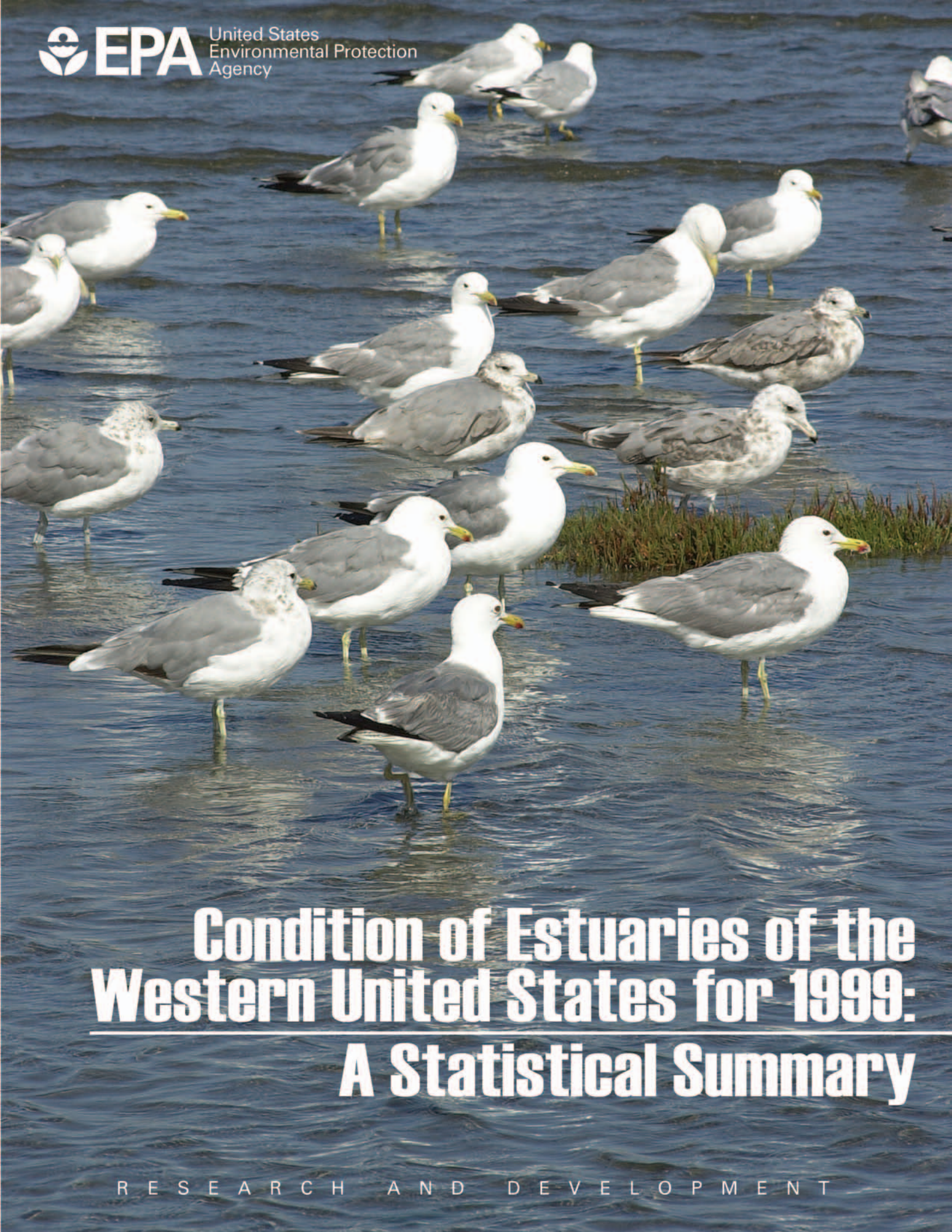

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Condition of Estuaries of the Western United States for 1999: A Statistical Summary

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Condition of Estuaries of the Western United States for 1999: A Statistical Summary

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Washington, DC 20460

List of Authors

Walter G. Nelson[1], Henry Lee II[1], Janet O. Lamberson[1], Virginia Engle[2], Linda Harwell[2], Lisa M. Smith[2]

List of Author Affiliations

[1] Western Ecology Division, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Newport OR 97365

[2] Gulf Ecology Division, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Gulf Breeze FL 32561

Preface

This document is the statistical summary for the western states, coastal component of the nationwide Environmental Monitoring and Assessment Program (EMAP). The focus of the study during 1999 was the small estuaries of Washington, Oregon, and California (excluding Puget Sound, the main channel of the Columbia River, and San Francisco Bay). EMAP-West is a partnership of the States of California, Oregon and Washington, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency (EPA). The program is administered through the EPA and implemented through partnerships with a combination of federal and state agencies, universities and the private sector.

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Many individuals within EPA made important contributions to Western Coastal EMAP. Critical guidance and vision in establishing this program was provided by Kevin Summers of Gulf Ecology Division. Tony Olsen of Western Ecology Division (WED) has made numerous comments which have helped to improve the quality of this document. Lorraine Edmond of the Region 10 Office of EPA and Terrence Fleming of the Region 9 Office of EPA have ably served as the regional liaisons with the state participants in their regions. Robert Ozretich of WED performed a detailed review of the database contents used for this analysis, and we additionally thank him for his extensive quality assurance review of this document.

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Biomonitoring of Environmental Status and Trends Program (BEST)

Christine Bunck

Columbia Environmental Research Center

Don Tillet

Marine Ecotoxicology Research Station

Scott Carr

Gulf Breeze Project Office

Tom Heitmuller

Steve Robb

Pete Bourgeois

U.S. Environmental Protection Agency

Office of Research and Development

Tony Olsen

Steve Hale

John Macauley

Region 9

Terrence Fleming

Janet Hashimoto

Region 10

Lorraine Edmond

Gretchen Hayslip

Indus Corporation

Patrick Clinton

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Executive Summary

As a part of the National Coastal Assessment, the Environmental Monitoring and Assessment Program (EMAP) initiated a five-year Western Coastal component in 1999. The objectives of the program were: to assess the condition of estuarine resources of Washington, Oregon and California based on a range of indicators of environmental quality using an integrated survey design; to establish a baseline for evaluating how the conditions of the estuarine resources of these states change with time; to develop and validate improved methods for use in future coastal monitoring and assessment efforts in the western coastal states; and to transfer the technical approaches and methods for designing, conducting and analyzing data from probability based environmental assessments to the states and tribes.

The focus of the study during 1999 was the small estuaries of Washington, Oregon, and California, excluding Puget Sound, the main channel of the Columbia River, and San Francisco Bay, which were sampled in 2000 during the second year of the program. The environmental condition indicators used in this study included measures of: 1) general habitat condition (depth, salinity, temperature, pH, total suspended solids, sediment characteristics), 2) water quality indicators (chlorophyll *a*, nutrients), 3) pollutant exposure indicators (dissolved oxygen concentration, sediment contaminants, fish tissue contaminants, sediment toxicity), and 4) benthic condition indicators (diversity and abundance of benthic infaunal and demersal fish species, fish pathological anomalies).

The study utilized a stratified random sampling design, with the base study consisting of 150 sites equally divided among the three states. Additionally, intensification studies were conducted that consisted of 30 sites located in Tillamook Bay, Oregon, and 30 sites distributed among the mouths of river dominated estuaries in northern California. All sites were combined for statistical analysis. Cumulative distribution functions (CDFs) were produced using appropriate sampling area weightings to represent the areal extent associated with given values of an indicator variable for the small estuaries of the West Coast.

Reflecting the fact that the sampling effort spanned both the Columbian and Californian Biogeographic Provinces, the indicators of general habitat condition showed wide ranges of values, e.g., bottom water temperatures from 8.5 to 32.1 °C. Approximately 54% of the area of the small West Coast estuaries would be classified as euhaline ($\geq$30 psu) based on the EMAP sampling. Approximately 65% of the estuarine area had sandy sediments (<20% silt clay), 29% had intermediate muddy sands (20-80% silt clay), and 6 % had mud sediments (>80% silt clay). The TOC content of sediments was $\leq$ 1% in approximately 84% of the area of the small West Coast estuaries.

The pH of bottom waters for the small estuaries of West Coast states had the surprisingly wide range of from 5.1 to 10.2, with extreme values associated with low salinity locations. There was no geographic pattern to high values of chlorophyll *a*.

Most water quality indicators showed similar CDF patterns, with high values being observed in a very small percentage of estuarine area, thus generating extensive right hand tails to CDF distributions. For example, the average water column concentration of nitrate/nitrite of small West Coast estuaries ranged from 0 to 3472 µg L^{-1}, but only 2.7 % of estuarine area had nitrate/nitrite values that exceeded concentrations of 300 µgL^{-1}. Approximately 75% of estuarine area had molar ratios of average water column total nitrogen to total phosphorus (N/P) values $\leq$ 16, suggesting nitrogen limitation. While total suspended solids (TSS) ranged from 0 to 276.2 mg L^{-1}, approximately 95% of estuarine area had TSS $\leq$ 19.1 mg L^{-1}. Only about 12 % of estuarine area showed an indication of strong water column stratification as indicated by the difference in surface and bottom salinities, suggesting the estuarine areas sampled are generally well mixed.

Among pollution exposure indicators, less than four percent of estuarine area had dissolved oxygen concentrations in bottom waters below 5 mg/L. High values of potentially toxic metals generally occurred in a very small percentage of the estuarine area sampled, with maximum values of many of the metals being observed in the highly urbanized Los Angeles Harbor (cadmium, copper, lead, selenium, silver, tin, zinc). DDT and other pesticides were detected in a relatively small percentage of estuarine area. Seventy- three percent of estuarine area had non-detectable levels of total PCBs. Highest levels of organic contaminants (pesticides, PAHs) generally were associated with urbanized estuaries of southern California.

Sediment toxicity tests with the amphipod *Ampelisca abdita* had control-corrected survivorship $\leq$ 80 % in only about 9 % of estuarine area. Using sediment pore water bioassays, the control corrected, percent fertilization of eggs of the sea urchin *Arbacia punctulata* was $\leq$ 91 % in only about 10.5 % of estuarine area for the 100% of the water quality adjusted (WQA) porewater treatment. Survivorship was higher for both 50% and 25% WQA porewater treatments. For a similar test using percent successful development of *Arbacia punctulata* embryos, the control-corrected normal development of embryos was $\leq$ 91 % in about 49 % of area of small West Coast estuaries for the 100% of the WQA porewater treatment. Normal embryo development was higher for both 50% and 25% WQA porewater treatments.

There was a total of 144 successful trawls across the three states, but due to the number of stations without successful trawls, the analysis of the fish trawl data is limited to summary statistics and species composition, and no CDFs are presented. The number of individuals per trawl averaged 33.7 fish per trawl, with a low of 13.9 in Oregon and a high of 68.0 in California. Species richness averaged 3.53 fish species per trawl, with a low of 2.63 in Oregon and a high of 5.46 in California. A report on the frequency of fish pathologies will be produced separately by NOAA.

Obtaining the target organisms (flatfish) for tissue analysis of contaminants proved difficult, and tissue analyses were conducted on only 53% of the total stations occupied. Thus cumulative distribution functions were not computed. There was no consistent spatial pattern in location of maximum fish tissue metal concentrations, with highest

values of mercury being recorded in several California estuaries, highest arsenic and lead values being recorded in several Washington estuaries, and highest copper values being recorded in an Oregon estuary. Maximum fish tissue residues for total PCBs were associated with urbanized estuaries in California, which were also associated with highest sediment concentrations of these contaminants. Tissue residues of DDT and its metabolites were considerably higher than other pesticides measured.

A total of 187 samples of benthic infauna (>1 mm) were obtained using either grabs or a combination of smaller corers to obtain equivalent surface area (0.1 m^2). Reflecting the wide geographic distribution of sampling, a total of 841 non-colonial benthic taxa were recorded. Species richness ranged from 1 to 157 taxa per sample. Lowest species richness tended to be associated with low salinity sites, and highest species richness was associated with salinities > 30 psu. About 50% of the area of small West Coast estuaries had species richness $\leq$ 17 species per sample. The northern California intensive study sites tended to have lower species richness and H′ diversity values than other stations.

Benthic infaunal abundance averaged 1378.9 individuals per sample, with lowest mean abundance per sample in Washington estuaries and highest mean abundance values in California estuaries, particularly the northern California intensive study sites. About 50% of the area of small West Coast estuaries had mean infaunal abundance $\leq$ 151 individuals per sample. Two amphipod species *(Americorophium spinicorne, Americorophium salmonis*), which had extremely high abundances in several northern California locations, made up 54 % of total infaunal abundance in the study. Among the 10 most abundant taxa at all study sites, nonindigenous and cryptogenic (species of uncertain geographic origin) species made up 6 % of total infaunal abundance.

The 1999 Western Coastal EMAP study provides the first quantitative assessment of the condition of the small estuaries of Washington, Oregon and California. When these data are combined with the data collected in 2000 from the three largest estuarine systems on the West Coast (Puget Sound, Columbia River, San Francisco Bay), there will exist the first comprehensive data set for evaluating the overall condition of all estuarine systems of the West Coast.

1.0 Introduction

1.1 Program Background

Safeguarding the natural environment is fundamental to the mission of the US Environmental Protection Agency (EPA). The legislative mandate to undertake this part of the Agency's mission is embodied, in part, in the Clean Water Act (CWA). Sections of this Act require the states to report the condition of their aquatic resources and list those not meeting their designated use (Sections 305b and 303d, respectively). Calls for improvements in environmental monitoring date back to the late 1970's, and have been recently reiterated by the General Accounting Office (GAO, 2000). The GAO report shows that problems with monitoring of aquatic resources continue to limit states' abilities to carry out several key management and regulatory activities on water quality. At the national level, there is a clear need for coordinated monitoring of the nation's ecological resources. As a response to these needs at state and national levels, the EPA Office of Research and Development (ORD) has undertaken research to support the Agency's Regional Offices and the states in their efforts to meet the CWA reporting requirements. The Environmental Monitoring and Assessment Program (EMAP) is one of the key components of that research and EMAP-West is the newest regional research effort in EMAP. From 1999 through 2005, EMAP-West will seek to develop and demonstrate the tools needed to measure ecological condition of the aquatic resources in the 14 western states in EPA's Regions 8,9, and 10.

The Coastal Component of EMAP-West is a partnership with the states of California, Oregon and Washington, the National Oceanic and Atmospheric Administration, and the Biomonitoring of Environmental Status and Trends Program (BEST) of the U.S. Geological Survey, to measure the condition of the estuaries of these three states. Sampling began during the summer of 1999 and the initial phase of estuarine sampling was completed in 2000. Data from this program will be the basis for individual reports of condition for each state, and will be used to provide data to the National Coastal Assessment.

The US EPA's National Coastal Assessment (NCA) is a five-year effort led by EPA's Office of Research and Development to evaluate the assessment methods it has developed to advance the science of ecosystem condition monitoring. This program will survey the condition of the Nation's coastal resources (estuaries and offshore waters) by creating an integrated, comprehensive coastal monitoring program among the coastal states to assess coastal ecological condition. The NCA is accomplished through strategic partnerships with all 24 U.S. coastal states. Using a compatible, probabilistic design and a common set of survey indicators, each state conducts the survey and assesses the condition of its coastal resources independently. Because of the compatible design, these state estimates can be aggregated to assess conditions at the EPA Regional, biogeographical, and national levels.

This report provides a statistical summary of the data from the first year of sampling (1999) for the small estuarine systems of the states of Washington, Oregon, and California (excluding Puget Sound, the main channel of the Columbia River, and San Francisco Bay).

1.2 The Western United States Context for a Coastal Condition Assessment

Nationwide, growth of the human population is disproportionally concentrated in the coastal zone (Culliton et al., 1990). Within the coastal region of the western U.S., greatest population expansion has been in the major urban areas of Seattle, Portland, the San Francisco Bay area, and much of Southern California. These metro areas are either directly located on coastal water bodies or, like Portland, are on major rivers and thus influence the estuaries downstream. While development around the estuaries between north Puget Sound and Point Reyes, CA, has been less intense, substantial population growth is taking place across the region. Human population growth in the coastal zone of the west is a principal driver for many ecological stressors such as habitat loss, pollution, and nutrient enhancement which alter coastal ecosystems and affect the sustainability of coastal ecological resources (Copping and Bryant, 1993). Increased globalization of the economy is a major driver influencing the introduction of exotic species into ports and harbors. Major environmental policy decisions at local, state and federal levels related to land use planning, growth management, habitat restoration and resource utilization will determine the future trajectory for estuarine conditions of the western U.S.

Changes associated with human population growth in the western coastal region tend to be most obvious in the larger, urban areas, but all coastal resources have been subjected to significant alterations over the last 150 years. In one of the earliest ecological alterations, sea otters, a known ecological keystone species (Simenstad et al., 1978), were largely removed from western coastal ecosystems by 1810, and populations have never recovered. The wave of western mining in the late 1800's had limited effects on most coastal systems in terms of altering estuaries or causing chemical pollution (Durning, 1996). Outside of the major ports, western estuaries are believed to have generally low concentrations of toxic pollutants because of relatively low population densities and low levels of heavy industry (Copping and Bryant, 1993), but data for most estuaries are sparse.

Due to exploitative fishing in the Pacific Northwest, native oyster populations were largely wiped out by the late 1800's, and salmon catch peaked by the early 1900's (Durning, 1996). Resource exploitation for agriculture, logging and damming each resulted in massive changes to land use practices throughout the region. In the Chesapeake Bay region, deforestation associated with human settlement and agricultural clearing was shown to have led to a 100% increase in sediment accumulation rates (Cooper and Brush, 1991) during the 1800's. Sedimentation problems associated with land use changes may be especially acute along the West Coast north of San Francisco due to the combination of steep coastal watersheds, high

rainfall, and timber harvesting. Nutrient and sediment loadings from population centers will augment the increased flux of these materials resulting from the larger scale watershed alterations associated with logging of the coastal mountains (Howarth et al., 1991).

The increase in regional and international marine commerce along the West Coast has resulted in the introduction of nonindigenous species. The effect of nonindigenous species on estuarine habitats has only recently come under scrutiny (Carlton and Geller, 1993), but the potential for ecological transformation is great. Some 367 marine invertebrate taxa were recorded in the ballast water of ships arriving in Coos Bay, Oregon, from Japan (Carlton and Geller, 1993). In Washington state, the introduction of smooth cordgrass, *Spartina alterniflora*, has resulted in the conversion of hundreds of hectares of mud flat to salt marsh habitat with consequences to the ecosystem that have not yet been fully defined (Simenstad and Thom, 1995).

Benthic environments are areas where many types of impacts from the stressors described above will tend to accumulate. Deposition of toxic materials, accumulation of sediment organics, and oxygen deficiency of bottom waters typically have a greater impact on benthic organisms than on planktonic and nektonic organisms because of their more sedentary nature. Long-term studies of the macrobenthos (Reish, 1986; Holland and Shaughnessey, 1986) demonstrate that macrobenthos are a sensitive indicator of pollutant effects. Benthic assemblages are also closely linked to both lower and higher trophic levels, as well as to processes influencing water and sediment quality, and therefore appear to integrate responses of the entire estuarine system (Leppäkoski, 1979; Holland and Shaughnessey, 1986).

Biologically, the EMAP Western Coastal study area is represented by two biogeographic provinces, the Columbian Province, which extends from the Washington border with Canada to Point Conception, California, and the Californian Province, which extends from Point Conception to the Mexican border. Within the biogeographic provinces there are also major transitions in the distribution of the human population. Major population centers occur in the southern end of Puget Sound, around San Francisco Bay, and generally surrounding most of the estuaries of southern California. In contrast, the region of coastline from north of San Francisco Bay through northern Puget Sound has a much lower population density. While it may be presumed that the magnitude of anthropogenic impacts will tend to show a similar distribution, this hypothesis has not yet been tested for West Coast estuaries.

1.3 Objectives

The EMAP sampling program conducted in the small estuaries of the West Coast in 1999 was the first-year component of the larger EMAP Western Coastal Program, which has the following objectives:

1. To assess the condition of estuarine resources of Washington, Oregon and California based on a range of indicators of environmental quality using an integrated survey design;

2. To establish a baseline for evaluating how the conditions of the estuarine resources of these states change with time;

3. To develop and validate improved methods for use in future coastal monitoring and assessment efforts in the western coastal states;

4. To transfer the technical approaches and methods for designing, conducting and analyzing data from probability based environmental assessments to the states and tribes.

2.0 Methods

2.1 Sampling Design and Statistical Analysis Methods

2.1.1 Background

The EMAP approach to evaluating the condition of ecological resources is described in reports such as Diaz-Ramos et al. (1996), Stevens (1997), Stevens and Olsen (1999), and is also presented in summaries provided on the internet at the URL:

http://www.epa.gov/nheerl/arm/index.htm

A brief summary from these documents follows.

Given that it is generally impossible to completely census an extensive resource such as the set of all estuaries on the West Coast, a more practical approach to evaluating resource condition is to sample selected portions of the resource using probability based sampling. Studies based on random samples of the resource rather than on a complete census are termed sample surveys. Sample surveys offer the advantages of being affordable, and of allowing extrapolations to be made of the overall condition of the resource based on the random samples collected. Survey methods are widely used in national programs such as forest inventories, agricultural statistics survey, national resource inventory, consumer price index, labor surveys, and such activities as voter opinion surveys.

A survey design provides the approach to selecting samples in such a way that they provide valid estimates for the entire resource of interest. Designing and executing a sample survey involves five steps: (1) creating a list of all units of the target population from which to select the sample, (2) selecting a random sample of units from this list, (3) collecting data from the selected units, (4) summarizing the data with statistical analysis procedures appropriate for the survey design, and (5) communicating the results. The list or map that identifies every unit within the population of interest is termed the sampling frame.

The sampling frame for the EMAP Western Coastal Program was developed from USGS 1:100,000-scale digital line graphs and stored as a GIS data layer in the ARC/INFO program. A series of programs and scripts (Bourgeois et al., 1998) was written to create a random sampling generator (RSG) that runs in ArcView. Site selection consisted of using the RSG to first overlay a user-defined sampling grid of hexagons over the spatial resource which consisted of all estuaries of the West Coast. The area of the hexagons was controlled by adjusting the distance to hexagon centers, and by defining how many sample stations were to be generated for each sampling region. After the sampling grid was overlaid on the estuarine resource, the program randomly selected hexagons and randomly located a sampling point within the hexagon. Only one sampling site was selected from any hexagon selected. The program

determined whether a sampling point fell in water or on land, and sites that fell on land were not included. The RSG was run iteratively until a hexagon size was determined which generated the desired number of sampling sites within the resource (Bourgeois et al., 1998).

Hexagon size may be different for classes of estuarine systems of different areal extent. The final data analysis which provides the estimates of resource condition then weights the samples based on the area of the estuarine class. Stevens (1997) terms this a random tessellation stratified survey design applied to each estuarine resource class.

2.1.2 Sampling Design

2.1.2.1 1999 West Coast Design

The assessment of condition of small estuaries conducted in 1999 was the first phase of a planned two-year comprehensive assessment of all estuaries of the states of Washington, Oregon and California. The complete assessment will require the integrated analysis of data collected from the smaller estuarine systems in 1999 and the larger estuarine systems in 2000. The intent of the design is to be able to combine data from all stations for analysis, using the inclusion probabilities, defined as the total estuarine area in km^2 within a given design stratum (= estuarine size class), to weight the representation of samples in the combined analysis.

The West Coast sampling frame was constructed as a GIS coverage that would include the total area of the estuarine resource of interest. Available GIS coverages were not perfect representations of the estuarine resource, and so the coverages were defined to ensure that they included the resource, but may have possibly included some nearby land or inland water. The inland boundary of the sampling frame was defined as the head of salt water influence, while the seaward boundary was defined by the confluence with the ocean. Sample locations could fall within any water depth contained within the estuarine resource which was bounded by the shoreline. In some cases, extremely shallow sites were deemed inaccessible by field crews with the sampling gear specified (Section 2.6). Emergent salt marsh areas were not included in the sampling frame because the required indicators to deal with marsh habitats were not available.

