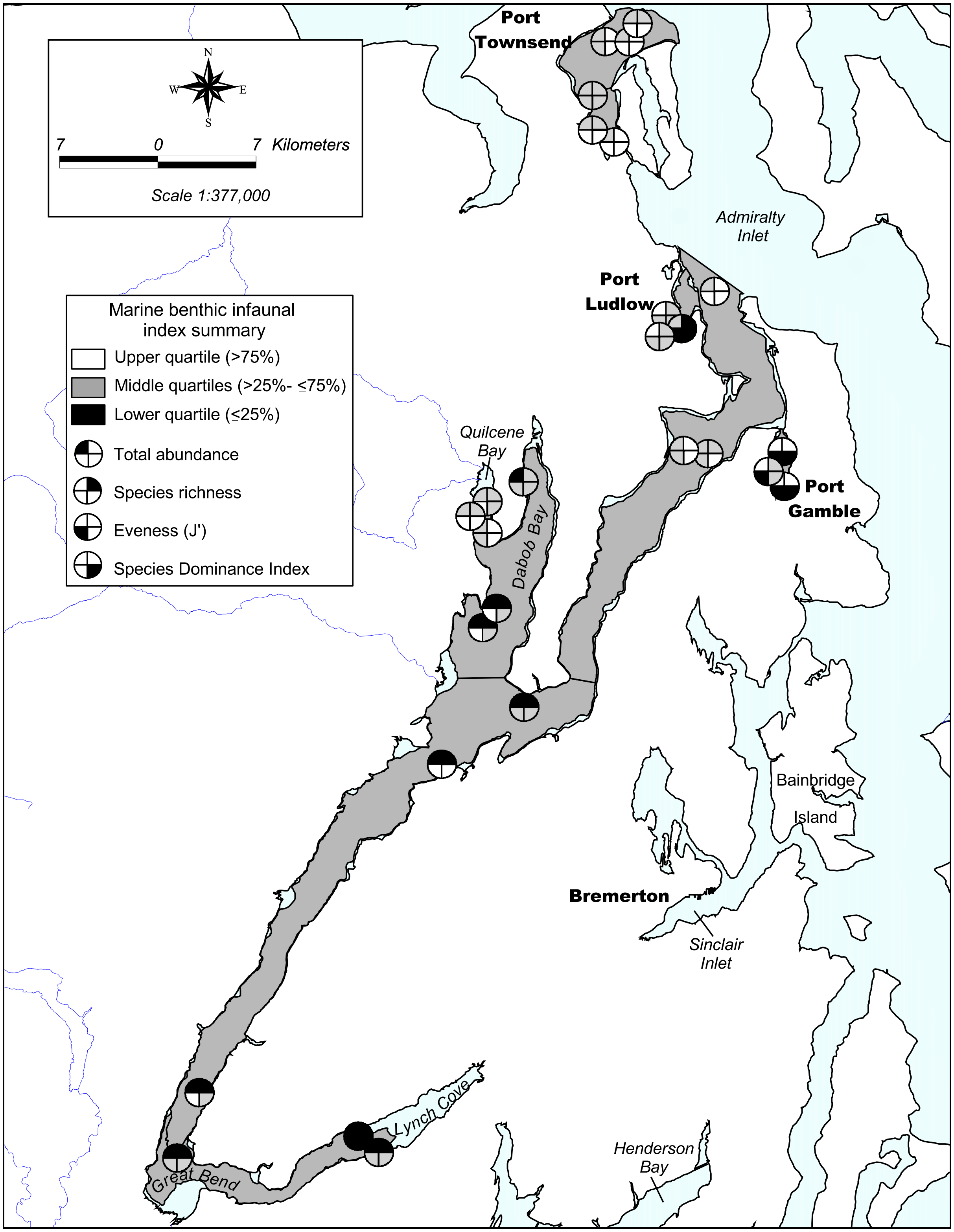

Figure 22. Summary of spatial patterns of benthic infaunal indices for Hood Canal and Port Townsend sampling stations from the PSAMP/NOAA bioeffects survey, Port Townsend to Lynch Cove.

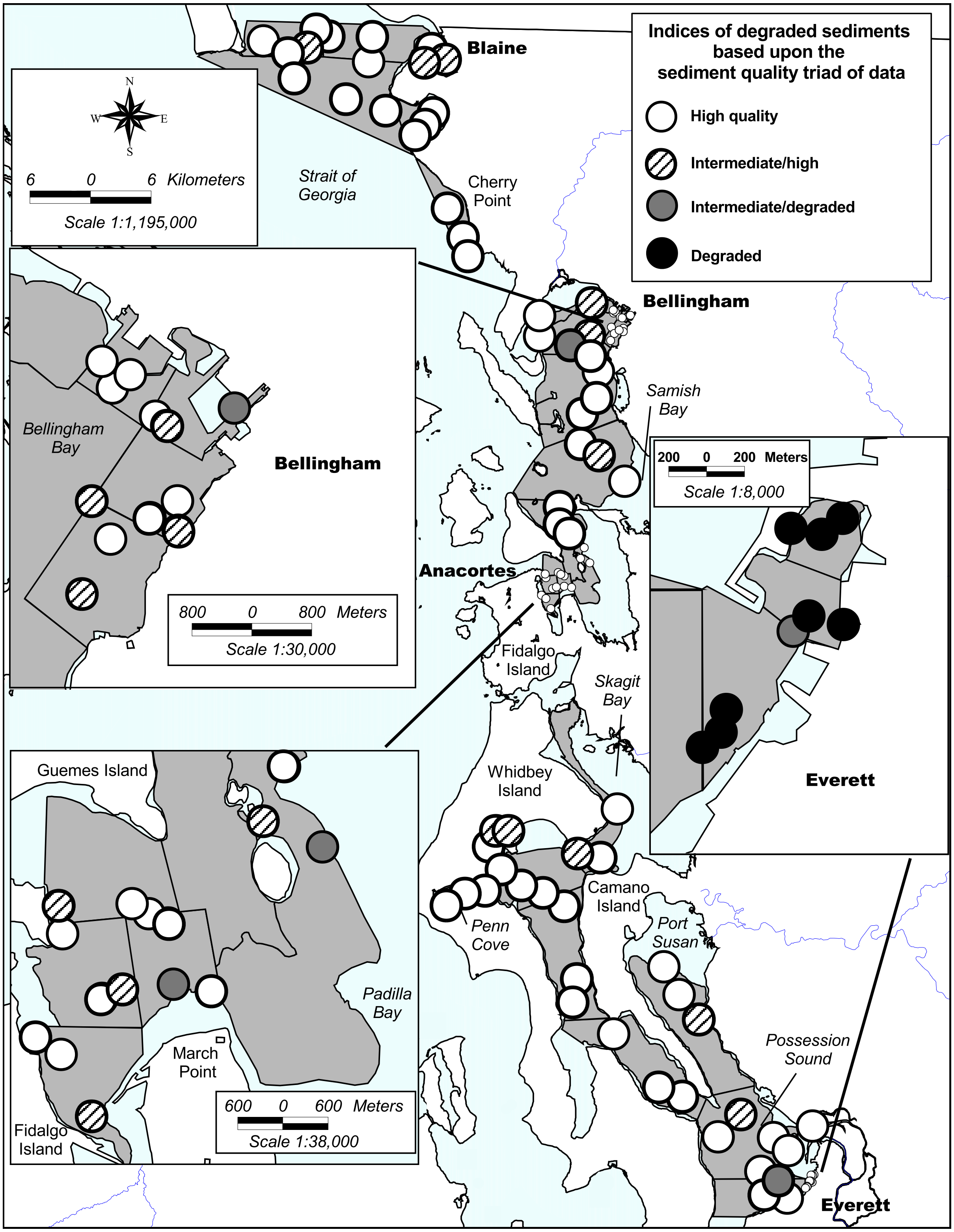

Figure 23. Summary of spatial patterns for indices of degraded sediments based upon the sediment quality triad of data for Strait of Georgia, Whidbey Basin, and Admiralty Inlet sampling stations from the PSAMP/NOAA bioeffects survey, Boundary Bay to Everett.

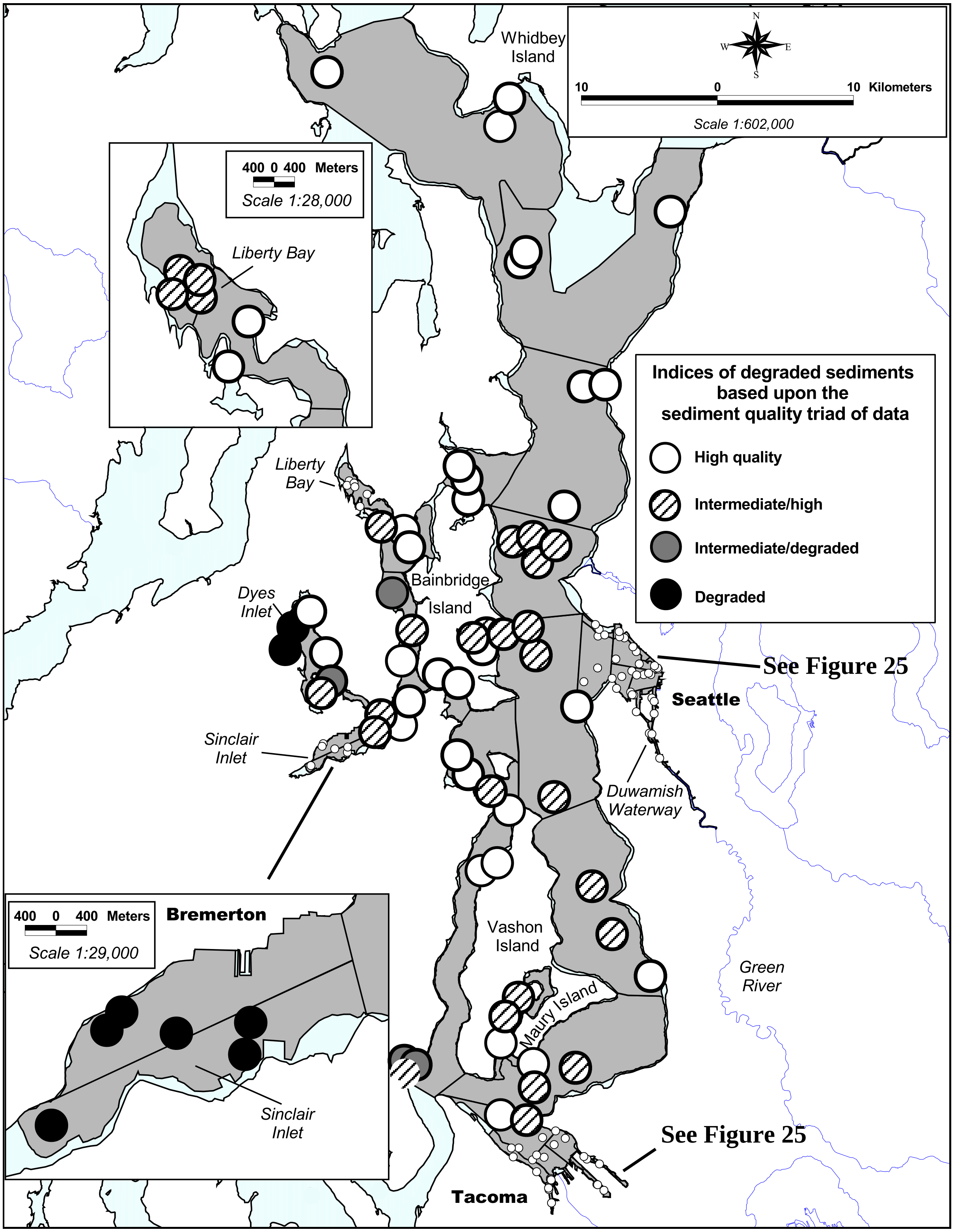

Figure 24. Summary of spatial patterns for indices of degraded sediments based upon the sediment quality triad of data for central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Admiralty Inlet, Possession Sound to Commencement Bay.

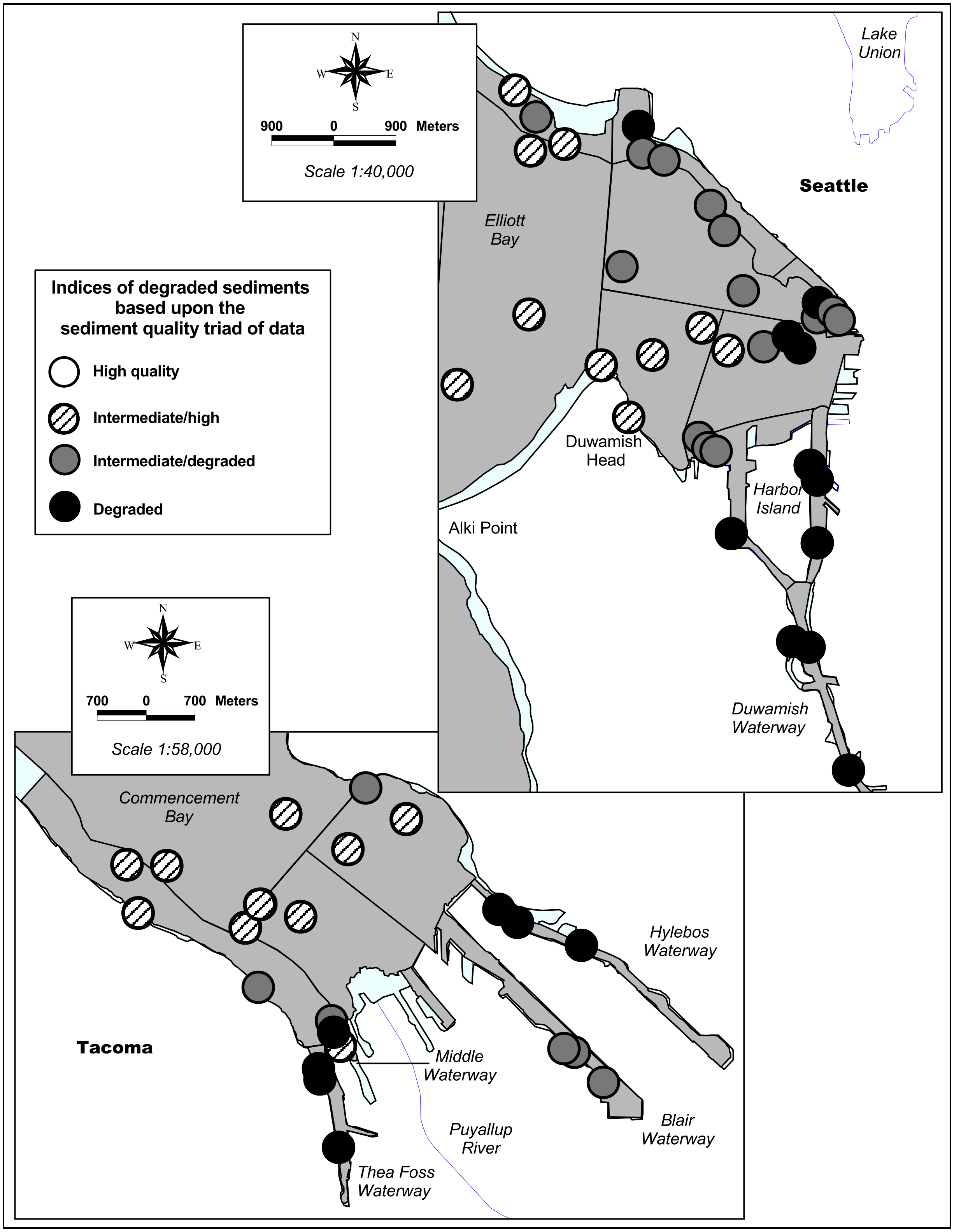

Figure 25. Summary of spatial patterns for indices of degraded sediments based upon the sediment quality triad of data for central Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Elliott Bay and Commencement Bay.

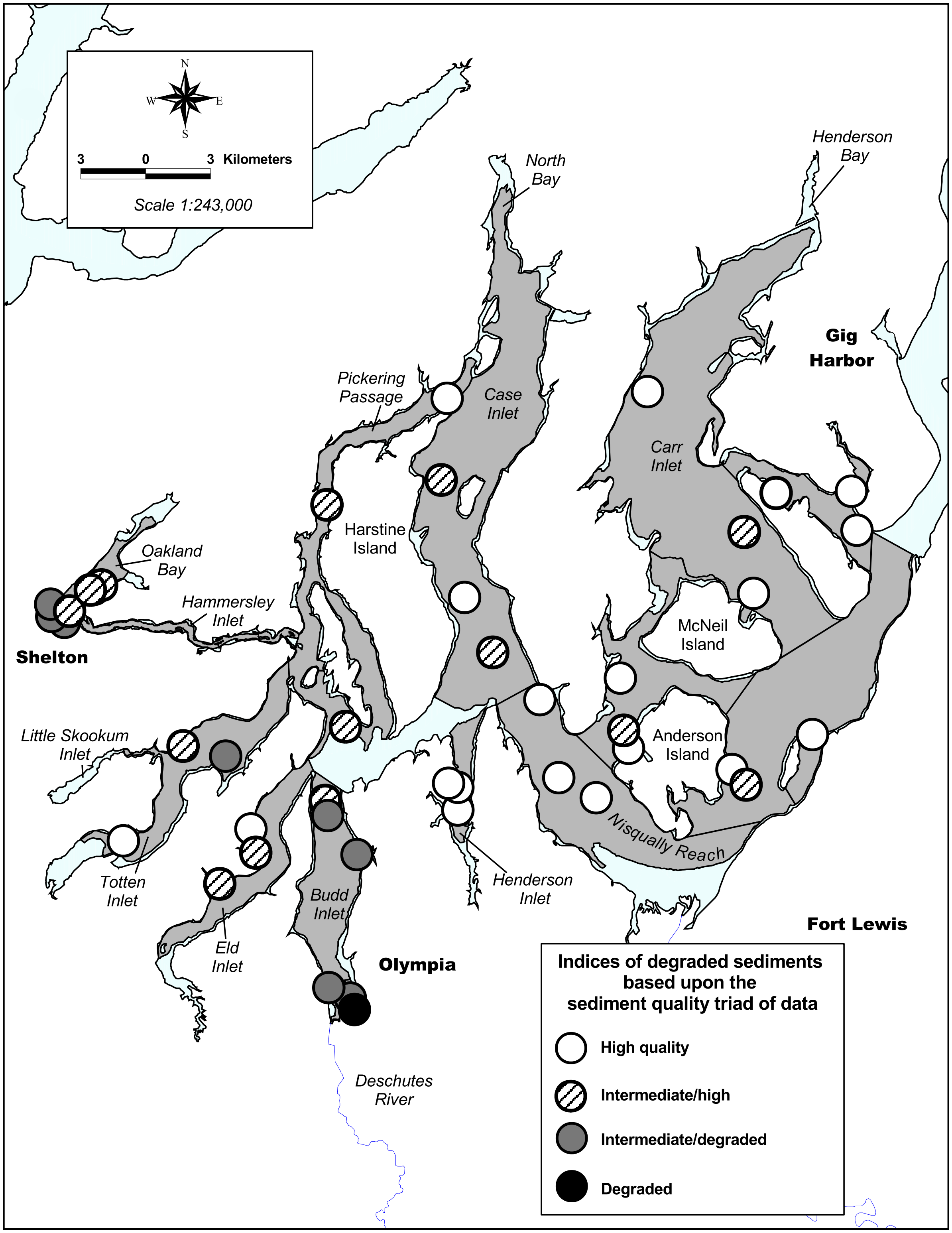

Figure 26. Summary of spatial patterns for indices of degraded sediments based upon the sediment quality triad of data for south Puget Sound sampling stations from the PSAMP/NOAA bioeffects survey, Tacoma Narrows to Shelton Harbor.

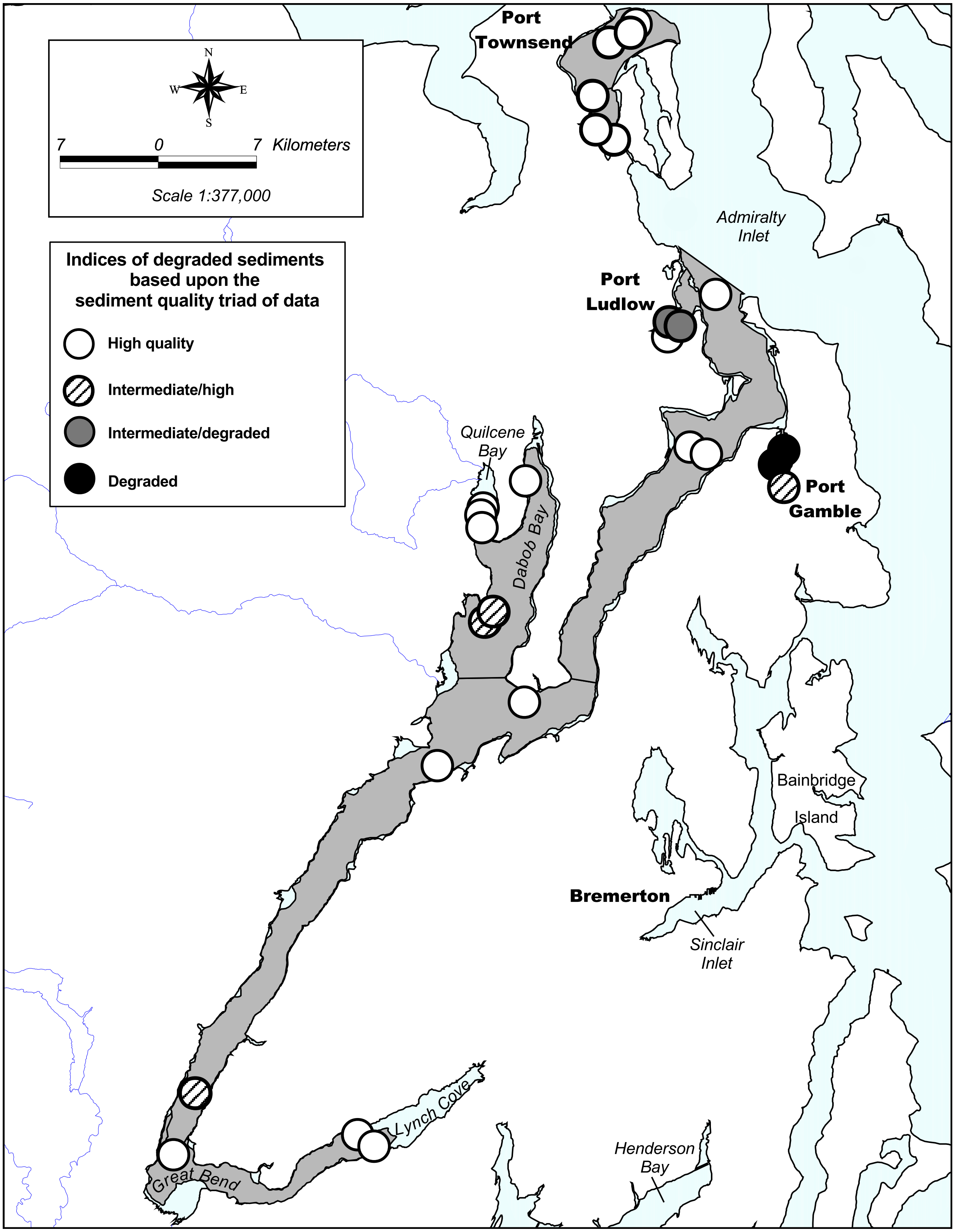

Figure 27. Summary of spatial patterns for indices of degraded sediments based upon the sediment quality triad of data for Hood Canal and Port Townsend sampling stations from the PSAMP/NOAA bioeffects survey, Port Townsend to Lynch Cove.