For the state of Washington, the 1999 design included only estuaries along the coastline outside of the Puget Sound system, and consisted of a total of 50 sites (Table 2.1). Tributary estuaries of the Columbia River located within Washington state were included in the 1999 sampling effort, while the main channel area was not sampled until 2000 (as part of the 2000 Oregon design). The sampling frame used three hexagonal grid sizes to cover the size range of estuaries: 0.86, 7.79, 36.58 km^2. The hexagonal grid sizes were used to locate random sample sites within a total of four strata representing differing total areas of the estuarine resource in Washington (Table 2.1). To insure some level of sampling across the entire range of estuarine sizes, sampling effort was partitioned as 10 stations within the smallest estuarine size class, 25 stations

within the two strata representing the medium sized estuaries, and 15 stations in the largest size class. No alternate or oversample sites were included in the design.

The Oregon 1999 design included only small estuaries of the state and consisted of 50 sites. Tributary estuaries of the Columbia River located within Oregon were included in the 1999 sampling effort, while the main channel area was not sampled until 2000. The sampling frame for small estuaries utilized four hex sizes to cover the size range of estuaries: 1.24, 3.46, 4.58, and 7.28 km^2. Approximately equal sampling effort was placed in each of the four estuarine strata, which represented differing size classes of estuaries, to insure some level of sampling across the entire range of estuarine sizes. An intensive sampling effort was also designed for Tillamook Bay, where a total of 30 sites were selected using a hex size of 1.04 km^2. No points from the base study design were placed in Tillamook Bay. All sites from both the base study and intensive study were combined for analysis. No alternate or oversample sites were included in the design.

The 1999 California base study design included all estuaries of the state with the exception of San Francisco Bay, and consisted of a total of 50 sites. The sampling frame utilized three hexagonal grid sizes to cover the size range of estuaries in the sampling frame: 0.86, 7.79, and 12.50 km^2. Approximately equal sampling effort was placed in each of the three estuarine size classes (<5, 5-25 and >25 km^2) to ensure some level of sampling across the entire range of estuarine sizes. No alternate or oversample sites were selected during the design, and thus any sites which could not be sampled were not replaced.

The estuarine systems on the northern California coast, with the exception of the Arcata and Humboldt Bay systems, are relatively poorly studied. A number of the rivers which discharge directly into the Pacific Ocean have been listed as failing to meet designated uses and have been designated for development of Total Maximum Daily Loadings (TMDL). At the request of the Region 9 Office of EPA, an intensive study was conducted to sample the river mouth estuaries of both TMDL listed and non-TMDL listed systems of Northern California. The purpose of this assessment was to determine if there was any difference in the estimates of condition for the two categories of estuarine resource.

Using finer scale hexagonal grids, 30 sites were randomly selected at the mouths of the river systems in Northern California. The design for this intensive study incorporated 6 differing hexagonal grid sizes: 0.0346, 0.0498, 0.0585, 0.0800, 0.0914, and 0.1060 km^2. The hexagonal grid sizes were used to locate random sample sites within a total of seven strata representing differing total areas of the estuarine resource in these Northern California river mouth systems (Table 2-1). Sample sites were divided equally between streams with and without TMDL listings (Table 2-1). No alternate or oversample sites were selected during the design, and thus any sites which could not be sampled were not replaced.

While the intent of the California design was to be able to integrate all study sites seamlessly into combined analyses, an inadvertent design change occurred which somewhat complicates interpretation of results. In defining the target population for the Northern California sites, a restriction of sampling to a distance of 0.25 km from the estuarine mouth was imposed. This definition differs from that of the remainder of the West Coast assessment which used a target population defined by the head of salt in the estuary. In order to prevent duplicative sampling effort, the intensive study of northern California small river systems had been excluded from the frame for the base California study. Thus, a small area (approximately 10 km^2) representing the portion of the Northern California river systems excluded from the intensive study was inadvertently omitted from the California sampling frame.

2.1.2.2 2000 West Coast Design

While results of the 2000 sampling effort are not presented in this report, a description of the sample design for 2000 is provided in order to demonstrate the overall plan for the western coastal assessment effort.

The Washington 2000 sampling design included only the large "estuary" of Puget Sound and its tributaries. Site selection for this estuary used a combined approach in order to allow collaboration with a survey previously conducted by NOAA under the NOAA National Status and Trends Program. The overall design combined the existing NOAA probability based, randomized monitoring design with the EMAP Western Coastal study design. The EMAP hexagonal grid was extended to include Canadian waters at the north end of Puget Sound, and then was overlaid on the existing NOAA monitoring sites. If a NOAA site fell within a hexagon, the site was designated as the EMAP sampling point. If not, a random site was selected based on the EMAP protocols. The design incorporated three different hex sizes, two covering most of the Puget Sound region (86.6, 250.28 km^2), and one used for intensifying in the region of the San Juan Islands (21.65 km^2). There were 41 stations selected based on the NOAA sampling stations, in addition to 30 new EMAP stations, of which 10 were associated with the San Juan Islands. No alternate or oversampling sites were included in the design frame.

The Oregon 2000 design included only the main channel area of Columbia River. The Columbia River system was split into two subpopulations, the lower, saline portion and the upper, freshwater portion, with hex sizes of 13.85 and 5.4 km^2 and total numbers of stations of 20 and 30, respectively. No alternate or oversample sites were included in the design.

The 2000 California design included only San Francisco Bay and its tributaries. Site selection for this estuary used a combined approach in order to allow collaboration with a survey being conducted by NOAA under the NOAA National Status and Trends Program. An EMAP sampling design was developed specifically for NOAA to implement a multiyear monitoring program to characterize condition of the small systems within the

San Francisco Bay. To insure complete coverage of the bay for the EMAP Western Coastal study, the NOAA design was augmented with a sampling design which split the Bay into two subpopulations (open bay and smaller surrounding systems). For the open bay, a hex size of 36.58 km^2 was used and 31 sites were generated. For the smaller systems, a different hexagon size (3.46 km^2) was used to generate 19 sites for sampling. This grid was overlaid on the newly designed NOAA small systems monitoring project. If a NOAA site fell within a hexagon, the site was used as the sampling point. If not, a random point was generated based on the standard randomization routines used by Western Coastal EMAP as part of the National Coastal Assessment. No alternate or oversample sites were selected.

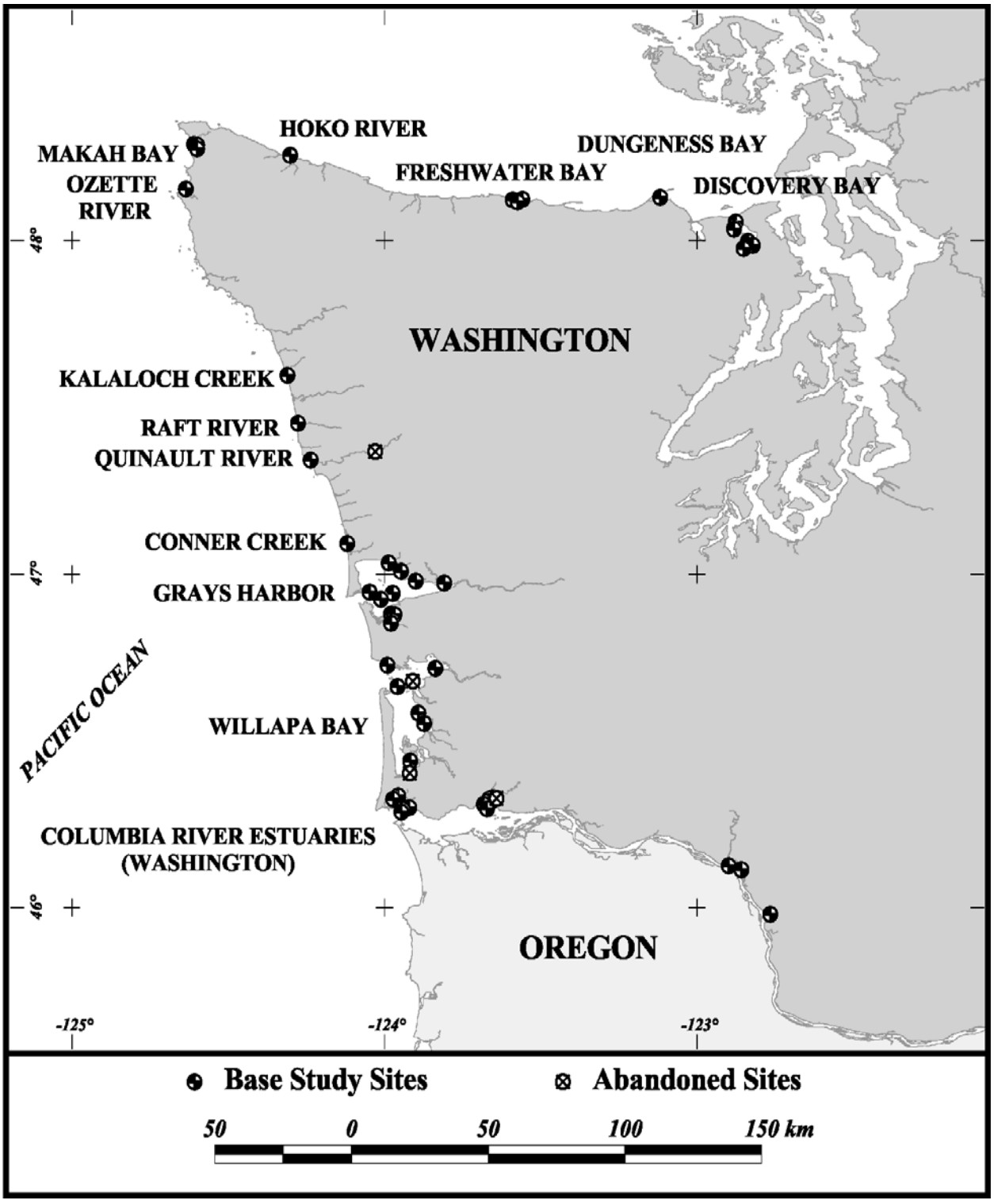

Figure 2-1. Location of Washington EMAP survey sites.

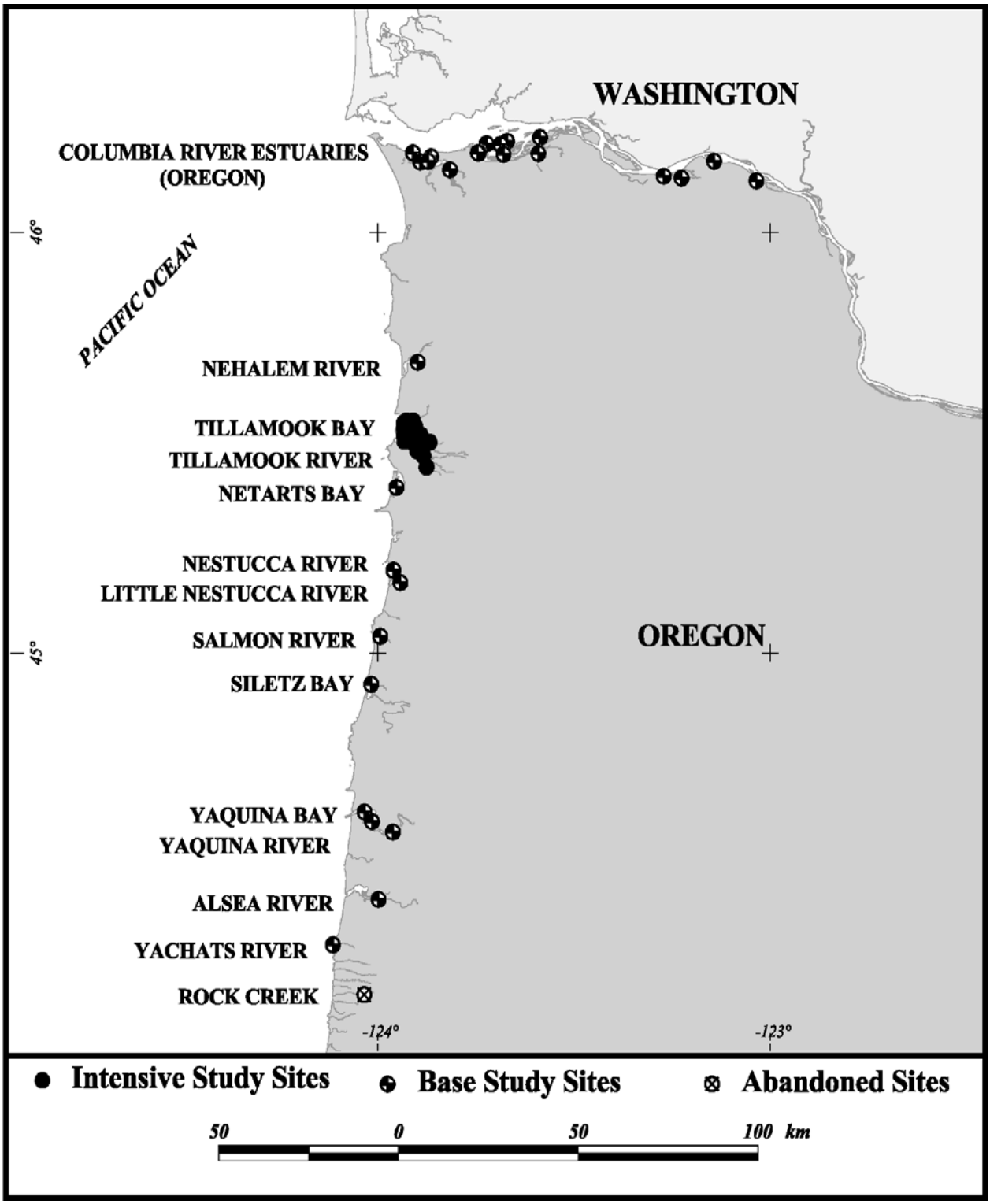

Figure 2-2. Location of EMAP survey sites along the northern portion of the Oregon coast, including survey sites for the intensification study of Tillamook Bay.

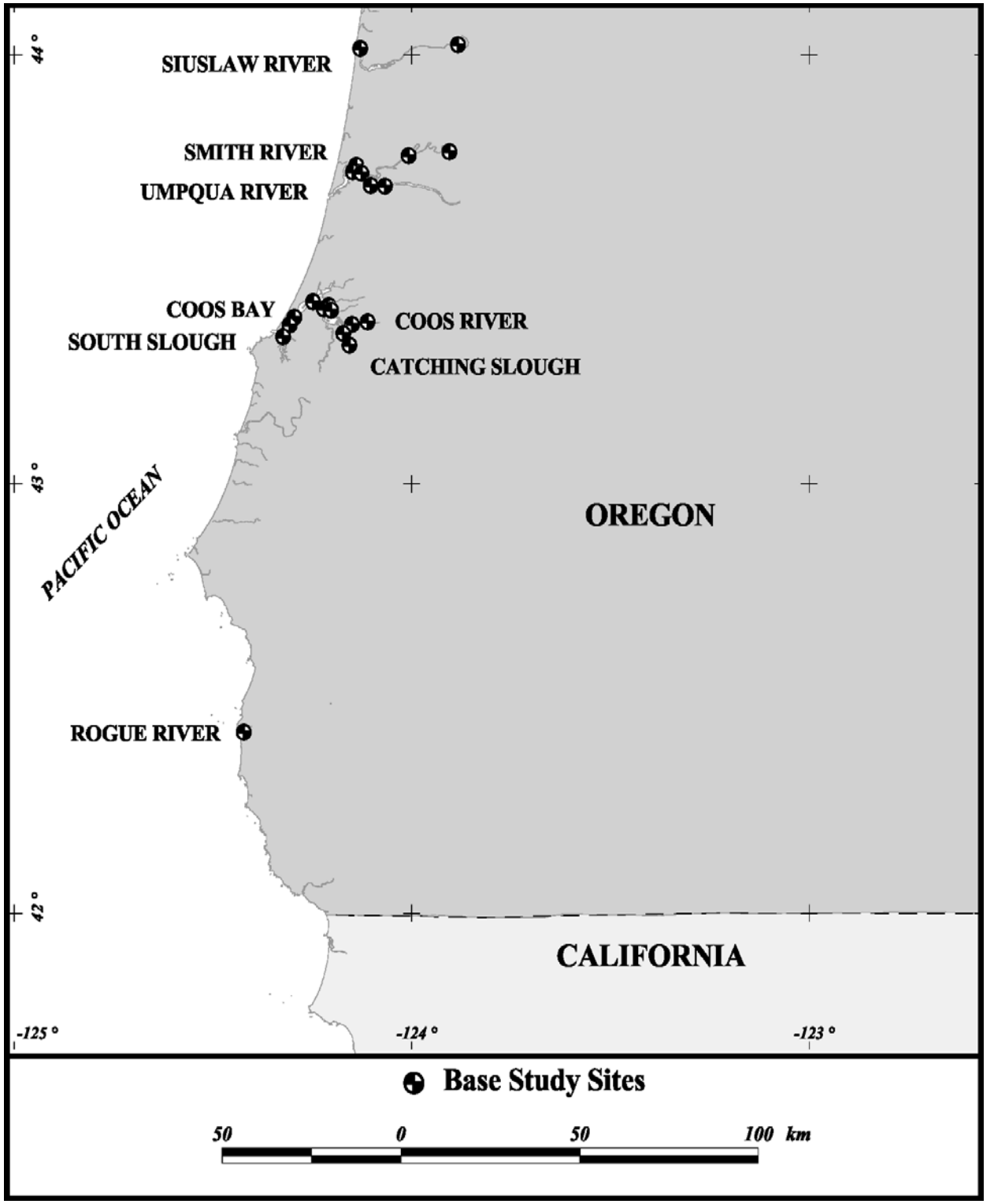

Figure 2-3. Location of EMAP survey sites along the southern portion of the Oregon coast.

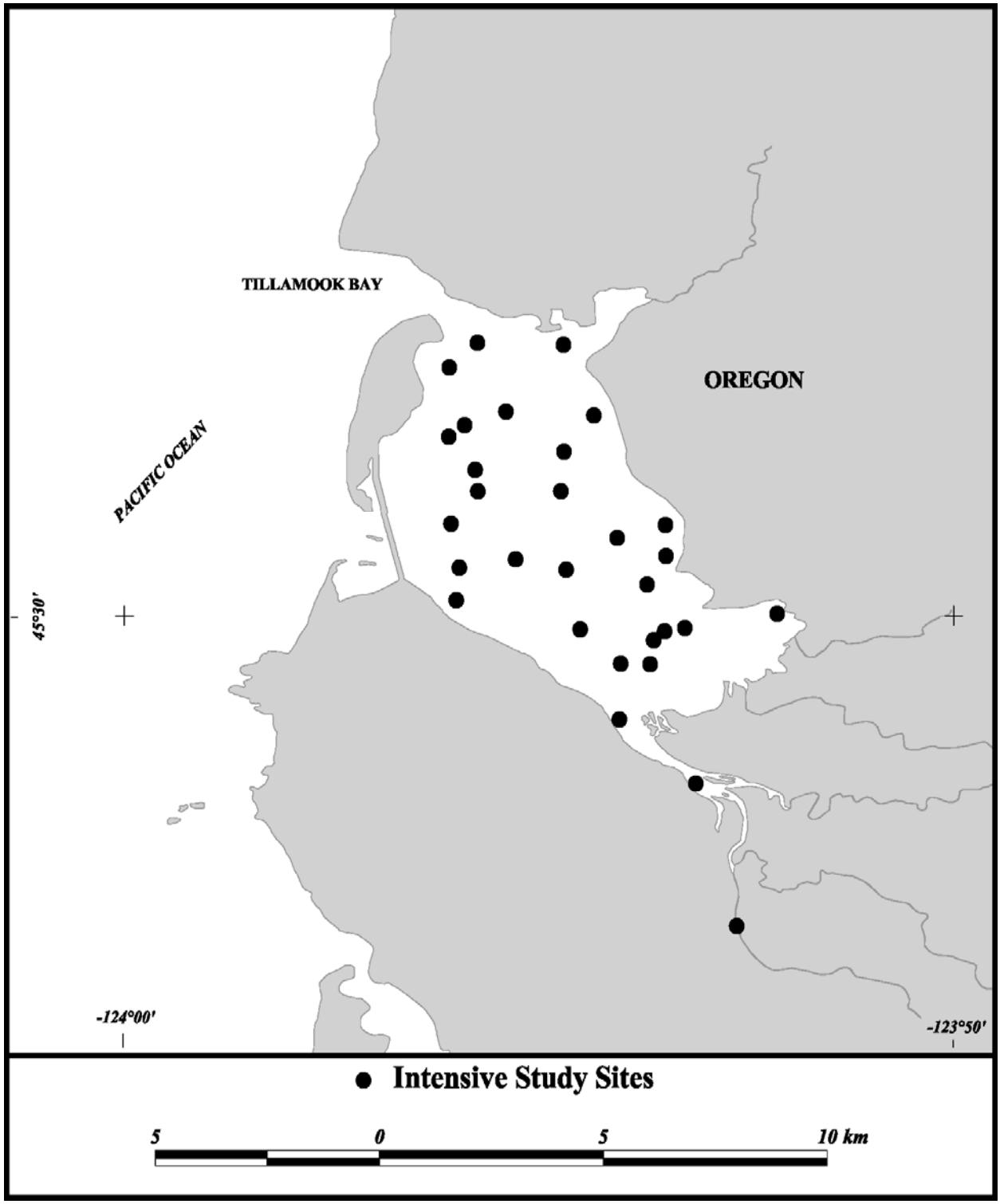

Figure 2-4. Location of EMAP survey sites for the intensification study of Tillamook Bay, Oregon.

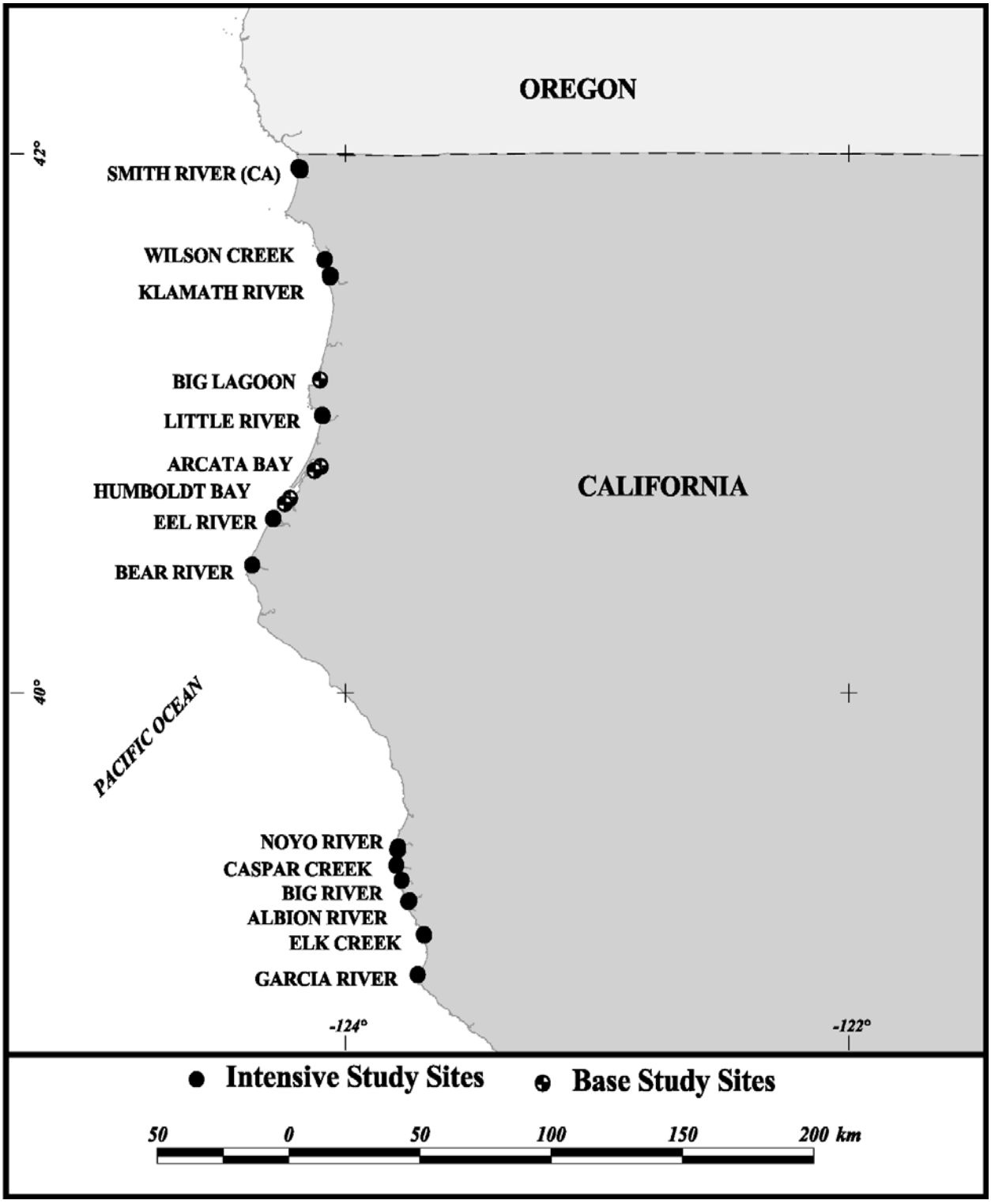

Figure 2-5. Location of California EMAP survey sites in Northern California from the Oregon border to the Garcia River.