Table 1. Estimated incidence and spatial extent of chemical contamination in six Puget Sound regions and in the entire survey area. The number and percent of stations and the number and percent of the total region (km^2) were calculated for those stations where at least one chemical concentration was measured at levels above state criteria (SQS/CSL) and/or ERM guidelines (shaded area = total number of stations and area of each region).

Sediment guideline or criteria exceeded	Incidence		Spatial Extent	
	No. of stations	Pct of stations	km^2	Pct. of total region
Strait of Georgia	**61**	**100.0**	**429.1**	**100.0**
ERM	1	1.6	8.8	2.1
SQS	43	70.5	331.0	77.1
excluding benzoic acid, 4-methylphenol, and phenol	9	14.8	43.5	10.1
CSL	31	50.8	245.1	57.1
excluding benzoic acid, 4-methylphenol, and phenol	1	1.6	8.8	2.1
Total for any one guideline or criteria exceeded	43	70.5	331.0	77.1
excluding benzoic acid, 4-methylphenol, and phenol	9	14.8	43.5	10.1
Whidbey Basin	**39**	**100.0**	**344.8**	**100.0**
ERM	8	20.5	0.6	0.2
SQS	28	71.8	198.8	57.7
excluding benzoic acid, 4-methylphenol, and phenol	5	12.8	30.9	9.0
CSL	27	69.2	189.2	54.9
excluding benzoic acid, 4-methylphenol, and phenol	4	10.3	30.9	9.0
Total for any one guideline or criteria exceeded	28	71.8	198.8	57.7
excluding benzoic acid, 4-methylphenol, and phenol	10	25.6	31.3	9.1
Admiralty Inlet	**9**	**100.0**	**186.4**	**100.0**
ERM	0	0.0	0.0	0.0
SQS	7	77.8	126.9	68.1
excluding benzoic acid, 4-methylphenol, and phenol	0	0.0	0.0	0.0
CSL	7	77.8	126.9	68.1
excluding benzoic acid, 4-methylphenol, and phenol	0	0.0	0.0	0.0
Total for any one guideline or criteria exceeded	7	77.8	126.9	68.1
excluding Benzoic Acid, 4-methylphenol, and Phenol	0	0.0	0.0	0.0
Central Sound	**128**	**100.0**	**689.6**	**100.0**
ERM	27	21.1	12.8	1.9
SQS	93	72.7	543.1	78.8
excluding benzoic acid, 4-methylphenol, and phenol	42	32.8	31.4	4.6
CSL	87	68.0	541.2	78.5
excluding benzoic acid, 4-methylphenol, and phenol	19	14.8	18.1	2.6
Total for any one guideline or criteria exceeded	94	73.4	543.9	78.9
excluding benzoic acid, 4-methylphenol, and phenol	43	33.6	32.2	4.7

Sediment guideline or criteria exceeded	Incidence		Spatial Extent	
	No. of stations	Pct of stations	km^2	Pct. of total region
South Sound	**42**	**100.0**	**397.0**	**100.0**
ERM	1	2.4	5.7	1.4
SQS	9	21.4	54.5	13.7
excluding benzoic acid, 4-methylphenol, and phenol	5	11.9	32.5	8.2
CSL	8	19.0	44.0	11.1
excluding benzoic acid, 4-methylphenol, and phenol	3	7.1	21.7	5.5
Total for any one guideline or criteria exceeded	9	21.4	54.5	13.7
excluding benzoic acid, 4-methylphenol, and phenol	5	11.9	32.5	8.2
Hood Canal	**21**	**100.0**	**316.4**	**100.0**
ERM	2	9.5	2.8	0.9
SQS	1	4.8	1.6	0.5
excluding benzoic acid, 4-methylphenol, and phenol	1	4.8	1.6	0.5
CSL	0	0.0	0.0	0.0
excluding benzoic acid, 4-methylphenol, and phenol	0	0.0	0.0	0.0
Total for any one guideline or criteria exceeded	3	14.3	4.3	1.4
excluding benzoic acid, 4-methylphenol, and phenol	3	14.3	4.3	1.4
Total Study Area	**300**	**100.0**	**2363.3**	**100.0**
ERM	39	13.0	30	1.3
SQS	181	60.3	1256	53.1
excluding benzoic acid, 4-methylphenol, and phenol	62	20.7	139	5.9
CSL	160	53.3	1146	48.5
excluding benzoic acid, 4-methylphenol, and phenol	27	9.0	79	3.4
Total for any one guideline or criteria exceeded	184	61.3	1259	53.3
excluding benzoic acid, 4-methylphenol, and phenol	70	23.3	143	6.1

Table 2. Estimated incidence and spatial extent of chemical contamination in five Puget Sound stratum types and in the entire survey area. The number and percent of stations and the number and percent of the total study area (km^2) were calculated for those stations where at least one chemical concentration was measured at levels above state criteria and/or national guidelines (shaded area = total number of stations and area of each stratum).

Sediment guideline or criteria exceeded	Incidence		Spatial Extent	
	No. of stations	Pct. of stations	km^2	Pct. of total strata
Harbor	**59**	**100.0**	**68.4**	**100.0**
ERM	30	46.9	9.1	13.3
SQS	45	70.3	15.8	23.1
excluding benzoic acid, 4-methylphenol, and phenol	36	56.3	14.3	20.9
CSL	38	59.4	12.4	18.1
excluding benzoic acid, 4-methylphenol, and phenol	15	23.4	7.5	11.0
Total for any one guideline or criteria exceeded	45	70.3	15.8	23.1
excluding benzoic acid, 4-methylphenol, and phenol	41	64.1	15.0	21.9
Urban	**64**	**100.0**	**151.8**	**100.0**
ERM	5	9.3	4.3	2.9
SQS	37	68.5	89.1	58.7
excluding benzoic acid, 4-methylphenol, and phenol	14	25.9	24.5	16.1
CSL	32	59.3	67.6	44.6
excluding benzoic acid, 4-methylphenol, and phenol	6	11.1	12.9	8.5
Total for any one guideline or criteria exceeded	38	70.4	89.8	59.2
excluding benzoic acid, 4-methylphenol, and phenol	15	27.8	25.3	16.7
Passage	**54**	**100.0**	**626.7**	**100.0**
ERM	0	0.0	0.0	0.0
SQS	40	74.1	426.3	68.0
excluding benzoic acid, 4-methylphenol, and phenol	5	9.3	56.3	9.0
CSL	38	70.4	396.8	63.3
excluding benzoic acid, 4-methylphenol, and phenol	3	5.6	24.4	3.9
Total for any one guideline or criteria exceeded	40	74.1	426.3	68.0
excluding benzoic acid, 4-methylphenol, and phenol	5	9.3	56.3	9.0
Basin	**42**	**100.0**	**889.6**	**100.0**
ERM	0	0.0	0.0	0.0
SQS	26	61.9	534.4	60.1
excluding benzoic acid, 4-methylphenol, and phenol	2	4.8	4.0	0.5
CSL	24	57.1	508.9	57.2
excluding benzoic acid, 4-methylphenol, and phenol	0	0.0	0.0	0.0
Total for any one guideline or criteria exceeded	26	61.9	534.4	60.1
excluding benzoic acid, 4-methylphenol, and phenol	2	4.8	4.0	0.5

Table 2. Concluded.

Sediment guideline or criteria exceeded	Incidence		Spatial Extent	
	No. of stations	Pct. of stations	km^2	Pct. of total strata
Rural	**81**	**100.0**	**626.7**	**100.0**
ERM	4	4.9	17.3	2.8
SQS	33	40.7	190.4	30.4
excluding benzoic acid, 4-methylphenol, and phenol	5	6.2	40.7	6.5
CSL	28	34.6	160.6	25.6
excluding benzoic acid, 4-methylphenol, and phenol	3	3.7	34.8	5.6
Total for any one guideline or criteria exceeded	35	43.2	193.1	30.8
excluding benzoic acid, 4-methylphenol, and phenol	7	8.6	43.5	6.9
Total Study Area	**300**	**100.0**	**2363.3**	**100.0**
ERM	39	13.0	30.7	1.3
SQS	181	60.3	1256.0	53.1
excluding benzoic acid, 4-methylphenol, and phenol	62	20.7	139.8	5.9
CSL	160	53.3	1146.3	48.5
excluding benzoic acid, 4-methylphenol, and phenol	27	9.0	79.6	3.4
Total for any one guideline or criteria exceeded	184	61.3	1259.5	53.3
excluding benzoic acid, 4-methylphenol, and phenol	70	23.3	144.1	6.1

Table 3. Estimated incidence and spatial extent of toxicity in six Puget Sound regions and in the entire survey area. The number and percent of regions and the number and percent of the total study area (km^2) were calculated for those stations where toxicity results were statistically significant. Critical values in bold were used for calculation of total critical values exceeded (shaded area = total number of stations and area of each region).

Toxicity test critical values	Incidence: No. of stations	Incidence: Pct. of stations	Spatial Extent: km^2	Spatial Extent: Pct. of total region
Strait of Georgia	**61**	**100.0**	**429.1**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	5	8.2	19.5	4.5
50% pore water	2	3.3	11.1	2.6
25% pore water	1	1.6	5.6	1.3
Microbial bioluminescence				
<80% of controls	61	100.0	429.1	100.0
<0.51 mg/ml	1	1.6	8.6	2.0
<0.06 mg/ml	0	0.0	0.0	0.0
Cytochrome p-450 HRGS				
>11.1 µg/g	5	8.2	9.7	2.3
>37.1 µg/g	0	0.0	0.0	0.0
Total for any one individual critical value exceeded	11	18.0	37.8	8.8
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	0	0.0	0.0	0.0
Whidbey Basin	**39**	**100.0**	**344.8**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	10	25.6	21.1	6.1
50% pore water	5	12.8	0.4	0.1
25% pore water	5	12.8	2.7	0.8
Microbial bioluminescence				
<80% of controls	37	94.9	332.7	96.5
<0.51 mg/ml	4	10.3	0.4	0.1
<0.06 mg/ml	0	0.0	0.0	0.0

Table 3. Continued.

Toxicity test critical values	Incidence: No. of stations	Incidence: Pct. of stations	Spatial Extent: km^2	Spatial Extent: Pct. of total region
Cytochrome p-450 HRGS				
>11.1 µg/g	10	25.6	10.3	3.0
>37.1 µg/g	4	10.3	0.4	0.1
Total for any one individual critical value exceeded	11	28.2	30.7	8.9
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	4	10.3	0.4	0.1
Admiralty Inlet	**9**	**100.0**	**186.4**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	0	0.0	0.0	0.0
50% pore water	0	0.0	0.0	0.0
25% pore water	0	0.0	0.0	0.0
Microbial bioluminescence				
<80% of controls	3	33.3	58.3	31.3
<0.51 mg/ml	0	0.0	0.0	0.0
<0.06 mg/ml	0	0.0	0.0	0.0
Cytochrome p-450 HRGS				
>11.1 µg/g	0	0.0	0.0	0.0
>37.1 µg/g	0	0.0	0.0	0.0
Total for any one individual critical value exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	0	0.0	0.0	0.0
Central Sound	**128**	**100.0**	**689.6**	**100.0**
Amphipod survival				
<80% of controls	1	0.8	1.0	0.1
Urchin fertilization (<80% of controls)				
100% pore water	10	7.8	4.1	0.6
50% pore water	4	3.1	1.6	0.2
25% pore water	3	2.3	4.2	0.6
Microbial bioluminescence				
<80% of controls	85	66.4	338.5	49.1
<0.51 mg/ml	2	1.6	1.2	0.2
<0.06 mg/ml	0	0.0	0.0	0.0

Table 3. Continued.

Toxicity test critical values	Incidence		Spatial Extent	
	No. of stations	Pct. of stations	km²	Pct. of total region
Cytochrome p-450 HRGS				
>11.1 µg/g	93	72.7	310.5	45.0
>37.1 µg/g	40	31.3	49.4	7.2
Total for any one individual critical value exceeded	95	74.2	311.9	45.2
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	1	0.8	0.1	0.0
South Sound	**42**	**100.0**	**397.0**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	4	9.5	10.3	2.6
50% pore water	3	7.1	4.5	1.1
25% pore water	3	7.1	2.2	0.6
Microbial bioluminescence				
<80% of controls	39	92.9	331.9	83.6
<0.51 mg/ml	1	2.4	0.3	0.1
<0.06 mg/ml	0	0.0	0.0	0.0
Cytochrome p-450 HRGS				
>11.1 µg/g	20	47.6	177.9	44.8
>37.1 µg/g	3	7.1	15.8	4.0
Total for any one individual critical value exceeded	21	50.0	183.6	46.3
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	1	2.4	0.3	0.1
Hood Canal	**21**	**100.0**	**316.4**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	3	14.3	38.5	12.2
50% pore water	0	0.0	0.0	0.0
25% pore water	0	0.0	0.0	0.0
Microbial bioluminescence				
<80% of controls	12	57.1	138.8	43.9
<0.51 mg/ml	0	0.0	0.0	0.0
<0.06 mg/ml	0	0.0	0.0	0.0

Table 3. Concluded.

Toxicity test critical values	Incidence		Spatial Extent	
	No. of stations	Pct. of stations	km^2	Pct. of total region
Cytochrome p-450 HRGS				
>11.1 µg/g	6	28.6	77.8	24.6
>37.1 µg/g	1	4.8	1.6	0.5
Total for any one individual critical value exceeded	6	28.6	77.8	24.6
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	0	0.0	0.0	0.0
Total Study Area	**300**	**100.0**	**2363.3**	**100.0**
Amphipod survival				
<80% of controls	1	0.3	1	0.04
Urchin fertilization (<80% of controls)				
100% pore water	32	10.7	93.5	4.0
50% pore water	14	4.7	17.7	0.7
25% pore water	12	4.0	14.6	0.6
Microbial bioluminescence				
<80% of controls	237	79.0	1629.3	68.9
<0.51 mg/ml	8	2.7	10.5	0.4
<0.06 mg/ml	0	0.0	0.0	0.0
Cytochrome p-450 HRGS				
>11.1 µg/g	134	44.7	586.3	24.8
>37.1 µg/g	48	16.0	67.0	2.8
Total for any one individual critical value exceeded	144	48.0	641.9	27.2
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	6	2.0	0.8	0.0

Table 4. Estimated incidence and spatial extent of toxicity in five Puget Sound stratum types and in the entire survey area. The number and percent of strata and the number and percent of the total study area (km^2) were calculated for those stations where toxicity results were statistically significant. Criteria in bold were used for calculation of total criteria exceeded (shaded area = total number of stations and area of each stratum).

Toxicity test critical values	Incidence: No. of stations	Incidence: Pct. of stations	Spatial Extent: km^2	Spatial Extent: Pct. of total strata
Harbor	**59**	**100.0**	**68.4**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	19	32.2	3.9	5.7
50% pore water	11	18.6	2.6	3.8
25% pore water	8	13.6	2.3	3.4
Microbial bioluminescence				
<80% of controls	52	88.1	66.6	97.4
<0.51 mg/ml	7	11.9	1.9	2.8
<0.06 mg/ml	0	0.0	0.0	0.0
Cytochrome p-450 HRGS				
>11.1 μg/g	54	91.5	62.1	90.8
>37.1 μg/g	36	61.0	24.4	35.7
Total for any one individual critical value exceeded	54	91.5	62.1	90.8
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	6	10.2	0.8	1.2
Urban	**64**	**100.0**	**151.8**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	3	4.7	11.5	7.6
50% pore water	2	3.1	11.1	7.3
25% pore water	1	1.6	5.6	3.7
Microbial bioluminescence				
<80% of controls	44	68.8	113.8	75.0
<0.51 mg/ml	1	1.6	8.6	5.7
<0.06 mg/ml	0	0.0	0.0	0.0

Table 4. Continued.

Toxicity test critical values	Incidence		Spatial Extent	
	No. of stations	Pct. of stations	km^2	Pct. of total strata
Cytochrome p-450 HRGS				
>11.1 µg/g	38	59.4	58.9	38.8
>37.1 µg/g	9	14.1	7.0	4.6
Total for any one individual critical value exceeded	42	65.6	79.0	52.0
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	0	0.0	0.0	0.0
Passage	**54**	**100.0**	**626.7**	**100.0**
Amphipod survival				
<80% of controls	1	1.9	1.0	0.2
Urchin fertilization (<80% of controls)				
100% pore water	1	1.9	1.0	0.2
50% pore water	0	0.0	0.0	0.0
25% pore water	0	0.0	0.0	0.0
Microbial bioluminescence				
<80% of controls	47	87.0	472.5	75.4
<0.51 mg/ml	0	0.0	0.0	0.0
<0.06 mg/ml	0	0.0	0.0	0.0
Cytochrome p-450 HRGS				
>11.1 µg/g	8	14.8	23.8	3.8
>37.1 µg/g	0	0.0	0.0	0.0
Total for any one individual critical value exceeded	9	16.7	24.8	4.0
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	0	0.0	0.0	0.0
Basin	**42**	**100.0**	**889.6**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	0	0.0	0.0	0.0
50% pore water	0	0.0	0.0	0.0
25% pore water	1	2.4	2.8	0.3
Microbial bioluminescence				
<80% of controls	27	64.3	510.9	57.4
<0.51 mg/ml	0	0.0	0.0	0.0
<0.06 mg/ml	0	0.0	0.0	0.0

Table 4. Continued.

Toxicity test critical values	Incidence		Spatial Extent	
	No. of stations	Pct. of stations	km^2	Pct. of total strata
Cytochrome p-450 HRGS				
>11.1 µg/g	15	35.7	278.1	31.3
>37.1 µg/g	2	4.8	34.0	3.8
Total for any one individual critical value exceeded	15	35.7	278.1	31.3
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	0	0.0	0.0	0.0
Rural	**81**	**100.0**	**626.7**	**100.0**
Amphipod survival				
<80% of controls	0	0.0	0.0	0.0
Urchin fertilization (<80% of controls)				
100% pore water	9	11.1	77.0	12.3
50% pore water	1	1.2	4.0	0.6
25% pore water	2	2.5	4.0	0.6
Microbial bioluminescence				
<80% of controls	67	82.7	465.5	74.3
<0.51 mg/ml	0	0.0	0.0	0.0
<0.06 mg/ml	0	0.0	0.0	0.0
Cytochrome p-450 HRGS				
>11.1 µg/g	19	23.5	163.5	26.1
>37.1 µg/g	1	1.2	1.6	0.3
Total for any one individual critical value exceeded	24	29.6	198.0	31.6
Total for all critical values exceeded	0	0.0	0.0	0.0
Total for all critical values exceeded (excluding amphipod survival)	0	0.0	0.0	0.0
Total Study Area	**300**	**100.0**	**2363.3**	**100.0**
Amphipod survival				
<80% of controls	1	0.3	1	0.04
Urchin fertilization (<80% of controls)				
100% pore water	32	10.7	93.4	4.0
50% pore water	14	4.7	17.7	0.7
25% pore water	12	4.0	14.7	0.6
Microbial bioluminescence				
<80% of controls	237	79.0	1629.3	68.9
<0.51 mg/ml	8	2.7	10.5	0.4
<0.06 mg/ml	0	0.0	0	0.0

Table 4. Concluded.

Toxicity test critical values	Incidence		Spatial Extent	
	No. of stations	Pct. of stations	km^2	Pct. of total strata
Cytochrome p-450 HRGS				
>11.1 µg/g	134	44.7	586.3	24.8
>37.1 µg/g	48	16.0	67	2.8
Total for any one individual critical value exceeded	144	48.0	641.9	27.2
Total for all critical values exceeded	0	0.0	0	0.0
Total for all critical values exceeded (excluding amphipod survival)	6	2.0	0.8	0.03

Table 5. Summary of nine indices of benthic infaunal diversity and abundance in six sampling regions of Puget Sound, based upon the 300 samples analyzed in the PSAMP/NOAA survey.

					Abundance				
Summary Statistics	Total Abundance	Number of Taxa	Even-ness (J')	SDI*	Annelida	Arthro-poda	Mollusca	Echino-dermata	Misc. Taxa
Strait of Georgia (61)									
Mean	1350.4	50.5	0.6	8.0	627.8	387.0	220.4	101.7	13.5
Median	856.0	45.0	0.6	5.0	272.0	176.0	105.0	41.0	6.0
Std. Dev.	1455.6	20.0	0.2	5.7	1030.3	468.1	369.0	149.9	22.3
Whidbey Basin (39)									
Mean	414.5	40.0	0.7	7.8	221.0	47.0	139.0	1.2	6.3
Median	318.0	40.0	0.7	6.0	158.0	36.0	90.0	1.0	5.0
Std. Dev.	300.3	19.5	0.1	5.0	223.9	57.9	154.9	1.8	5.3
Admiralty Inlet (9)									
Mean	763.7	87.6	0.7	17.9	293.1	231.3	171.4	54.2	13.6
Median	667.0	77.0	0.8	17.0	292.0	67.0	161.0	7.0	6.0
Std. Dev.	615.9	43.9	0.1	8.7	223.8	423.0	71.1	137.8	18.3
Central Sound (128)									
Mean	779.8	64.3	0.7	11.1	425.7	118.6	204.3	23.8	7.4
Median	644.5	61.0	0.7	9.0	219.0	81.0	139.5	3.0	6.0
Std. Dev.	563.7	23.8	0.1	8.2	487.0	143.3	188.1	51.4	5.6
South Sound (42)									
Mean	340.2	43.5	0.7	10.5	165.5	69.6	42.1	43.4	19.7
Median	269.5	36.0	0.8	8.0	139.0	21.5	31.0	3.0	6.0
Std. Dev.	255.3	27.1	0.2	7.3	126.8	104.5	42.7	99.2	54.9
Hood Canal (21)									
Mean	704.7	49.2	0.7	9.4	477.8	98.0	116.1	3.2	9.6
Median	516.0	46.0	0.7	10.0	198.0	41.0	90.0	2.0	4.0
Std. Dev.	812.6	25.4	0.2	5.7	741.9	163.1	115.2	3.5	14.5

* SDI = Swartz's Dominance Index

Table 6. Summary statistics for nine indices of benthic community structure for samples in each of five stratum types in Puget Sound.