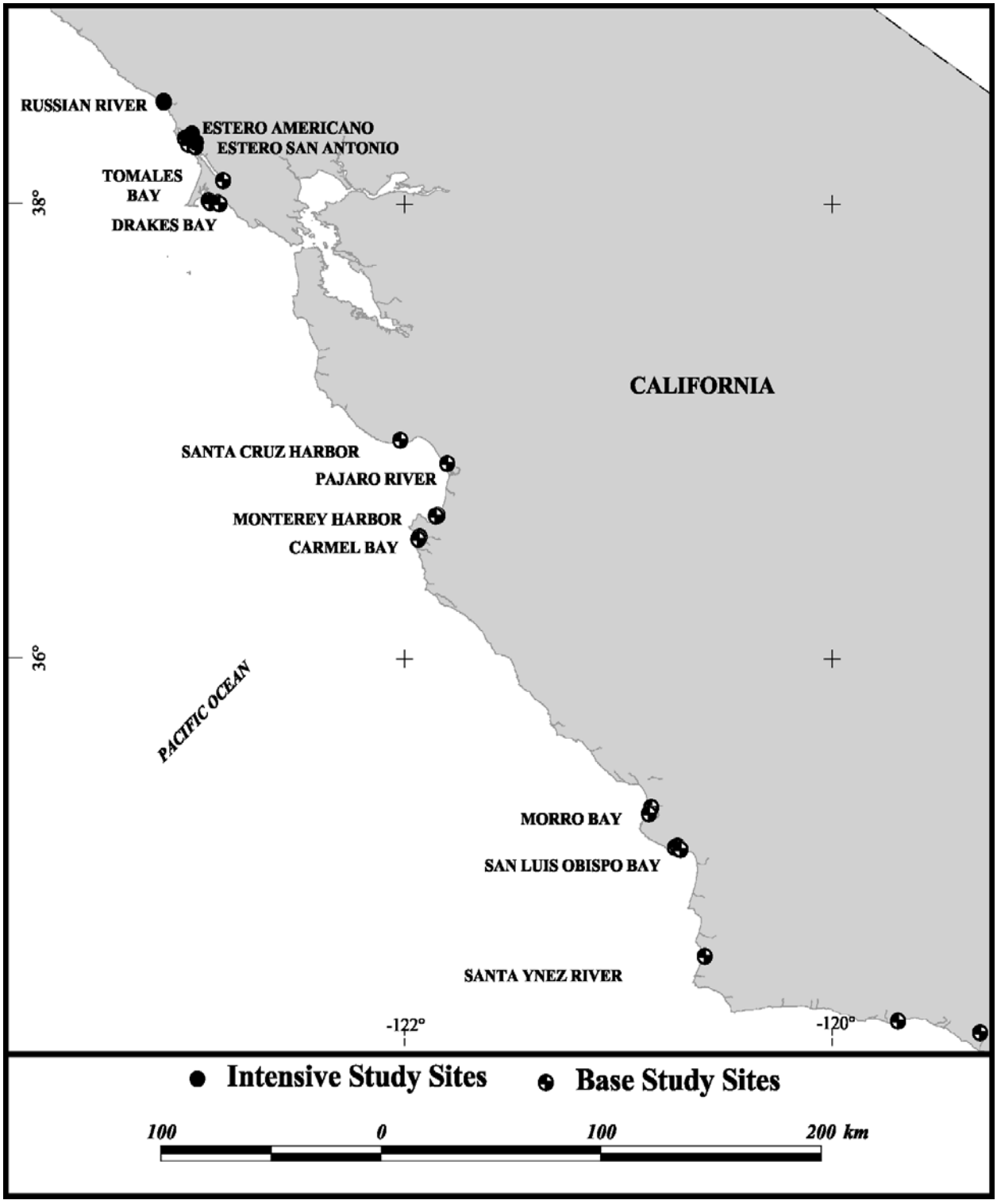

Figure 2-6. Location of California EMAP survey sites in Northern and Central California from the Russian River to the Santa Ynez River.

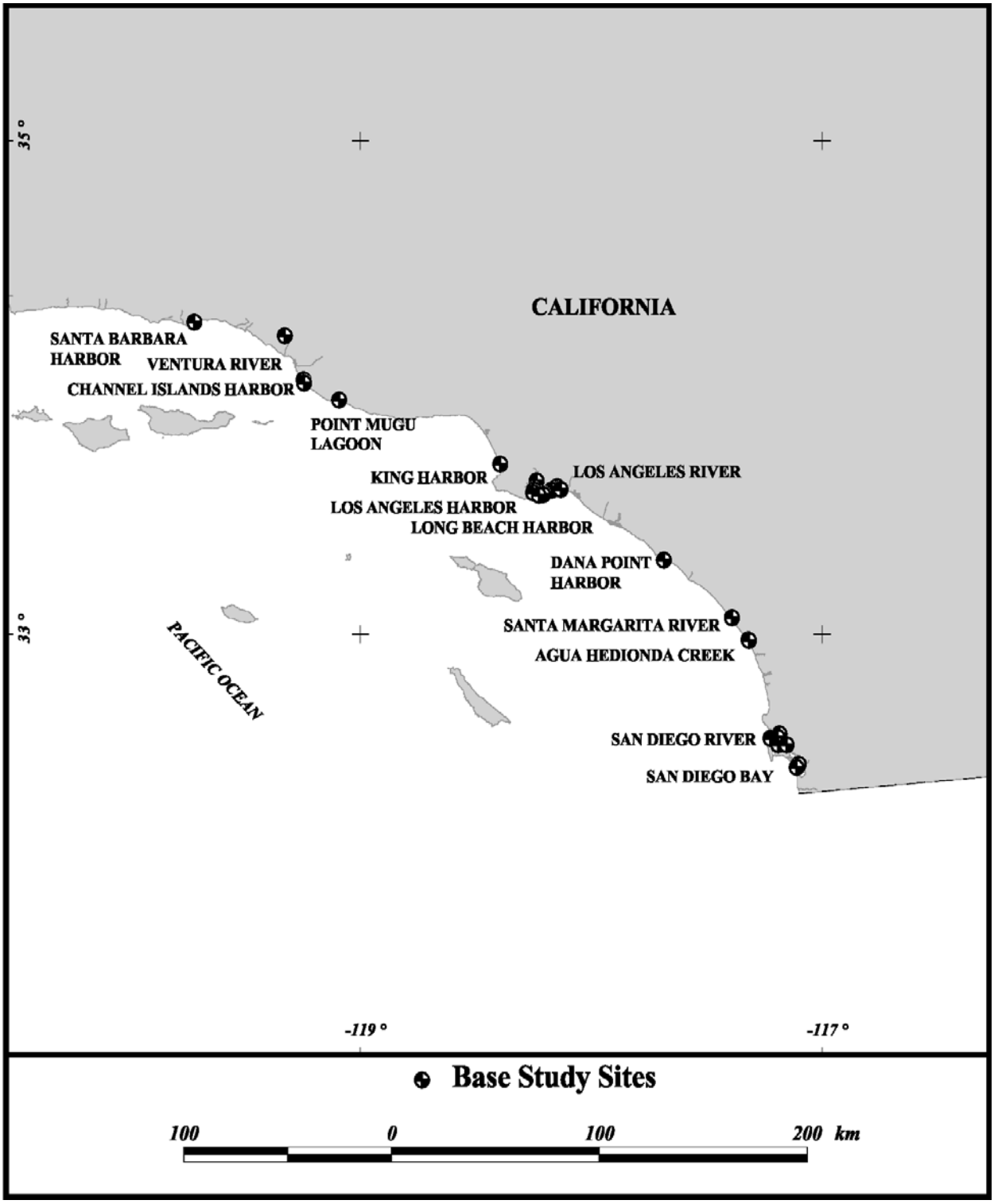

Figure 2-7. Location of California EMAP survey sites in Central and Southern California from Santa Barbara to the Mexican border.

Table 2-1. West Coast sampling sites with station coordinates of locations sampled. The northern California small estuary TMDL study sites are noted as either Y = TMDL Site, N = Non-TMDL Site. Frame area represents the total estuarine area within a stratum. An * in a station location indicates the site was abandoned prior to sampling.

EMAP Sta. No.	Latitude	Longitude	Estuary	Hex Size	Frame Area km^2	Stratum	TMDL
WA99-0001	48.320	-124.680	Makah Bay	7.79	77.288	WA99-002	N/A
WA99-0002	48.314	-124.670	Makah Bay	7.79	77.288	WA99-002	N/A
WA99-0003	48.305	-124.671	Makah Bay	7.79	77.288	WA99-002	N/A
WA99-0004	48.288	-124.365	Hoko River	0.86	8.363	WA99-001	N/A
WA99-0005	48.181	-124.708	Ozette River	0.86	8.363	WA99-001	N/A
WA99-0006	48.149	-123.633	Freshwater Bay	7.79	77.288	WA99-002	N/A
WA99-0007	48.148	-123.601	Freshwater Bay	7.79	77.288	WA99-002	N/A
WA99-0008	48.143	-123.616	Freshwater Bay	7.79	77.288	WA99-002	N/A
WA99-0009	48.160	-123.148	Dungeness Bay	7.79	111.478	WA99-003	N/A
WA99-0010	48.079	-122.900	Discovery Bay	7.79	111.478	WA99-003	N/A
WA99-0011	48.058	-122.905	Discovery Bay	7.79	111.478	WA99-003	N/A
WA99-0012	48.021	-122.859	Discovery Bay	7.79	111.478	WA99-003	N/A
WA99-0013	48.003	-122.843	Discovery Bay	7.79	111.478	WA99-003	N/A
WA99-0014	47.997	-122.874	Discovery Bay	7.79	111.478	WA99-003	N/A
WA99-0015	47.606	-124.373	KalalochCreek	0.86	8.363	WA99-001	N/A
WA99-0016	47.463	-124.339	Raft River	0.86	8.363	WA99-001	N/A
WA99-0017	47.347	-124.298	Quinault River	7.79	77.288	WA99-002	N/A
WA99-0018	*	*	Quinault River	7.79	77.288	WA99-002	N/A
WA99-0019	47.089	-124.176	Conner Creek	0.86	8.363	WA99-001	N/A
WA99-0020	47.004	-124.040	Grays Harbor	36.58	562.230	WA99-004	N/A
WA99-0021	47.005	-124.000	Grass Creek	0.86	8.363	WA99-001	N/A
WA99-0022	46.966	-123.951	Grays Harbor	36.58	562.230	WA99-004	N/A
WA99-0023	46.940	-124.104	Grays Harbor	36.58	562.230	WA99-004	N/A
WA99-0024	46.935	-124.028	Grays Harbor	36.58	562.230	WA99-004	N/A
WA99-0025	46.967	-123.858	Grays Harbor	36.58	562.230	WA99-004	N/A
WA99-0026	46.921	-124.067	Grays Harbor	36.58	562.230	WA99-004	N/A
WA99-0027	46.873	-124.034	Beardslee Slough	0.86	8.363	WA99-001	N/A
WA99-0028	46.870	-124.022	Beardslee Slough	0.86	8.363	WA99-001	N/A
WA99-0029	46.848	-124.032	Grays Harbor	36.58	562.230	WA99-004	N/A
WA99-0030	46.715	-124.045	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0031	46.704	-123.887	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0032	*	*	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0033	46.650	-124.012	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0034	46.567	-123.942	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0035	46.539	-123.924	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0036	46.418	-123.418	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0037	*	*	Willapa Bay	36.58	562.230	WA99-004	N/A
WA99-0038	46.310	-124.009	Baker Bay	7.79	111.478	WA99-003	N/A
WA99-0039	46.301	-124.026	Baker Bay	7.79	111.478	WA99-003	N/A
WA99-0040	46.273	-123.973	Baker Bay	7.79	111.478	WA99-003	N/A
WA99-0041	*	*	Grays River	0.86	8.363	WA99-001	N/A
WA99-0042	46.263	-123.998	Baker Bay	7.79	111.478	WA99-003	N/A
WA99-0043	46.302	-123.711	Grays Bay	7.79	111.478	WA99-003	N/A
WA99-0044	46.300	-123.698	Grays Bay	7.79	111.478	WA99-003	N/A
WA99-0045	46.295	-123.703	Grays Bay	7.79	111.478	WA99-003	N/A
WA99-0046	46.287	-123.727	Grays Bay	7.79	111.478	WA99-003	N/A
WA99-0047	46.275	-123.717	Grays Bay	7.79	111.478	WA99-003	N/A
WA99-0048	46.095	-122.922	Cowlitz River	7.79	77.288	WA99-002	N/A
WA99-0049	46.085	-122.880	Carrolls Channel	7.79	77.288	WA99-002	N/A
WA99-0050	45.947	-122.786	Martin Slough	0.86	8.363	WA99-001	N/A
OR99-0001	46.188	-123.912	Youngs Bay	3.46	43.192	OR99-003	N/A
OR99-0002	46.211	-123.724	Cathlamet Bay	3.46	43.192	OR99-003	N/A
OR99-0003	46.180	-123.865	Youngs Bay	3.46	43.192	OR99-003	N/A
OR99-0004	46.217	-123.672	Cathlamet Bay	3.46	43.192	OR99-003	N/A
OR99-0005	46.167	-123.893	Youngs Bay	3.46	43.192	OR99-003	N/A
OR99-0006	46.208	-123.688	Cathlamet Bay	3.46	43.192	OR99-003	N/A
OR99-0007	46.169	-123.872	Youngs Bay	3.46	43.192	OR99-003	N/A
OR99-0008	46.226	-123.588	Marsh Island Creek	1.24	13.578	OR99-001	N/A
OR99-0009	46.190	-123.744	Cathlamet Bay	3.46	43.192	OR99-003	N/A

Table continued on next page

OR99-0010	46.189	-123.746	Cathlamet Bay	3.46	43.192	OR99-003	N/A
OR99-0011	46.186	-123.681	Cathlamet Bay	3.46	43.192	OR99-003	N/A
OR99-0012	46.149	-123.817	Youngs River	7.28	99.605	OR99-002	N/A
OR99-0013	46.187	-123.592	Knappa Slough	1.24	13.578	OR99-001	N/A
OR99-0014	46.170	-123.144	Bradbury Slough	7.28	99.605	OR99-002	N/A
OR99-0015	46.134	-123.272	Wallace Slough	7.28	99.605	OR99-002	N/A
OR99-0016	46.129	-123.226	Clatskanie River	1.24	13.578	OR99-001	N/A
OR99-0017	46.123	-123.036	Rinearson Slough	1.24	13.578	OR99-001	N/A
OR99-0018	45.691	-123.899	Nehalem River	7.28	99.605	OR99-002	N/A
OR99-0019	45.394	-123.953	Netarts Bay	7.28	99.605	OR99-002	N/A
OR99-0020	45.197	-123.961	Nestucca River	1.24	13.578	OR99-001	N/A
OR99-0021	45.166	-123.944	Little Nestucca River	1.24	13.578	OR99-001	N/A
OR99-0022	45.040	-123.994	Salmon River	1.24	13.578	OR99-001	N/A
OR99-0023	44.925	-124.018	Siletz Bay	7.28	99.605	OR99-002	N/A
OR99-0024	44.622	-124.034	Yaquina Bay	7.28	99.605	OR99-002	N/A
OR99-0025	44.599	-124.016	Yaquina River	7.28	99.605	OR99-002	N/A
OR99-0026	44.574	-123.963	Yaquina River	7.28	99.605	OR99-002	N/A
OR99-0027	44.414	-123.999	Alsea River	1.24	13.578	OR99-001	N/A
OR99-0028	44.305	-124.115	Yachats River	1.24	13.578	OR99-001	N/A
OR99-0029	44.188	-124.036	Rock Creek	1.24	13.578	OR99-001	N/A
OR99-0030	44.011	-124.126	Siuslaw River	7.28	99.605	OR99-002	N/A
OR99-0031	44.022	-123.881	Siuslaw River	7.28	99.605	OR99-002	N/A
OR99-0032	44.740	-124.136	Umpqua River	4.58	59.163	OR99-004	N/A
OR99-0033	43.762	-124.005	Smith River (OR)	7.28	99.605	OR99-002	N/A
OR99-0034	43.725	-124.146	Umpqua River	4.58	59.163	OR99-004	N/A
OR99-0035	44.772	-123.903	Smith River (OR)	7.28	99.605	OR99-002	N/A
OR99-0036	43.722	-124.124	Umpqua River	4.58	59.163	OR99-004	N/A
OR99-0037	43.693	-124.100	Scholfield Creek	1.24	13.578	OR99-001	N/A
OR99-0038	43.692	-124.065	Umpqua River	4.58	59.163	OR99-004	N/A
OR99-0039	43.423	-124.246	Coos Bay	4.58	59.163	OR99-004	N/A
OR99-0040	43.414	-124.207	Coos Bay	4.58	59.163	OR99-004	N/A
OR99-0041	43.406	-124.218	Coos Bay	4.58	59.163	OR99-004	N/A
OR99-0042	43.386	-124.292	Coos Bay	4.58	59.163	OR99-004	N/A
OR99-0043	43.404	-124.199	Coos Bay	4.58	59.163	OR99-004	N/A
OR99-0044	43.368	-124.304	Coos Bay	4.58	59.163	OR99-004	N/A
OR99-0045	43.341	-124.320	South Slough	7.28	99.605	OR99-002	N/A
OR99-0046	43.370	-124.148	Coos River	1.24	13.578	OR99-001	N/A
OR99-0047	43.377	-124.108	Coos River	1.24	13.578	OR99-001	N/A
OR99-0048	43.350	-124.169	Catching Slough	1.24	13.578	OR99-001	N/A
OR99-0049	43.321	-124.154	Catching Slough	1.24	13.578	OR99-001	N/A
OR99-0050	42.423	-124.419	Rogue River	7.28	99.605	OR99-002	N/A
OR99-0051	45.552	-123.929	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0052	45.547	-123.935	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0053	45.551	-123.912	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0054	45.534	-123.935	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0055	45.539	-123.923	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0056	45.536	-123.932	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0057	45.538	-123.906	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0058	45.528	-123.929	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0059	45.531	-123.912	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0060	45.524	-123.929	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0061	45.517	-123.934	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0062	45.524	-123.912	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0063	45.511	-123.921	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0064	45.517	-123.891	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0065	45.509	-123.933	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0066	45.515	-123.901	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0067	45.503	-123.933	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0068	45.509	-123.911	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0069	45.511	-123.891	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0070	45.498	-123.887	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0071	45.506	-123.895	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0072	45.498	-123.908	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0073	45.497	-123.891	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0074	45.491	-123.894	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0075	45.501	-123.869	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0076	45.495	-123.894	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0077	45.491	-123.900	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0078	45.481	-123.900	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0079	45.468	-123.885	Tillamook Bay	1.04	33.732	OR99-005	N/A
OR99-0080	45.441	-123.877	Tillamook River	1.04	33.732	OR99-005	N/A

CA99-0001	41.162	-124.118	Big Lagoon	7.79	102.651	CA99-002	N/A
CA99-0002	40.837	-124.117	Arcata Bay	12.5	268.504	CA99-001	N/A
CA99-0003	40.824	-124.142	Arcata Bay	12.5	268.504	CA99-001	N/A
CA99-0004	40.720	-124.238	Humboldt Bay	12.5	268.504	CA99-001	N/A
CA99-0005	40.703	-124.258	Humboldt Bay	12.5	268.504	CA99-001	N/A
CA99-0006	38.287	-123.028	Bodega Bay	12.5	268.504	CA99-001	N/A
CA99-0007	38.263	-123.012	Bodega Bay	12.5	268.504	CA99-001	N/A
CA99-0008	38.249	-122.978	Bodega Bay	12.5	268.504	CA99-001	N/A
CA99-0009	38.104	-122.848	Tomales Bay	12.5	268.504	CA99-001	N/A
CA99-0010	38.015	-122.917	Drakes Bay	12.5	268.504	CA99-001	N/A
CA99-0011	38.006	-122.910	Drakes Bay	12.5	268.504	CA99-001	N/A
CA99-0012	38.006	-122.873	Drakes Bay	12.5	268.504	CA99-001	N/A
CA99-0013	38.002	-122.865	Drakes Bay	12.5	268.504	CA99-001	N/A
CA99-0014	36.961	-122.019	Santa Cruz Harbor	7.79	102.651	CA99-002	N/A
CA99-0015	36.859	-121.801	Pajaro River	0.86	13.837	CA99-003	N/A
CA99-0016	36.633	-121.845	Monterey Harbor	7.79	102.651	CA99-002	N/A
CA99-0017	36.628	-121.853	Monterey Harbor	7.79	102.651	CA99-002	N/A
CA99-0018	36.537	-121.930	Carmel Bay	7.79	102.651	CA99-002	N/A
CA99-0019	36.525	-121.936	Carmel Bay	7.79	102.651	CA99-002	N/A
CA99-0020	35.346	-120.847	Morro Bay	7.79	102.651	CA99-002	N/A
CA99-0021	35.318	-120.858	Morro Bay	7.79	102.651	CA99-002	N/A
CA99-0022	35.171	-120.737	San Luis Obispo Bay	7.79	102.651	CA99-002	N/A
CA99-0023	35.173	-120.725	San Luis Obispo Bay	7.79	102.651	CA99-002	N/A
CA99-0024	35.161	-120.710	San Luis Obispo Bay	7.79	102.651	CA99-002	N/A
CA99-0025	34.692	-120.597	Santa Ynez River	0.86	13.837	CA99-003	N/A
CA99-0026	34.407	-119.693	Santa Barbara Harbor	0.86	13.837	CA99-003	N/A
CA99-0027	34.354	-119.309	Ventura River	0.86	13.837	CA99-003	N/A
CA99-0028	34.180	-119.230	Channel Islands Harbor	0.86	13.837	CA99-003	N/A
CA99-0029	34.167	-119.227	Channel Islands Harbor	0.86	13.837	CA99-003	N/A
CA99-0030	34.097	-119.079	Point Mugu Lagoon	0.86	13.837	CA99-003	N/A
CA99-0031	33.844	-118.395	King Harbor	0.86	13.837	CA99-003	N/A
CA99-0032	33.777	-118.242	Los Angeles River	0.86	13.837	CA99-003	N/A
CA99-0033	33.742	-118.252	Los Angeles Harbor	12.5	268.504	CA99-001	N/A
CA99-0034	33.755	-118.154	Long Beach Harbor	7.79	102.651	CA99-002	N/A
CA99-0035	33.741	-118.177	Long Beach Harbor	7.79	102.651	CA99-002	N/A
CA99-0036	33.730	-118.256	Los Angeles Harbor	12.5	268.504	CA99-001	N/A
CA99-0037	33.743	-118.140	Long Beach Harbor	7.79	102.651	CA99-002	N/A
CA99-0038	33.724	-118.214	Los Angeles Harbor	12.5	268.504	CA99-001	N/A
CA99-0039	33.719	-118.233	Los Angeles Harbor	12.5	268.504	CA99-001	N/A
CA99-0040	33.461	-117.702	Dana Point Harbor	0.86	13.837	CA99-003	N/A
CA99-0041	33.234	-117.412	Santa Margarita River	0.86	13.837	CA99-003	N/A
CA99-0042	33.145	-117.342	Agua Hedionda Creek	0.86	13.837	CA99-003	N/A
CA99-0043	33.143	-117.339	Agua Hedionda Creek	0.86	13.837	CA99-003	N/A
CA99-0044	32.772	-117.210	Mission Bay	7.79	102.651	CA99-002	N/A
CA99-0045	32.755	-117.248	San Diego River	0.86	13.837	CA99-003	N/A
CA99-0046	32.759	-117.219	San Diego River	0.86	13.837	CA99-003	N/A
CA99-0047	32.727	-117.215	San Diego Bay	12.5	268.504	CA99-001	N/A
CA99-0048	32.726	-117.180	San Diego Bay	12.5	268.504	CA99-001	N/A
CA99-0049	32.651	-117.129	San Diego Bay	12.5	268.504	CA99-001	N/A
CA99-0050	32.639	-117.138	San Diego Bay	12.5	268.504	CA99-001	N/A
CA99-0051	41.945	-124.201	Smith River (CA)	0.10	0.654	CA99-006	N
CA99-0052	41.947	-124.204	Smith River (CA)	0.106	0.654	CA99-006	N
CA99-0053	41.944	-124.197	Smith River (CA)	0.106	0.654	CA99-006	N
CA99-0054	41.941	-124.196	Smith River (CA)	0.106	0.654	CA99-006	N
CA99-0055	41.937	-124.196	Smith River (CA)	0.106	0.654	CA99-006	N
CA99-0056	41.606	-124.100	Wilson Creek	0.08	0.014	CA99-004	N
CA99-0057	41.605	-124.101	Wilson Creek	0.08	0.014	CA99-004	N
CA99-0058	41.547	-124.081	Klamath River	0.0346	0.309	CA99-009	Y
CA99-0059	41.546	-124.075	Klamath River	0.0346	0.309	CA99-009	Y
CA99-0060	41.541	-124.079	Klamath River	0.0346	0.309	CA99-009	Y
CA99-0061	41.028	-124.112	Little River	0.08	0.018	CA99-005	N
CA99-0062	41.027	-124.109	Little River	0.08	0.018	CA99-005	N
CA99-0063	40.644	-124.305	Eel River	0.0914	0.219	CA99-010	Y
CA99-0064	40.646	-124.304	Eel River	0.0914	0.219	CA99-010	Y
CA99-0065	40.475	-124.388	Bear River	0.08	0.018	CA99-005	N
CA99-0066	39.427	-123.808	Noyo River	0.0585	0.427	CA99-007	Y
CA99-0067	39.417	-123.812	Hare Creek	0.08	0.018	CA99-005	N
CA99-0068	39.418	-123.809	Hare Creek	0.08	0.018	CA99-005	N
CA99-0069	39.361	-123.815	Caspar Creek	0.08	0.014	CA99-004	N
CA99-0070	39.303	-123.794	Big River	0.0585	0.427	CA99-007	Y