					Abundance				
Station Number	**Total Abundance**	**Number of Taxa**	**Evenness (J')**	**SDI***	**Annelida**	**Arthro- poda**	**Mollusca**	**Echino- dermata**	**Misc. Taxa**
Harbor (59)									
Mean	974.2	51.4	0.6	7.3	642.2	149.2	152.8	25.3	4.7
Median	806.0	50.0	0.6	5.0	394.0	52.0	95.0	1.0	4.0
Std. Dev.	918.6	27.4	0.2	6.1	746.9	253.7	174.6	56.6	4.3
Urban (64)									
Mean	955.0	60.4	0.6	9.8	492.1	185.4	195.5	74.0	8.0
Median	714.0	61.0	0.6	7.5	271.5	74.0	147.5	8.5	6.0
Std. Dev.	883.2	26.0	0.1	7.4	662.0	270.4	193.6	150.8	7.6
Passage (54)									
Mean	596.4	64.4	0.7	13.1	229.9	111.6	180.1	55.4	19.4
Median	514.5	56.0	0.8	12.5	164.0	58.0	122.0	5.0	9.0
Std. Dev.	449.2	27.3	0.1	7.4	188.6	214.8	176.1	114.0	48.8
Basin (42)									
Mean	415.0	58.1	0.8	14.4	133.6	134.8	121.5	14.3	10.8
Median	325.5	53.0	0.8	13.0	100.5	75.0	89.0	3.0	8.5
Std. Dev.	300.8	25.3	0.1	9.0	83.7	177.6	124.4	28.0	11.0
Rural (81)									
Mean	815.9	45.8	0.7	7.9	415.0	189.2	177.9	22.9	10.8
Median	531.0	43.0	0.7	6.0	166.0	43.0	87.0	5.0	5.0
Std. Dev.	1112.0	22.0	0.1	5.1	742.5	358.4	325.3	36.1	19.0

* SDI = Swartz's Dominance Index

Table 7. Estimated spatial extent of four categories of relative sediment quality in six Puget Sound monitoring regions based upon the Sediment Quality Triad (excluding nickel, benzoic acid, phenol, 4-methylphenol). Shaded rows indicate the total numbers of stations and area of each region.

Sediment Quality Index Category (number of parameters impaired /station)	No. of stations	Pct. of stations	km^2	Pct. of total study area
Strait of Georgia	**61**	**100.0**	**429.1**	**100.0**
High (0)	**43**	**70.5**	**345.6**	**80.5**
Intermediate/High (1)	**15**	**24.6**	**77.3**	**18.0**
Chemistry	6	9.8	37.2	8.7
Toxicity	8	13.1	31.5	7.3
Infaunal	1	1.6	8.6	2.0
Intermediate/Degraded (2)	**3**	**4.9**	**6.3**	**1.5**
Chemistry/Toxicity	3	4.9	6.3	1.5
Chemistry/Infauna	0	0.0	0.0	0.0
Infaunal/Toxicity	0	0.0	0.0	0.0
Degraded (3)	**0**	**0.0**	**0.0**	**0.0**
Whidbey Basin	**39**	**100.0**	**344.8**	**100.0**
High (0)	**24**	**61.5**	**282.5**	**81.9**
Intermediate/High (1)	**5**	**12.8**	**51.9**	**15.1**
Chemistry	2	5.1	30.7	8.9
Toxicity	1	2.6	20.4	5.9
Infaunal	2	5.1	0.8	0.2
Intermediate/Degraded (2)	**2**	**5.1**	**9.7**	**2.8**
Chemistry/Toxicity	0	0.0	0.0	0.0
Chemistry/Infauna	0	0.0	0.0	0.0
Infaunal/Toxicity	2	5.1	9.7	2.8
Degraded (3)	**8**	**20.5**	**0.6**	**0.2**
Admiralty Inlet	**9**	**100.0**	**186.4**	**100.0**
High (0)	**9**	**100.0**	**186.4**	**100.0**
Intermediate/High (1)	**0**	**0.0**	**0.0**	**0.0**
Chemistry	0	0.0	0.0	0.0
Toxicity	0	0.0	0.0	0.0
Infaunal	0	0.0	0.0	0.0
Intermediate/Degraded (2)	**0**	**0.0**	**0.0**	**0.0**
Chemistry/Toxicity	0	0.0	0.0	0.0
Chemistry/Infauna	0	0.0	0.0	0.0
Infaunal/Toxicity	0	0.0	0.0	0.0
Degraded (3)	**0**	**0.0**	**0.0**	**0.0**
Central Sound	**128**	**100.0**	**689.6**	**100.0**
High (0)	**30**	**(23.4)**	**373.7**	**(54.2)**
Intermediate/High (1)	**47**	**(36.7)**	**282.0**	**(40.9)**
Chemistry	3	(2.3)	3.9	(0.6)
Toxicity	44	(34.4)	278.1	(40.3)
Infaunal	0	(0.0)	0.0	(0.0)

Table 7. Concluded.

Sediment Quality Index Category (number of parameters impaired /station)	No. of stations	Pct. of stations	km^2	Pct. of total study area
Intermediate/Degraded (2)	**25**	**(19.5)**	**14.5**	**(2.1)**
Chemistry/Toxicity	14	(10.9)	8.8	(1.3)
Chemistry/Infauna	0	(0.0)	0.0	(0.0)
Infaunal/Toxicity	11	(8.6)	5.6	(0.8)
Degraded (3)	**26**	**(20.3)**	**19.4**	**(2.8)**
South Sound	**42**	**100.0**	**397.0**	**100.0**
High (0)	**19**	**45.2**	**192.3**	**48.4**
Intermediate/High (1)	**14**	**33.3**	**141.6**	**35.7**
Chemistry	2	4.8	21.0	5.3
Toxicity	12	28.6	120.5	30.4
Infaunal	0	0.0	0.0	0.0
Intermediate/Degraded (2)	**8**	**19.0**	**62.9**	**15.8**
Chemistry/Toxicity	2	4.8	11.2	2.8
Chemistry/Infauna	0	0.0	0.0	0.0
Infaunal/Toxicity	6	14.3	51.7	13.0
Degraded (3)	**1**	**2.4**	**0.3**	**0.1**
Hood Canal	**21**	**100.0**	**316.4**	**100.0**
High (0)	**13**	**61.9**	**235.6**	**74.5**
Intermediate/High (1)	**4**	**19.0**	**74.9**	**23.7**
Chemistry	0	0.0	0.0	0.0
Toxicity	3	14.3	73.5	23.2
Infaunal	1	4.8	1.4	0.4
Intermediate/Degraded (2)	**2**	**9.5**	**3.1**	**1.0**
Chemistry/Toxicity	0	0.0	0.0	0.0
Chemistry/Infauna	1	4.8	1.6	0.5
Infaunal/Toxicity	1	4.8	1.6	0.5
Degraded (3)	**2**	**9.5**	**2.8**	**0.9**
Total Study Area	**300**	**100.0**	**2363.3**	**100.0**
High (0)	**138**	**(46.0)**	**1616.1**	**(68.4)**
Intermediate/High (1)	**85**	**(28.3)**	**627.6**	**(26.6)**
Chemistry	13	(4.3)	92.8	(3.9)
Toxicity	68	(22.7)	524.0	(22.2)
Infaunal	4	(1.3)	10.8	(0.5)
Intermediate/Degraded (2)	**40**	**(13.3)**	**96.5**	**(4.1)**
Chemistry/Toxicity	19	(6.3)	26.3	(1.1)
Chemistry/Infauna	1	(0.3)	1.6	(0.1)
Infaunal/Toxicity	20	(6.7)	68.6	(2.9)
Degraded (3)	**37**	**(12.3)**	**23.1**	**(1.0)**

Table 8. Estimated spatial extent of four categories of relative sediment quality in five Puget Sound stratum types based upon the Sediment Quality Triad (excluding nickel, benzoic acid, phenol, 4-methylphenol). Shaded rows indicate the total numbers of stations and area of each stratum type.

Sediment Quality Index Category (number of parameters impaired /station)	No. of stations	Pct. of stations	km^2	Pct. of total study area
Harbor	**59**	**100.0**	**68.4**	**100.0**
High (0)	**4**	**6.8**	**5.1**	**7.4**
Intermediate/High (1)	**5**	**8.5**	**2.5**	**3.6**
Chemistry	1	1.7	1.2	1.8
Toxicity	4	6.8	1.2	1.8
Infaunal	0	0.0	0.0	0.0
Intermediate/Degraded (2)	**20**	**33.9**	**50.8**	**74.3**
Chemistry/Toxicity	10	16.9	3.4	4.9
Chemistry/Infauna	0	0.0	0.0	0.0
Infaunal/Toxicity	10	16.9	47.5	69.4
Degraded (3)	**30**	**50.8**	**10.1**	**14.7**
Urban	**64**	**100.0**	**151.8**	**100.0**
High (0)	**17**	**(26.6)**	**58.6**	**(38.6)**
Intermediate/High (1)	**29**	**(45.3)**	**64.6**	**(42.6)**
Chemistry	4	(6.3)	5.6	(3.7)
Toxicity	24	(37.5)	50.4	(33.2)
Infaunal	1	(1.6)	8.6	(5.7)
Intermediate/Degraded (2)	**13.0**	**(20.3)**	**18.3**	**(12.1)**
Chemistry/Toxicity	6	(9.4)	9.4	(6.2)
Chemistry/Infauna	0	(0.0)	0.0	(0.0)
Infaunal/Toxicity	7	(10.9)	8.9	(5.9)
Degraded (3)	**5**	**(7.8)**	**10.3**	**(6.8)**
Passage	**54**	**100.0**	**626.7**	**100.0**
High (0)	**41**	**75.9**	**549.0**	**87.6**
Intermediate/High (1)	**11**	**20.4**	**73.3**	**11.7**
Chemistry	4	7.4	52.9	8.4
Toxicity	7	13.0	20.4	3.3
Infaunal	0	0.0	0.0	0.0
Intermediate/Degraded (2)	**2**	**3.7**	**4.4**	**0.7**
Chemistry/Toxicity	1	1.9	3.4	0.5
Chemistry/Infauna	0	0.0	0.0	0.0
Infaunal/Toxicity	1	1.9	1.0	0.2
Degraded (3)	**0**	**0.0**	**0.0**	**0.0**
Basin	**42**	**100.0**	**889.6**	**100.0**
High (0)	**25**	**59.5**	**607.5**	**68.3**
Intermediate/High (1)	**17**	**40.5**	**282.1**	**31.7**
Chemistry	2	4.8	4.0	0.5
Toxicity	15	35.7	278.1	31.3
Infaunal	0	0.0	0.0	0.0

Table 8. Concluded.

Sediment Quality Index Category (number of parameters impaired /station)	No. of stations	Pct. of stations	km^2	Pct. of total study area
Intermediate/Degraded (2)	**0**	**0.0**	**0.0**	**0.0**
Chemistry/Toxicity	0	0.0	0.0	0.0
Chemistry/Infauna	0	0.0	0.0	0.0
Infaunal/Toxicity	0	0.0	0.0	0.0
Degraded (3)	**0**	**0.0**	**0.0**	**0.0**
Rural	**81**	**100.0**	**626.7**	**100.0**
High (0)	**51**	**63.0**	**395.9**	**63.2**
Intermediate/High (1)	**23**	**28.4**	**205.1**	**32.7**
Chemistry	2	2.5	29.0	4.6
Toxicity	18	22.2	173.9	27.8
Infaunal	3	3.7	2.2	0.4
Intermediate/Degraded (2)	**5**	**6.2**	**22.9**	**3.7**
Chemistry/Toxicity	2	2.5	10.1	1.6
Chemistry/Infauna	1	1.2	1.6	0.2
Infaunal/Toxicity	2	2.5	11.2	1.8
Degraded (3)	**2**	**2.5**	**2.8**	**0.4**
Total Study Area	**300**	**100.0**	**2363.3**	**100.0**
High (0)	**138**	**(46.0)**	**1616.1**	**(68.4)**
Intermediate/High (1)	**85**	**(28.3)**	**627.6**	**(26.6)**
Chemistry	13	(4.3)	92.8	(3.9)
Toxicity	68	(22.7)	524.0	(22.2)
Infaunal	4	(1.3)	10.8	(0.5)
Intermediate/Degraded (2)	**40**	**(13.3)**	**96.5**	**(4.1)**
Chemistry/Toxicity	19	(6.3)	26.3	(1.1)
Chemistry/Infauna	1	(0.3)	1.6	(0.1)
Infaunal/Toxicity	20	(6.7)	68.6	(2.9)
Degraded (3)	**37**	**(12.3)**	**23.1**	**(1.0)**

Table 9. Summary statistics for nine indices of benthic community structure for samples in each of four categories of sediment quality in Puget Sound as classified with the triad analysis.

					Abundance				
Summary Statistics	**Total Abundance**	**Number of Taxa**	**Evenness (J')**	**SDI***	**Annelida**	**Arthro-poda**	**Mollusca**	**Echino-dermata**	**Misc. Taxa**
High (138)									
Mean	700.4	57.5	0.7	12.1	274.0	201.7	170.5	43.2	10.9
Median	540.0	51.5	0.7	10.0	167.0	79.0	105.0	7.0	8.0
Std. Dev.	745.7	26.2	0.1	8.0	433.2	312.4	265.2	88.4	12.5
Intermediate/High (85)									
Mean	834.0	52.8	0.7	9.4	468.6	153.9	151.0	45.6	14.8
Median	490.0	47.0	0.7	8.0	177.0	56.0	93.0	3.0	5.0
Std. Dev.	1142.1	25.9	0.1	6.2	841.7	299.3	169.6	118.7	41.4
Intermediate/Degraded (40)									
Mean	798.3	60.4	0.6	9.3	464.8	87.6	215.0	24.6	6.3
Median	735.5	60.5	0.6	8.0	317.0	47.5	149.5	2.0	4.0
Std. Dev.	589.6	28.1	0.2	6.9	454.6	121.7	203.1	74.8	5.8
Degraded (37)									
Mean	941.7	45.5	0.5	4.6	670.1	88.0	156.8	23.0	3.9
Median	825.0	46.0	0.5	4.0	354.0	38.0	69.0	1.0	2.0
Std. Dev.	776.6	22.5	0.2	3.2	668.5	119.1	187.9	52.4	4.0

* SDI = Swartz's Dominance Index

Table 10. Comparisons of the percentages of sediment samples in which one or more sediment quality guidelines were exceeded and the spatial area that they represented in different databases and estuarine regions of the U.S.

Location, database, and criteria or guideline used*	Numbers of samples exceeding at least one SQG* value: Ratio	Numbers of samples exceeding at least one SQG* value: Percent	As percent of study area: km^2	As percent of study area: Percent	Source of Data
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 (excludes qualified data)	62/300	20.7	139.8	5.9	NOAA/PSAMP 1997-99
National Inventories					
U.S. EPA 1996 National Sediment Quality Inventory					U.S. EPA, 1997
• exceeded two or more SQGs or were toxic	5460/21,000	26.0			
U.S. NOAA/EMAP data base 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 data base					
• exceeded at least one sediment quality criteria (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
NOAA/EMAP database for North Carolina estuaries	44/175	25.1	1855.4	21±5	Hyland et al., 2000
EMAP - Louisiana estuaries				5±5	U.S. EPA/EMAP website
EMAP - Mississippi estuaries				0.0	U.S. EPA/EMAP website
EMAP - Alabama estuaries				29±30	U.S. EPA/EMAP website
EMAP - Florida panhandle estuaries				4.0	U.S. EPA/EMAP website
Mid-Atlantic Integrated Assessment estuaries				6.0	U.S. EPA/EMAP website
Tampa Bay, FL estuary surveys	7/537	1.2			Steve Grabe, Hillsborough Co.
Southern California Bight shelf survey (1994)	51/261	19.5	3520.0	12.3	SCCWRP website

Table 10. Concluded.

Location, database, and criteria or guideline used*	Numbers of samples exceeding at least one SQG* value: Ratio	Numbers of samples exceeding at least one SQG* value: Percent	As percent of study area: km^2	As percent of study area: Percent	Source of Data
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			
<u>Regional Inventories: Industrial harbors</u>					
New York/New Jersey Harbor R-EMAP survey; 1993/94			250.5	50	Darvene Adams, U.S. EPA Region 2
New York/New Jersey Harbor R-EMAP survey; 1998			235.5	47	Darvene Adams, U.S. 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

*Unless indicated as otherwise, all data were calculated as incidence of samples in which one or more sediment quality guidelines (SQG), usually ERM values (Long et al., 1995), were exceeded.

Table 11. Concordance in results of toxicity tests, calculated as the numbers and percentages of stations and as the area (km^2) and percentages of the total study area in which results of two or more tests exceeded critical values.

Toxicity Test and Critical Values	No. of stations	Pct. of stations	km^2	Pct. of total study area
Total Study Area	**300**	**100.0**	**2363.3**	**100.0**
Amphipod survival (<80% of controls)/ Urchin fertilization* (<80% of control)	0	0.0	0.0	0.0
Amphipod survival (<80% of controls) Microbial bioluminescence (<0.51 mg/ml)	0	0.0	0.0	0.0
Amphipod survival (<80% of controls)/ Cytochrome p-450 HRGS (>11.1 µg/g)	0	0.0	0.0	0.0
Urchin fertilization*(<80% of control)/ Microbial bioluminescence (<0.51 mg/ml)	0	0.0	0.0	0.0
Urchin fertilization* (<80% of control)/ Cytochrome p-450 HRGS (>11.1 µg/g)	18	6.0	46.6	2.0
Microbial bioluminescence (<0.51 mg/ml)/ Cytochrome p-450 HRGS (>11.1 µg/g)	1	0.3	1.1	0.05
Urchin fertilization* (80% of control)/ Microbial bioluminescence (<0.51 mg/ml)/ Cytochrome p-450 HRGS (>11.1 µg/g)	6	2.0	0.8	0.03
Total for no individual critical value exceeded	156	52.0	1721.4	72.7
Total for any one individual critical value exceeded	144	48.0	641.9	27.2
Total for all critical values exceeded	0	0.0	0.0	0.0

*100% porewater

Table 12. Regional comparison of the spatial extent of toxicity in amphipod survival tests performed by NOAA and U.S. EPA.

NOAA Regions and EMAP Provinces	Total area of survey (km^2)	Amphipod survival: toxic area (km^2)	Amphipod survival: Pct. of area toxic	Reference
NOAA Regions				
Northeastern (MA, CT, NY, NJ)	490.7	186.1	37.9	Long (2000a)
Southeastern (SC, GA, FL)	1937	63.1	3.2	Long (2000a)
Southern California bays (CA)	99.7	34.4	34.5	Long (2000a)
Puget Sound (WA)	2363.3	1	0.04	present study
Cumulative NOAA National estuarine total for 1997	7280	432	5.9	Long (2000a)
EMAP Provinces				
Louisianian province	25725	2161	8.4	Summers et al., (1993)
Virginian province	23574	2357	10	Schimmel et al. (1994)
Carolinian province	8834.9	88	1	Hyland et al. (2000)
Californian province	3756	0	0	Bay (1996)
Cumulative EMAP estuarine total	64677	4750	7.3	Long (2000a)

**Ampelisca abdita* used in all regions except southern California where the test taxa was *Rhepoxynius abronius.*

Table 13. Spatial extent of toxicity (km2 and percentages of total area) in sea urchin fertilization tests performed with 100% sediment pore waters from 22 U. S. bays and estuaries (from Long, 2000a). Unless specified differently, tests were performed with Arbacia punctulata.

				Urchin fertilization in 100% pore waters	
Survey areas	**Year sampled**	**No. of sediment samples**	**Total area of survey (km^2)**	**toxic area (km^2)**	**Pct. of area toxic**
San Pedro Bay, CA[a]	92	105	53.8	52.6	97.7%
Tampa Bay, FL	92/93	165	550	463.6	84.3%
San Diego Bay, CA[b]	93	117	40.2	25.6	76.0%
Mission Bay, CA[b]	93	11	6.1	4.0	65.9%
Tijuana River, CA[b]	93	6	0.3	0.2	56.2%
San Diego River, CA[b]	93	2	0.5	0.3	52.0%
Biscayne Bay, FL	95/96	226	484.2	229.5	47.4%
Choctawhatchee Bay, FL	94	37	254.5	113.1	44.4%
California coastal lagoons	94	30	5	2.1	42.7%
Winyah Bay, GA	93	9	7.3	3.1	42.2%
Apalachicola Bay, FL	94	9	187.6	63.6	33.9%
Galveston Bay, TX	96	75	1351.1	432.0	32.0%
Charleston Harbor, SC	93	63	41.1	12.5	30.4%
Savannah River, GA	94	60	13.1	2.42	18.4%
Delaware Bay, DE	97	73	2346.8	247.5	10.5%
Boston Harbor, MA	93	55	56.1	3.8	6.6%
Sabine Lake, TX/LA	95	66	245.9	14.0	5.7%
Pensacola Bay, FL	93	40	273	14.4	5.3%
Puget Sound, WA[c]	97/98/99	300	2363.3	93.5	4.0%
St. Simons Sound, SC	94	20	24.6	0.7	2.6%
St. Andrew Bay, FL	93	31	127.2	2.3	1.8%
Leadenwah Creek, SC	93	9	1.7	0	0.0%
Cumulative National estuarine totals based upon data collected through*:					
•1995		**940**	**2082.6**	**886.3**	**42.6%**
•1996		**1136**	**3723.3**	**1439.8**	**38.7%**
•1997		**1309**	**6837.8**	**1728.0**	**25.3%**

[a] Tests performed for embryological development of *Haliotis rufescens*
[b] Tests performed for embryological development of *Strongylocentrotus purpuratus*
[c] Tests performed for fertilization success of *S. purpuratus*
* from Long, 2000a

Table 14. Spatial extent of toxicity (km^2 and percentages of total area) in microbial bioluminescence tests performed with solvent extracts of sediments from 18 U. S. bays and estuaries.