Table continued on next page

CA99-0071	39.226	-123.770	Albion River	0.0914	0.219	CA99-010	Y
CA99-0072	39.225	-123.768	Albion River	0.0914	0.219	CA99-010	Y
CA99-0073	39.227	-123.764	Albion River	0.0914	0.219	CA99-010	Y
CA99-0074	39.103	-123.707	Elk Creek	0.08	0.014	CA99-004	N
CA99-0075	39.102	-123.705	Elk Creek	0.08	0.014	CA99-004	N
CA99-0076	38.954	-123.730	Garcia River	0.0585	0.427	CA99-007	Y
CA99-0077	38.451	-123.127	Russian River	0.0498	0.104	CA99-008	Y
CA99-0078	38.449	-123.125	Russian River	0.0498	0.104	CA99-008	Y
CA99-0079	38.307	-122.995	Estero Americano	0.0585	0.427	CA99-007	Y
CA99-0080	38.270	-122.976	Estero San Antonio	0.0585	0.427	CA99-007	Y

2.2 Data Analysis

Analysis of indicator data was conducted by calculation of cumulative distribution functions (CDFs), an analysis approach that has been used extensively in other EMAP coastal studies (Summers et al., 1993; Strobel et al.,1994; Hyland et al., 1996). The CDFs describe the full distribution of indicator values in relation to their areal extent across the sampling region of interest. The approximate 95% confidence intervals for the CDFs also were computed based on estimates of variance. A detailed discussion of methods for calculation of the CDFs used in EMAP analyses is provided in Diaz-Ramos et al. (1996).

The Horvitz-Thompson ratio estimate of the CDF is given by the formula:

$$\hat{F}(x_k) = \frac{\sum_{i=1}^{n} \frac{1}{\pi_i} I(y_i \le x_k)}{\hat{N}} \quad ; \quad \hat{N} = \sum_{i=1}^{n} \frac{1}{\pi_i}$$

$\hat{F}(x_k)$ = estimated CDF (proportion) for indicator value x_k

n = number of samples

y_i = the sample response for site i

x_k = the k th CDF response indicator

$$I(y_i \le x_k) = \begin{cases} 1, y_i \le x_k \\ 0, otherwise \end{cases}$$

π_i = selection probability for site i

$\hat{N}$ = the estimated population size

The selection probability for a site is 1/area of the hexagon, e.g. the hexagon area of California estuaries in the base study in the size class 5-25 km^2. When calculating the mean for a variable, the same equation is used with Y_i replacing the indicator function.

The Horvitz-Thompson unbiased estimate of the variance for the ratio estimate is given by the formula:

$$\hat{V}\left[\hat{F}(x_k)\right] = \frac{\sum_{i=1}^{n}\frac{d_i^2}{\pi_i^2} + \sum_{i=1}^{n}\sum_{j\neq 1}^{n} d_i d_j \left(\frac{1}{\pi_i}\frac{1}{\pi_j} - \frac{1}{\pi_{ij}}\right)}{\hat{N}^2} \quad ;$$

$$\hat{N} = \sum_{i=1}^{n}\frac{1}{\pi_i}, \quad d_i = I(y_i \le x_k) - \hat{F}(x_k), \quad d_j = I(y_j \le x_k) - \hat{F}(x_k)$$

$\hat{F}(x_k)$ = estimated CDF (proportion) for indicator value x_k

$$I(y_i \le x_k) = \begin{cases} 1, y_i \le x_k \\ 0, otherwise \end{cases}$$

x_k = the kth indicator level of interest

y_i = value of indicator for the ith unit sampled

π_i = inclusion density evaluated at the location of the ith sample point

π_{ij} = joint inclusion density evaluated at the locations of the ith and jthsample points

n = number of units sampled

The joint inclusion probabilities are given by

$$\pi_{ij} = \frac{(n-1) * \pi_i \pi_j}{n}$$

When estimating the CDF across several strata, the above estimates for each stratum must be combined. The equations are

$$\hat{F}(x_k) = \sum_{i=1}^{s} \left(\frac{A_i}{A} \right) \hat{F}_i(x_k)$$

$\hat{F}(x_k)$ = estimated CDF

$\hat{F}_i(x_k)$ = estimated CDF for stratum i

A_i = area for stratum i

S = number of strata

A = total area of all strata

and the variance estimate across strata is

$$\hat{V} = \sum_{i=1}^{s} \left(\frac{A_i}{A} \right)^2 \hat{V}_i$$

$\hat{V}$ = estimated variance for all strata

$\hat{V}_i$ = estimated variance for stratum i

A_i = area for stratum i

S = number of strata

A = total area of all strata

2.3 Indicators

The condition of West Coast estuarine resources was evaluated by collecting data for a standard set of environmental parameters at all stations within the survey (Table 2-2). Field procedures followed methods outlined in the USEPA National Coastal Assessment Field Operations Manual (USEPA, 2001b). The environmental indicators were similar to those used in previous EMAP estuarine surveys in other regions of the country (Weisberg et al., 1992; Macauley et al., 1994, 1995; Strobel et al., 1994, 1995; Hyland et al., 1996, 1998). Indicators were divided into those representing general habitat condition (Habitat Indicators), condition of benthic and demersal faunal resources (Biotic Condition Indicators), and exposure to pollutants (Exposure Indicators). Habitat indicators describe the general physical and chemical conditions at the study site, and are often important in providing information used to interpret the results of biotic condition indicators (e.g., salinity and sediment grain size with regard to benthic community composition). Biotic condition indicators are measures of the status of the benthic biological resources in response to site environmental conditions. The Exposure indicators used in this survey quantify the amounts and types of pollutant materials (metals, hydrocarbons, pesticides) that may be harmful to the biological resources present. Some indicators may overlap the above categories. For example, dissolved oxygen is clearly an indicator of habitat condition, but may also be considered an exposure indicator because of the potentially harmful effects of low dissolved oxygen levels to many members of the benthic community.

In addition to the core set of indicators, a number of supplemental indicators were conducted either by EMAP or by external collaborators during the EMAP Western Coastal survey (Table 2-3). An additional sediment toxicity test was conducted for the California stations composing the base study. The amphipod *Eohaustorius estuarius* acute toxicity test was used in order to compare the sensitivity of this species with *Ampelisca abdita*, which is the most commonly used amphipod bioassay species in the EMAP program. Scientists with the USGS/BEST program conducted two sediment porewater toxicity tests using the sea urchin *Arbacia punctulata* (fertilization toxicity test, embryo development toxicity test) (USGS, 2000), and conducted the H4IIE bioassay (bioassay-derived 2,3,7,8-tetrachlorodibenzo - *p* -dioxin equivalents (TCDD-EQ)) for exposure of fish to planar halogenated hydrocarbons (USGS, 2001). Results of the sea urchin bioassay tests are included in the present report, while the details of the H4IIe bioassay are provided in USGS (2001). Results of the *Eohaustorius* toxicity test are not presented here, since this test was done only with California sediments, but will be provided in a separate statistical data report for the state of California.

Table 2-2. Core environmental indicators for the EMAP Western Coastal survey.

Habitat Indicators	**Benthic Condition Indicators**
Salinity	Infaunal species composition
Water depth	Infaunal abundance
pH	Infaunal species richness and diversity
Water temperature	Demersal fish species composition
Total suspended solids	Demersal fish abundance
Chlorophyll *a* concentration	Demersal fish species richness and diversity
Nutrient concentrations (nitrates, nitrites, ammonia, & phosphate)	External pathological anomalies in fish
Percent light transmission	**Exposure Indicators**
Secchi depth	Dissolved oxygen (DO) concentration
Percent silt-clay of sediments	Sediment contaminants
Percent total organic carbon (TOC) in sediments	Fish tissue contaminants
	Sediment toxicity (*Ampelisca abdita* acute toxicity test)

Table 2-3. Environmental indicators under development or conducted by collaborators during the EMAP Western Coastal survey.

Benthic Condition Indicators
West Coast benthic infaunal index - EMAP
Exposure Indicators
Sediment toxicity (amphipod *Eohaustorius estuarius* acute toxicity test) - EMAP (California only)
Sediment porewater toxicity (sea urchin *Arbacia punctulata* fertilization toxicity test) - USGS/BEST[1]
Sediment porewater toxicity (sea urchin *Arbacia punctulata* embryo development toxicity test) - USGS/BEST[1]
H4IIE Bioassay-derived 2,3,7,8-tetrachlorodibenzo - *p* -dioxin equivalents (TCDD-EQ) for exposure of fish to planar halogenated hydrocarbons - USGS/BEST[2]

[1] USGS, 2000
[2] USGS, 2001

2.3.1 Water Measurements

2.3.1.1 Hydrographic Profile

Water column profiles were performed at each site to measure dissolved oxygen (DO), salinity, temperature, pH, and depth. Both secchi depth and a measurement of light attenuation using photosynthetically active radiation (PAR) were made at each station. Methods and procedures used for hydrographic profiling follow guidance provided in the NCA Quality Assurance Project Plan document (US EPA, 2001).

Basic water quality parameters were measured by different instruments in each state. Washington field crews used the Seabird SBE 19 CTD with data logging capability. In Oregon there were two field crews. The Oregon Dept. of Environmental Quality field crew used a YSI 6920 datasonde. The field crew provided by National Marine Fisheries Service used a Hydrolab datasonde. California used a Hydrolab Datasonde 4a with a cable connection to a deck display. Prior to conducting a CTD (Conductivity, Temperature, Depth) cast, the instrument was allowed 2-3 minutes of warmup while being maintained near the surface, after which the instrument was slowly lowered at the rate of approximately 1 meter per second during the down cast. Individual measurements were made at discrete intervals (with sufficient time for equilibration) as follows:

Shallow sites ($\leq$ 2 m) - 0.5-m intervals;
Typical depths (>2<10 m) - 0.5 m (near-surface) and every 1-m interval to near-bottom (0.5 m off-bottom);
Deep sites (>10 m) - 0.5 m (near-surface) and every 1-m interval to 10 m, then at 5-m intervals, thereafter, to near-bottom (0.5 m off-bottom).

Near-bottom conditions were measured at 0.5 m above the bottom by first ascertaining whether the instrument was on the bottom (slack line/cable), and then pulling it up approximately 0.5 m. A delay of 2-3 minutes was used to allow disturbed conditions to settle before taking the near-bottom measurements. The profile was repeated on the ascent and recorded for validation purposes, but only data from the descent were reported in the final data.

Measurements of light penetration were recorded using a hand-held LiCor LI-1400 light meter for conditions at discrete depth intervals in a manner similar to that for profiling water quality parameters with the hand-held water quality probes. The underwater sensor was hand lowered according to the regime described above and at each discrete interval, the deck reading and underwater reading were recorded. If the light measurements became negative before reaching bottom, the measurement was terminated at that depth. The profile was repeated on the ascent. As an indicator of water column light conditions, the transmissivity at 1 m depth was calculated.

The California field crew measured ambient light data in two ways. The Hydrolab datasonde unit had a LiCor spherical irradiance sensor (LI -193SA) mounted to the sensor package. For boat deployments, the deck sensor recording ambient light was a cosine collector (LI-190SA)). However, many of the California sample locations were too shallow to allow sampling from a boat, and required walking in to the sample site. At these stations, the field crew took ambient irradiance with the spherical sensor in air, and then took several subsurface readings with the same sensor. The difference in geometry between the deck reference sensor and submerged sensor was corrected for during the analysis of light transmission. An empirical comparison of similar LiCor spherical and flat sensors, both calibrated for air measurements, was conducted. The spherical sensor collected an average of two times the light measured by the flat sensor. All ambient light measurements for California stations sampled by boat were first corrected by this factor. The minimum depth where the first submerged light reading was taken varied widely among stations, which made inter-station comparison difficult. Therefore, the submerged and corresponding in air light measurements, together with the depth of the measurement, were used to compute the light extinction coefficient k, using the relationship $k = (\ln(I_0) - \ln(I_d))/d$, where I_0 = in air measure of light, I_d = submerged light, and d = the depth of the first submerged light measurement. The value of k that was computed was assumed to characterize the light attenuation down to a depth of 1m, and light at a depth of 1 m (I_{1m}) was then calculated as $I_{1m} = e^{(-kd)}$, where d = 1m. Percent light transmission at 1m was then computed as $(I_{1m} / I_0) * 100$.

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

2.3.1.2 Water Quality Indicators

The water column was sampled at each site for dissolved nutrients (N and P species), chlorophyll *a* concentration, and total suspended solids (TSS). Sampling varied slightly among the states but generally followed the guidance provided in the NCA Quality Assurance Project Plan document (US EPA, 2001). At shallow sites (<2 m), water samples were taken at 0.5 m (near-surface) and 0.5 m off-bottom. If the depth was so shallow that the near-surface and near-bottom overlapped, then only a mid-depth sample was taken. For sites deeper than 2 m, samples were taken at 0.5 m (near-surface), mid-depth, and 0.5 m off-bottom.

For TSS analysis, 1 liter of unfiltered seawater was collected at the depths described above. The samples were held in 1-L polypropylene bottles on wet ice in the field and stored at 4°C until analyzed.

For Washington samples, water used for nutrient, chlorophyll, and dissolved oxygen samples was collected from discrete depths using 1.7-liter Nisken bottle and transferred to two 66-ml plastic bottles. The chlorophyll samples were filtered by placing them in a

funnel containing a 0.7-µm GFF filter attached to a receiving bottle. A hand pump was used to pull the seawater past the filter and into a receiving flask. The GFF filter was then folded in half and placed in a labeled glass centrifuge tube containing 10 ml of 90 % acetone, and placed on ice until the tubes could be frozen at the end of the day. A 0.45-µm syringe filter was used with a pre-cleaned, 60-ml plastic syringe to filter approximately 40 ml of water for nutrient analyses into 60-ml plastic bottles.

In California, samples were obtained by using a Wildco 1.2-liter stainless steel Kemmerer sampler. A second water sample was collected from each of the same depths and an approximately 1-liter subsample was poured into a clean, wide-mouth polycarbonate container for the chlorophyll and nutrient analyses. Two disposable, graduated 50-cc polypropylene syringes fitted with a stainless steel or polypropylene filtering assembly were used to filter the water sample through 0.7-µm GFF filters, and the volume of water (up to 200 ml for each syringe) filtered was recorded. Both filters were carefully removed using tweezers, folded once upon the pigment side, placed in a prelabeled, disposable petri dish, and capped. The petri dish was wrapped in aluminum foil, placed in a small styrofoam ice chest with several pounds of dry ice, and kept frozen until analyzed. The syringe and filtering assembly were washed with deionized water and stored in a clean compartment between sampling stations. For nutrients, approximately 40 ml of filtrate from the chlorophyll filtration (surface water) were collected into two prelabeled, clean 60-ml Nalgene screw-capped bottles, stored in the dry ice chest, and kept frozen on dry ice until analyzed.

Dissolved Oxygen was measured at Washington stations with a Beckman DO sensor deployed on the Seabird CTD, at Oregon stations with a Yellow Springs Instruments model 6562 DO sensor on the YSI datasonde, and at California stations with a Hydrolab DO sensor on the Hydrolab datasonde.

2.3.2 Sediment Toxicity Testing

2.3.2.1 Sediment Collection for Toxicity Testing, Chemical Analysis and Grain Size

Combined sediment for toxicity testing and chemical analysis was collected at all sites from the top 2-3 centimeters of surficial sediment. Procedures for sediment collection followed the guidance provided in the NCA Quality Assurance Project Plan document (US EPA, 2001). Where possible, sediment grabs were taken with a 0.1-m^2 van Veen sampler. The top 2-3 centimeters of surficial sediment were scooped from each individual grab, composited in a pre-cleaned container and homogenized within the container by thorough stirring. Sediment from 2-9 grabs was composited to collect approximately 6 liters of sediment. Where station depth precluded sampling with a boat and van Veen grab, the sampling crew walked in to the sample site, and the top 2-3 cm of sediment at the site was scooped from the sediment surface and processed similarly to sediment collected by grab. This occurred at the following stations: 4 sites in Washington: WA99-0015, WA99-0016, WA99-0017, WA99-0019; 33 sites in California:

CA99-0001, CA99-0015, CA99-0021, CA99-0025, CA99-0030, CA99-0037, CA99-0041, CA99-0045-46, CA99-0051-57, CA99-0059-65, CA99-0067-71, CA99-0073-74, CA99-0076, CA99-0079-80. The composited sediment was held on ice and distributed to individual containers for toxicity testing and chemical analyses either on board the research vessel or at the laboratory. Aliquots of the homogenized sediment were distributed to pre-cleaned containers for analysis of sediment organics, trace metals, grain size and toxicity testing. Toxicity-test sediment was held at 4˚C to await initiation of toxicity testing within 7 days of collection.

2.3.2.2 Laboratory Test Methods

2.3.2.2.1 Amphipod Toxicity Tests

The 10-day, solid-phase toxicity test with the marine amphipod *Ampelisca abdita* was used to evaluate potential toxicity of sediments from all sites. Procedures followed the general guidelines provided in ASTM Protocol E1367-92 (ASTM, 1991), the EPA amphipod sediment toxicity test manual (USEPA,1994a) and the EMAP Laboratory Methods Manual (USEPA,1994b). The *Ampelisca* test is a 10-d acute toxicity test which measures the effect of sediment exposure on amphipod survival under static aerated conditions.

Approximately 3–3.5 L of surface sediments (composite of upper 2-3 cm from multiple grabs) were collected from the sampling sites and stored in glass or polyethylene jars at 4 ˚C in the dark until testing. Toxicity tests were conducted with subsamples of the same sediment on which the analysis of organic and trace metal contaminants and other sediment characteristics was performed.

Ampelisca abdita were collected from the Narrow (=Pettaquamscutt) River, Rhode Island, by Eastern Aquatic Biosupply, or from San Pablo Bay in the San Francisco Estuary by Brezina and Associates. Amphipods were shipped via overnight carrier to the Marine Pollution Studies Laboratory at Granite Canyon, CA (CA and WA sediments), Southern California Coastal Water Research Project (SCCWRP - CA sediments) or the Northwestern Aquatic Sciences, Inc., laboratory in Newport, Oregon (OR sediments), where the *Ampelisca* tests were conducted. Amphipods were acclimated for 2-9 days prior to testing. During the acclimation period, the amphipods were not fed (WA and CA) or were fed a commercially available dried algal mix (OR). Healthy juvenile amphipods of approximately the same size (0.5–1.0 mm) were used to initiate tests. The general health of each batch of amphipods was evaluated in a reference toxicity test (i.e., “positive control”), which was run for 96 h in a dilution series with seawater (no sediment phase) and the reference toxicants cadmium chloride or sodium dodecyl sulfate (SDS). LC_{50} values for reference toxicants were computed for comparison with other reported toxicity ranges for the same reference toxicant and test species.

Treatments for the definitive tests with field samples consisted of five replicates of each field sediment sample (100% sediment) and a negative control. A negative control was run with each batch of field samples, which ranged from 4 to18 samples per batch. Control sediment was ambient sediment from the amphipod collection sites. Twenty amphipods were randomly distributed to each of five replicates per each treatment including the control. Amphipods were not fed during the tests. All tests were conducted under static conditions with aeration, and were monitored for water quality (temperature, salinity, dissolved oxygen, pH, and total ammonia in the overlying water). Target test temperature for *A. abdita* was 20 ˚C and target salinity was 28 psu.

The negative controls provided a basis of comparison for determining statistical differences in survival in the field sediments. In addition, control survival provided a measure of the acceptability of final test results. Test results with *A. abdita* were considered valid if mean control survival (among the 5 replicates) was not less than 90% and survival in no single control replicate was less than 80%. Test batches where these QA requirements were not met were not included in the CDF analysis.

One-liter glass containers with covers were used as test chambers. Each chamber was filled with 200 ml of sediment and 600–800 ml of filtered seawater. The sediment was press-sieved, through either a 1.0-mm screen for control samples or a 2.0-mm screen for field samples, to remove ambient fauna prior to placing the sediment in a test chamber. Light was held constant during the 10-day test to inhibit amphipod emergence from the sediment, thus maximizing exposure to the test sediment.

At the conclusion of a test, the sediment from each chamber was sieved through a 0.5-mm screen to remove amphipods. The number of animals dead, alive, or missing was recorded. Sediments with >10% missing animals were re-examined under a dissecting microscope to ensure that no living specimens had been missed. Amphipods still unaccounted for were considered to have died and decomposed in the sediment.

A variety of quality control procedures were incorporated to assure acceptability of amphipod test results and comparability of the data with other studies. As described above, these provisions included the use of standard ASTM and EMAP protocols, positive controls run with a reference toxicant, negative “performance” controls run with reference sediment from the amphipod collection site, and routine monitoring of water quality variables to identify any departures from optimum tolerance ranges.

2.3.2.2.2 Sea Urchin Toxicity Tests

The Biomonitoring and Environmental Status and Trends Program (BEST) of the U.S. Geological Survey obtained sediment samples collected by EMAP and conducted two types of sea urchin toxicity tests. The fertilization and embryological development toxicity tests were conducted with sediment porewater using gametes of the sea urchin *Arbacia punctulata*. Methods and results are described in a technical report (USGS, 2000).

Sediments for testing were held on ice or refrigerated at 4°C and shipped in insulated coolers within 7 days to the BEST laboratory. Pore water was extracted from the test sediments within 24 hours of receipt using a pneumatic device, centrifuged to remove suspended particulate material, then stored frozen. Sediments that were received by the BEST laboratory at temperatures exceeding acceptable temperature criteria were excluded from the CDF analysis.

Sediment pore water was thawed two days prior to testing and stored at 4°C. Water quality parameters (salinity, temperature, DO) were measured in the thawed pore water and adjusted if necessary. Samples were tested at a temperature and salinity of 20 $\pm$ 2°C and 30 $\pm$ 1psu. Other water quality parameters that were measured included dissolved oxygen, pH, sulfide, ammonia and dissolved organic carbon.

Toxicity was determined using percent fertilization and embryological development (percent normal pluteus stage) as endpoints with gametes of the sea urchin *Arbacia punctulata*. A seawater dilution series (100, 50 and 25%) was used to determine the toxicity of the sediment porewater samples. Filtered seawater and reconstituted brine were used as dilution blanks. Reference pore water from an uncontaminated site in Redfish Bay, TX, was included in each test as a negative control. A dilution series with sodium dodecyl sulfate was used as a positive control. Toxicity was determined with statistical comparisons among treatments using ANOVA and Dunnett's one-tailed t-test on the arcsine square root transformed data.

2.3.3 Biotic Condition Indicators

2.3.3.1 Benthic Community Structure

Sediment samples to enumerate the benthic infauna were collected at all sampling sites unless rocky bottom or other factors prohibited obtaining a benthic sample (see section 2.6). Procedures followed the guidance provided in the NCA Quality Assurance Project Plan document (US EPA, 2001). The standard sampling gear for all three states was a 0.1-m^2 van Veen grab sampler. All Oregon sites were sampled using this gear. In both Washington and California, some stations in shallow water required modified methods when field crews walked into the site. In California, sites with a water depth less than approximately 1 meter were sampled with hand-held cores. At these shallower areas, a composite of sixteen 0.0065-m^2 cores was taken, for a total surface area of 0.1-m^2. Eight of the base California stations and 23 of the Northern California intensive sites were sampled with these cores. To evaluate the efficiency of smaller sample sizes, a single 0.0065-m^2 core was taken from the van Veen grabs at 24 sites in Southern California. For this analysis, the results from the sub-cores and the remainder of the van Veen grab were combined. In Washington, four shallow-water sites (WA99-0015, WA99-0016, WA99-0017, WA99-0019) were sampled using a 5-gallon bucket sampler with an area of 0.049 m^2. Because of the difference in area, these four samples were excluded from the analysis of benthic community structure.

The majority of the grab and core samples penetrated a minimum of 5 cm deep. The eleven samples that penetrated 3-4 cm are included in the present analysis. After collection, samples were sieved through nested 0.5-mm and 1.0-mm mesh screens. An elutriation process was used to minimize damage to soft-bodied animals and the material retained on the screens was relaxed in 1 kg of MgS04 per 20 L of seawater for 30 minutes. The residue was then preserved in the field in sodium borate-buffered 10% formalin.

The preserved samples were sent to analytical laboratories where they were transferred to 70% ethanol within 2 weeks of field collection. The 1.0-mm mesh screen samples were then sorted from the debris. The 0.5-mm mesh samples were not included as part of EMAP West and were not sorted. The organisms were then identified to the lowest practical taxonomic level (most often species), and counted by the primary taxonomists (see Table 2-10). Secondary QA taxonomists ensured that uniform nomenclature was used across the entire Western Coastal EMAP region; these recognized taxonomic experts identified and resolved taxonomic discrepancies among the sets of primary taxonomists. In the analyses for this report, all insect taxa were grouped as Insecta. Individual insect taxa will be identified in later versions of the database.

The benthic infaunal data were used to compute total numbers of individuals and total number of species per 0.1-m^2 sample. The Shannon-Weaver information diversity index H′ was calculated (log base 2) per 0.1-m^2 sample. Species were classified as native, nonindigenous, cryptogenic, or indeterminate. Cryptogenic species are species of uncertain geographic origin (Carlton, 1996), while indeterminate taxa are those taxa not identified to a sufficiently low level to classify as native, nonindigenous, or cryptogenic (Lee et al., in press). Species were classified using Cohen and Carlton (1995) as the primary source and a report by TN and Associates (2001) for taxa not classified by Cohen and Carlton. The TN and A report specifically classified the benthic species collected by the 1999 EMAP survey as native, nonindigenous, or cryptogenic.

2.3.3.2 Fish Trawls

Fish trawls were conducted at each site, where possible, to collect fish/shellfish for community structure and abundance estimates, collect target species for contaminant analyses, and collect specimens for histopathological examination. In some cases, it was necessary to use beach seines instead of trawls to collect fish for tissue analysis. Only trawls were used to evaluate fish community structure because consistency between beach seines was impossible to maintain.

Trawls were conducted by using a 16-ft otter trawl with 1.5-inch mesh in the body and wings and 1.25-inch mesh in the cod end. Community structure data (i.e, the fish data on richness and abundance and individual lengths) were based on a trawl(s) of 10 minute duration. In open water, the trawl was conducted in a straight line with the site location near center. Timing of the trawl began after the length of towline had been payed out and the net began its plow. The speed over bottom was approximately 2

knots. When possible, trawling was conducted for the entire 10-minute period, after which the ship's transmission was placed in neutral and the trawl net retrieved and brought aboard. In constrained areas where 10-minute trawls were not possible, two 5-minute trawls were conducted. Contents of the bag were emptied into an appropriately sized trough or livebox to await sorting, identifying, measuring, and sub-sampling. Trawling was the last field activity performed because of possible disturbance to conditions at the site. Every effort was made to return any rare or endangered species back to the water before they suffered undue stress.

In Oregon and Washington, fish for tissue and histopathological analysis were collected with a 120-foot long beach seine where waters were too shallow to use the otter trawl. The seine had 1-inch mesh in the wings and 3/8-inch mesh in the bag end. In California, a 100-foot seine with 1/8-inch mesh was used for fish collections in shallow waters.

2.3.3.3 Fish Community Structure

Fish from a successful trawl (full time on bottom with no hangs or other interruptions) were first sorted by species and identified to genus and species. Up to thirty individuals per species were measured by using a fish measuring board to the nearest centimeter (fork length when tail forked, otherwise overall length - snout to tip of caudal). The lengths were recorded on a field form and a total count made for each species. All fish not retained for histopathology or tissue chemistry were returned to the estuary.

2.3.3.4 Fish Contaminant Sampling

Several species of demersal soles, flounders, and dabs were designated as target species for the analyses of chemical contaminants in whole-body tissue. These flatfish are common along the entire U.S. Pacific Coast and are intimately associated with the sediments. Where the target flatfish species were not collected in sufficient numbers, perchiform species were collected. These species live in the water column but feed primarily or opportunistically on the benthos. In cases where neither flatfish species nor perches were collected, other species that feed primarily or opportunistically on the benthos were collected for tissue analysis. A total of 16 species were collected for tissue analysis in the base study sites in all three states and a total of 17 species if the intensive study stations are included. The species analyzed for tissue contaminants were (species occurring in no or only one base study station are identified):

Pleuronectiformes

Citharichthys sordidus - Pacific sanddab
Citharichthys stigmaeus - speckled sanddab
Paralichthys californicus - California halibut
Platichthys stellatus - starry flounder
Pleuronectes isolepis - butter sole (1 base study station OR)

Pleuronectes vetulus - English sole
Psettichthys melanostictus - sand sole
Symphurus atricauda - California tonguefish (1 base study station CA)

Perciformes

Cymatogaster aggregata - shiner perch
Embiotoca lateralis - stripped sea perch (1 base study station OR)
Gasterosteus aculeatus - threespine stickleback (1 base study and 1 intensive study station CA)
Genyonemus lineatus - white croaker
Paralabrax maculatofasciatus - spotted sand bass (1 base study station CA)
Paralabrax nebulifer - barred sand bass

Other

Atherinops affinis - topsmelt (1 base station CA)
Leptocottus armatus - Pacific staghorn sculpin
Oligocottus rimensis - saddleback sculpin (2 Northern CA intensive study stations)

At sites where target species were captured in sufficient numbers, 3 to 30 individuals of a species were combined into a composited sample. Due to their small size, up to 220 individual *Gasterosteus aculeatus* (threespine stickleback) were composited to obtain a sufficient tissue sample at one of the intensive sites in California. In all cases, the fish were first measured and recorded on the sampling form as chemistry fish. The fish were then rinsed with site water, individually wrapped with heavy duty aluminum foil (with the length of each individual fish printed on the foil wrap to facilitate the possible later selection of specific individuals at the laboratory), and placed together in a plastic, Ziploc bag labeled with the Station ID Code and a Species ID Code (e.g., the first four letters of both the genus and species). The fish tissue chemistry samples were held on wet ice in the field until they were transferred to shore and frozen to await laboratory analysis.

2.3.3.5 Fish Contaminant Chemistry Analyses

Neutral organic and metal contaminants were measured in the whole-body tissues of the seventeen species of fish listed above (Section 2.4.3.4). Contaminant concentrations were determined for each of the composited tissue samples. A total of 11 metals, 20 polychlorinated biphenyls (PCBs), DDT and its primary metabolites, and an additional 13 pesticides were measured in the fish samples. Oregon measured PCB 110 and PCB77 as PCB 110/77. Compounds not measured in all three states (e.g., PCB187) are not reported here. PAHs were not measured in fish tissues because of their rapid metabolism in vertebrates. The analytes measured in all three states in fish and sediments are summarized in Table 2-4. Table 2-5 summarizes the sample collection, preservation, and holding time requirements for sediment and tissue samples. Table 2-6 summarizes the analytical methods used in the three states for

both sediments and tissues. For tissue chemistry analyses, the NCA Quality Assurance Program Plan (EPA 2001) recommended that internal standards known as surrogates be run, and suggested that reported concentrations for analytes be adjusted to correct for recovery of surrogates. The state analytical laboratories generally used surrogates only as an indication of whether a re-extraction of a sample was required.

2.3.3.6 Fish Gross Pathology

Any fish pathologies (e.g., tumors) observed on fish collected in the trawls were photographed, then excised and placed into labeled pathology containers, and put immediately into Dietrich's solution. Excised tissue included the entire pathology and some adjacent healthy tissue. Pathology information, including cartridge number, fish species, size, station ID, trawl number, pathology location, description, and sample depth was recorded onto a Cumulative Fish Pathology Log. At the end of the field collection, all samples were sent to Dr. Mark Meyers at NMFS/NOAA in Seattle for analysis. A separate fish pathology report will be prepared by NOAA.

2.3.4 Sediment Chemistry

A total of 15 metals, 20 PCB congeners (PCBs), DDT and its primary metabolites, 12 pesticides, 21 polynuclear aromatic aromatics (PAHs), and total organic carbon (TOC) were measured in sediments in all three states (Table 2-4). Oregon measured PCB 110 and PCB77 as PCB 110/77. Compounds not measured in all three states (e.g., hexaclorobenzene) are not reported here. With a few additions, this suite of compounds is the same as measured in the NOAA NS&T Program.

Sediment for chemical analysis was collected from the top 2-3 centimeters in benthic grabs and stored in pre-cleaned glass containers (see Table 2-5). Sediment samples for chemical analysis were taken from the same sediment composite used for the sediment toxicity tests. Approximately 250-300 ml of sediment was collected from each station for analysis of the organic pollutants and another 250-300 ml for analysis of the metals and TOC (Table 2-5). Table 2-6 lists the analytical methods used for each compound. For sediment chemistry analyses, the NCA Quality Assurance Program Plan (EPA 2001) recommended that internal standards known as surrogates be run, and suggested that reported concentrations for analytes be adjusted to correct for recovery of surrogates. The state analytical laboratories generally used surrogates only as an indication of whether re-extraction of a sample was required. The exception was the laboratory for the State of Washington which made surrogate recovery corrections to the reported values for PAHs only.

Table 2-4. Compounds analyzed in all three states in sediments and fish tissues. PAHs and TOC were analyzed only in sediments. Toxaphene was analyzed only in tissues. Oregon combined the analysis of PCB110 and PCB77 into a single measurement of PCB 110/77.

Polyaromatic Hydrocarbons (PAHs)	PCB Congeners (Congener Number and Compound)	DDT and Other Chlorinated Pesticides	Metals and Misc.
Low Molecular Weight PAHs (sediments only) 1-methylnaphthalene 1-methylphenanthrene 2-methylnaphthalene 2,6-dimethylnaphthalene 2,3,5-trimethylnaphthalene Acenaphthene Acenaphthylene Anthracene Biphenyl Fluorene Naphthalene High Molecular Weight PAHs (sediments only) Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Benzo(g,h,i)perylene Chrysene Dibenz(a,h)anthracene Fluoranthene Indeno(1,2,3-c,d)pyrene Pyrene	8: 2,4'-dichlorobiphenyl 18: 2,2',5-trichlorobiphenyl 28: 2,4,4'-trichlorobiphenyl 44: 2,2',3,5'-tetrachlorobiphenyl 52: 2,2',5,5'-tetrachlorobiphenyl 66: 2,3',4,4'-tetrachlorobiphenyl 77: 3,3',4,4'-tetrachlorobiphenyl 101: 2,2',4,5,5'-pentachlorobiphenyl 105: 2,3,3',4,4'-pentachlorobiphenyl 110: 2,3,3',4',6-pentachlorobiphenyl 118: 2,3',4,4',5-pentachlorobiphenyl 126: 3,3',4,4',5-pentachlorobiphenyl 128: 2,2',3,3',4,4'-hexachlorobiphenyl 138: 2,2',3,4,4',5'-hexachlorobiphenyl 153: 2,2',4,4',5,5'-hexachlorobiphenyl 170: 2,2',3,3',4,4',5-heptachlorobiphenyl 180: 2,2',3,4,4',5,5'-heptachlorobiphenyl 195: 2,2',3,3',4,4',5,6-octachlorobiphenyl 206: 2,2',3,3',4,4',5,5',6-nonachlorobiphenyl 209: 2,2'3,3',4,4',5,5',6,6 '-decachlorobiphenyl	DDTs 2,4-DDD 4,4'-DDD 2,4'-DDE 4,4'-DDE 2,4'-DDT 4,4'-DDT Cyclopentadienes Aldrin Dieldrin Endrin Chlordanes Alpha-Chlordane Heptachlor Heptachlor Epoxide Trans-Nonachlor Others Endosulfan I Endosulfan II Endosulfan Sulfate Lindane (gamma-BHC) Mirex Toxaphene (tissue only)	Metals Aluminum Antimony (sediment only) Arsenic Cadmium Chromium Copper Iron (sediment only) Lead Manganese (sediment only) Mercury Nickel Selenium Silver Tin (sediment only) Zinc Miscellaneous Total organic carbon (sediment only)

Table 2-5. Summary of EMAP-Coastal chemistry sample collection, preservation, and holding time requirements for sediment and fish tissues. Modified from Table 5-3 (U.S. EPA, 2001a).

Parameter	Container	Volume	Sample Size	Sample Preservation	Max. Sampling Holding Time	Max. Extract Holding Time
Sediment - Organics	500-ml pre-cleaned glass	250 - 300 ml	300 g (approx.)	Freeze (-18^{o} C)	1 year	40 days
Sediment - Metals	125-ml HDPE wide-mouth bottle	100 - 150 ml	75 - 100 g (approx.)	Freeze (-18^{o} C)	1 year	a
Sediment - TOC	Glass jar	100 - 150 ml	30 - 50 ml (approx.)	Cool (4^{o} C)	6 months	a
Fish tissue	Whole fish individually wrapped in Al foil, then placed in water-tight plastic bag.	NA	NA	Freeze (-18^{o} C)	1 year	40 days

a - No EPA criterion exists. Every effort should be made to analyze the sample as soon as possible following extraction or, in the case of metals, digestion.

Table 2-6. Methods used to analyze for contaminants in sediments and tissues. NA = not analyzed.

Analyte	CA Sediment/Tissue	OR Sediment/Tissue	WA Sediment/Tissue
Aluminum	ICPMS/ICPMS	ICPAES/ICPAES	ICPAES/ICPAES
Antimony	ICPMS/ICPMS	GFAA/NA	ICPMS/NA
Arsenic	ICPMS/ICPMS	ICPAES/ICPAES	AA/AA
Cadmium	ICPMS/ICPMS	GFAA/GFAA	ICPMS/ICPMS
Chromium	ICPMS/ICPMS	ICPAES/ICPAES	ICPAES/ICPMS
Copper	ICPMS/ICPMS	ICPAES/ICPAES	ICPAES/ICPMS
Iron	FAA/NA	ICPAES/ICPAES	ICPAES/ICPAES
Lead	ICPMS/ICPMS	ICPAES/GFAA	ICPMS/ICPMS
Manganese	ICPMS/ICPMS	ICPAES/NA	ICPAES/NA
Mercury	FIMS/FIMS	CVAA/CVAA	CVAA/CVAA
Nickel	ICPMS/ICPMS	ICPAES/ICPAES	ICPAES/ICPMS
Selenium	HAA/ICPMS	HAA/HAA	AA/AA (FURNACE)
Silver	GFAA/ICPMS	GFAA/GFAA	ICPMS/ICPMS
Tin	ICPMS/NA	ICPAES/ICPAES	ICPMS/ICPMS
Zinc	ICPMS/ICPMS	ICPAES/ICPAES	ICPAES/ICPMS
PCB congeners	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
DDT, DDD, and DDE	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
PAHs	GCMS/NA	GCMS/NA	GCMS/NA
Aldrin	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Alpha-Chlordane	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Dieldrin	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Endosulfan I	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Endosulfan II	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD

Table continued on next page

Endosulfan Sulfate	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Endrin	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Heptachlor	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Heptachlor Epoxide	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Lindane (gamma-BHC)	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Mirex	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
Trans-Nonachlor	GCMS/GCMS	GCECD/GCECD	GCECD/GCECD
TOC	MARPCN I/NA	EPA415.1/NA	PSEP-TOC/NA
Percent fines	wet sieve/NA	gravimetric/NA	PSEP86/NA

Analytical Methods: CVAA = cold vapor atomic absorption, FAA = flame atomic absorption, FIMS = flow injection mercury system, GCECD = gas chromatography with electron capture detection, GCMS = gas chromatography/mass spectroscopy, GFAA = graphite furnace atomic absorption spectrometry, ICPAES = inductively coupled plasma/atomic emission spectrometry, ICPMS = inductively coupled plasma/mass spectrometry , HAA = hydride atomic absorption, MARPCN I = high temperature combustion method.

2.4 Quality Assurance/ Quality Control

The quality assurance/quality control (QA/QC) program for the Western Coastal EMAP program is defined by the “Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan 2001-2004" (US EPA, 2001a). The NCA has established Data Quality Objectives (DQO) for estimates of current status for indicators of condition which are stated as: "For each indicator of condition, estimate the portion of the resource in degraded condition within ±10% for the overall system and ±10% for subregions (i.e., states) with 90% confidence based on a completed sampling regime." An assessment of this standard for the combined 1999/2000 data from the states of Washington, Oregon and California is presented in the Quality Assurance Appendix of the National Coastal Condition Report II (EPA, 2004). The level of uncertainty for the combined west coast data set for all major indicators was $\leq$ 5%.

In general, the quality assurance elements for the EMAP Western Coastal program included initial training workshops on all sampling and analysis requirements and initial laboratory capability exercises, program-wide audits of field and laboratory operations, documentation of chain-of-custody, and maintaining open lines of communication and information exchange. Information management needs were demonstrated to all participants by the Western Coastal EMAP information manager. Other quality control measures were incorporated to assure data reliability and comparability and are described in the NCA plan. These include the use of standard NCA protocols, routine instrument calibrations, measures of analytical accuracy and precision (e.g., analysis of standard reference materials, spiked samples, and field and laboratory replicates), measures of the quality of test organisms and overall data acceptability in sediment bioassays (e.g., use of positive and negative controls), range checks on the various types of data, cross-checks between original data sheets (field or lab) and the various computer-entered data sets, and participation in intercalibration exercises.

Accuracy is used to estimate systematic error (measured vs. true or expected), while precision is used to determine random error (variability between individual measurements). Collectively, they provide an estimate of the total error or uncertainty associated with an individual measured value. Measurement quality objectives (MQO) for all NCA field and laboratory parameters are expressed in terms of accuracy, precision, and completeness goals in the NCA QA Project Plan (US EPA, 2001a, Table A7-1). These MQOs were established from considerations of instrument manufacturers specifications, scientific experience, and/or historical data. However, accuracy and precision goals may not be definable for all parameters due to the nature of the measurement type (e.g., fish pathology, no expected value).

2.4.1 QA of Chemical Analyses

Details of the quality assurance procedures used to generate chemical concentrations within both sediments and tissue samples with acceptable levels of precision and accuracy are given in U.S. EPA (2001a). Briefly, a performance-based approach was used, which depending upon the compound included 1) continuous laboratory evaluation through the use of Certified Reference Materials (CRMs) and/or Laboratory Control Materials (LCMs), 2) laboratory spiked sample matrices, 3) laboratory reagent blanks, 4) calibration standards, and 5) laboratory and field replicates.

Control limit criteria for “relative accuracy” were based on comparing the laboratory’s value to the true or “accepted” values in CRMs or LCMs (see U.S. EPA, 2001a for details). The specific requirements for PAHs and PCBs/pesticides are that the “Lab’s value should be within ±30% of true value on average for all analytes; not to exceed ±35% of true value for more than 30% of individual analytes.” (U.S. EPA 2001a). In addition to evaluating the individual PAH and PCB analytes, relative accuracy for total PAHs and PCBs was determined for each combined group of organic compounds. Metals and other inorganic compounds were treated individually, and the laboratory's value for each analyte should be within ±20% of the upper or lower 95% confidence limit of the CRM or LCM. Because of inherent variability at low concentrations, these control limit criteria were applied only to analytes having CRM or LCM values $\geq$10 times the MDL.

To evaluate precision, each laboratory periodically analyzed CRM or LCM samples using a control limit of 3 standard deviations of the mean (Taylor, 1987). Based on analysis of all the samples in a given year, an overall relative standard deviation (RSD, or coefficient of variation) of less than 30% was considered acceptable precision for analytes with CRM concentrations $\geq$ 10 times the MDL.

In order to evaluate the MQOs for precision, various analytical quality assurance/quality control (QA/QC) samples were used, field measurement procedures were followed, and field vouchers were collected. For analytical purposes, Method Detection Limits (MDL’s) were calculated for the detection of each analyte at low levels distinguished above background noise, taking into consideration the relative sensitivity of an analytical method, based on the combined factors of instrument signal, sample size, and sample processing steps. The MDL is defined as “the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte." (Code of Federal Regulations 40 CFR Part 136). Approved laboratories were expected to perform in general accord with the target MDLs presented for NCA analytes (US EPA, 2001a, Table A7-2). Because of analytical uncertainties close to the MDL, there is greater confidence with concentrations above the Reporting Limit (RL), which is the concentration of a substance in a matrix that can be reliably quantified during routine laboratory operations. Typically, RLs are 3 to 5 times the MDL. Concentrations between the MDL and the RL were used in generating the CDF and

mean for the analyte. Values below the MDL were set to 0 and this value was used in calculating both the CDFs and means.

Table 2-7 lists the units, method detection limits (MDL), and reporting limits (RL) for each compound measured in sediment samples in all three states. The analytical methods are those used in the NOAA NS&T Program (Lauenstein and Cantillo, 1993) or documented in the EMAP-E Laboratory Methods Manual (U.S. EPA, 1993). The target MDLs for the National Coastal Assessment (US EPA, 2001a) were achieved in almost 90% of sediment analytes across the three states (Table 2-7). Exceedances of the target MDL could potentially affect the frequency with which a compound is detected, but would have little effect on the shape of the CDF since such exceedances occur at the low end of the concentration distribution.

Table 2-8 lists the units, method detection limits (MDL), and reporting limit (RL) for the tissue analytes. The target MDLs for the National Coastal Assessment (US EPA, 2001a) were achieved in over 90% of tissue analytes across the three states (Table 2-8). As mentioned for the sediments, exceedances of the target MDL could potentially affect the frequency with which a compound is detected, but would have little effect on the shape of the CDF since such exceedances occur at the low end of the concentration distribution.

Prior to analysis of 1999 field samples, state laboratories participating in the NCA program performed a demonstration of capability using SRMs provided by EPA. Results of this exercise are described in EPA (2004, Appendix A). In summary, results were deemed acceptable for Washington and California and marginal for Oregon.

A post-analysis assessment of the success of the analytical laboratories in meeting NCA QA/QC guidelines was conducted by the QA officer of the Western Ecology Division. These results are summarized in Table 2-9. Accuracy of results as assessed by comparison to either an SRM, CRM, or LCM was within guidelines for all states for analysis of metals in both sediment and tissues. For sediment PCBs and pesticides, performance of the Oregon laboratory was less than the desired level, and the performance of the California laboratories, while acceptable, was based on a limited number of analytes in the LCM. For sediment PAHs, performance of the Oregon laboratory was acceptable based on the LCM and less than desired based on the SRM. In several cases, accuracy could not be assessed for the field samples because laboratories did not analyze reference tissue material for PCBs (Washington) or pesticides (Washington, California), although ability to meet standards was demonstrated in the initial lab capability exercise.