Survey areas	Year sampled	No. of sediment samples	Total area of survey (km^2)	Microbial bioluminescence: toxic area (km^2)	Microbial bioluminescence: Pct. of area toxic
Choctawhatchee Bay, FL	94	37	254.5	254.5	100.0%
St. Andrew Bay, FL	93	31	127.2	127	100.0%
Apalachicola Bay, FL	94	9	187.6	186.8	99.6%
Pensacola Bay, FL	93	40	273.0	262.8	96.4%
Galveston Bay, TX	96	75	1351.1	1143.7	84.6%
Sabine Lake, TX/LA	95	66	245.9	194.2	79.0%
Winyah Bay, GA	93	9	7.3	5.1	70.0%
Long Island Sound, NY/CT	91	60	71.9	48.8	67.9%
Savannah River, GA	94	60	13.1	7.49	57.1%
Biscayne Bay, FL	95/96	226	484.2	248.4	51.3%
St. Simons Sound, SC	94	20	24.6	11.4	46.4%
Boston Harbor, MA	93	55	56.1	25.8	44.9%
Charleston Harbor, SC	93	63	41.1	17.6	42.9%
Hudson-Raritan Estuary, NY/NJ	91	117	350.0	136.1	38.9%
Leadenwah Creek, SC	93	9	1.7	0.34	20.1%
Delaware Bay, DE[A]	97	73	2346.8	114.0	4.9%
Puget Sound, WA [A]	97/98/99	300	2363.3	10.5	0.4%
Tampa Bay, FL	92/93	165	550.0	0.6	0.1%
Cumulative National estuarine totals based upon data collected through:**					
•1995		**846**	**2416.2**	**1482.3**	**61.3%**
•1996		**1042**	**4039.2**	**2670.7**	**66.1%**
•1997		**1215**	**7160.0**	**2802.4**	**39.1%**

[A] Critical value of <0.51 mg/ml
** from Long, 2000a

Table 15. Spatial extent of toxicity (km^2 and percentages of total area) in cytochrome P-450 HRGS tests performed with solvent extracts of sediments from 6 U. S. bays and estuaries.

				P-450 HRGS (>11.1 ug/g)		HRGS (>37.1 ug/g)	
Survey areas	**Year(s) sampled**	**No. of samples**	**Total area of survey (km^2)**	**toxic area (km^2)**	**Pct. of area toxic**	**toxic area (km^2)**	**Pct. of area toxic**
California coastal lagoons	1994	30	5	2.3	46.8	0	0
Puget Sound, WA	1997-99	300	2363.3	586.3	24.8	67	2.8
Delaware Bay, DE	1997	73	2346.8	145.2	6.2	80.5	3.4
Galveston Bay, TX	1996	75	1351.5	56.7	4.2	0	0
Biscayne Bay, FL	1996	121	271.4	8.8	3.3	0	0
Sabine Lake, TX/LA	1995	65	245.9	6.7	2.7	1.7	0.7
Cumulative National estuarine totals based upon data collected through*:							
•1997		**664**	**6583.9**	**806**	**12.2**	**149.2**	**2.3**

* from Long, 2000a

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Appendix A

Triad data - Results of selected toxicity, chemistry, and infaunal analysis for all 1997-1999 Puget Sound stations.

- **Amphipod:** *p<0.05, avg. survival >80% of CLIS control; ** p<0.05 and avg. survival <80% of control - one-way, unpaired t-test

- **Urchin fertilization:** *p<0.05, **p<0.01 and <80% of controls. Dunnett's T-test

- **Microtox:** ^ = mean EC50 <0.51 mg/ml determined as the 80% lower prediction limit (LPL) with the lowest (i.e., most toxic) samples removed, but >0.06 mg/ml determined as the 90% lower prediction limit (LPL) earlier in this report.

- **Cytochrome P-450 HRGS as µgB[a]p/g:** ++value 11.1 benzo[a]pyrene equivalents (ug/g sediment) determined as the 80% upper prediction limit (UPL); +++ = value >37.1 benzo[a]pyrene equivalents (ug/g sediment) determined as the 90% upper prediction limit (UPL)

- As there are no accepted guidelines or criteria for the determination of impaired infaunal assemblages, best professional judgment was used to indicate whether the infaunal assemblage as each station appeared to be impacted, based on a combination of benthic indices examined. An assemblage was classified as impacted primarily if it had a combination of low benthic indicators, although some of the impacted stations possessed high total abundance and/or Swartz's Dominance Index, due to high abundance of 1 or 2 pollution tolerant taxa.

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Appendix A. Selected results for chemistry, toxicity, and infaunal analyses for all 1997-1999 Puget Sound stations.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
1, 1, Drayton Harbor	5.56	0	0.07		**Other:** Phenol		98.0		117.0		2.37		6.46		487	53	0.85	16	272	109	19	68	19	no	Nephtys cornuta	45
																									Protomedeia grandimana	45
																									Amage sp	33
																									Rochefortia tumida	32
1, 2, Drayton Harbor	5.56	0	0.10		**Other:** Phenol	**Other:** Phenol	98.0		29.0	**	1.80		8.51		122	24	0.88	10	59	24	0	35	4	no	Nephtys cornuta	17
																									Protomedeia grandimana	15
																									Macoma nasuta	13
																									Glycinde polygnatha	13
1, 3, Drayton Harbor	5.56	0	0.09		**Other:** Phenol		103.0		0.0	**	1.33		10.51		54	11	0.89	5	37	0	0	17	0	no	Nephtys cornuta	14
																									Prionospio (Minuspio) lighti	8
																									Terebellides californica	8
																									Macoma nasuta	7
2, 4, Semiahmoo Bay	10.97	0	0.10				96.0		118.0		2.73		2.72		864	49	0.56	5	74	572	51	160	7	no	Eudorella pacifica	388
																									Psephidia lordi	109
																									Protomedeia grandimana	103
																									Amphiodia urtica/periercta complex	43
2, 5, Semiahmoo Bay	10.97	1	0.12		**Other:** Benzoic Acid, Phenol	**Other:** Benzoic Acid, Phenol	91.0		118.0		1.06		2.51		1118	29	0.44	2	411	653	41	13	0	no	Protomedeia grandimana	612
																									Terebellides horikoshii	273
																									Prionospio (Minuspio) lighti	90
																									Amphiodia urtica/periercta complex	39
2, 6, Semiahmoo Bay	10.97	1	0.11		**Other:** Benzoic Acid, Phenol	**Other:** Benzoic Acid, Phenol	99.0		117.0		2.50		8.71		1100	37	0.44	2	85	925	24	66	0	no	Protomedeia grandimana	675
																									Pontoporeia femorata	176
																									Terebellides horikoshii	44
																									Pinnixa schmitti	38
3, 7, West Boundary Bay	8.82	0	0.06				96.0		117.0		6.83		0.27		5055	64	0.48	3	358	2062	46	2581	8	no	Rochefortia tumida	1635
																									Ampelisca agassizi	1299
																									Psephidia lordi	885
																									Euphilomedes carcharodonta	373

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
3, 8, West Boundary Bay	8.82	0	0.08		**Other**: Phenol	**Other:** Phenol	100.0		117.0		1.02		2.17		783	43	0.61	5	555	106	65	57	0	no	Prionospio (Minuspio) lighti	283
																									Terebellides horikoshii	141
																									Protomedeia grandimana	79
																									Paraprionospio pinnata	67
3, 9, West Boundary Bay	8.82	0	0.15	**Metals:** Mercury	**Metals:** Mercury; **Other:** Benzoic Acid, Phenol	**Metals:** Mercury; **Other:** Benzoic Acid, Phenol	99.0		118.0		1.67		2.32		197	33	0.74	8	128	6	25	37	1	no	Terebellides horikoshii	63
																									Lumbrineris cruzensis	23
																									Amphiodia urtica/periercta complex	23
																									Axinopsida serricata	15
4, 10, South Boundary Bay	24.28	0	0.10		**Other**: Phenol	**Other:** Phenol	99.0		118.0		9.37		5.83		521	56	0.76	11	150	165	18	123	65	no	Eudorella pacifica	91
																									Acila castrensis	65
																									Pulsellum salishorum	63
																									Levinsenia gracilis	52
4, 11, South Boundary Bay	24.28	1	0.11		**Other**: Phenol	**Other:** Phenol	93.0		117.0		1.57		3.03		1083	38	0.57	4	141	653	28	261	0	no	Protomedeia grandimana	447
																									Eudorella pacifica	170
																									Psephidia lordi	162
																									Lumbrineris cruzensis	48
4, 12, South Boundary Bay	24.28	1	0.11		**Other**: Phenol	**Other:** Phenol	101.0		116.0		2.23		2.57		856	51	0.58	5	77	615	54	94	16	no	Eudorella pacifica	304
																									Protomedeia grandimana	238
																									Amphiodia urtica/periercta complex	50
																									Psephidia lordi	30
4, 13, South Boundary Bay	24.28	0	0.10		**Other**: Phenol		95.0		116.0		4.37		3.95		554	59	0.76	12	124	240	80	105	5	no	Eudorella pacifica	104
																									Amphiodia urtica/periercta complex	74
																									Acila castrensis	50
																									Protomedeia grandimana	45
5, 14, Birch Bay	4.74	0	0.10		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol, Phenol	96.0		117.0		1.46		2.01		965	40	0.63	5	89	455	24	392	5	no	Protomedeia grandimana	280
																									Rochefortia tumida	197
																									Psephidia lordi	153
																									Megamoera borealis	59
5, 15, Birch Bay	4.74	0	0.10		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol, Phenol	97.0		118.0		2.90		2.40		1235	43	0.56	4	48	554	103	527	3	no	Psephidia lordi	436
																									Eudorella pacifica	307
																									Protomedeia grandimana	146
																									Amphiodia urtica/periercta complex	85
5, 16, Birch Bay	4.74	0	0.09		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol, Phenol	99.0		118.0		2.63		2.67		746	38	0.58	5	90	434	21	199	2	no	Protomedeia grandimana	351
																									Rochefortia tumida	111

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
																									Psephidia lordi	63
																									Pontoporeia femorata	23
6, 17, Cherry Point	6.19	0	0.12		**Other:** Phenol		99.0		115.0		4.90		3.01		1454	74	0.62	9	227	223	14	956	34	no	Psephidia lordi	586
																									Axinopsida serricata	112
																									Eudorella pacifica	85
																									Levinsenia gracilis	71
6, 18, Cherry Point	6.19	0	0.11		**Other:** Phenol		100.0		112.0		2.40		2.83		1092	52	0.53	4	98	268	25	689	12	no	Rochefortia tumida	548
																									Rhepoxynius boreovariatus	110
																									Tellina modesta	104
																									Protomedeia grandimana	74
6, 19, Cherry Point	6.19	0	0.10		**Other:** Phenol		98.0		115.0		12.17		3.04		792	63	0.77	13	263	68	20	362	79	no	Axinopsida serricata	105
																									Levinsenia gracilis	85
																									Acila castrensis	81
																									Pulsellum salishorum	74
7, 20, Bellingham Bay	3.17	2	0.16				98.0		113.0		7.33		1.49		1860	49	0.39	2	1270	503	70	7	10	no	Owenia fusiformis	1145
																									Euphilomedes carcharodonta	260
																									Protomedeia prudens/Cheirimedeia zotea	186
																									Amphiodia urtica/periercta complex	54
7, 21, Bellingham Bay	3.17	3	0.20				96.0		113.0		5.43		1.72		2672	55	0.39	2	1794	748	93	25	12	no	Owenia fusiformis	1620
																									Euphilomedes carcharodonta	408
																									Protomedeia prudens/Cheirimedeia zotea	235
																									Amphiodia urtica/periercta complex	79
7, 22, Bellingham Bay	3.17	3	0.20				97.0		46.0	**	1.57		1.63		1846	41	0.51	5	1661	36	20	4	125	no	Aphelochaeta monilaris	1059
																									Nephtys cornuta	124
																									Scoletoma luti	107
																									Heteromastus filobranchus	71

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
8, 23, Bellingham Bay	1.27	3	0.21				99.0		114.0		8.23		2.63		5125	31	0.25	1	4228	712	170	7	8	no	Owenia fusiformis	4155
																									Euphilomedes carcharodonta	384
																									Protomedeia prudens/Cheirimedeia zotea	203
																									Amphiodia urtica/periercta complex	152
8, 24, Bellingham Bay	1.27	3	0.20				104.0		115.0		5.93		2.98		2786	36	0.40	3	1843	759	173	4	7	no	Owenia fusiformis	1720
																									Euphilomedes carcharodonta	347
																									Protomedeia prudens/Cheirimedeia zotea	294
																									Amphiodia urtica/periercta complex	164
8, 25, Bellingham Bay	1.27	3	0.21				99.0		114.0		4.00		2.06		984	37	0.49	3	58	802	116	1	7	no	Protomedeia prudens/Cheirimedeia zotea	358
																									Euphilomedes carcharodonta	355
																									Amphiodia urtica/periercta complex	109
																									Pinnixa schmitti	17
9A, 26, Bellingham Bay	1.24	4	0.23				101.0		119.0		12.87		4.70		1602	30	0.55	3	186	1135	266	0	15	no	Protomedeia prudens/Cheirimedeia zotea	594
																									Euphilomedes carcharodonta	423
																									Amphiodia urtica/periercta complex	250
																									Owenia fusiformis	57
9A, 27, Bellingham Bay	1.24	6	0.23		**Metals:** Mercury		99.0		119.0		12.00		3.31		1908	40	0.57	4	549	1118	221	4	16	no	Protomedeia prudens/Cheirimedeia zotea	600
																									Euphilomedes carcharodonta	381
																									Cirratulus spectabilis	319
																									Amphiodia urtica/periercta complex	216

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
9A, 28, Bellingham Bay	1.24	15	0.28		**Metals:** Mercury; **Other**: Phenol		93.0		117.0		0.63		19.09	++	143	35	0.79	11	102	9	14	16	2	no	Nephtys cornuta	40
																									Aphelochaeta monilaris	14
																									Amphiuridae	13
																									Podarke pugettensis	8
10, 29, Bellingham Bay	2.47	9	0.23		**Other:** Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol, Phenol	**Other:** 4-Methylphenol, Phenol	98.0		120.0		2.13		3.00		5783	41	0.35	2	4129	1194	420	27	13	no	Owenia fusiformis	4048
																									Protomedeia prudens/Cheirimedeia zotea	496
																									Amphiodia urtica/periercta complex	365
																									Euphilomedes carcharodonta	237
10, 30, Bellingham Bay	2.47	11	0.28		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	91.0		121.0		1.93		16.08	++	1908	36	0.59	4	773	444	595	93	3	no	Amphiodia urtica/periercta complex	516
																									Owenia fusiformis	392
																									Pholoe sp Cmplx	321
																									Euphilomedes carcharodonta	252
10, 31, Bellingham Bay	2.47	10	0.24		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	96.0		118.0		3.07		2.92		280	33	0.79	9	108	20	95	55	2	no	Amphiodia urtica/periercta complex	52
																									Amphiuridae	43
																									Pholoe sp Cmplx	35
																									Axinopsida serricata	27
11, 32, Bellingham Bay	8.59	3	0.20				102.0		94.0		0.47	^	3.31		403	33	0.61	5	287	5	13	96	2	no	Aphelochaeta monilaris	170
																									Axinopsida serricata	78
																									Heteromastus filobranchus	35
																									Glycera nana	17
11, 33, Bellingham Bay	8.59	4	0.18				102.0		117.0		2.17		4.09		379	47	0.71	10	272	24	19	62	2	no	Aphelochaeta monilaris	119
																									Axinopsida serricata	51
																									Heteromastus filobranchus	42
																									Lumbrineris cruzensis	15
11, 34, Bellingham Bay	8.59	3	0.18		**Other:** Phenol		94.0		103.0		0.51		2.76		1303	30	0.28	1	1139	11	10	141	2	yes	Aphelochaeta monilaris	1037
																									Axinopsida serricata	127
																									Heteromastus filiformis	24
																									Lumbrineris cruzensis	20

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
12, 35, Bellingham Bay	18.96	1	0.11		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	100.0		117.0		2.90		3.12		520	41	0.68	7	261	34	163	58	4	no	Amphiodia urtica/periercta complex	142
																									Levinsenia gracilis	126
																									Cossura pygodactylata	38
																									Ennucula tenuis	35
12, 36, Bellingham Bay	18.96	3	0.13		**Other:** Phenol		102.0		109.0		20.97		3.01		409	34	0.68	5	129	26	191	62	1	no	Amphiodia urtica/periercta complex	128
																									Amphiuridae	62
																									Levinsenia gracilis	60
																									Axinopsida serricata	43
12, 37, Bellingham Bay	18.96	3	0.18				95.0		114.0		2.67		4.50		232	44	0.83	15	157	26	7	37	5	no	Aphelochaeta monilaris	32
																									Heteromastus filiformis	32
																									Axinopsida serricata	21
																									Lumbrineris cruzensis	18
13, 38, Samish / Bellingham Bay	21.37	1	0.11		**Other:** Di-N-Butylphthalate, 4-Methylphenol, Phenol	**Other:** 4-Methylphenol, Phenol	99.0		116.0		21.03		9.23		1202	40	0.55	4	397	173	564	63	5	no	Amphiodia urtica/periercta complex	507
																									Prionospio (Minuspio) lighti	246
																									Eudorella pacifica	110
																									Levinsenia gracilis	64
13, 39, Samish / Bellingham Bay	21.37	1	0.10		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	104.0		117.0		5.17		3.80		509	49	0.75	12	121	65	24	240	59	no	Acila castrensis	140
																									Pulsellum salishorum	58
																									Eudorella pacifica	35
																									Levinsenia gracilis	29
13, 40, Samish / Bellingham Bay	21.37	0	0.06				94.0		115.0		0.98		2.99		2529	83	0.58	5	511	928	347	722	21	no	Rochefortia tumida	598
																									Ampelisca agassizi	597
																									Owenia fusiformis	334
																									Amphiodia urtica/periercta complex	334
14, 41, Inner Padilla Bay	4.38	1	0.07		**Other:** Di-N-Butylphthalate, Phenol	**Other:** Phenol	101.0		103.0		0.54		12.41	++	2651	76	0.57	7	1989	185	124	349	4	no	Oligochaeta	1168
																									Exogone lourei	323
																									Dorvillea annulata	139
																									Rochefortia tumida	139

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
14, 42, Inner Padilla Bay	4.38	1	0.07		**Other:** Phenol	**Other:** Phenol	91.0		112.0		2.80		7.64		1189	72	0.69	11	370	385	93	332	9	no	Rochefortia tumida	224
																									Aoroides intermedius	222
																									Owenia fusiformis	156
																									Caprella laeviuscula	85
14, 43, Inner Padilla Bay	4.38	1	0.07		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	100.0		51.0	**	1.83		1.78		7671	110	0.48	4	5084	2016	66	430	75	no	Owenia fusiformis	2996
																									Leptochelia savignyi	1680
																									Exogone lourei	910
																									Exogone dwisula	192
15, 44, Outer Padilla Bay	7.23	1	0.10		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	91.0		116.0		6.47		6.32		498	52	0.80	12	121	176	63	136	2	no	Eudorella pacifica	68
																									Acila castrensis	57
																									Amphiodia urtica/periercta complex	56
																									Levinsenia gracilis	35
15, 45, Outer Padilla Bay	7.23	1	0.11		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	95.0		120.0		2.67		1.50		634	49	0.74	10	85	143	11	389	6	no	Acila castrensis	148
																									Psephidia lordi	81
																									Eudorella pacifica	79
																									Ennucula tenuis	39
15, 46, Outer Padilla Bay	7.23	1	0.10		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	93.0		118.0		4.73		2.68		398	54	0.80	14	61	88	23	222	4	no	Acila castrensis	75
																									Psephidia lordi	35
																									Eudorella pacifica	27
																									Heterophoxus affinis	25
16, 47, March Point	0.69	0	0.08		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	91.0		114.0		3.70		11.10		633	91	0.80	22	333	19	1	271	9	no	Psephidia lordi	88
																									Axinopsida serricata	71
																									Prionospio steenstrupi/jubata	41
																									Maldane sarsi	32
16, 48, March Point	0.69	0	0.08		**Other:** Di-N-Butylphthalate, Phenol		94.0		114.0		6.47		12.19	++	587	90	0.81	21	354	47	14	151	21	no	Prionospio steenstrupi/jubata	87
																									Axinopsida serricata	38
																									Tharyx sp N1	30
																									Psephidia lordi	29
16, 49, March Point	0.69	1	0.08		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	100.0		112.0		1.23		9.79		1555	65	0.65	8	755	396	78	309	17	no	Owenia fusiformis	424
																									Protomedeia grandimana	249
																									Rochefortia tumida	190
																									Oligochaeta	105

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
17, 50, Inner Fidalgo Bay	0.84	4	0.11		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	90.0		115.0		1.10		1.89		623	50	0.68	9	358	78	16	165	6	no	Oligochaeta	220
																									Rochefortia tumida	59
																									Euphilomedes carcharodonta	51
																									Capitella capitata hyperspecies	35
17, 51, Inner Fidalgo Bay	0.84	2	0.11		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	96.0		51.0	**	3.83		3.70		1358	72	0.51	5	613	43	15	675	12	no	Psephidia lordi	569
																									Owenia fusiformis	386
																									Aricidea lopezi	26
																									Terebellides horikoshii	24
17, 52, Inner Fidalgo Bay	0.84	5	0.11				93.0		101.0		0.89		3.72		339	41	0.74	8	166	72	11	85	5	no	Euphilomedes carcharodonta	67
																									Oligochaeta	48
																									Psephidia lordi	37
																									Glycinde polygnatha	33
18, 53, Outer Fidalgo Bay	0.94	1	0.09		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	91.0		113.0		2.80		10.79		748	63	0.78	14	308	181	72	167	20	no	Protomedeia grandimana	127
																									Amphiodia urtica/periercta complex	71
																									Aphelochaeta sp N1	69
																									Rochefortia tumida	68
18, 54, Outer Fidalgo Bay	0.94	1	0.10		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	98.0		111.0		3.27		12.11	++	707	50	0.71	9	276	140	9	275	7	no	Rochefortia tumida	204
																									Protomedeia grandimana	90
																									Aphelochaeta monilaris	75
																									Owenia fusiformis	41
18, 55, Outer Fidalgo Bay	0.94	0	0.09				98.0		115.0		11.33		6.60		633	103	0.82	25	305	51	63	204	10	no	Psephidia lordi	75
																									Amphiodia urtica/periercta complex	59
																									Scoletoma luti	41
																									Nephtys cornuta	36
19, 56, March Point	1.24	0	0.07		**Other:** Di-N-Butylphthalate		95.0		119.0		15.73		4.88		495	71	0.67	17	85	35	8	365	2	no	Psephidia lordi	217
																									Alvania compacta	22
																									Protothaca staminea	16
																									Axinopsida serricata	16