The NCA analytical laboratory accuracy standards are based on the evaluation of individual analytes (e.g. PCB congeners) while the NCA sediment condition indicators are based on <u>total</u> sediment or tissue PAHs and PCBs. If the total PCB concentration in the SRM is compared to the estimated total recovery of PCBs in sediments for all congeners by the Oregon laboratory, the values are within 16% . A similar analysis for

Table 2-7. Units, method detection limits (MDL), and reporting limits (RL) for sediment chemistry for compounds measured in all three states. The method detection limits and the reporting limits for Oregon and Washington are means of all the reported sediment values, including non-detects. Target MDLs are from the National Coastal Assessment (US EPA, 2001a). NR = not reported. NA = not applicable.

Analyte	Units (dry wt.)	Target MDL	CA MDL/RL	OR MDL/RL	WA MDL/RL
Aluminum	µg/g	1500	0.05/0.15	1/4	20/100
Antimony	µg/g	0.2	0.002/0.006	0.3/1	0.02/0.1
Arsenic	µg/g	1.5	0.1/0.3	0.3/1	0.2/0.3
Cadmium	µg/g	0.05	0.002/0.006	0.03/0.09	0.01/0.05
Chromium	µg/g	5.0	0.03/0.09	0.06/0.2	NR/0.5
Copper	µg/g	5.0	0.03/0.09	0.2/0.6	0.5/1
Iron	µg/g	500	2.0/6.0	0.8/2.5	20/100
Lead	µg/g	1.0	0.002/0.006	0.2/0.7	0.01/0.2
Manganese	µg/g	1.0	0.003/0.009	0.1/0.3	0.2/1
Mercury	µg/g	0.01	0.015/0.045	0.002/0.007	0.001/0.005
Nickel	µg/g	1.0	0.006/0.018	0.3/1.0	1/1
Selenium	µg/g	0.1	0.002/0.006	0.09/0.3	0.1/0.1
Silver	µg/g	0.05	0.008/0.024	0.0075/0.025	0.1/0.2
Tin	µg/g	0.1	0.002/0.006	0.3/0.9	0.02/0.1

Zinc	µg/g	2.0	0.02/0.06	0.3/0.9	1/1
PCB congeners	ng/g	1.0	1/5	0.87/1.10	0.06/0.59
DDT, DDD, and DDE	ng/g	1.0	1/5	0.01/0.92	0.06/0.61
PAHs	ng/g	10	5/13	2.65/30	1.1/1.1
Aldrin	ng/g	1.0	1/5	0.01/0.92	0.06/0.59
Alpha-Chlordane	ng/g	1.0	2/5	0.01/0.92	0.06/0.59
Dieldrin	ng/g	1.0	1/5	0.1/0.92	0.06/0.59
Endosulfan I	ng/g	1.0	5/10	0.1/0.92	0.06/0.59
Endosulfan II	ng/g	1.0	5/10	0.1/0.92	0.06/0.59
Endosulfan Sulfate	ng/g	1.0	5/10	0.02/1.70	0.06/0.59
Endrin	ng/g	1.0	5/10	0.1/0.92	0.06/0.59
Heptachlor	ng/g	1.0	1/5	0.1/0.92	0.06/0.59
Heptachlor Epoxide	ng/g	1.0	1/5	0.1/0.92	0.06/0.60
Lindane (gamma-BHC)	ng/g	1.0	2/5	0.1/0.92	0.060/0.63
Mirex	ng/g	1.0	2/5	0.1/0.92	0.06/0.59
Trans-Nonachlor	ng/g	1.0	1/5	0.1/0.92	0.05/0.59
TOC	percent	NA	0.01/0.01	0.0005/0.0005	0.1/0.1
Percent fines	percent	NA	NR	0.1/1	0.1/0.1

Table 2-8. Units, method detection limits (MDL), and reporting limits (RL) for tissue chemistry for compounds measured in all three states. The reporting limits for Oregon and Washington are means of all the reported tissue values, including non-detects. The reporting limits for the PCBs in Oregon and Washington are mean of all the congeners. The PCB reporting limits in California are the range in individual congeners. Target MDLs are from the National Coastal Assessment (US EPA, 2001a). NA = not applicable.

Analyte	Units (wet wt.)	Target MDL	CA MDL/RL	OR MDL/RL	WA MDL
Aluminum	µg/g	10.0	0.012/0.036	0.5/0.67	2/10
Arsenic	µg/g	2.0	0.025/0.075	0.15/0.17	0.2/1.5
Cadmium	µg/g	0.2	0.0005/0.0015	0.025/0.023	0.01/0.05
Chromium	µg/g	0.1	0.007/0.021	0.03/0.03	0.1/0.2
Copper	µg/g	5.0	0.007/0.021	0.1/0.10	0.5/0.5
Lead	µg/g	0.1	0.0005/0.0015	0.095/0.10	0.01/0.05
Mercury	µg/g	0.01	0.005/0.015	0.016/0.015	0.01/3
Nickel	µg/g	0.05	0.0015/0.0045	0.15/0.17	0.5/0.5
Selenium	µg/g	1.0	0.025/0.075	0.1/0.1	0.1/0.3
Silver	µg/g	0.5	0.002/0.006	0.0085/0.0083	0.01/0.01
Zinc	µg/g	50.0	0.005/0.015	0.15/0.17	1/1
PCB congeners	ng/g	2.0	1/ 2-5	0.2-4.9/1.14	0.1/0.41
DDT, DDD, and DDE	ng/g	2.0	1/2	0.01/1.14	0.1/0.51

Aldrin	ng/g	2.0	1/2	0.01/1.14	0.1/0.47
Alpha-Chlordane	ng/g	2.0	2/4	0.01/1.14	0.1/0.59
Dieldrin	ng/g	2.0	1/2	0.01/1.14	0.1/0.67
Endosulfan I	ng/g	2.0	1/2	0.01/1.14	0.1/0.66
Endosulfan II	ng/g	2.0	5/10	0.01/1.14	0.1/0.66
Endosulfan Sulfate	ng/g	2.0	2/4	0.02/2.25	0.1/0.80
Endrin	ng/g	2.0	5/10	0.01/1.14	0.1/0.66
Heptachlor	ng/g	2.0	2/4	0.01/1.14	0.1/0.37
Heptachlor Epoxide	ng/g	2.0	5/10	0.01/1.14	0.1/0.66
Lindane (gamma-BHC)	ng/g	2.0	2/4	0.01/1.14	0.1/0.66
Mirex	ng/g	2.0	5/10	0.01/1.14	0.1/0.38
Toxaphene	ng/g	2.0	10/20	0.01/11.4	0.1/13.3
Trans-Nonachlor	ng/g	2.0	1/5	0.01/1.14	0.1/0.36
% Moisture	percent	NA	NA	NA	NA

Table 2-9. Summary of performance of state analytical laboratories with regard to QA/QC criteria for analysis of reference materials, matrix spike recoveries, and relative percent differences (RPD) of duplicates. MS = matrix spike, SRM = Standard Reference Material, CRM = Certified Reference Material, LCM = Laboratory Reference Material, NA = not analyzed.

Analyte	Material	State	Mean of all analytes < ±30%	Less than 30% of analytes were within 35% of true value (% exceeding if >30%) SRM/CRM/LCM (# analytes reported / # of analytes in SRM/CRM/LCM)	Matrix spike recovery within 50%-150%	RPDs MS / non-zero duplicate samples average <30%
PAHs	Sediment	CA	Yes	Yes LCM (15/22)	No MSs	NA/Yes
		OR	No Yes	No (44%) SRM 1944 (18/19) Yes LCM (22/22)	No	No MS dups/Yes
		WA	Yes	Yes SRM 1944 (19/19)	No MSs	NA/Yes
Metals	Sediment	CA	Yes	Yes LCM (14/15)	? - no true values**	Yes/No sample dups
		OR	Yes	Yes LCM (15/15)	Yes	No MS dups/Yes
		WA	Yes	Yes LCM (14/15)	Yes	Yes/Yes
	Tissue	CA	Yes	Yes LCM (11/13)	? - no true values**	Yes/Yes
		OR	Yes	Yes LCM (13/13)	Yes	No MS dups/Yes
		WA	Yes	Yes LCM (12/13)	Yes	Yes/Yes
PCBs	Sediment	CA	Yes	Yes LCM (13/21)	No MSs	NA/no non-zeros
		OR	No	No (76%) SRM 1944 (19/19)	No MSs	NA/No (low values)
		WA	Yes	Yes SRM 1944 (17/19)	Yes	Yes/No (low values)
		CA	Yes*	Yes CRM (8*/21)	Yes	Yes/Yes

	Tissue	**OR**	Yes	Yes LCM (21/21)	Yes	No MS dups/Yes
		WA	No	no reference material used	Yes	Yes/Yes
Pesticides	**Sediment**	**CA**	Yes*	Yes LCM (3*/20)	No MSs	NA/no non-zeros
		OR	No	NO (140%) SRM 1944 (8/8)	Yes	No MS dups/Yes
		WA	Yes	Yes SRM 1944 (8/8)	Yes	Yes/No (low values)
	Tissue	**CA**	No	no reference material used	Yes	Yes/No (low values)
		OR	Yes	Yes LCM (20/20)	Yes	No dups/Yes
		WA	No	no reference material used	Yes	Yes/Yes

* Fewer than 50% of NCA analytes were present in LCM.
** Duplicate values, but not true values, were reported for matrix spikes by the analytical laboratory.

the recovery of total PAHs in sediments versus the SRM by the Oregon lab was within 24%. These values are within ± 30% of the true value and are considered adequate for the purpose of inclusion of the Oregon total PCB and total PAH data in the computation of a regional CDF.

2.4.2 QA of Taxonomy

Quality control of taxonomic identifications involved the establishment of a network of secondary QA/QC taxonomic specialists who confirmed identifications made by the primary taxonomists (Table 2-10), and provided standardization of identifications among the state participants.

In order to assure uniform taxonomy and nomenclature among the primary taxonomists for each group, and to avoid problems with data standardization at the end of the project, progressive QA/QC and standardization were implemented. At frequent, regular intervals (i.e., monthly), as primary taxonomy was completed, vouchers, voucher sheets, and a portion of the QA samples were sent to the QA taxonomists. Immediate feedback from the QA taxonomists to the primary taxonomists was used to correct work and standardize between regional taxonomists. Each voucher was accompanied by a voucher sheet listing the following information: major taxon (e.g., Annelida), family, genus, species, sample from which the specimen was taken; references used in the identification; and any characteristics of the specimen that differ from the original description. Provisional species were described in detail on the voucher sheet.

As voucher specimens and bulk samples were processed by the QA taxonomist, any differences in identifications or counts were discussed and resolved with the primary taxonomist. The original data set remained with the primary taxonomist, and changes agreed upon between the primary and QA taxonomists were made by the primary taxonomist on a copy of the original data set. Changes to the data based on QA/QC analysis were tracked in writing by both the primary and QA taxonomists.

Table 2-10. Listing of primary and QA/QC taxonomists by taxon and region for the 1999 Western Coastal EMAP study.

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

*NC: Northern California, SC: Southern California, WO: Washington & Oregon

2.5 Data management

Data management for the West Coast stations sampled in 1999 is a component of the overall EMAP Western Coastal Information Management Program. The Information Management System is based on a centralized data storage model using standardized data transfer protocols (SDTP) for data exchange among program participants. The 1999 data were submitted to the Information Manager (IM) located at the Southern California Coastal Water Research Program (SCCWRP) for entry into the relational database (Microsoft Access 2000).

The data flow consists of interactions among four levels. Field crew leaders and laboratory supervisors are responsible for compiling data generated by their organizations and for entering the data into one or more of the SDTP tables. The State IM Coordinator is responsible for compiling all data generated within a state into a unified state database. The Western EMAP IM Coordinator (WIMC) is responsible for working with State Coordinators to develop the SDTP, and for creation and management of the centralized West Coast EMAP database. The EMAP IM Coordinator, located at the Atlantic Ecology Division of EPA at Narragansett, Rhode Island, is responsible for accepting data from Western EMAP, for placing it in the national EMAP database, and for transferring it to other EPA databases, such as STORET.

Once all data tables of a particular data type (e.g., all tables containing fish data) were certified by the WIMC, integrated multi-state data tables were provided to the Western EMAP Quality Assurance Coordinator (QAC). The QAC reviewed the data with respect to scientific content. Necessary corrections resulting from this review process were returned to the Western EMAP IM Coordinator, who was responsible for working with the State IM Coordinator to make necessary changes.

Following certification of all portions of the data by the QAC, the WIMC submitted the integrated multi-state data set to the EMAP IM Coordinator, who is the point of contact for data requests about the integrated data set.

Details of the Western EMAP Information Management process are provided in Cooper (2000). The structure of each of the relational database tables and supporting database look-up tables used by the states to submit data to the WIMC are also provided in this document (Cooper, 2000).

2.6 Unsamplable Area

In Washington, 6 stations (WA99-0005, Ozette River; WA99-0028, Beardslee Slough; WA99-0018, Quinault River; WA99-0032, WA99-0037, Willapa Bay; WA99-0041, Grays River) proved to be inaccessible to sampling and were abandoned (Table 2-1).

In Oregon, station OR99-0029 was abandoned prior to sampling because inspection found that it fell too far upstream and was not visited. Station OR99-0075, part of the

Tillamook Bay intensification study, was not sampled because the station was located in a marsh area. No sediment contaminant analyses were conducted at OR99-0044 or OR99-0051 because of grab failures due to large amounts of rock and shell in the substrate.

In California, all stations were visited. Among the base study stations, there were no grab or trawl samples obtained at CA99-3019 (Carmel Bay) or CA99-3024 (San Luis Obispo Bay) because of rocky substrate at the sites. Site CA99-3027, located in the Ventura River, was not sampled because the station location was actually located on land and the adjacent aquatic habitat could not be sampled because it consisted of a large boulder substrate. Among the northern California intensification sites, no grab or trawl samples were obtained at stations CA99-3058 (Klamath River), CA99-3066 (Noyo River), CA99-3072 (Albion River), and CA99-3075 (Elk Creek) because of the presence of rocky substrates. No trawl was obtained at station CA99-3056 (Wilson River) because there was insufficient room to deploy gear.

3.0 Indicator Results

3.1 Habitat Indicators

3.1.1 Salinity

Salinity in the bottom water for the small estuaries of West Coast states ranged from 0 psu to 34.2 psu across the 201 stations where bottom salinities were collected. Approximately fifty percent of the area of the small estuaries had a salinity ≥ 30.9 psu (Figure 3.1 -1). About 54% of the area of the West Coast states estuaries would be classified as euhaline (≥ 30 psu) based on the EMAP sampling. The extended left tail of the CDF indicates that a number of samples were taken at low salinities, but that these sites constituted a modest percentage of the total estuarine area. Approximately 19% of the area of the small estuaries had salinities less than 20 psu, while only 11% of estuarine area is represented by salinities less than 5 psu. The range of values for surface salinity was identical to that in bottom water, and the CDF of surface salinity values was very similar to that for bottom salinities. In interpreting these results, it is important to recognize that salinity can vary both tidally and seasonally, as well as with depth in the water column, and that these single measurements are "snapshots" during the sampling events.

3.1.2 Water Temperature

Temperature in the bottom water for the small estuaries of West Coast states ranged from 8.5 °C to 32.1 °C across the 201 stations where bottom temperatures were collected. The relatively wide range of bottom water temperature values reflects the two biogeographic provinces which were sampled in West Coast states. The range of surface water temperatures was very similar to that for bottom water temperatures (9.3 °C to 32.1 °C). Approximately 13% of the area of the small estuaries had a temperature at the bottom ≥ 20 °C, with about 19.6 % of area having bottom water temperatures ≤ 11.1 °C (Figure 3.1 -2). These temperatures are representative of summer conditions in the region.

3.1.3 pH

The pH of bottom waters for the small estuaries of West Coast states had the surprisingly wide range of from 5.1 to 10.2 across the 197 stations where bottom pH measurements were collected. The range for pH in surface water samples was identical to that for bottom waters. Approximately 91% of the area of the small estuaries had a pH ≤ 8.0 (Figure 3.1 -3). Values of pH ≥ 9 tended to be found at sites with low salinity (≤ 7 psu), with the exception of the station from Point Mugu Lagoon, California, where a pH of 9.3 and a salinity of 33.4 psu were recorded. Values of pH ≤ 6.5 tended to be found at sites with low salinity (≤ 1 psu).

3.1.4 Sediment Characteristics

The percent silt-clay of sediments ranged from 0 % to 96.4 % at the 190 stations from which soft sediment samples could be obtained (Figure 3.1 -4). About 65% of the area of the small estuaries had sediments composed of sands (< 20 % silt-clay), about 29.4 % was composed of intermediate muddy sands (20-80 % silt-clay), and only about 5.6 % was composed of muds (>80 % silt-clay).

Percent total organic carbon (TOC) in sediments of small west coast estuaries ranged from 0 % to 7.4 % at the 190 stations from which soft sediment samples could be obtained (Figure 3.1 -5). About 84% of the area of the small estuaries had sediments with TOC levels $\leq$ 1.0 %.

3.1.5 Water Quality Parameters

Water quality parameters are presented as water column mean values based on the concentration averaged over the surface, mid-water, and bottom water samples. Water depths during sampling ranged between 0.3 m and 30 m depth.

Chlorophyll a

The average water column concentration of chlorophyll *a* of small west coast estuaries (Figure 3.1 -6) ranged from 0.4 to 47.6 µg L^{-1} across the 202 stations where chlorophyll measurements were collected. Approximately 88% of total estuarine area was characterized by average chlorophyll *a* concentrations $\leq$ 7.9 µg L^{-1}, while approximately 0.6 % of estuarine area had chlorophyll *a* values that exceeded concentrations of 15 µg L^{-1}. There was no geographic concentration of high chlorophyll values.

Nutrients

The average water column concentration of nitrate + nitrite of small west coast estuaries (Figure 3.1 -7) ranged from 0 to 3472 µg L^{-1} across the 202 stations where nitrate + nitrite measurements were collected. Approximately 95% of total estuarine area was characterized by nitrate + nitrite concentrations $\leq$ 263 µg L^{-1}, while approximately 2.7 % of estuarine area had nitrate + nitrite values that exceeded concentrations of 300 µg L^{-1}.

The average water column concentration of ammonium in small west coast estuaries (Figure 3.1 -8) ranged from 0 to 580 µg L^{-1} across the 202 stations where ammonium measurements were collected. Approximately 90% of total estuarine area was characterized by ammonium concentrations $\leq$ 125 µg L^{-1}.

The average water column concentration of total nitrogen (nitrate + nitrite + ammonium) in small west coast estuaries (Figure 3.1 -9) ranged from 3.2 to 3519 µg L^{-1} across the 202 stations where total nitrogen measurements were collected. Approximately 90% of total estuarine area was characterized by total nitrogen concentrations $\leq$ 218 µg L^{-1}.

The average water column orthophosphate concentration of small west coast estuaries (Figure 3.1 -10) ranged from 0 to 563.3 µg L^{-1} across the 202 stations where orthophosphate measurements were collected. Approximately 95% of total estuarine area was characterized by orthophosphate concentrations ≤ 158 µg L^{-1}.

The ratio of total nitrogen (nitrate + nitrite + ammonium) concentration to total orthophosphate concentration was calculated as an indicator of which nutrient may be controlling primary production in west coast small estuaries. A ratio above 16 is generally considered indicative of phosphorus limitation, and a ratio below 16 is indicative of nitrogen limitation (Geider and La Roche, 2002). The N/P ratio (Figure 3.1 -11) ranged from 0.16 to 393.5 across the 190 stations where sufficient measurements were collected. Approximately 75% of estuarine area had N/P values ≤ 16. The long right tail of the CDF was due to four stations representing less than 1 % of estuarine area with N/P ratios ≥ 100.

Total Suspended Solids

The average water column concentrations of total suspended solids (TSS) in the water column of small west coast estuaries (Figure 3.1-12) ranged from 0 to 276.2 mg L^{-1} across the 201 stations where TSS measurements were collected. Approximately 95% of total estuarine area was characterized by TSS concentrations ≤ 19.1 mg L^{-1}.

Percent Light Transmission

The percent light transmission of the water column (adjusted to a reference sample depth of 1 m) in small west coast estuaries (Figure 3.1 -13) ranged from 0 to 87.6% of surface illumination. Approximately 21.3 % of total estuarine area showed a percent light transmission of ≤10 %, and approximately 46.8 % of total estuarine area showed a percent light transmission of ≤20 %.

3.1.6 Water Column Stratification

As an indicator of water column stratification, two indices were calculated for the 201 stations with temperature and salinity data. The first index was the simple difference between bottom and surface salinities. The second index ($\Delta\sigma_t$) was the difference between the computed bottom and surface σ_t values, where σ_t is the density of a parcel of water with a given salinity and tmperature relative to atmospheric pressure. Results of the two indices were extremely similar.

The simple stratification index ranged between -1.2 and 20.2 psu. Less than 4% of estuarine area showed index values < 0, indicating bottom waters less saline than surface waters (Figure 3.1 -14). Approximately 12% of estuarine area had index values ≥ 2 psu, indicating strong stratification. The $\Delta\sigma_t$ index had values ranging from -0.08 to +16.2. Approximately 3% of estuarine area showed $\Delta\sigma_t$ index values < 0, indicating

bottom waters less saline than surface waters (Figure 3.1 -15). Approximately 12% of estuarine area had $\Delta\sigma_t$ index values $\geq$ 2, indicating strong stratification.

The limited indication of strong water column stratification within the small west coast estuaries sampled is consistent with the large tidal amplitude across much of the region, which should lead to a high degree of water column mixing. Additionally the sampling period is during the summer period of low rainfall and low freshwater runoff which should also reduce the extent of vertical stratification during the sample period.

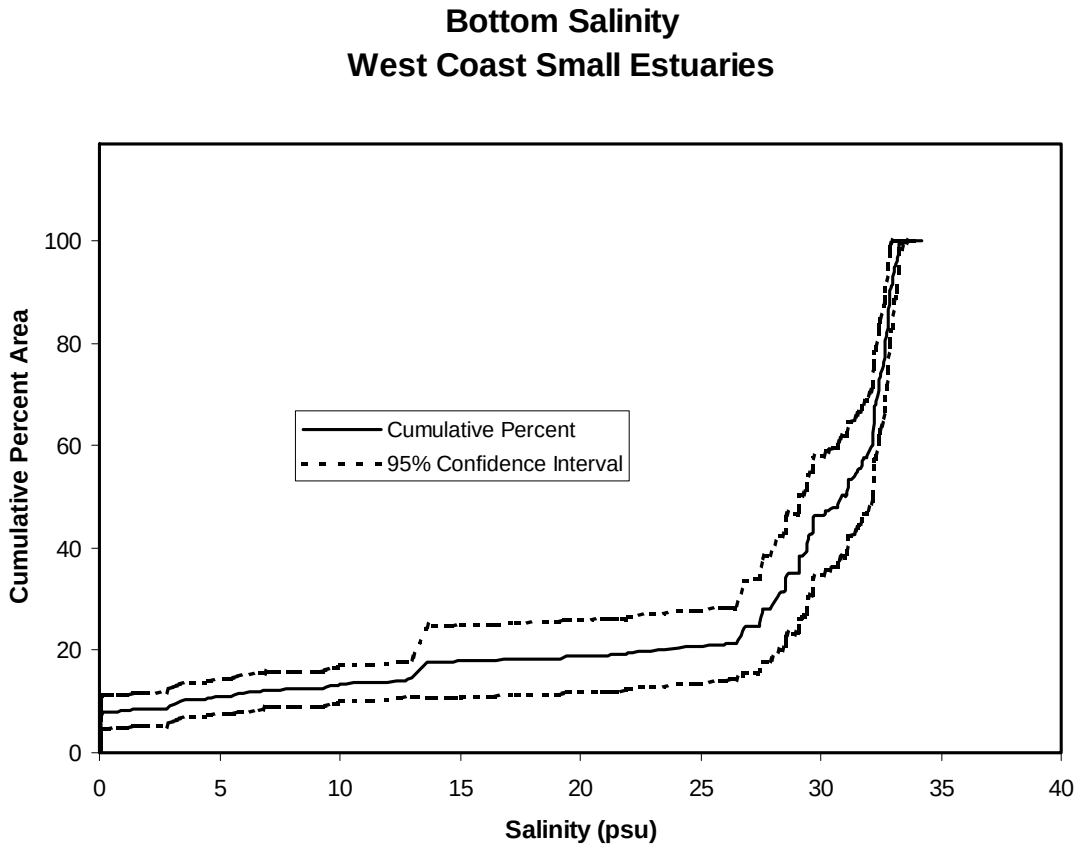

Figure 3.1-1. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. salinity of bottom waters.