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
19, 57, March Point	1.24	0	0.09				101.0		121.0		19.00		8.91		203	45	0.85	14	45	18	11	128	1	no	Psephidia lordi	28
																									Leitoscoloplos pugettensis	19
																									Axinopsida serricata	16
																									Parvilucina tenuisculpta	15
19, 58, March Point	1.24	0	0.07				100.0		120.0		9.80		5.12		646	95	0.82	24	319	21	10	290	6	no	Axinopsida serricata	76
																									Owenia fusiformis	65
																									Psephidia lordi	56
																									Magelona longicornis	32
9B, 59, Bellingham Bay	2.01	6	0.25				96.0		103.0		4.13		3.08		1232	31	0.63	4	326	720	180	4	2	no	Euphilomedes carcharodonta	321
																									Protomedeia prudens/Cheirimedeia zotea	264
																									Owenia fusiformis	189
																									Amphiodia urtica/periercta complex	170
9B, 60, Bellingham Bay	2.01	16	0.32		**Metals:** Mercury; **Other:** 4-Methylphenol	**Other:** 4-Methylphenol	94.0		104.0		3.47		8.64		3444	39	0.42	3	2380	595	437	16	16	no	Owenia fusiformis	2146
																									Amphiodia urtica/periercta complex	402
																									Protomedeia prudens/Cheirimedeia zotea	186
																									Euphilomedes carcharodonta	167
9B, 61, Bellingham Bay	2.01	10	0.24		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	98.0		98.0		2.73		2.41		2672	38	0.57	4	702	1294	650	15	11	no	Amphiodia urtica/periercta complex	589
																									Owenia fusiformis	584
																									Euphilomedes carcharodonta	565
																									Protomedeia prudens/Cheirimedeia zotea	453
21, 62, Skagit Bay	10.47	1	0.11		**Other:** 4-Methylphenol, Phenol	**Other:** 4-Methylphenol	94.0		102.0		6.30		0.62		900	51	0.49	4	206	85	1	588	20	no	Axinopsida serricata	536
																									Sternaspis cf fossor	90
																									Euphilomedes carcharodonta	37
																									Scoletoma luti	26

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
21, 63, Skagit Bay	10.47	0	0.09				97.0		100.0		8.90		0.36		408	64	0.76	13	231	93	0	80	4	no	Scalibregma inflatum	93
																									Scoletoma luti	46
																									Astyris gausapata	36
																									Rhepoxynius boreovariatus	27
21, 64, Skagit Bay	10.47	2	0.12		**Other:** Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol	**Other:** Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol	101.0		95.0		3.97		0.87		797	71	0.51	6	255	19	3	513	7	no	Axinopsida serricata	448
																									Sternaspis cf fossor	82
																									Prionospio steenstrupi/jubata	19
																									Scoletoma luti	18
22, 65, North Saratoga Passage	13.65	1	0.11		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	97.0		90.0		1.50		1.10		603	60	0.65	7	373	39	1	177	13	no	Spiochaetopterus costarum	184
																									Axinopsida serricata	106
																									Heteromastus filobranchus	68
																									Aoroides intermedius	32
22, 66, North Saratoga Passage	13.65	3	0.15		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	98.0		88.0		2.13		2.43		600	36	0.59	3	404	13	0	177	6	no	Heteromastus filiformis	204
																									Axinopsida serricata	142
																									Scalibregma inflatum	109
																									Sternaspis cf fossor	24
22, 67, North Saratoga Passage	13.65	3	0.13		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	96.0		96.0		2.43		3.04		272	40	0.77	9	179	27	0	61	5	no	Axinopsida serricata	54
																									Cossura pygodactylata	42
																									Prionospio steenstrupi/jubata	29
																									Heteromastus filobranchus	20
23, 68, Oak Harbor	0.41	2	0.14		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	98.0		103.0		1.16		4.72		1110	43	0.57	5	966	5	0	134	5	yes	Aphelochaeta sp N1	450
																									Oligochaeta	173
																									Aphelochaeta monilaris	138
																									Psephidia lordi	71
23, 69, Oak Harbor	0.41	2	0.13		**Other:** Benzoic Acid, 4-Methylphenol, Phenol	**Other:** Benzoic Acid, 4-Methylphenol, Phenol	94.0		103.0		1.11		4.54		194	32	0.81	10	95	6	0	90	3	no	Psephidia lordi	46
																									Heteromastus filobranchus	29
																									Macoma nasuta	12
																									Rochefortia tumida	11
23, 70, Oak Harbor	0.41	3	0.15		**Other**: 4-Methylphenol	**Other**: 4-Methylphenol	99.0		103.0		0.61		3.50		1159	40	0.49	4	980	4	0	163	12	yes	Aphelochaeta sp N1	623
																									Aphelochaeta sp	119
																									Psephidia lordi	112
																									Oligochaeta	81

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (+=>11.1ugB[a]p/g, ++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
24, 71, Penn Cove	3.06	5	0.16		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	82.0		104.0		2.13		2.28		650	23	0.55	3	577	3	1	65	4	no	Paraprionospio pinnata	288
																									Scalibregma inflatum	140
																									Heteromastus filiformis	65
																									Axinopsida serricata	63
24, 72, Penn Cove	3.06	3	0.14		**Other:** 4-Methylphenol, Phenol	**Other**: 4-Methylphenol	94.0		100.0		13.77		3.63		697	51	0.57	4	533	14	3	139	8	no	Heteromastus filobranchus	309
																									Axinopsida serricata	95
																									Scalibregma inflatum	64
																									Sigambra nr bassi	57
24, 73, Penn Cove	3.06	3	0.15		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	98.0		102.0		0.94		2.74		318	36	0.71	6	215	2	1	90	10	no	Axinopsida serricata	62
																									Paraprionospio pinnata	53
																									Sigambra nr bassi	51
																									Scalibregma inflatum	50
25, 74, Mid-Saratoga Passage	17.39	3	0.15		**Other**: 4-Methylphenol	**Other**: 4-Methylphenol	94.0		97.0		4.20		2.61		223	32	0.81	10	141	15	0	64	3	no	Axinopsida serricata	59
																									Cossura pygodactylata	21
																									Heteromastus filobranchus	18
																									Prionospio (Minuspio) lighti	15
25, 75, Mid-Saratoga Passage	17.39	3	0.16		**Other**: 4-Methylphenol	**Other**: 4-Methylphenol	97.0		92.0		4.10		2.83		253	31	0.63	6	81	38	1	128	5	no	Axinopsida serricata	125
																									Cossura bansei	21
																									Prionospio steenstrupi/jubata	15
																									Eudorella pacifica	13
25, 76, Mid-Saratoga Passage	17.39	3	0.15		**Other:** Benzoic Acid	**Other:** Benzoic Acid	94.0		94.0		3.80		4.66		225	36	0.60	5	81	25	1	117	1	no	Axinopsida serricata	115
																									Levinsenia gracilis	22
																									Cossuridae	16
																									Spiochaetopterus costarum	8
26, 77, South Saratoga Passage	17.08	1	0.10				102.0		101.0		45.50		1.06		429	71	0.73	15	203	37	1	179	9	no	Myriochele heeri	93
																									Axinopsida serricata	84
																									Adontorhina cyclia	42
																									Leitoscoloplos pugettensis	14
26, 78, South Saratoga Passage	17.08	3	0.15		**Other**: 4-Methylphenol	**Other**: 4-Methylphenol	95.0		102.0		11.13		4.15		137	44	0.88	16	93	19	4	7	14	no	Heteromastus filobranchus	17
																									Eudorella pacifica	10
																									Sternaspis cf fossor	9
																									Euclymeninae	9

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
26, 79, South Saratoga Passage	17.08	3	0.17		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	97.0		101.0		9.67		3.78		203	44	0.76	10	153	24	3	11	12	no	Prionospio (Minuspio) lighti	51
																									Heteromastus filobranchus	24
																									Prionospio steenstrupi/jubata	19
																									Eudorella pacifica	14
27, 80, Port Susan	20.40	3	0.20				98.0		98.0		77.73		3.72		312	44	0.70	10	238	30	0	42	2	no	Levinsenia gracilis	111
																									Scoletoma luti	41
																									Ennucula tenuis	20
																									Trochochaeta multisetosa	14
27, 81, Port Susan	20.40	3	0.21				99.0		95.0		12.60		2.79		128	33	0.72	10	48	13	2	62	3	no	Axinopsida serricata	54
																									Levinsenia gracilis	9
																									Onuphis elegans	7
																									Chaetozone sp	6
27, 82, Port Susan	20.40	3	0.20				96.0		76.0	**	6.70		5.76		148	18	0.72	4	39	57	3	45	4	no	Eudorella pacifica	44
																									Axinopsida serricata	37
																									Pista wui	23
																									Bathymedon pumilus	9
28, 83, Possession Sound	20.21	2	0.14				101.0		121.0		7.07		7.05		269	70	0.87	25	147	43	2	59	18	no	Adontorhina cyclia	36
																									Scoletoma luti	24
																									Sternaspis cf fossor	14
																									Leitoscoloplos pugettensis	14
28, 84, Possession Sound	20.21	5	0.16				99.0		120.0		8.13		4.83		332	44	0.73	10	158	26	4	131	13	no	Axinopsida serricata	102
																									Heteromastus filobranchus	40
																									Microclymene caudata	22
																									Prionospio (Minuspio) lighti	20
28, 85, Possession Sound	20.21	4	0.18		**Other:** Bis(2-Ethylhexyl) Phthalate	**Other:** Bis(2-Ethylhexyl) Phthalate	99.0		119.0		9.67		5.46		322	31	0.62	5	98	43	1	174	6	no	Axinopsida serricata	154
																									Eudorella pacifica	31
																									Chaetozone commonalis	22
																									Prionospio steenstrupi/jubata	21

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
29, 86, Inner Everett Harbor	0.05	22	1.77	**HPAHs:** Fluoranthene, Pyrene Total HPAH; **LPAHs:** Acenaphthene, Anthracene, Fluorene, Phenanthrene, Total LPAH; **Other:** Total congeners	**Other:** Benzoic Acid, 4-Methylphenol, Phenol, Total Aroclors	**Other:** Benzoic Acid, 4-Methylphenol	96.0		23.0	**	0.51		202.20	+++	54	7	0.73	3	12	42	0	0	0	yes	Nebalia pugettensis Cmplx	22
																									Aoroides spinosus	18
																									Capitella capitata hyperspecies	7
																									Eteone sp	4
29, 87, Inner Everett Harbor	0.05	20	0.40	**LPAHs:** Total LPAH	**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	84.0		12.0	**	0.69		33.10	++	109	9	0.57	2	57	52	0	0	0	yes	Capitella capitata hyperspecies	52
																									Aoroides spinosus	40
																									Nebalia pugettensis Cmplx	8
																									Desdimelita desdichada	3
29, 88, Inner Everett Harbor	0.05	23	0.41	**LPAHs:** Total LPAH	**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	90.0		50.0	**	0.94		115.80	+++	40	4	0.64	2	19	21	0	0	0	yes	Nebalia pugettensis Cmplx	20
																									Capitella capitata hyperspecies	18
																									Eteone sp	1
																									Aoroides sp	1
30, 89, Middle Everett Harbor	0.06	21	0.51	**HPAHs:** Pyrene; **LPAHs:** Acenaphthene, Fluorene, Phenanthrene, Total LPAH	**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	89.0		0.0	**	0.20	^	25.80	++	74	7	0.25	1	69	3	0	2	0	yes	Capitella capitata hyperspecies	67
																									Macoma carlottensis	2
																									Neotrypaea sp	1
																									Aoroides sp	1
30, 90, Middle Everett Harbor	0.06	21	0.43	**HPAHs:** Pyrene; **LPAHs:** Total LPAH	**Other:** Benzoic Acid, Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol, Phenol	**Other:** Benzoic Acid, Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol, Phenol	92.0		1.0	**	0.71		129.20	+++	663	46	0.67	6	354	290	0	18	1	yes	Leptochelia savignyi	146
																									Capitella capitata hyperspecies	106
																									Prionospio (Minuspio) lighti	102
																									Nebalia pugettensis Cmplx	88
30, 91, Middle Everett Harbor	0.06	15	0.26		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	97.0		0.0	**	0.58		86.40	+++	92	21	0.82	8	36	48	0	4	4	yes	Euphilomedes carcharodonta	28
																									Capitella capitata hyperspecies	9
																									Americhelidium variabilum	8
																									Nebalia pugettensis Cmplx	7

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
31, 92, Outer Everett Harbor	0.12	19	0.45	**HPAHs:** Pyrene; **LPAHs**: Acenaphthene, Fluorene, Phenanthrene, Total LPAH	**Other:** Benzoic Acid, 4-Methylphenol, Phenol	**Other:** Benzoic Acid, 4-Methylphenol, Phenol	92.0		5.0	**	0.40	^	28.80	++	226	34	0.75	9	111	73	0	42	0	yes	Capitella capitata hyperspecies	69
																									Euphilomedes carcharodonta	32
																									Macoma carlottensis	15
																									Pleusymtes coquilla	14
31, 93, Outer Everett Harbor	0.12	19	0.46	**LPAHs:** Acenaphthene, Fluorene, Phenanthrene, Total LPAH	**Other:** Benzoic Acid, 4-Methylphenol, Phenol	**Other:** Benzoic Acid, 4-Methylphenol, Phenol	97.0		2.0	**	0.42	^	29.20	++	574	50	0.74	10	280	70	1	217	6	yes	Capitella capitata hyperspecies	134
																									Rochefortia tumida	65
																									Axinopsida serricata	62
																									Euphilomedes carcharodonta	48
31, 94, Outer Everett Harbor	0.12	22	0.89	**Metals:** Arsenic, Copper, Lead, Zinc; **LPAHs:** Phenanthrene, Total LPAH	**Metals:** Arsenic, Copper, Zinc; **Other:** Benzoic Acid, 4-Methylphenol, Phenol	**Metals:** Arsenic, Copper; **Other:** Benzoic Acid, 4-Methylphenol, Phenol	100.0		68.0	**	0.44	^	28.70	++	813	78	0.78	16	337	211	8	250	7	yes	Euphilomedes carcharodonta	136
																									Axinopsida serricata	67
																									Rochefortia tumida	63
																									Capitella capitata hyperspecies	59
32, 95, Port Gardner	9.65	2	0.12				93.0		120.0		145.00		3.20		582	63	0.66	10	168	37	0	364	13	no	Axinopsida serricata	224
																									Macoma carlottensis	45
																									Macoma sp	41
																									Adontorhina cyclia	41
32, 96, Port Gardner	9.65	5	0.22		**Other:** Phenol		100.0		119.0		4.63		7.70		259	51	0.80	14	111	36	5	96	11	no	Axinopsida serricata	58
																									Heteromastus filobranchus	24
																									Eudorella pacifica	17
																									Macoma sp	15
32, 97, Port Gardner	9.65	5	0.14		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	96.0		113.0		9.17		22.90	++	851	60	0.53	6	269	40	1	539	2	yes	Axinopsida serricata	462
																									Prionospio (Minuspio) lighti	64
																									Heteromastus filobranchus	39
																									Macoma carlottensis	33
33, 98, Snohomish River Delta	2.37	2	0.11				99.0		121.0		2.50		4.20		579	57	0.80	14	270	170	0	126	13	no	Euphilomedes carcharodonta	84
																									Scoletoma luti	75
																									Heteromastus filobranchus	57
																									Euphilomedes producta	32

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (+=>11.1ugB[a]p/g, ++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
33, 99, Snohomish River Delta	2.37	1	0.08				93.0		119.0		57.57		0.30		537	23	0.51	2	29	44	1	463	0	no	Tellina nuculoides	231
																									Psephidia lordi	174
																									Rochefortia tumida	52
																									Lamprops quadriplicatus	18
33, 100, Snohomish River Delta	2.37	0	0.07				90.0		94.0		120.63		0.30		24	6	0.88	3	2	16	0	4	2	no	Eohaustorius washingtonianus	8
																									Grandifoxus grandis	7
																									Macoma balthica	4
																									Pygospio sp N1	2
1, 106, South Port Townsend	2.67		0.07		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	93.9		118.6		1.37		7.10		302	61	0.85	20	149	47	8	95	3	no	Acila castrensis	37
																									Paraprionospio pinnata	36
																									Eudorella pacifica	20
																									Parvilucina tenuisculpta	17
1, 107, South Port Townsend	2.67	3	0.24		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	100.0		117.0		3.07		5.70		580	81	0.82	24	292	66	3	218	1	no	Acila castrensis	119
																									Pinnixa schmitti	31
																									Spiochaetopterus costarum	25
																									Lumbrineris cruzensis	23
1, 108, South Port Townsend	2.67		0.09		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	100.0		118.2		13.30		4.90		707	47	0.60	6	99	73	421	106	8	no	Amphiodia urtica/periercta complex	309
																									Amphiodia sp	107
																									Heterophoxus affinis	41
																									Terebellides reishi	37
2, 109, Port Townsend	6.51	1	0.08		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	93.9		116.7		10.67		1.20		702	131	0.83	34	333	181	3	161	24	no	Microclymene caudata	82
																									Alvania compacta	44
																									Cheirimedeia zotea	34
																									Gammaropsis ellisi	28
2, 110, Port Townsend	6.51		0.06				98.0		116.7		44.67		1.20		667	77	0.70	13	353	67	17	224	6	no	Spiophanes bombyx	196
																									Nutricola lordi	97
																									Owenia fusiformis	46
																									Rochefortia tumida	26
2, 111, Port Townsend	6.51		0.07		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	89.8		115.3		17.07		4.30		809	112	0.77	24	481	42	7	268	11	no	Nutricola lordi	121
																									Microclymene caudata	85
																									Terebellides reishi	82
																									Axinopsida serricata	58

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
4, 112, South Admiralty Inlet	52.94		0.08		**Other:** Benzoic Acid	**Other:** Benzoic Acid	96.9		112.0		3.13		4.30		2325	176	0.54	17	758	1349	26	133	59	no	Erichthonius rubricornis	1198
																									Microclymene caudata	135
																									Oligochaeta	57
																									Pholoides asperus	40
4, 116, South Admiralty Inlet	52.94		0.06		**Other:** Benzoic Acid	**Other:** Benzoic Acid	101.0		118.4		23.57		0.40		554	53	0.71	8	95	197	3	254	5	no	Rhepoxynius daboius	94
																									Pinnixa schmitti	85
																									Tellina modesta	82
																									Axinopsida serricata	49
4, 117, South Admiralty Inlet	52.94	1	0.06				95.9		117.9		18.60		0.60		227	50	0.81	15	78	60	0	84	5	no	Nutricola lordi	53
																									Photis bifurcata	22
																									Orchomene cf pinguis	14
																									Scoloplos armiger	12
5, 118, Possession Sound	40.15	3	0.13		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	93.4		117.0		4.87		9.30		110	46	0.91	19	67	14	4	19	6	no	Euclymeninae	12
																									Adontorhina cyclia	7
																									Eudorella pacifica	7
																									Levinsenia gracilis	7
5, 119, Possession Sound	40.15		0.06		**Other:** Benzoic Acid	**Other:** Benzoic Acid	97.9		117.7		30.80		0.70		198	36	0.73	8	86	85	2	17	8	no	Rhepoxynius daboius	60
																									Spiophanes bombyx	32
																									Scoloplos armiger	18
																									Pinnixa schmitti	16
5, 120, Possession Sound	40.15	1	0.07		**Other:** Benzoic Acid	**Other:** Benzoic Acid	102.1		117.9		23.27		0.50		201	33	0.73	6	92	80	0	29	0	no	Spiophanes bombyx	49
																									Pinnixa schmitti	44
																									Rhepoxynius daboius	25
																									Tellina modesta	13
6, 121, Central Basin	29.26		0.06		**Other:** Benzoic Acid	**Other:** Benzoic Acid	89.0		115.5		8.67		2.10		1274	61	0.58	5	109	677	0	475	13	no	Euphilomedes carcharodonta	517
																									Solamen columbianum	194
																									Lirobittium sp	101
																									Cheirimedeia cf macrocarpa	89
6, 122, Central Basin	29.26	1	0.11		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	98.9		117.7		2.97		9.00		240	46	0.84	14	82	53	1	92	12	no	Axinopsida serricata	36
																									Macoma carlottensis	19
																									Macoma sp	18
																									Euphilomedes producta	15

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
6, 123, Central Basin	29.26	1	0.10		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	85.7		117.9		5.37		6.10		314	31	0.70	5	30	127	3	147	7	no	Macoma carlottensis	80
																									Euphilomedes producta	55
																									Eudorella pacifica	54
																									Macoma sp	42
7, 124, Port Madison	5.48		0.07		**Other:** Benzoic Acid	**Other:** Benzoic Acid	105.7		117.4		2.80		3.20		725	72	0.73	12	182	212	190	138	3	no	Euphilomedes carcharodonta	117
																									Amphiodia sp	106
																									Amphiodia urtica/periercta complex	78
																									Pinnixa schmitti	59
7, 125, Port Madison	5.48		0.08		**Other:** Benzoic Acid	**Other:** Benzoic Acid	101.1		117.0		2.97		4.70		850	85	0.76	14	280	319	103	135	13	no	Euphilomedes carcharodonta	123
																									Euphilomedes producta	89
																									Amphiodia urtica/periercta complex	74
																									Polycirrus californicus	64
7, 126, Port Madison	5.48		0.05		**Other:** Benzoic Acid	**Other:** Benzoic Acid	98.9		117.0		48.70		2.40		629	91	0.77	18	219	176	101	130	3	no	Amphiodia urtica/periercta complex	83
																									Rhepoxynius boreovariatus	69
																									Euphilomedes carcharodonta	46
																									Polycirrus californicus	45
8, 127, West Point	11.43		0.14		**Other:** Benzoic Acid	**Other:** Benzoic Acid	103.4		118.6		3.73		17.00	++	447	50	0.79	11	149	156	0	137	5	no	Euphilomedes producta	57
																									Axinopsida serricata	49
																									Macoma carlottensis	40
																									Dyopedos sp	39
8, 128, West Point	11.43	16	0.26		**Other:** Benzoic Acid	**Other:** Benzoic Acid	95.5		117.7		24.67		71.10	+++	568	68	0.64	7	201	139	1	222	5	no	Axinopsida serricata	152
																									Euphilomedes producta	121
																									Levinsenia gracilis	55
																									Macoma carlottensis	40
8, 129, West Point	11.43	2	0.14		**Other:** Benzoic Acid	**Other:** Benzoic Acid	95.5		118.6		10.37		19.10	++	424	61	0.77	13	154	118	1	136	15	no	Euphilomedes producta	86
																									Axinopsida serricata	54
																									Ampharete cf crassiseta	37
																									Levinsenia gracilis	27