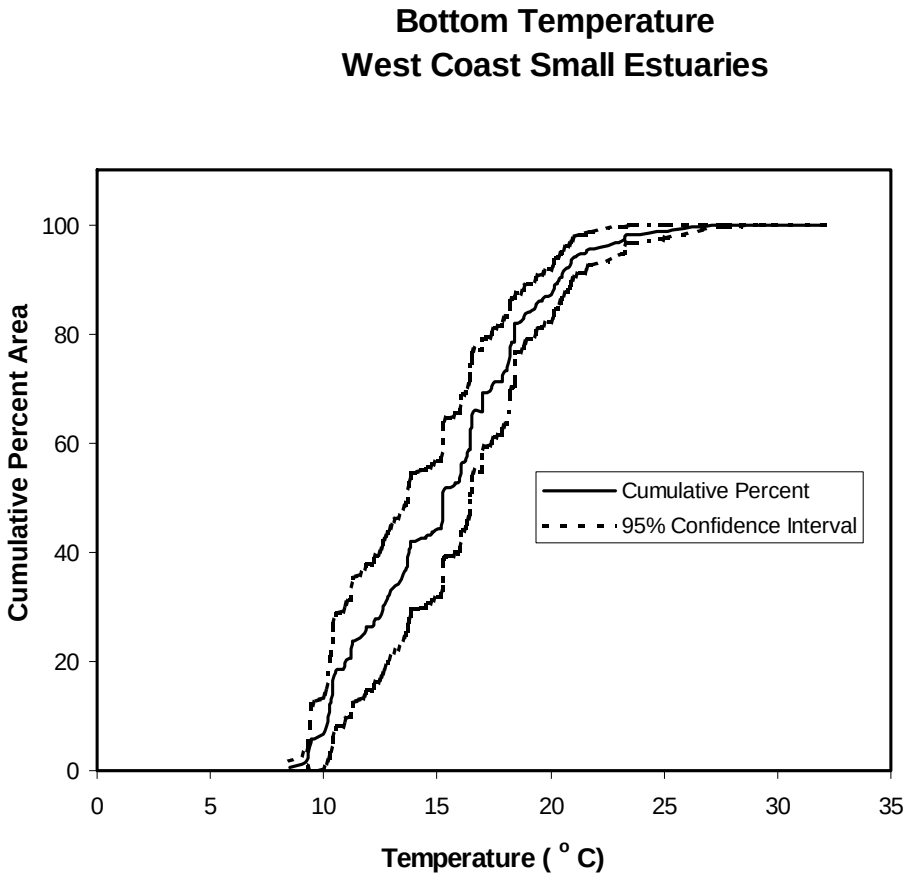

Figure 3.1-2. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. temperature of bottom waters.

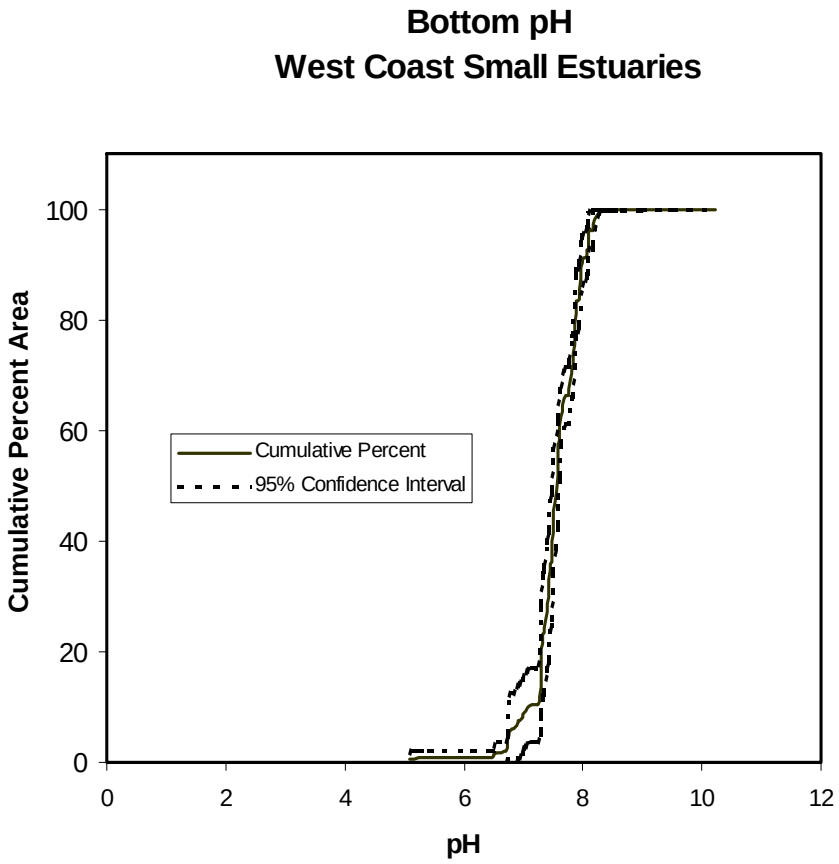

Figure 3.1-3. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. pH in bottom waters.

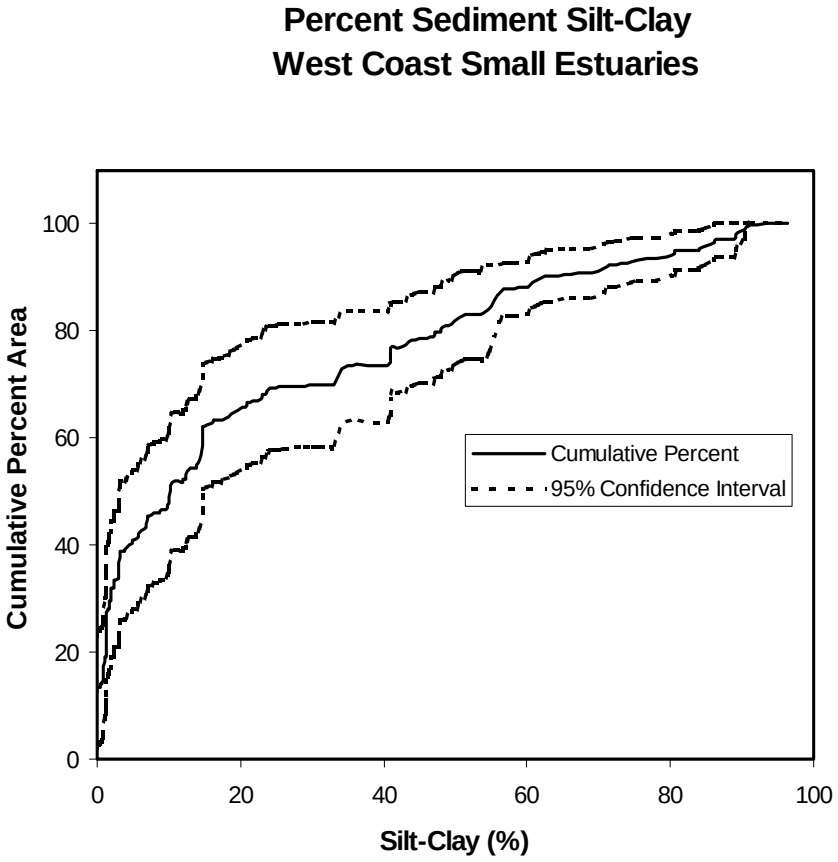

Figure 3.1-4. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. percent silt-clay of sediments.

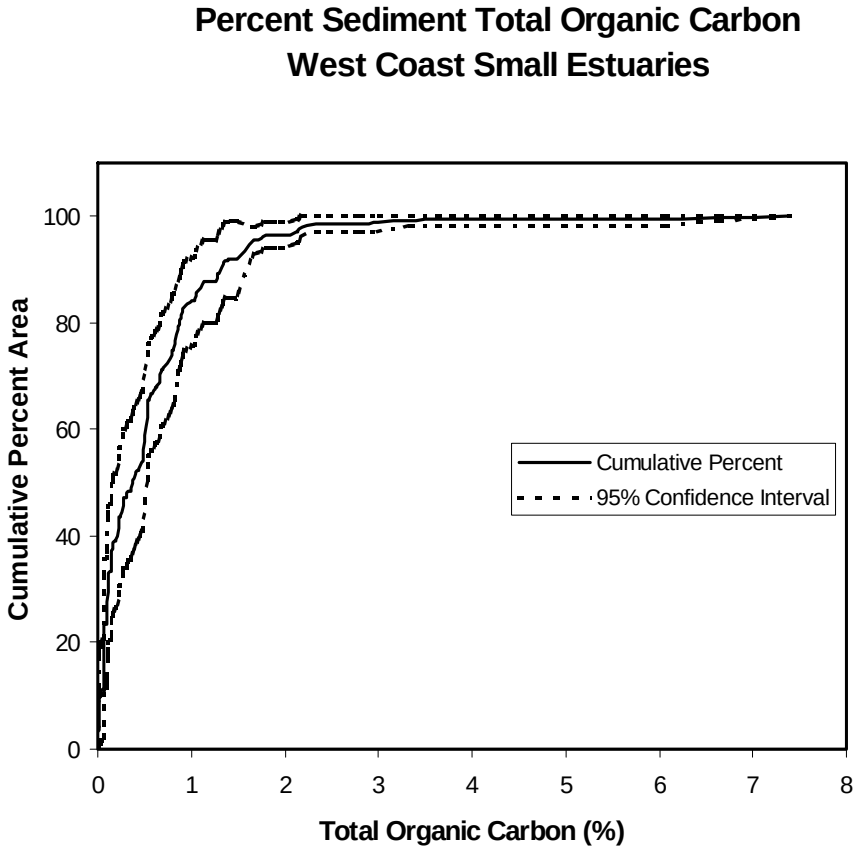

Figure 3.1-5. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. percent total organic carbon of sediments.

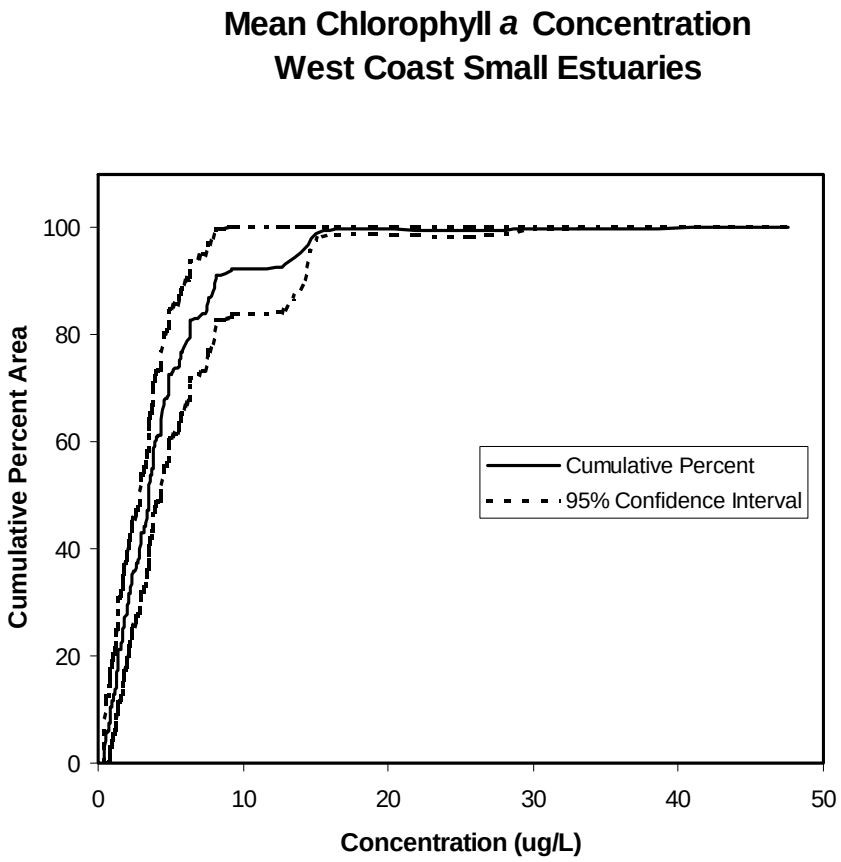

Figure 3.1-6. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column mean concentration of chlorophyll *a*.

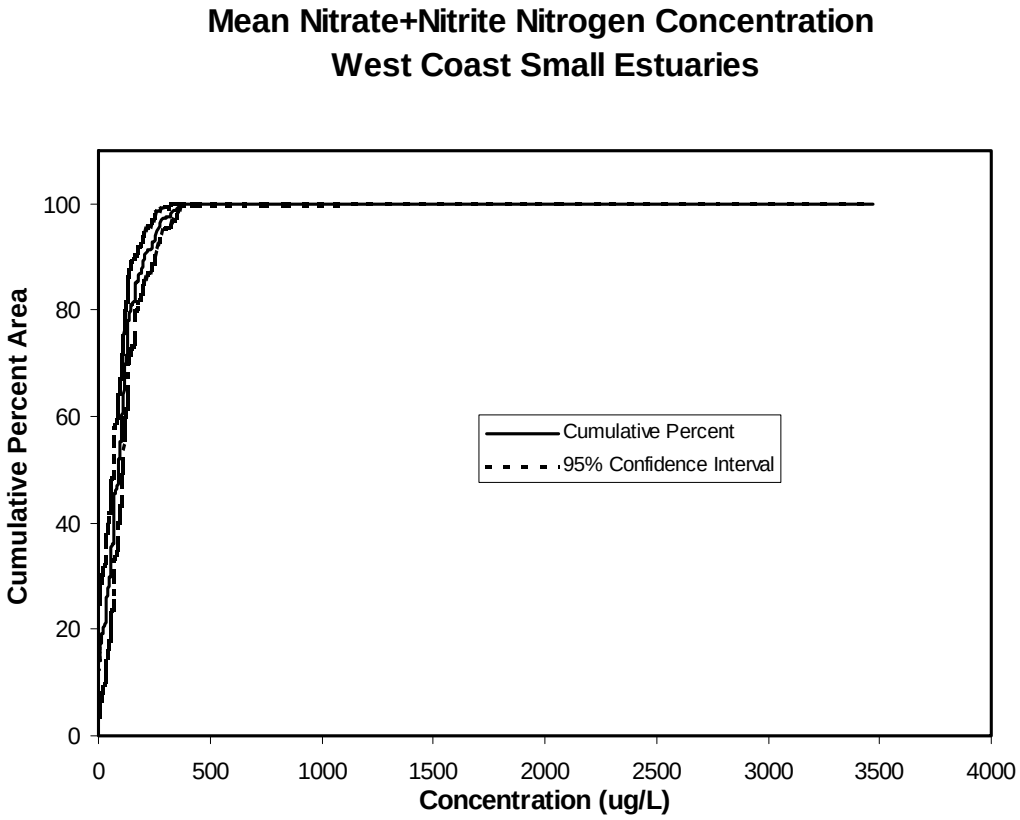

Figure 3.1-7. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column mean nitrate + nitrite concentration.

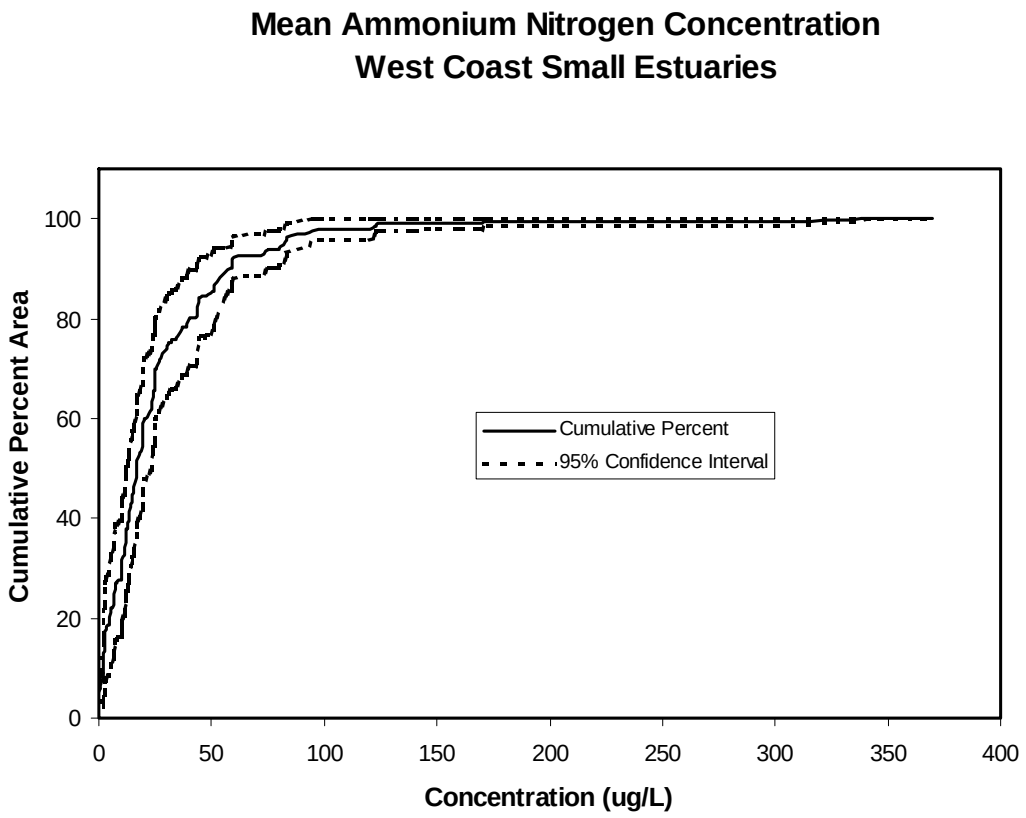

Figure 3.1-8. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column mean ammonium concentration.

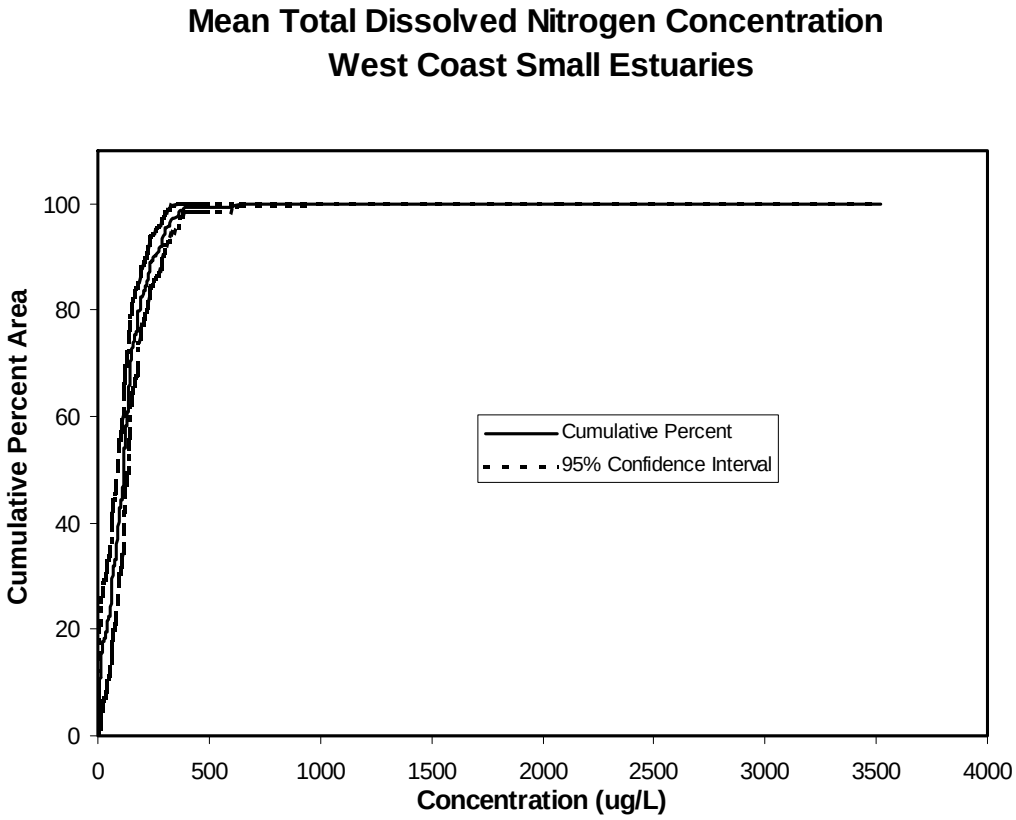

Figure 3.1-9. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column mean total nitrogen (nitrate + nitrite + ammonium) concentration.

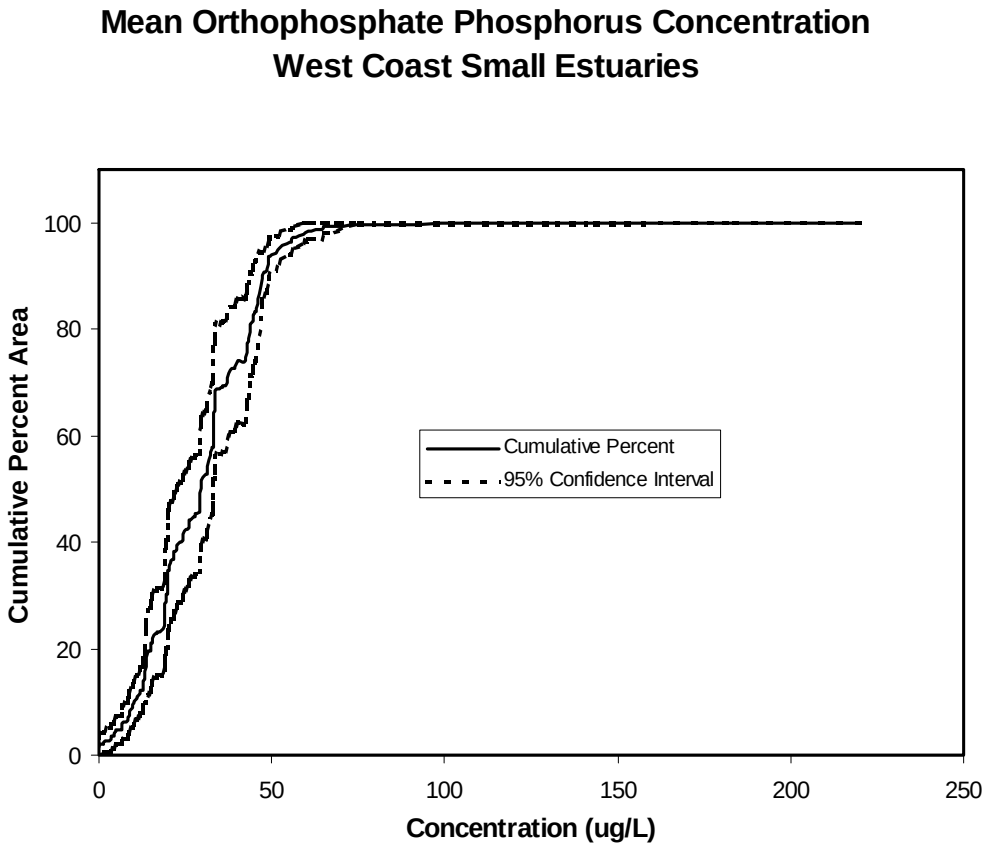

Figure 3.1-10. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column mean orthophosphate concentration.