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
8, 113, West Point	11.43		0.09		**Other:** 4-Methylphenol	**Other:** 4-Methylphenol	95.9		118.2		2.90		11.70	++	231	37	0.78	9	85	50	2	91	3	no	Axinopsida serricata	56
																									Euphilomedes producta	28
																									Levinsenia gracilis	20
																									Prionospio (Minuspio) lighti	18
9, 130, Eagle Harbor	0.40	17	0.33		**Other:** Benzoic Acid	**Other:** Benzoic Acid	96.6		117.9		1.97		48.30	+++	863	95	0.73	17	541	93	4	218	7	no	Aphelochaeta sp N1	202
																									Parvilucina tenuisculpta	110
																									Axinopsida serricata	40
																									Scoletoma luti	36
9, 131, Eagle Harbor	0.40	19	0.36		**Other:** Benzoic Acid, Phenol	**Other:** Benzoic Acid	103.4		118.9		0.87		96.50	+++	761	55	0.67	8	339	244	3	172	3	no	Eudorella pacifica	196
																									Aphelochaeta sp N1	139
																									Nutricola lordi	72
																									Aphelochaeta monilaris	60
9, 132, Eagle Harbor	0.40	5	0.14				100.0		118.4		1.77		14.70	++	1455	82	0.49	5	1143	201	2	105	4	no	Aphelochaeta sp N1	798
																									Euphilomedes carcharodonta	172
																									Mediomastus sp	62
																									Scoletoma luti	43
10, 133, Central Sound	9.30		0.07		**Other:** Benzoic Acid	**Other**: Benzoic Acid	97.8		105.4		12.13		8.70		531	77	0.73	16	124	178	32	179	18	no	Axinopsida serricata	116
																									Euphilomedes producta	67
																									Euphilomedes carcharodonta	63
																									Parvilucina tenuisculpta	37
10, 134, Central Sound	9.30		0.06		**Other:** Benzoic Acid	**Other**: Benzoic Acid	94.7		105.7		4.60		7.50		363	54	0.68	9	76	184	5	87	11	no	Euphilomedes carcharodonta	114
																									Parvilucina tenuisculpta	52
																									Euphilomedes producta	50
																									Mediomastus sp	15
10, 135, Central Sound	9.30		0.06		**Other:** Benzoic Acid	**Other**: Benzoic Acid	94.7		106.1		28.63		13.50	++	304	73	0.86	22	180	43	3	70	8	no	Prionospio steenstrupi/jubata	32
																									Mediomastus sp	26
																									Magelona longicornis	24
																									Astyris gausapata	16

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
11, 136, Central Sound	25.71	3	0.18		**Other:** Benzoic Acid, Phenol	**Other:** Benzoic Acid, Phenol	93.5		106.7		6.30		13.70	++	198	38	0.81	11	63	71	0	53	11	no	Euphilomedes producta	35
																									Prionospio (Minuspio) lighti	34
																									Macoma carlottensis	16
																									Axinopsida serricata	14
11, 137, Central Sound	25.71	5	0.20		**Other:** Benzoic Acid	**Other**: Benzoic Acid	101.1		105.4		9.93		15.70	++	230	40	0.82	10	85	67	0	66	12	no	Euphilomedes producta	29
																									Axinopsida serricata	28
																									Sigambra nr bassi	22
																									Macoma carlottensis	17
11, 138, Central Sound	25.71	4	0.15		**Other:** Benzoic Acid	**Other**: Benzoic Acid	106.5		105.0		2.43		17.10	++	168	40	0.82	13	50	79	2	28	9	no	Eudorella pacifica	30
																									Euphilomedes producta	29
																									Prionospio (Minuspio) lighti	10
																									Macoma carlottensis	8
12, 139, East Passage	25.78	2	0.10		**Other:** Benzoic Acid	**Other**: Benzoic Acid	94.4		106.5		21.13		17.80	++	337	55	0.72	10	81	94	2	151	9	no	Axinopsida serricata	66
																									Macoma carlottensis	59
																									Euphilomedes producta	43
																									Eudorellopsis integra	36
12, 140, East Passage	25.78	4	0.13		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	97.8		105.4		3.63		23.80	++	144	35	0.83	11	63	46	2	29	4	no	Axinopsida serricata	22
																									Levinsenia gracilis	20
																									Eudorella pacifica	17
																									Cossura bansei	12
12, 141, East Passage	25.78		0.06		**Other:** Benzoic Acid	**Other**: Benzoic Acid	80.0		102.5		64.10		5.80		265	78	0.91	32	177	38	3	33	14	no	Pionosyllis uraga	23
																									Lumbrineris californiensis	19
																									Nicomache lumbricalis	11
																									Demonax rugosus	9
13, 142, Liberty Bay	0.65	4	0.13				94.3		105.4		5.27		16.70	++	325	26	0.70	6	109	102	107	4	3	no	Amphiodia urtica/periercta complex	96
																									Pinnixa schmitti	79
																									Aphelochaeta sp N1	25
																									Nephtys cornuta	22
13, 143, Liberty Bay	0.65	4	0.16		**Other:** Benzoic Acid	**Other**: Benzoic Acid	96.6		105.9		1.47		24.80	++	309	28	0.74	7	171	75	31	32	0	no	Aphelochaeta sp N1	84
																									Pinnixa occidentalis	37
																									Eudorella pacifica	34
																									Amphiodia urtica/periercta complex	29

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
13, 144, Liberty Bay	0.65	4	0.16		**Other:** Benzoic Acid	**Other**: Benzoic Acid	92.0		106.3		1.17		27.70	++	293	28	0.69	7	56	105	90	40	2	no	Pinnixa schmitti	90
																									Amphiodia urtica/periercta complex	79
																									Eudorella pacifica	14
																									Paraprionospio pinnata	13
14, 145, Keyport	0.94		0.04		**Other:** Benzoic Acid	**Other**: Benzoic Acid	105.7		106.1		2.83		2.50		354	48	0.87	16	179	61	3	107	4	no	Aphelochaeta sp N1	34
																									Nutricola lordi	31
																									Leitoscoloplos pugettensis	24
																									Scoloplos acmeceps	22
14, 146, Keyport	0.94	4	0.12		**Other:** Benzoic Acid	**Other**: Benzoic Acid	103.4		104.6		1.10		32.00	++	650	28	0.56	3	63	200	353	34	0	no	Amphiodia urtica/periercta complex	254
																									Pinnixa schmitti	161
																									Amphiodia sp	94
																									Eudorella pacifica	39
14, 147, Keyport	0.94		0.07		**Other:** Benzoic Acid	**Other**: Benzoic Acid	98.9		105.7		5.63		5.60		543	84	0.75	17	354	25	4	149	11	no	Aphelochaeta sp N1	124
																									Ampharete labrops	58
																									Alvania compacta	36
																									Nutricola lordi	30
15, 148, NW Bainbridge Island	4.42	3	0.12		**Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	98.9		105.7		0.94		26.40	++	349	33	0.76	8	112	31	135	69	2	no	Amphiodia sp	82
																									Acteocina culcitella	48
																									Amphiodia urtica/periercta complex	44
																									Eudorella pacifica	24
15, 149, NW Bainbridge Island	4.42		0.04		**Other:** Benzoic Acid	**Other**: Benzoic Acid	95.5		103.9		1.09		6.60		810	72	0.67	13	204	112	13	466	15	no	Alvania compacta	290
																									Rochefortia tumida	93
																									Phyllochaetopterus prolifica	61
																									Heptacarpus stimpsoni	52
15, 150, NW Bainbridge Island	4.42		0.07		**Other:** Benzoic Acid	**Other**: Benzoic Acid	93.2		105.9		1.23		9.30		435	44	0.70	7	136	17	148	127	7	no	Amphiodia urtica/periercta complex	89
																									Acteocina culcitella	84
																									Amphiodia sp	55
																									Pholoe sp Cmplx	55

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
16, 151, SW Bainbridge Island	3.42	5	0.18		**Other:** Benzoic Acid, Benzyl Alcohol	**Other:** Benzoic Acid, Benzyl Alcohol	98.9		106.3		0.82		31.60	++	337	37	0.72	6	99	14	144	70	10	no	Amphiodia sp	69
																									Amphiodia urtica/periercta complex	64
																									Pholoe sp Cmplx	36
																									Acila castrensis	35
16, 152, SW Bainbridge Island	3.42		0.08		**Other:** Benzoic Acid	**Other**: Benzoic Acid	98.9		105.4		4.60		7.60		859	87	0.69	15	165	122	86	475	11	no	Acila castrensis	289
																									Euphilomedes carcharodonta	70
																									Amphiodia urtica/periercta complex	50
																									Axinopsida serricata	33
16, 153, SW Bainbridge Island	3.42	4	0.19		**Other:** Benzoic Acid	**Other**: Benzoic Acid	100.0		104.4		1.97		27.90	++	243	40	0.84	14	83	8	58	87	7	no	Axinopsida serricata	40
																									Amphiodia urtica/periercta complex	35
																									Amphiodia sp	23
																									Sigambra nr bassi	11
17, 154, Rich Passage	3.34		0.04		**Other:** Benzoic Acid	**Other**: Benzoic Acid	97.9		104.8		7.80		1.90		658	98	0.77	23	199	41	5	395	18	no	Nutricola lordi	138
																									Alvania compacta	75
																									Tellina modesta	44
																									Parvilucina tenuisculpta	24
17, 155, Rich Passage	3.34		0.04		**Other:** Benzoic Acid	**Other**: Benzoic Acid	98.9		105.7		20.27		1.60		951	68	0.61	6	93	138	0	709	11	no	Nutricola lordi	290
																									Tellina modesta	220
																									Euphilomedes carcharodonta	79
																									Parvilucina tenuisculpta	57
17, 156, Rich Passage	3.34		0.07		**Other:** Benzoic Acid	**Other**: Benzoic Acid	97.9		105.0		30.17		10.00		573	102	0.81	24	234	189	19	105	26	no	Pinnixa occidentalis	64
																									Euphilomedes carcharodonta	62
																									Rochefortia tumida	37
																									Mediomastus sp	29
18, 157, Port Orchard	1.94		0.07		**Other:** Benzoic Acid	**Other**: Benzoic Acid	102.2		113.0		3.20		14.10	++	808	90	0.67	12	163	159	37	443	6	no	Acila castrensis	246
																									Euphilomedes carcharodonta	119
																									Nutricola lordi	42
																									Prionospio (Minuspio) lighti	30

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
18, 158, Port Orchard	1.94		0.05		**Other:** Benzoic Acid	**Other**: Benzoic Acid	84.6		113.0		4.70		7.60		631	112	0.76	27	241	84	26	265	15	no	Alvania compacta Phyllochaetopterus prolifica Lumbrineris californiensis Magelona longicornis	173 39 20 19
18, 159, Port Orchard	1.94		0.06		**Other:** Benzoic Acid	**Other**: Benzoic Acid	92.0		97.0		2.27		12.40	++	563	97	0.82	28	137	122	46	241	17	no	Alvania compacta Rochefortia tumida Aoroides columbiae Amphipholis squamata	78 64 45 23
19, 160, Sinclair Inlet	1.03	9	0.35	Metals: Mercury	**Metals**: Mercury; **HPAHs:** Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene **Other:** Benzoic Acid, Butylbenzylphthalate, Total Aroclors	**Metals:** Mercury; **Other:** Benzoic Acid	99.0		2.0	**	0.81		29.40	++	149	21	0.63	4	132	3	0	9	5	yes	Aphelochaeta sp N1 Paraprionospio pinnata Terebellides californica Nephtys cornuta	73 23 11 9
19, 161, Sinclair Inlet	1.03	7	0.27		**Metals:** Mercury; **Other:** Benzoic Acid	**Metals:** Mercury; **Other:** Benzoic Acid	104.4		103.0		0.82		44.50	+++	1283	32	0.39	2	1165	52	24	41	1	yes	Aphelochaeta sp N1 Nephtys cornuta Eudorella pacifica Lumbrineris cruzensis	856 209 34 33
19, 162, Sinclair Inlet	1.03	8	0.30	Metals: Mercury	**Metals:** Mercury; **Other:** Benzoic Acid	**Metals:** Mercury; **Other:** Benzoic Acid	86.8		113.0		1.63		35.50	++	559	44	0.71	7	220	166	105	64	4	yes	Eudorella pacifica Amphiodia urtica/periercta complex Aphelochaeta monilaris Pinnixa schmitti	102 96 90 44
20, 163, Sinclair Inlet	1.04	8	0.44	Metals: Mercury	**Metals:** Mercury; **Other:** Benzoic Acid	**Metals:** Mercury; **Other:** Benzoic Acid	93.4		113.0		1.02		27.70	++	565	32	0.69	6	326	113	86	33	7	yes	Aphelochaeta sp N1 Amphiodia urtica/periercta complex Eudorella pacifica Pinnixa schmitti	186 83 74 35
20, 164, Sinclair Inlet	1.04	9	0.42	Metals: Mercury	**Metals:** Mercury; **Other:** Benzoic Acid	**Metals:** Mercury; **Other:** Benzoic Acid	101.1		112.0		1.50		64.90	+++	1336	53	0.50	5	1067	132	21	108	8	yes	Aphelochaeta sp N1 Eudorella pacifica Scoletoma luti Prionospio (Minuspio) lighti	782 82 80 42

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
20, 165, Sinclair Inlet	1.04	11	0.55	Metals: Mercury	**Metals:** Mercury; **Other:** Benzoic Acid	**Metals:** Mercury; **Other:** Benzoic Acid	100.0		81.0		6.83		39.40	+++	663	36	0.69	6	269	277	73	34	10	yes	Eudorella pacifica	199
																									Pinnixa schmitti	73
																									Amphiodia urtica/periercta complex	73
																									Lumbrineris cruzensis	70
21, 166, Port Washing-ton Narrows	1.00		0.06		**Other:** Benzoic Acid	**Other**: Benzoic Acid	104.4		111.0		3.40		6.50		651	85	0.79	20	196	162	5	270	18	no	Euphilomedes carcharodonta	92
																									Alvania compacta	79
																									Nutricola lordi	58
																									Aphelochaeta sp N1	29
21, 167, Port Washing-ton Narrows	1.00		0.08		**Other:** Benzoic Acid	**Other**: Benzoic Acid	46.7	**	82.0	*	3.30		9.90		826	76	0.70	10	412	156	22	221	15	no	Alvania compacta	193
																									Aphelochaeta sp N1	100
																									Phyllochaetopterus prolifica	88
																									Ampelisca lobata	56
21, 168, Port Washing-ton Narrows	1.00	7	0.17		**Other:** Benzoic Acid	**Other**: Benzoic Acid	96.7		69.0	**	0.65		32.30	++	1232	48	0.26	1	1103	30	2	93	4	yes	Aphelochaeta sp N1	1023
																									Alvania compacta	35
																									Odostomia sp	21
																									Scoletoma luti	13
22, 169, Dyes Inlet	3.88		0.05		**Other:** Benzoic Acid	**Other**: Benzoic Acid	101.1		94.0		4.10		3.60		1574	73	0.65	9	1123	248	17	179	7	no	Phyllochaetopterus prolifica	455
																									Circeis sp	240
																									Aphelochaeta sp N1	137
																									Caprella mendax	122
22, 170, Dyes Inlet	3.88	10	0.26		**Other:** Benzoic Acid Benzyl Alcohol	**Other**: Benzoic Acid	100.0		101.0		1.04		27.60	++	893	32	0.59	4	266	364	200	57	6	yes	Pinnixa schmitti	271
																									Amphiodia urtica/periercta complex	196
																									Aphelochaeta sp N1	181
																									Eudorella pacifica	92
22, 171, Dyes Inlet	3.88	10	0.26		**Metals**: Mercury; **Other:** Benzoic Acid, Benzyl Alcohol	**Metals:** Mercury; **Other:** Benzoic Acid	101.1		92.0		2.03		30.40	++	1112	38	0.55	4	260	574	224	48	6	yes	Pinnixa schmitti	440
																									Amphiodia urtica/periercta complex	220
																									Eudorella pacifica	130
																									Terebellides californica	62

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
23, 172, Outer Elliott Bay	2.79	5	0.20		**Other:** Benzoic Acid	**Other**: Benzoic Acid	102.2		94.0		2.13		17.80	++	188	43	0.81	13	69	48	0	60	11	no	Axinopsida serricata	46
																									Euphilomedes producta	17
																									Spiophanes berkeleyorum	14
																									Heterophoxus affinis	10
23, 173, Outer Elliott Bay	2.79	7	0.28		**Other:** Benzoic Acid	**Other**: Benzoic Acid	106.7		102.0		4.97		19.80	++	470	56	0.59	6	174	56	5	230	5	no	Axinopsida serricata	216
																									Spiochaetopterus costarum	52
																									Euphilomedes producta	28
																									Spiophanes berkeleyorum	26
23, 174, Outer Elliott Bay	2.79		0.09		**Other:** Benzoic Acid, Butylbenzylphthalate	**Other**: Benzoic Acid	96.7		93.0		35.97		10.50		495	126	0.83	37	309	83	30	64	9	no	Prionospio steenstrupi/jubata	76
																									Pholoides asperus	29
																									Dipolydora cardalia	27
																									Euphilomedes carcharodonta	21
23, 175, Outer Elliott Bay	2.79		0.07		**Other:** Benzoic Acid	**Other**: Benzoic Acid	97.8		96.0		5.23		3.30		631	137	0.89	48	352	114	28	114	23	no	Euphilomedes carcharodonta	36
																									Dipolydora socialis	27
																									Prionospio steenstrupi/jubata	24
																									Mediomastus sp	21
24, 176, Shoreline Elliott Bay	0.42	5	0.31		**Metals:** Mercury**;** **HPAHs:** Benzo(g,h,i)perylene; **LPAHs:** Phenanthrene**;** **Other:** Benzoic Acid, Butylbenzylphthalate Total Aroclors	**Other**: Benzoic Acid	92.2		82.0	*	2.27		12.50	++	876	113	0.77	22	501	97	12	255	11	no	Alvania compacta	132
																									Spiochaetopterus costarum	98
																									Parvilucina tenuisculpta	72
																									Dipolydora cardalia	43
24, 177, Shoreline Elliott Bay	0.42	2	0.08		**Other:** Benzoic Acid	**Other**: Benzoic Acid	101.1		75.0	**	2.57		3.40		1378	61	0.52	4	78	475	1	822	2	no	Euphilomedes carcharodonta	456
																									Nutricola lordi	440
																									Tellina modesta	100
																									Lirularia lirulata	92
24, 178, Shoreline Elliott Bay	0.42		0.14		**Other:** Benzoic Acid, Total Aroclors	**Other**: Benzoic Acid	101.1		106.0		86.83		10.70		343	80	0.78	21	179	104	1	56	3	no	Euphilomedes carcharodonta	70
																									Prionospio steenstrupi/jubata	38
																									Magelona longicornis	27
																									Pinnixa schmitti	19
25, 179, h li	0.33	13	0.52		**HPAHs:**	**Other**: Benzoic Acid	95.6		81.0	*	25.10		38.80	+++	478	69	0.73	12	254	83	0	137	4	no	Levinsenia gracilis	70

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
Shoreline Elliott Bay					Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene; **Other:** Benzoic Acid, Total Aroclors																				Prionospio steenstrupi/jubata	64
																									Axinopsida serricata	62
																									Euphilomedes carcharodonta	52
25, 180, Shoreline Elliott Bay	0.33	15	0.57		**HPAHs:** Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene; **Other:** Benzoic Acid, Total Aroclors	**Other**: Benzoic Acid	97.8		68.0	**	17.50		34.40	++	639	76	0.79	18	350	66	3	215	5	no	Prionospio steenstrupi/jubata	87
																									Parvilucina tenuisculpta	82
																									Axinopsida serricata	73
																									Euphilomedes producta	39
25, 181, Shoreline Elliott Bay	0.33	24	1.59	Other: Total congeners	**Metals:** Mercury; **HPAHs:** Benzo(g,h,i)perylene; **Other:** Benzoic Acid, Total Aroclors	**Other**: Benzoic Acid	87.8		96.0		17.20		32.80	++	457	85	0.83	27	212	88	2	142	13	no	Euphilomedes producta	69
																									Axinopsida serricata	55
																									Levinsenia gracilis	19
																									Chaetozone nr setosa	17
25, 115, Shoreline Elliott Bay	0.33	24	0.83		**HPAHs:** Benzo(a)pyrene, Benzo(g,h,i)perylene; **Other:** Benzoic Acid, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	97.0		6.0	**	0.79		144.80	+++	1161	43	0.25	1	1092	9	0	60	0	yes	Aphelochaeta sp N1	962
																									Lumbrineris californiensis	43
																									Turbonilla sp	35
																									Spiochaetopterus costarum	12
26, 182, Shoreline Elliott Bay	0.11	24	1.36	Metals: Mercury**;** **LPAHs:** Total LPAH**;** **Other:** Pyrene, Total Congeners	**Metals:** Mercury; **HPAHs:** Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene; **Other:** Benzoic Acid, Total Aroclors	**Metlas:** Mercury; **Other**: Benzoic Acid	97.8		83.0	*	26.47		216.10	+++	571	88	0.79	23	309	37	21	188	16	no	Axinopsida serricata	115
																									Levinsenia gracilis	73
																									Aricidea lopezi	22
																									Euphilomedes producta	18

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
26, 183, Shoreline Elliott Bay	0.11	20	0.52		**HPAHs:** Benzo(a)anthracene, Benzo(a)pyrene, Benzo(g,h,i)perylene, Chrysene, Indeno(1,2,3-c,d)pyre, Fluoranthene, Total Benzofluranthenes, Total HPAH; **LPAHs:** Fluorene, Phenanthrene; **Other:** Benzoic Acid, Dibenzofuran	**Other**: Benzoic Acid	100.0		88.0		3.17		107.20	+++	740	105	0.79	23	435	133	3	159	10	no	Prionospio steenstrupi/jubata	79
																									Euphilomedes carcharodonta	65
																									Parvilucina tenuisculpta	61
																									Lumbrineris californiensis	59
26, 184, Shoreline Elliott Bay	0.11	22	1.31	**HPAHs:** Benzo(a)anthracene, Benzo(a)pyrene, Fluoranthene, Pyrene, Total HPAH; **LPAHs:** Anthracene, Phenanthrene, Total LPAH; Total PAH	**HPAHs:** Benzo(a)pyrene, Benzo(g,h,i)perylene, Total Benzofluranthenes, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Total HPAH; **LPAHs:** Phenanthrene; **Other:** Benzoic Acid	**HPAHs:** Fluoranthene; **Other**: Benzoic Acid	103.2		84.0	*	7.90		223.20	+++	731	89	0.79	21	488	57	2	177	7	no	Lumbrineris californiensis	97
																									Prionospio steenstrupi/jubata	82
																									Parvilucina tenuisculpta	77
																									Aphelochaeta sp N1	39
27, 185, Mid Elliott Bay	1.04	7	0.39		**Other:** Bis(2-Ethylhexyl) Phthalate		104.3		120.0		18.20		19.70	++	269	32	0.74	9	106	57	1	101	4	no	Axinopsida serricata	98
																									Prionospio (Minuspio) lighti	23
																									Levinsenia gracilis	17
																									Spiophanes berkeleyorum	15
27, 186, Mid Elliott Bay	1.04	13	0.57	**Metals:** Mercury	**Metals:** Mercury; **Other:** Total Aroclors	**Metals:** Mercury	101.1		116.0		34.00		54.90	+++	655	70	0.61	9	169	84	3	392	7	no	Axinopsida serricata	294
																									Euphilomedes producta	56
																									Euphilomedes carcharodonta	26
																									Parvilucina tenuisculpta	26
27, 187, Mid Elliott Bay	1.04	12	0.55		**Other:** Benzoic Acid, Phenol	**Other:** Benzoic Acid	107.7		115.0		37.73		26.50	++	334	46	0.47	5	69	30	1	227	7	yes	Axinopsida serricata	222
																									Spiophanes berkeleyorum	11
																									Cossura bansei	8
																									Protomedeia grandimana	7

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
27, 188, Mid Elliott Bay	1.04	23	1.47	**Metals:** Mercury; **HPAHs**: Benzo(a)pyrene, Pyrene, Total HPAH; **LPAHs:** Phenanthrene, Total LPAH; **Other:** Total congeners	**Metals:** Mercury; **HPAHs:** Benzo(g,h,i)perylene, Fluoranthene; **Other:** Benzoic Acid, Benzyl Alcohol, 2,4-Dimethylphenol	**Metals:** Mercury; **Other:** Benzoic Acid, 2,4-Dimethylphenol	105.5		115.0		67.17		152.90	+++	825	67	0.51	5	166	72	8	563	16	yes	Axinopsida serricata	471
																									Euphilomedes producta	51
																									Levinsenia gracilis	40
																									Parvilucina tenuisculpta	37
28, 189, Mid Elliott Bay	0.70	16	0.43		**Other:** Benzoic Acid	**Other**: Benzoic Acid	108.8		109.0		9.47		139.80	+++	928	101	0.71	17	361	312	28	219	8	no	Euphilomedes carcharodonta	222
																									Parvilucina tenuisculpta	148
																									Spiochaetopterus costarum	52
																									Pinnixa schmitti	43
28, 190, Mid Elliott Bay	0.70		0.06		**Other:** Benzoic Acid, Di-N-Butylphthalate	**Other**: Benzoic Acid	106.6		117.0		5.93		3.60		1717	71	0.45	3	114	909	0	688	6	no	Euphilomedes carcharodonta	858
																									Nutricola lordi	392
																									Tellina modesta	103
																									Astyris gausapata	50
28, 191, Mid Elliott Bay	0.70	13	0.45		**Other:** Benzoic Acid	**Other**: Benzoic Acid	103.3		113.0		179.30		29.10	++	328	57	0.69	12	155	36	1	132	4	no	Axinopsida serricata	124
																									Levinsenia gracilis	28
																									Maldane sarsi	20
																									Spiophanes berkeleyorum	17
28, 192, Mid Elliott Bay	0.70	9	0.36				103.3		107.0		35.17		49.10	+++	883	91	0.71	14	608	112	7	151	5	no	Microclymene caudata	224
																									Axinopsida serricata	84
																									Euphilomedes producta	73
																									Proclea graffi	66
29, 193, Mid Elliott Bay	0.73	9	0.37				101.1		92.0		50.73		32.80	++	847	54	0.41	3	219	21	0	603	4	yes	Axinopsida serricata	574
																									Levinsenia gracilis	43
																									Nephtys cornuta	40
																									Aricidea lopezi	27
29, 194, Mid Elliott Bay	0.73	23	1.05	**HPAHs:** Dibenzo(a,h) anthracene; **Other:** Total congeners	**Metals:** Mercury; **HPAHs:** Dibenzo(a,h) anthracene; **Other:** 4-Methylphenol, Total Aroclors	**Metals:** Mercury; **Other:** 4-Methylphenol	102.2		106.0		62.40		74.10	+++	456	45	0.54	4	184	10	0	261	1	yes	Axinopsida serricata	247
																									Aricidea lopezi	38
																									Levinsenia gracilis	30
																									Spiophanes berkeleyorum	28

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
29, 195, Mid Elliott Bay	0.73	12	0.54				105.4		90.0		61.87		49.30	+++	365	66	0.79	16	271	46	1	44	3	no	Levinsenia gracilis	76
																									Axinopsida serricata	36
																									Prionospio (Minuspio) lighti	24
																									Nephtys cornuta	20
29, 196, Mid Elliott Bay	0.73	13	0.54	**Metals:** Mercury	**Metals:** Mercury	**Metals:** Mercury	100.0		108.0		55.63		28.60	++	471	41	0.45	3	131	18	2	320	0	yes	Axinopsida serricata	310
																									Aricidea lopezi	29
																									Levinsenia gracilis	27
																									Prionospio (Minuspio) lighti	12
30, 197, West Harbor Island	0.27	18	0.60	**Metals:** Arsenic, Zinc	**Metals:** Arsenic; **LPAHs:** Acenaphthene; **Other:** Benzoic Acid, Dibenzofuran, 4-Methylphenol	**Metals:** Arsenic; **Other:** Benzoic Acid, 4-Methylphenol	87.9		62.0	**	2.23		96.60	+++	806	71	0.68	12	394	103	1	304	4	no	Parvilucina tenuisculpta	261
																									Euphilomedes carcharodonta	89
																									Lumbrineris californiensis	64
																									Prionospio steenstrupi/jubata	47
30, 198, West Harbor Island	0.27	22	1.26	**LPAHs:** 2-Methylnaphthalene, Acenaphthene, Fluorene, Naphthalene, Total LPAH; **Other:** Total congeners	**LPAHs:** 2-Methylnaphthalene, Acenaphthene, Fluorene, Naphthalene, Total LPAH; **Other:** Benzoic Acid, Dibenzofuran, 4-Methylphenol, Total Aroclors	**LPAHs:** 2-Methylnaphthalene, Acenaphthene, Naphthalene, Total LPAH; **Other:** Benzoic Acid, Dibenzofuran, 4-Methylphenol	101.1		100.0		59.93		132.20	+++	1128	90	0.63	9	259	347	0	511	11	no	Axinopsida serricata	358
																									Euphilomedes carcharodonta	142
																									Euphilomedes producta	141
																									Parvilucina tenuisculpta	59
30, 199, West Harbor Island	0.27	22	0.96	**LPAHs:** Total LPAH	**LPAHs:** Acenaphthene; **Other**: Benzoic Acid, Dibenzofuran, 4-Methylphenol	**Other:** Benzoic Acid, 4-Methylphenol	90.1		73.0	**	64.80		148.10	+++	1391	84	0.65	10	473	406	11	495	6	no	Euphilomedes carcharodonta	357
																									Axinopsida serricata	212
																									Parvilucina tenuisculpta	154
																									Aphelochaeta sp N1	130
30, 114, West Harbor Island	0.27	21	1.34	**HPAHs:** Benzo(a)pyrene; **Other:** Total congeners	**HPAHs:** Benzo(g,h,i)perylene; **Other:** Benzoic Acid, 4-Methylphenol, Total Aroclors	**Other:** Benzoic Acid, 4-Methylphenol	94.9		86.0		0.79		111.40	+++	1077	47	0.39	2	982	21	0	73	1	yes	Aphelochaeta sp N1	763
																									Heteromastus filobranchus	60
																									Cossura pygodactylata	35
																									Scoletoma luti	35

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
31, 200, East Harbor Island	0.18	22	3.93	**Other:** Total congeners	**Other:** Benzoic Acid, 1,4-Dichlorobenzene, 4-Methylphenol, Total Aroclors	**Other:** Benzoic Acid, 4-Methylphenol, Total Aroclors	100.0		68.0	**	25.40		153.50	+++	980	56	0.60	5	802	27	0	149	2	yes	Aphelochaeta sp N1	352
																									Chaetozone nr setosa	168
																									Axinopsida serricata	95
																									Scoletoma luti	86
31, 201, East Harbor Island	0.18	23	1.60	**Other:** Total congeners	**Other**: Benzoic Acid, Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol, Total Aroclors	**Other:** Benzoic Acid, 4-Methylphenol	92.3		66.0	**	3.13		135.30	+++	1415	57	0.39	2	1281	37	0	95	2	yes	Aphelochaeta sp N1	955
																									Scoletoma luti	140
																									Axinopsida serricata	60
																									Aphelochaeta monilaris	44
31, 202, East Harbor Island	0.18	25	2.16	**Other:** Total congeners	**Other:** Benzoic Acid, 4-Methylphenol, Total Aroclors	**Other:** Benzoic Acid, 4-Methylphenol	90.1		100.0		7.67		133.20	+++	1572	42	0.45	3	891	23	0	657	1	yes	Axinopsida serricata	589
																									Aphelochaeta sp N1	514
																									Scoletoma luti	282
																									Aphelochaeta monilaris	22
32, 203, Duwamish	0.25	13	0.67		**Other:** Benzoic Acid, Total Aroclors	**Other:** Benzoic Acid	103.3		98.0		3.20		96.90	+++	3764	93	0.43	3	2970	94	0	688	12	yes	Aphelochaeta sp N1	2152
																									Nutricola lordi	430
																									Scoletoma luti	320
																									Aphelochaeta sp	91
32, 204, Duwamish	0.25	8	0.72	**Other:** Total congeners	**Other**: Benzoic Acid, Bis(2-Ethylhexyl) Phthalate, 4-Methylphenol, Total Aroclors	**Other:** Benzoic Acid, 4-Methylphenol	92.3		103.0		3.33		77.00	+++	1155	52	0.37	2	1002	31	1	117	4	yes	Aphelochaeta sp N1	814
																									Scoletoma luti	58
																									Macoma sp	47
																									Nutricola lordi	35
32, 205, Duwamish	0.25	20	2.01	**Other:** Total congeners	**HPAHs:** Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene, Chrysene; **Other:** Benzoic Acid, Butylbenzylphthalate, 4-Methylphenol, Pentachlorophenol, Total Aroclors	**Other:** Benzoic Acid, 4-Methylphenol	100.8		94.0		3.57		46.90	+++	1561	65	0.45	3	1314	17	1	226	3	yes	Aphelochaeta sp N1	660
																									Scoletoma luti	455
																									Nutricola lordi	98
																									Cossura pygodactylata	90
1, 206, Port Ludlow	1.56	9	0.16				103.0		106.8		0.97		102.90	+++	688	32	0.45	2	595	1	0	90	2	yes	Aphelochaeta sp	321
																									Aphelochaeta sp N1	235
																									Axinopsida serricata	33
																									Acila castrensis	14

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
1, 207, Port Ludlow	1.56	5	0.09		**LPAHs:** Naphthalene		97.0		106.6		6.87		4.40		953	58	0.60	6	687	115	0	148	3	yes	Aphelochaeta sp	293
																									Aphelochaeta sp N1	260
																									Euphilomedes carcharodonta	65
																									Nutricola lordi	47
1, 208, Port Ludlow	1.56	5	0.10				93.3		81.8		2.00		6.00		1574	47	0.64	6	645	731	0	198	0	no	Aoroides spinosus	411
																									Oligochaeta	350
																									Leptochelia savignyi	195
																									Aoroides sp	103
2, 209, Hood Canal (north)	35.68	0	0.09				106.7		105.5		7.40		6.70		403	66	0.65	13	87	217	4	87	8	no	Euphilomedes producta	184
																									Macoma carlottensis	24
																									Pinnixa sp	16
																									Macoma elimata	13
2, 210, Hood Canal (north)	35.68	0	0.07				108.6		106.1		8.60		6.70		516	83	0.78	19	127	133	10	211	35	no	Axinopsida serricata	68
																									Euphilomedes producta	68
																									Nutricola lordi	52
																									Leitoscoloplos pugettensis	36
2, 211, Hood Canal (north)	35.68	1	0.07				103.7		105.7		7.27		5.10		587	92	0.79	22	198	257	2	107	23	no	Photis parvidons	88
																									Photis sp	86
																									Spiophanes bombyx	36
																									Astyris gausapata	19
3, 212, Port Gamble Bay	1.38	6	0.11	**Metals:** Silver			100.0		105.9		2.23		15.00	++	1966	82	0.39	2	1764	119	7	69	7	yes	Aphelochaeta sp N1	1271
																									Cirratulidae	206
																									Euphilomedes carcharodonta	74
																									Scoletoma luti	55
3, 213, Port Gamble Bay	1.38	3	0.07				98.0		107.0		1.70		8.20		3475	84	0.33	2	3202	142	10	107	14	yes	Aphelochaeta sp N1	2556
																									Cirratulidae	132
																									Maldanidae	96
																									Owenia fusiformis	74
3, 214, Port Gamble Bay	1.38	18	0.50	**LPAHs:** Acenaphthylene, Naphthalene, Phenanthrene, Total LPAH			102.3		71.5	**	0.99		36.80	++	939	59	0.51	6	781	16	4	138	0	yes	Aphelochaeta sp N1	546
																									Dipolydora socialis	46
																									Odostomia sp	45
																									Paraprionospio pinnata	38

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
4, 215, Quilcene Bay	0.86	3	0.18				100.0		101.2		4.43		5.30		753	46	0.80	13	405	64	7	269	8	no	Trochochaeta multisetosa	127
																									Parvilucina tenuisculpta	85
																									Heteromastus filobranchus	71
																									Axinopsida serricata	45
4, 216, Quilcene Bay	0.86	2	0.09				96.6		104.4		19.60		3.60		744	70	0.79	16	344	56	6	325	13	no	Trochochaeta multisetosa	97
																									Macoma sp	89
																									Macoma carlottensis	60
																									Pectinaria californiensis	43
4, 217, Quilcene Bay	0.86	2	0.09				103.0		105.9		45.20		4.60		892	81	0.75	15	361	41	2	427	61	no	Axinopsida serricata	123
																									Macoma sp	109
																									Trochochaeta multisetosa	102
																									Macoma carlottensis	65
5, 218, Dabob Bay	18.57	2	0.09				98.0		105.7		29.80		3.60		280	42	0.74	10	147	3	0	127	3	no	Pectinaria californiensis	61
																									Axinopsida serricata	48
																									Macoma carlottensis	45
																									Levinsenia gracilis	21
5, 219, Dabob Bay	18.57	3	0.10				100.0		40.9	**	21.37		14.50	++	47	20	0.90	10	25	10	1	11	0	no	Macoma carlottensis	9
																									Leitoscoloplos pugettensis	5
																									Nephtys cornuta	5
																									Eudorella pacifica	4
5, 220, Dabob Bay	18.57	2	0.10				98.9		45.4	**	45.27		15.20	++	26	16	0.95	10	12	5	1	7	1	no	Macoma carlottensis	4
																									Pacifoculodes zernovi	3
																									Nephtys cornuta	3
																									Paraprionospio pinnata	2
6, 221, Hood Canal (central)	36.38	3	0.18				100.0		106.6		9.87		12.40	++	100	23	0.88	10	64	8	0	24	4	no	Mediomastus sp	16
																									Macoma carlottensis	12
																									Axinopsida serricata	12
																									Heteromastus filobranchus	11
6, 222, Hood Canal (central)	36.38	1	0.09				101.1		105.3		111.70		7.40		218	33	0.74	8	82	103	0	30	3	no	Eudorella pacifica	68
																									Pectinaria californiensis	35
																									Euphilomedes producta	18
																									Prionospio (Minuspio) lighti	13

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
6, 223, Hood Canal (central)	36.38	3	0.11				101.1		105.7		11.67		8.20		69	29	0.92	14	45	6	6	5	7	no	Leitoscoloplos pugettensis	11
																									Brisaster latifrons	5
																									Chaetoderma sp	5
																									Lumbrineris limicola	4
7, 224, Hood Canal (south)	11.03	4	0.14				95.6		105.7		5.80		8.00		139	29	0.71	7	124	2	7	4	2	no	Sigambra nr bassi	54
																									Spiophanes berkeleyorum	19
																									Paraprionospio pinnata	10
																									Heteromastus filobranchus	10
7, 225, Hood Canal (south)	11.03	4	0.13				96.7		106.4		2.73		9.40		144	15	0.54	2	134	0	0	7	3	no	Sigambra nr bassi	87
																									Paraprionospio pinnata	25
																									Axinopsida serricata	7
																									Glycinde polygnatha	6
7, 226, Hood Canal (south)	11.03	3	0.12				105.6		103.1		14.63		6.50		286	27	0.66	5	205	28	0	48	5	no	Spiophanes berkeleyorum	100
																									Heteromastus filobranchus	55
																									Macoma carlottensis	28
																									Eudorella pacifica	26
8, 227, Port of Shelton	15.23	16	0.22				103.2		97.5		1.13		56.60	+++	299	33	0.75	8	225	21	5	48	0	yes?	Nephtys cornuta	83
																									Oligochaeta	42
																									Capitella capitata hyperspecies	33
																									Prionospio (Minuspio) lighti	19
8, 228, Port of Shelton	15.23	5	0.15				101.1		98.8		1.57		21.30	++	235	34	0.79	9	156	17	0	59	3	yes?	Nephtys cornuta	52
																									Capitella capitata hyperspecies	31
																									Oligochaeta	18
																									Macoma nasuta	16
8, 229, Port of Shelton	15.23	7	0.15				104.3		99.2		0.99		26.40	++	198	44	0.82	13	131	25	0	40	2	yes?	Armandia brevis	35
																									Capitella capitata hyperspecies	18
																									Oligochaeta	17
																									Alvania compacta	16
9, 230, Oakland Bay	3.27	8	0.18				97.9		95.6		1.73		27.00	++	91	26	0.84	8	31	4	1	49	6	no	Cryptomya californica	14
																									Nutricola lordi	12
																									Macoma nasuta	12
																									Prionospio (Minuspio) lighti	10
9, 231, Oakland Bay	3.27	3	0.14				101.1		101.8		1.07		27.70	++	83	21	0.81	8	29	11	0	40	3	no	Nutricola lordi	25
																									Terebellides californica	12

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
																									Macoma nasuta	10
																									Pinnotheridae	5
9, 232, Oakland Bay	3.27	5	0.12				102.2		84.4		2.60		14.10	++	82	21	0.88	9	30	15	5	29	3	no	Macoma nasuta	12
																									Pinnixa occidentalis	11
																									Prionospio (Minuspio) lighti	10
																									Nutricola lordi	9
10, 233, Totten Inlet	5.72	3	0.09				100.0		106.1		1.57		12.70	++	212	24	0.81	7	132	44	14	20	2	no	Paraprionospio pinnata	44
																									Pinnixa occidentalis	26
																									Terebellides californica	26
																									Pholoe sp Cmplx	23
10, 234, Totten Inlet	5.72	3	0.10				96.9		102.5		4.17		8.00		114	16	0.72	4	98	8	0	7	1	no	Nephtys cornuta	38
																									Spiophanes berkeleyorum	31
																									Paraprionospio pinnata	12
																									Terebellides californica	6
10, 235, Totten Inlet	5.72	4	0.19	**Metals:** Mercury	**Metals:** Mercury	**Metals:** Mercury	100.0		70.2	**	3.83		8.30		259	38	0.84	12	121	39	48	32	19	no	Amphiodia urtica/periercta complex	41
																									Pholoe sp Cmplx	25
																									Levinsenia gracilis	21
																									Paraprionospio pinnata	21
11, 238, Eld Inlet	4.00	3	0.12				100.0		107.0		0.77		16.10	++	439	20	0.45	2	57	318	20	23	21	no	Eudorella pacifica	304
																									Paraprionospio pinnata	29
																									Amphiodia urtica/periercta complex	20
																									Stylatula elongata	17
11, 239, Eld Inlet	4.00	3	0.10				101.0		106.6		4.20		8.40		566	27	0.59	4	131	328	81	10	16	no	Eudorella pacifica	262
																									Pholoe sp Cmplx	82
																									Amphiodia urtica/periercta complex	71
																									Pinnotheridae	31
11, 240, Eld Inlet	4.00	4	0.11				97.9		7.8	**	4.27		15.00	++	40	10	0.88	5	37	2	0	1	0	no	Paraprionospio pinnata	10
																									Nephtys cornuta	7
																									Spiophanes berkeleyorum	6
																									Aphelochaeta sp N1	6

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
12, 236, Budd Inlet	5.45	3	0.12				96.9		92.6		2.00		18.50	++	273	23	0.38	2	230	10	1	29	3	yes	Aphelochaeta sp N1	204
																									Odostomia sp	18
																									Paraprionospio pinnata	13
																									Nephtys cornuta	5
12, 237, Budd Inlet	5.45	3	0.11		**Other:** Benzoic Acid, Benzyl Alcohol	**Other:** Benzoic Acid, Benzyl Alcohol	101.1		103.6		1.60		11.40	++	886	30	0.48	3	204	220	445	8	9	no	Amphiodia urtica/periercta complex	439
																									Eudorella pacifica	174
																									Pholoe sp Cmplx	127
																									Aphelochaeta sp N1	51
12, 241, Budd Inlet	5.45	3	0.10				102.1		105.9		1.30		25.60	++	836	39	0.57	4	263	207	302	24	40	no	Amphiodia urtica/periercta complex	232
																									Eudorella pacifica	197
																									Pholoe sp Cmplx	173
																									Amphiodia sp	55
13, 242, Port of Olympia	0.27	13	0.23				96.8		0.4	**	1.01		45.70	+++	0	0	0.00	0	0	0	0	0	0	yes		
13, 243, Port of Olympia	0.27	23	0.43		**Other:** Benzoic Acid, Bis(2-Ethylhexyl) Phthalate	**Other:** Benzoic Acid	101.1		0.0	**	0.31	^	122.70	+++	0	0	0.00	0	0	0	0	0	0	yes		
13, 244, Port of Olympia	0.27	4	0.13		**Other:** Phenol	**Other:** Phenol	98.9		100.1		0.74		20.10	++	123	18	0.64	4	112	1	1	7	2	yes	Nephtys cornuta	57
																									Paraprionospio pinnata	17
																									Sigambra nr bassi	16
																									Aphelochaeta sp N1	10
14, 245, Pickering Passage/ Squaxin Island	10.52	1	0.07		**Other:** Benzyl Alcohol		81.1		106.4		7.33		1.80		830	102	0.83	23	418	92	8	232	80	no	Edwardsia sipunculoides	52
																									Paleanotus bellis	51
																									Caulleriella pacifica	49
																									Astyris gausapata	48
14, 246, Pickering Passage/ Squaxin Island	10.52	0	0.07				101.1		106.6		7.87		4.20		690	97	0.82	25	509	19	2	137	23	no	Parvilucina tenuisculpta	76
																									Levinsenia gracilis	48
																									Mediomastus sp	42
																									Trochochaeta multisetosa	39

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
14, 247, Pickering Passage/ Squaxin Island	10.52	1	0.05		**Other:** Benzyl Alcohol	**Other:** Benzyl Alcohol	98.9		106.4		6.63		2.70		1069	92	0.67	17	522	48	15	130	354	no	Edwardsia sipunculoides	311
																									Micropodarke dubia	220
																									Polycirrus californicus	45
																									Rochefortia tumida	26
15, 248, Henderson Inlet	1.64	3	0.10				93.8		103.8		3.60		9.10		389	25	0.71	6	82	185	72	37	13	no	Eudorella pacifica	130
																									Amphiodia urtica/periercta complex	64
																									Pholoe sp Cmplx	44
																									Nutricola lordi	30
15, 249, Henderson Inlet	1.64	3	0.10				100.0		107.0		1.43		10.80		499	27	0.51	3	110	313	51	21	4	no	Eudorella pacifica	295
																									Amphiodia urtica/periercta complex	51
																									Paraprionospio pinnata	36
																									Oligochaeta	29
15, 250, Henderson Inlet	1.64	2	0.10		**Other:** Benzoic Acid, Phenol	**Other:** Benzoic Acid, Phenol	97.9		104.6		3.73		10.40		521	28	0.42	2	55	398	50	10	8	no	Eudorella pacifica	361
																									Amphiodia urtica/periercta complex	42
																									Heterophoxus affinis	19
																									Sigambra nr bassi	19
16, 251, Case Inlet	20.85	1	0.09				100.0		102.5		2.33		21.90	++	317	46	0.74	11	260	13	1	38	5	no	Levinsenia gracilis	84
																									Aricidea ramosa	51
																									Sigambra nr bassi	27
																									Parvilucina tenuisculpta	22
16, 252, Case Inlet	20.85	2	0.10				97.9		84.2		7.40		20.00	++	181	27	0.76	6	99	24	0	30	28	no	Aricidea ramosa	39
																									Levinsenia gracilis	29
																									Virgularia sp	26
																									Parvilucina tenuisculpta	18
16, 253, Case Inlet	20.85	2	0.10				97.9		101.4		4.87		9.00		206	44	0.82	13	153	6	1	32	14	no	Aricidea ramosa	34
																									Levinsenia gracilis	29
																									Parvilucina tenuisculpta	20
																									Dipolydora caulleryi	15
17, 254, Nisqually Reach	11.91	0	0.05				91.8		101.3		9.97		2.10		159	55	0.78	18	48	68	1	36	6	no	Euphilomedes carcharodonta	46
																									Astyris gausapata	21
																									Westwoodilla caecula	6
																									Prionospio steenstrupi/jubata	5
17, 255,	11.91	0	0.06				96.9		101.1		5.27		7.40		220	51	0.79	14	176	4	3	28	9	no	Dipolydora cardalia	41

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
Nisqually Reach																									Levinsenia gracilis	37
																									Parvilucina tenuisculpta	14
																									Sigambra nr bassi	13
17, 256, Nisqually Reach	11.91	0	0.06				95.9		100.1		8.13		5.50		466	68	0.78	15	290	32	98	30	16	no	Dipolydora cardalia	74
																									Amphiodia urtica/periercta complex	68
																									Levinsenia gracilis	46
																									Prionospio steenstrupi/jubata	22
18, 257, Drayton Passage	6.72	1	0.08				96.9		100.5		2.80		15.70	++	490	55	0.60	6	403	19	2	21	45	no	Levinsenia gracilis	209
																									Aricidea ramosa	77
																									Sigambra nr bassi	35
																									Virgularia sp	25
18, 258, Drayton Passage	6.72	0	0.05				97.9		100.1		7.37		2.00		296	80	0.84	24	93	85	27	86	5	no	Euphilomedes carcharodonta	44
																									Rochefortia tumida	24
																									Rhepoxynius boreovariatus	14
																									Astyris gausapata	13
18, 259, Drayton Passage	6.72	0	0.05				102.1		100.9		5.63		2.30		686	78	0.59	8	241	22	380	24	19	no	Amphiodia urtica/periercta complex	313
																									Scoletoma luti	60
																									Amphiodia sp	59
																									Dipolydora cardalia	30
19, 260, East Anderson Island/No. Cormorant Passage	16.50	1	0.10		**Other:** Benzoic Acid	**Other:** Benzoic Acid	99.0		100.1		6.57		12.40	++	228	51	0.87	17	149	30	10	34	5	no	Levinsenia gracilis	21
																									Dipolydora socialis	19
																									Sigambra nr bassi	18
																									Parvilucina tenuisculpta	17
19, 261, East Anderson Island/No. Cormorant Passage	16.50	1	0.09				99.0		99.9		5.07		9.00		311	62	0.84	19	213	14	25	42	17	no	Dipolydora socialis	35
																									Trochochaeta multisetosa	27
																									Parvilucina tenuisculpta	26
																									Praxillella pacifica	21

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
19, 262, East Anderson Island/No. Cormorant Passage	16.50	0	0.09				98.0		97.9		7.07		5.20		588	104	0.77	22	275	141	133	23	16	no	Amphiodia urtica/periercta complex	131
																									Euphilomedes carcharodonta	44
																									Rhepoxynius boreovariatus	28
																									Ampelisca lobata	26
20, 263, Carr Inlet	26.60	0	0.08				101.0		100.3		14.53		3.50		376	69	0.84	19	277	7	13	76	3	no	Praxillella sp	38
																									Trochochaeta multisetosa	32
																									Levinsenia gracilis	32
																									Axinopsida serricata	30
20, 264, Carr Inlet	26.60	4	0.20				101.0		100.7		15.80		7.00		94	19	0.72	5	35	0	0	59	0	no	Axinopsida serricata	40
																									Sigambra nr bassi	9
																									Parvilucina tenuisculpta	9
																									Levinsenia gracilis	8
20, 265, Carr Inlet	26.60	3	0.13				99.0		98.7		6.23		12.80	++	175	26	0.75	6	113	1	0	59	2	no	Parvilucina tenuisculpta	38
																									Prionospio (Minuspio) lighti	32
																									Levinsenia gracilis	26
																									Axinopsida serricata	14
21, 266, Hale Passage	3.63	0	0.04		**Other:** Benzoic Acid	**Other:** Benzoic Acid	101.0		100.5		6.63		2.00		274	66	0.87	22	150	18	0	96	10	no	Mediomastus californiensis	33
																									Parvilucina tenuisculpta	22
																									Mediomastus sp	15
																									Chaetozone sp N2	14
21, 267, Hale Passage	3.63	0	0.05				100.0		100.1		6.80		4.10		266	73	0.78	20	146	84	3	27	6	no	Euphilomedes carcharodonta	60
																									Dipolydora socialis	27
																									Prionospio steenstrupi/jubata	23
																									Streblosoma sp	20
21, 268, Hale Passage	3.63	0	0.07				99.0		99.9		6.43		1.60		222	57	0.85	17	147	30	3	33	9	no	Chaetozone sp N2	32
																									Mediomastus californiensis	23
																									Odontosyllis phosphorea	13
																									Diopatra ornata	13

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
22, 269, Gig Harbor	0.18	0	0.08				104.5		100.9		2.80		33.30	++	1107	61	0.52	3	922	98	0	87	0	yes	Aphelochaeta sp	407
																									Aphelochaeta sp N1	229
																									Rhynchospio glutaea	195
																									Odostomia sp	41
22, 270, Gig Harbor	0.18	1	0.14				97.7		100.5		0.95		31.30	++	1287	78	0.48	3	1178	60	0	38	11	yes	Aphelochaeta sp	559
																									Aphelochaeta sp N1	380
																									Lumbrineris californiensis	32
																									Phyllochaetopterus prolifica	30
22, 271, Gig Harbor	0.18	19	0.33				100.0		100.7		2.00		87.00	+++	807	64	0.61	6	537	136	23	108	3	yes	Aphelochaeta sp	256
																									Aphelochaeta sp N1	177
																									Eudorella pa	56
																									Euphilomedes	53
23, 272, Colvos Passage	13.88	0	0.08				97.0		100.5		29.80		3.90		367	96	0.88	31	205	102	2	48	10	no	Mediomastus sp	31
																									Mediomastus californiensis	20
																									Dipolydora socialis	17
																									Caprella sp	16
23, 273, Colvos Passage	13.88	1	0.08				91.0		100.3		31.47		2.30		261	73	0.84	23	133	82	5	31	10	no	Mediomastus sp	34
																									Tritella pilimana	31
																									Sabellidae	20
																									Pinnotheridae	13
23, 274, Colvos Passage	13.88	0	0.07				91.1		100.5		28.40		3.70		195	53	0.79	16	98	56	0	35	4	no	Mediomastus	37
																									Pinnotherida	34
																									Olivella bae	24
																									Prionospio l	7
24, 275, Quarter-master Harbor	3.42	0	0.05				98.9		99.7		51.07		5.20		510	90	0.80	20	275	120	2	109	4	no	Parvilucina tenuisculpta	67
																									Euphilomedes carcharodonta	53
																									Euphilomedes producta	39
																									Polycirrus sp	37
24, 276, Quarter-master Harbor	3.42	5	0.15				105.7		99.5		0.71		29.20	++	285	40	0.68	7	177	3	0	101	4	no	Nutricola lordi	83
																									Terebellides californica	66
																									Scalibregma inflatum	29
																									Heteromastus filobranchus	17

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
24, 277, Quarter-master Harbor	3.42	4	0.11				94.3		100.5		1.30		16.40	++	259	47	0.83	14	151	61	28	13	6	no	Eudorella pacifica	34
																									Terebellides californica	29
																									Amphiodia urtica/periercta complex	28
																									Polycirrus californicus	22
25, 278, East Passage	22.60	10	0.20				103.4		100.9		18.10		78.90	+++	1429	88	0.63	9	252	623	11	534	9	no	Axinopsida serricata	372
																									Eudorellopsis integra	308
																									Euphilomedes producta	165
																									Macoma carlottensis	77
25, 279, East Passage	22.60	5	0.14				100.0		100.1		3.63		24.50	++	454	39	0.48	4	62	55	3	319	15	no	Axinopsida serricata	292
																									Eudorellopsis integra	26
																									Eudorella pacifica	16
																									Levinsenia gracilis	13
25, 280, East Passage	22.60	1	0.08				97.7		98.7		175.30		1.50		193	66	0.86	26	124	29	1	34	5	no	Chaetozone sp N2	38
																									Astyris gausapata	15
																									Spiophanes bombyx	9
																									Diopatra ornata	9
26, 281, Outer Com-mencement Bay	3.24	5	0.12				98.9		100.1		3.77		11.80	++	344	56	0.73	13	144	33	3	158	6	no	Axinopsida serricata	104
																									Levinsenia gracilis	36
																									Macoma carlottensis	30
																									Prionospio (Minuspio) lighti	21
26, 282, Outer Com-mencement Bay	3.24	7	0.16				100.0		98.9		4.30		27.80	++	533	66	0.64	10	269	55	3	192	14	no	Axinopsida serricata	169
																									Levinsenia gracilis	132
																									Cossura pygodactylata	27
																									Mediomastus sp	14
26, 283, Outer Com-mencement Bay	3.24	4	0.14				94.6		100.5		11.57		18.80	++	721	60	0.57	6	178	131	2	382	28	no	Axinopsida serricata	337
																									Eudorellopsis integra	94
																									Levinsenia gracilis	43
																									Macoma carlottensis	29
26, 284, Outer Com-mencement Bay	3.24		0.16				101.1		100.5		6.47		7.00		609	89	0.73	19	217	126	2	257	7	no	Axinopsida serricata	163
																									Euphilomedes producta	73
																									Macoma carlottensis	50
																									Levinsenia gracilis	19

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
27, 285, S. E. Commencement Bay (shoreline)	0.79	3	0.12				101.1		100.7		9.07		19.80	++	635	98	0.80	24	264	207	16	144	4	no	Euphilomedes carcharodonta	124
																									Parvilucina tenuisculpta	39
																									Pinnotheridae	36
																									Chaetozone nr setosa	31
27, 286, S. E. Commencement Bay (shoreline)	0.79	8	0.14				102.2		100.7		5.77		26.40	++	751	68	0.62	9	182	95	1	468	5	no	Axinopsida serricata	316
																									Macoma carlottensis	83
																									Euphilomedes producta	52
																									Astyris gausapata	36
27, 287, S. E. Commencement Bay (shoreline)	0.79	20	0.53	**LPAHs:** Phenanthrene, Total LPAH			95.7		100.1		4.67		121.70	+++	1874	100	0.63	9	325	616	31	898	4	no	Axinopsida serricata	495
																									Euphilomedes carcharodonta	317
																									Euphilomedes producta	193
																									Macoma sp	172
28, 288, S. E. Commencement Bay	1.05	7	0.18				101.1		100.9		9.20		12.80	++	1477	63	0.49	6	1332	64	0	72	9	no	Cossura pygodactylata	862
																									Trochochaeta multisetosa	106
																									Levinsenia gracilis	45
																									Ampharete cf crassiseta	40
28, 289, S. E. Commencement Bay	1.05	8	0.14				104.3		101.3		11.00		18.20	++	984	69	0.73	10	767	42	0	169	6	no	Ampharete cf crassiseta	137
																									Cossura pygodactylata	114
																									Axinopsida serricata	104
																									Trochochaeta multisetosa	100
28, 290, S. E. Commencement Bay	1.05	8	0.12				100.0		100.9		7.87		18.80	++	2289	69	0.49	5	2124	51	0	109	5	no	Cossura pygodactylata	1248
																									Ampharete cf crassiseta	193
																									Ampharetidae sp	135
																									Trochochaeta multisetosa	90
29, 291, N.E. Commencement Bay	1.11	6	0.11				96.7		100.5		5.47		22.00	++	619	52	0.56	5	215	19	5	378	2	no	Axinopsida serricata	315
																									Ampharete finmarchica	57
																									Levinsenia gracilis	52
																									Macoma carlottensis	31
29, 292, N.E. Commencement Bay	1.11	6	0.14				95.5		99.5		4.03		28.40	++	974	85	0.67	12	533	48	22	357	14	no	Axinopsida serricata	281
																									Levinsenia gracilis	192
																									Cossura pygodactylata	41
																									Euchone incolor	32

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
29, 293, N.E. Com-mencement Bay	1.11	15	0.25				92.2		99.3		0.43	^	109.00	+++	2235	86	0.46	4	1792	47	10	363	23	yes	Aphelochaeta sp	1262
																									Alvania compacta	220
																									Aphelochaeta sp N1	153
																									Aphelochaeta monilaris	70
30, 294, Thea Foss Waterway	0.13	27	4.25	**Metals:** Lead; **HPAHs:** Benzo(a)anthracene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Fluoranthene, Pyrene, Chrysene, Total HPAH; **LPAHs:** 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene, Phenanthrene, Total LPAH; Total PAH; **Others:** Total congeners	**Metals:** Mercury; **HPAHs:** Benzo(g,h,i)perylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene; **LPAHs:** Acenaphthene, Fluorene, Phenanthrene; **Others:** Bis(2-Ethylhexyl) Phthalate, Dibenzofuran, 2,4-Dimethylphenol, Total Aroclors	**Metals:** Mercury; **Other:** 2,4-Dimethylphenol	90.2		28.8	**	0.32	^	1994.90	+++	304	43	0.77	10	103	36	0	164	1	yes	Alvania compacta	69
																									Capitella capitata hyperspecies	31
																									Lacuna vincta	31
																									Armandia brevis	23
30, 295, Thea Foss Waterway	0.13	21	0.52	**LPAHs:** Total LPAH	**Other:** Butylbenzylphthalate		101.1		100.5		1.37		529.10	+++	2924	53	0.43	3	2259	96	41	521	7	yes	Aphelochaeta sp	1708
																									Axinopsida serricata	360
																									Aphelochaeta sp N1	260
																									Pinnotheridae	88
30, 296, Thea Foss Waterway	0.13	21	0.55	**LPAHs:** Pyrene, Total LPAH	**HPAHs:** Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene		95.7		100.7		1.14		355.70	+++	1633	79	0.60	8	1070	91	38	427	7	yes	Aphelochaeta sp N1	612
																									Axinopsida serricata	237
																									Rochefortia tumida	94
																									Cossura pygodactylata	73
31, 297, Middle Waterway	0.02	19	0.41				100.0		99.1		3.03		44.20	+++	1847	117	0.59	12	1283	77	56	422	9	yes	Aphelochaeta sp N1	777
																									Axinopsida serricata	179
																									Parvilucina tenuisculpta	82
																									Alvania compacta	51
31, 298, Middle Waterway	0.02	18	0.29				94.6		101.0		0.89		73.30	+++	888	85	0.70	12	641	94	11	141	1	no	Aphelochaeta sp N1	232
																									Armandia brevis	92
																									Prionospio steenstrupi/jubata	51
																									Lumbrineris californiensis	49

Appendix A. Continued.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
31, 299, Middle Waterway	0.02	22	1.11	**Metals:** Copper, Mercury; **HPAH**: Benzo(a)anthracene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Pyrene, Total HPAH; **LPAH:** Acenaphthene, Anthracene, Fluorene, Phenanthrene, Total LPAH	**Metals:** Arsenic, Copper, Mercury; **HPAHs:** Benzo(a)anthracene, Benzo(a)pyrene, Benzo(g,h,i)perylene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Total HPAH; **LPAHs:** Acenaphthene, Fluorene, Phenanthrene, Total LPAH; **Other:** Dibenzofuran	**Metals:** Copper, Mercury; **HPAHs:** Dibenzo(a,h)anthracene; **LPAHs:** Acenaphthene	93.5		100.3		2.00		119.70	+++	1296	81	0.53	8	1179	38	5	64	10	yes	Aphelochaeta sp N1	706
																									Lumbrineris californiensis	65
																									Prionospio steenstrupi/jubata	52
																									Notomastus hemipodus	50
32, 300, Blair Waterway	0.39	4	0.13				101.1		100.9		3.27		36.70	++	889	50	0.60	5	507	6	0	375	1	yes	Axinopsida serricata	353
																									Aphelochaeta sp N1	152
																									Aphelochaeta monilaris	74
																									Scoletoma luti	48
32, 301, Blair Waterway	0.39	3	0.13				93.3		100.1		2.60		33.30	++	1010	50	0.53	3	726	6	0	278	0	yes	Aphelochaeta sp N1	410
																									Axinopsida serricata	257
																									Chaetozone nr setosa	92
																									Scoletoma luti	34
32, 302, Blair Waterway	0.39	2	0.16				94.4		100.7		4.33		19.90	++	1145	61	0.58	5	672	28	4	440	1	yes	Axinopsida serricata	377
																									Aphelochaeta sp N1	252
																									Aphelochaeta monilaris	142
																									Scoletoma luti	57
33, 303, Hylebos Waterway	0.22	24	2.05	**Other:** Total Congeners	**Other:** Hexachlorobenzene, Total Aroclors		101.1		98.3		0.88		176.20	+++	776	54	0.54	5	572	22	0	177	5	yes	Aphelochaeta sp N1	383
																									Axinopsida serricata	90
																									Aphelochaeta monilaris	63
																									Scoletoma luti	40
33, 304, Hylebos Waterway	0.22	12	0.58		**Other:** Hexachlorobenzene, Phenol, Total Aroclors		101.1		99.7		1.23		104.80	+++	533	55	0.59	6	469	12	0	51	1	yes	Aphelochaeta sp N1	258
																									Euchone incolor	41
																									Prionospio steenstrupi/jubata	31
																									Scoletoma luti	29

Appendix A. Concluded.

Stratum, sample, location	sample-wtd area (km2)	Number of ERLs exceeded	Mean ERM quotient	Compounds exceeding ERMs	Compounds exceeding SQSs	Compounds exceeding CSLs	Amphipod survival as % of control	% survival significantly different than controls & <80% of controls)	Mean Urchin fertilization in 100% pore water as % of control	Significance (<80% of controls)	Microtox EC50 (mg/ml)	Significance (<0.51 mg/mg)	Cytochrome P-450 HRGS as ugB[a]p/g	Significance (++=>11.1ugB[a]p/g, +++=>37.1ugB[a]p/g)	Total abundance	Taxa richness	Evenness	Species Dominance Index	Annelid abundance	Arthropod abundance	Echinoderm abundance	Mollusca abundance	Misc. abundance	Impaired infaunal assemblages*	Dominant taxa	Count
33, 305, Hylebos Waterway	0.22	19	1.08		**Other:** Hexachlorobenzene		86.0		100.7		0.82		73.30	+++	922	46	0.39	2	836	25	2	57	2	yes	Aphelochaeta sp N1	632
																									Aphelochaeta monilaris	67
																									Scoletoma luti	57
																									Axinopsida serricata	28

*As there are no accepted guidelines or criteria for the determination of impaired infaunal assemblages, best professional judgment was used to indicate whether the infaunal assemblage as each station appeared to be impacted, based on a combination of benthic indices examined. An assemblage was classified as impacted primarily if it had a combination of low benthic indicators, although some of the impacted stations possessed high total abundance and/or Swartz's Dominance Index, due to high abundance of 1 or 2 pollution tolerant taxa.