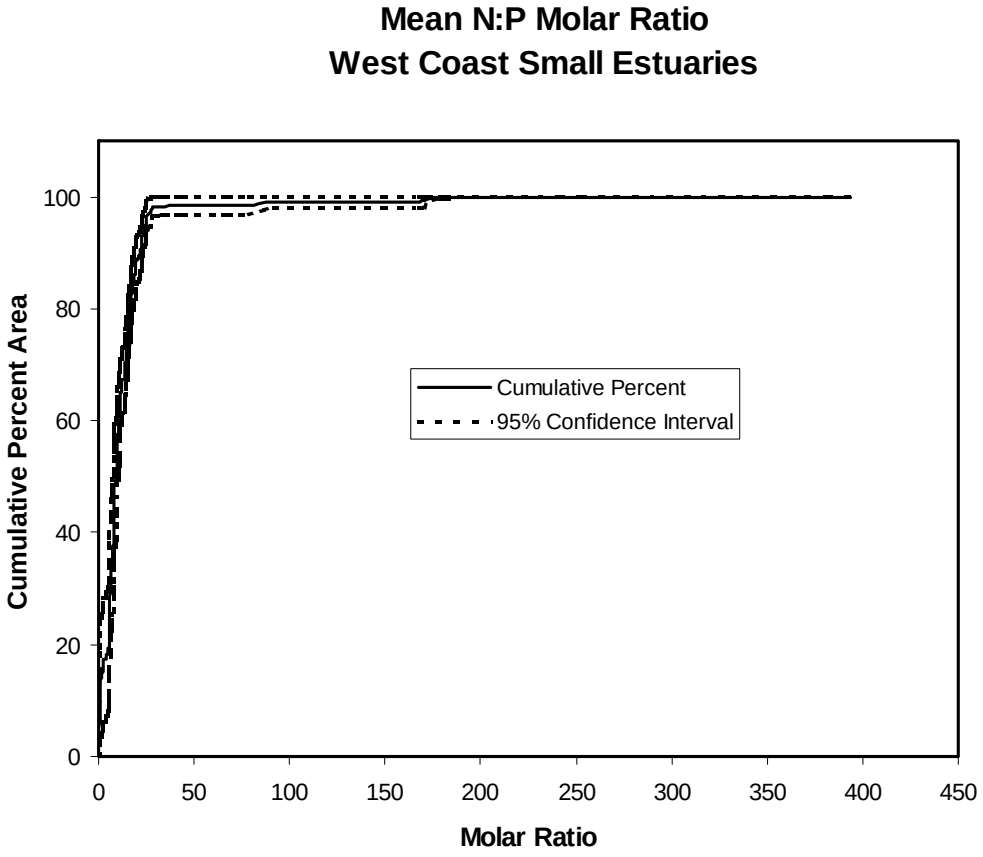

Figure 3.1-11. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column mean ratio of total nitrogen (nitrate + nitrite + ammonium) concentration to total orthophosphate concentration.

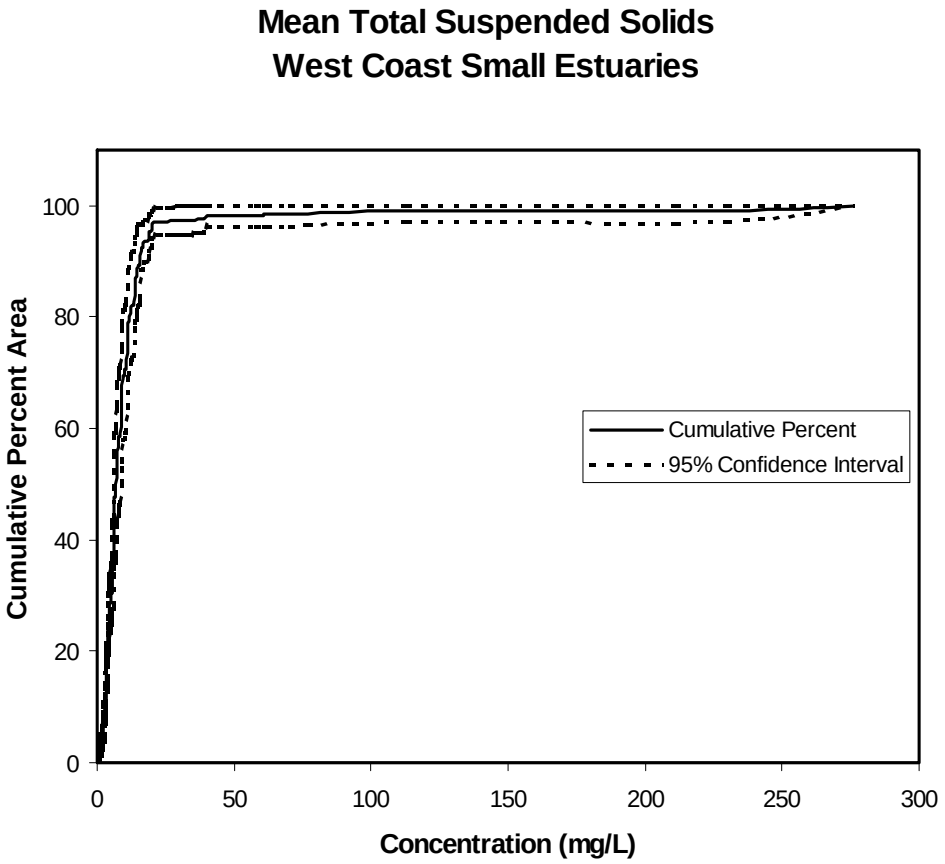

Figure 3.1-12. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column total suspended solids concentration.

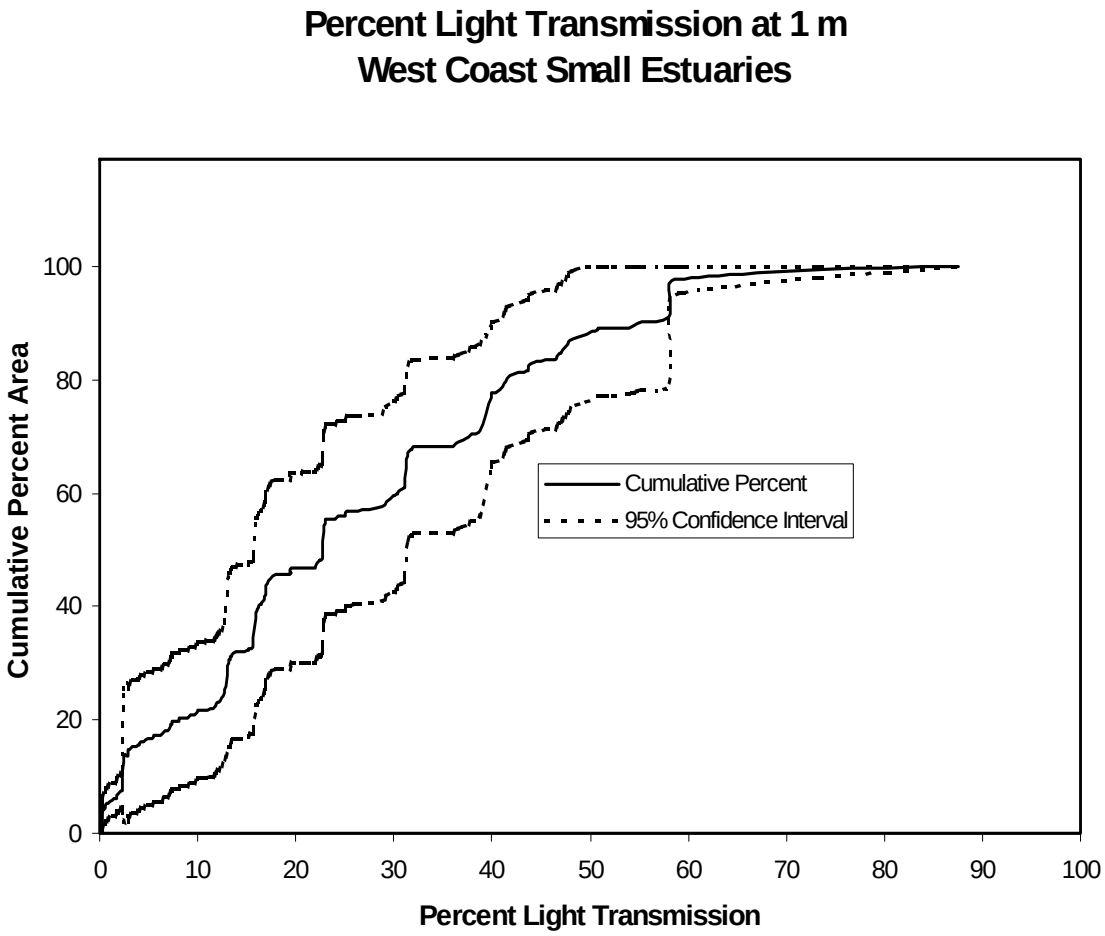

Figure 3.1-13. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. percent light transmission estimated at a reference depth of 1 m in the water column.

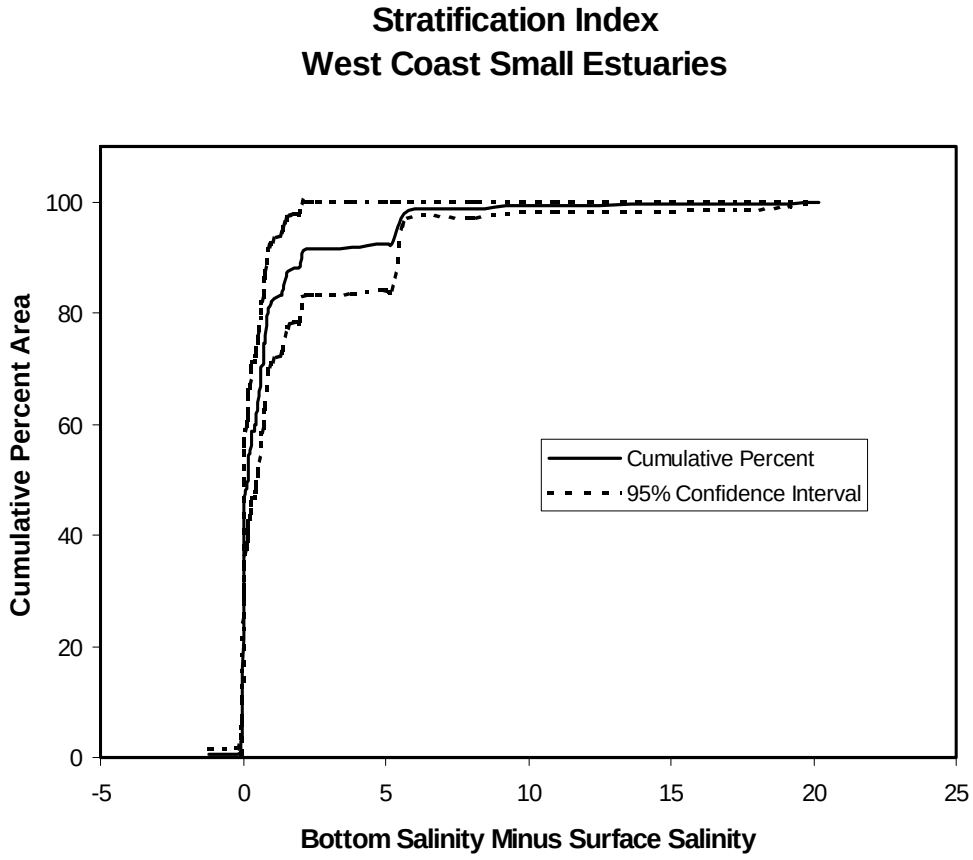

Figure 3.1-14. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. water column stratification index.

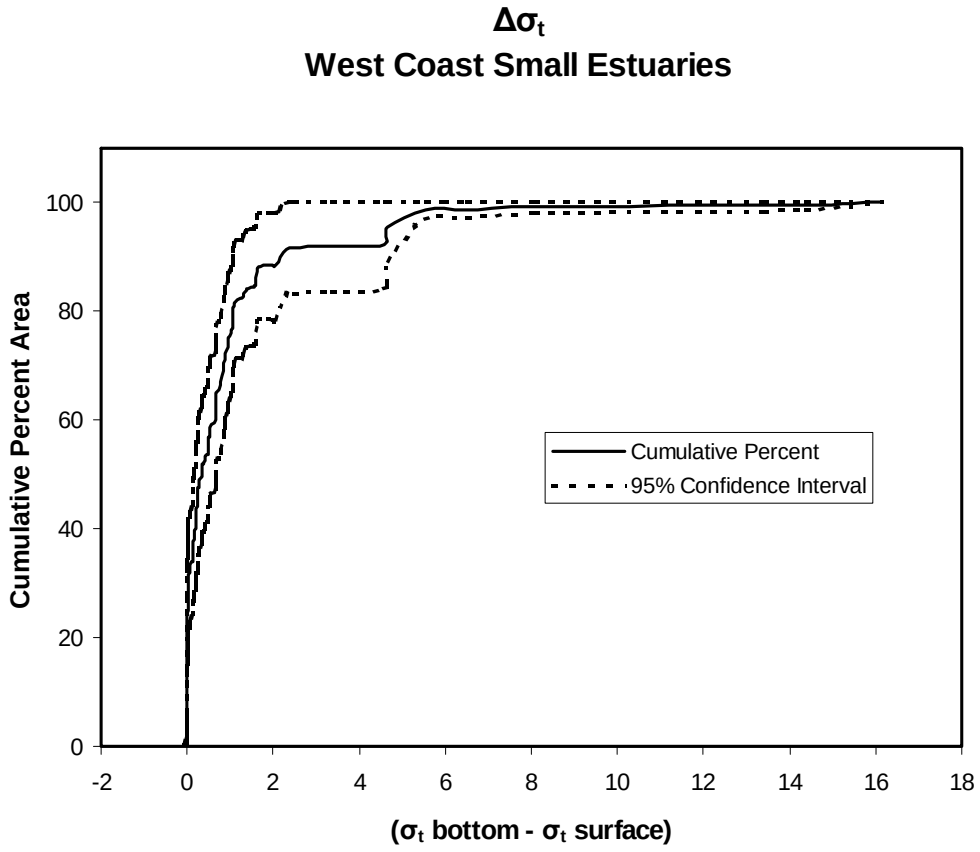

Figure 3.1-15. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. $\Delta\sigma_t$ stratification index.

3.2 Exposure Indicators

3.2.1 Dissolved Oxygen

Dissolved oxygen (DO) concentrations in the bottom water for the small estuaries of West Coast states ranged from 3.75 mg L^{-1} to 16.3 mg L^{-1} across the 200 stations where dissolved oxygen concentrations were measured. No observations were less than the value of 2 mg L^{-1} considered indicative of anoxia, less than four percent of estuarine area had a bottom DO concentration below 5 mg L^{-1}, and approximately 92% of the area of West Coast small estuaries had DO concentrations between 5 and 10 mg L^{-1} (Fig. 3.2-1). The range of dissolved oxygen (DO) concentrations in the surface waters was very similar to that for bottom waters (3.46 mg L^{-1} to 16.3 mg L^{-1}) (Fig. 3.2-2). Approximately 83% of the area of West Coast small estuaries had surface DO concentrations between 5 and 10 mg L^{-1}, while nearly 11 % had DO concentrations > 10 mg/L^{-1}.

3.2.2 Sediment Contaminants

3.2.2.1 Sediment Metals

Concentrations of metals in sediment were measured at 190 stations, except antimony and silver, which were measured at only 189 stations. The mean concentration of a metal was calculated using all available samples with the non-detects set to 0. For comparative purposes, mean concentrations of metals were also calculated using the subset of samples in which the metals were detected (Table 3.2-1).

Arsenic

Arsenic was detected in 189 of the stations and had a mean concentration of 6.11 µg/g (Table 3.2-1). The maximum concentration of 18.6 µg/g occurred in Grays Bay in the Columbia River, Washington. The next two highest concentrations of 17.6 and 17.1 µg/g occurred in Tillamook Bay, Oregon, and the Los Angeles Harbor, respectively. Fifty percent of the area of the West Coast small estuaries had concentrations less than 5.53 µg/g, and 90% of the area had concentrations less than 8.75 µg/g (Figure 3.2-3). Arsenic concentrations exceeded the ERL at 37 stations (14.8% of area), while no stations had values exceeding the ERM (Table 3.2-1).

Cadmium

Cadmium was detected in 164 of the stations and had a mean concentration of 0.219 µg/g (Table 3.2-1). The maximum concentration of 4.30 µg/g occurred in the Los Angeles Harbor. The only other value >1 µg/g was the 2.3 µg/g concentration in Discovery Bay, which opens into the Strait of Juan de Fuca, Washington. Fifty percent of the area of the West Coast small estuaries had cadmium concentrations less than 0.15 µg/g, and 90% of the area had concentrations less than 0.44 µg/g (Figure 3.2-4). Cadmium concentrations exceeded the ERL at only 2 stations (0.1% of area), while no stations had values exceeding the ERM (Table 3.2-1).

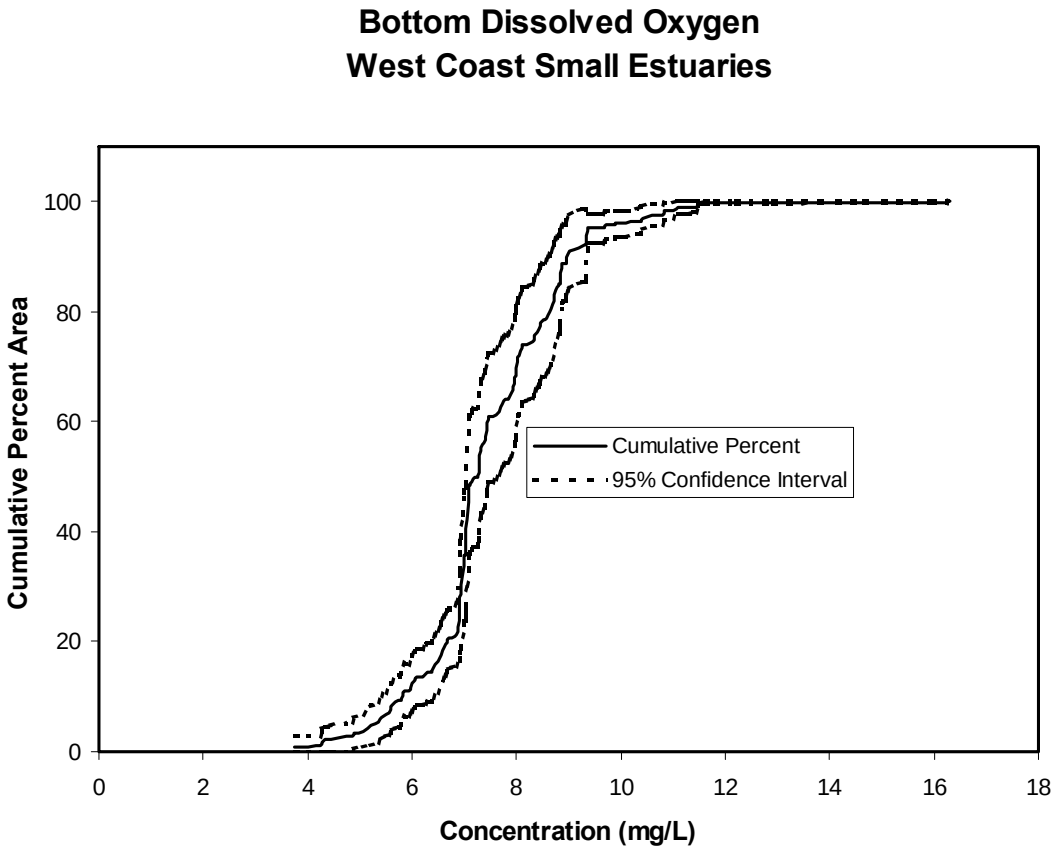

Figure 3.2-1. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. dissolved oxygen of bottom waters.

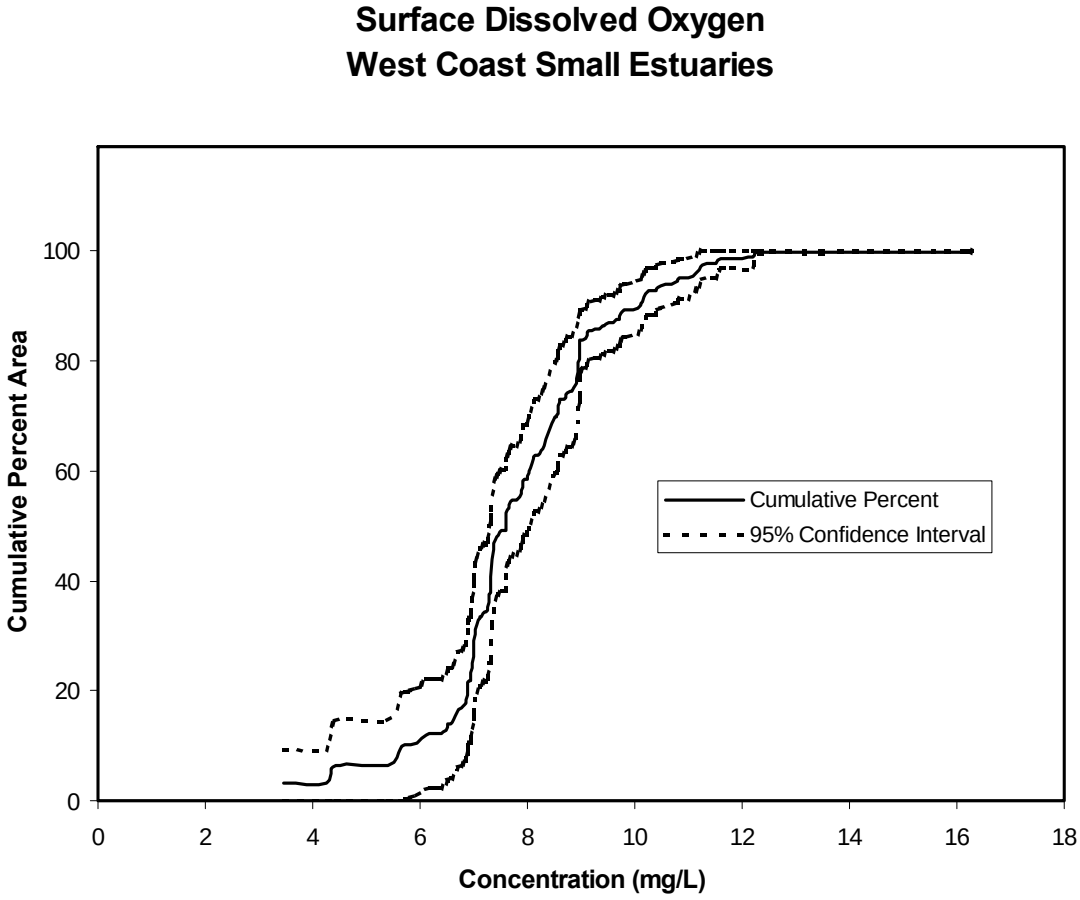

Figure 3.2-2. Percent area (and 95% C.I.) of small estuaries of the West Coast states vs. dissolved oxygen of surface waters.

Chromium
Chromium was detected at all 190 stations and had a mean concentration of 128 µg/g (Table 3.2-1). The two highest concentrations of 1770 and 1250 µg/g both occurred in the Smith River, California. These were the only concentrations >1000 µg/g. Fifty percent of the area of the West Coast small estuaries had concentrations less than 48.6 µg/g, and 90% of the area had concentrations less than 168 µg/g (Figure 3.2 -5). Chromium concentrations exceeded the ERL at 68 stations (27% of area), while 10 stations (2.5% of area) had values exceeding the ERM (Table 3.2-1).

Copper
Copper was detected at all 190 stations and had a mean concentration of 26.7 µg/g (Table 3.2-1). The maximum concentration of 398 occurred in the Los Angeles Harbor. The only other value >100 µg/g was the 156 µg/g value in Santa Barbara Harbor, California. Fifty percent of the area of the West Coast small estuaries had concentrations less than 14.5 µg/g, and 90% had concentrations less than 55.2 µg/g (Figure 3.2-6). Copper concentrations exceeded the ERL at 54 stations (21.2% of area), while 1 stations (0.1% of area) had a value exceeding the ERM (Table 3.2-1).

Lead
Lead was detected at all 190 stations and had mean concentration of 13.6 µg/g (Table 3.2-1). The maximum concentration of 293 µg/g occurred in the Los Angeles Harbor, and the second highest value of 80 µg/g occurred in Santa Barbara Harbor, California. Fifty percent of the area of the small estuaries had lead concentrations less than 8.87 µg/g, and 90% of the area had concentrations less than 20.4 µg/g (Figure 3.2-7). Lead concentrations exceeded the ERL at only 5 stations (1.3% of area), while 1 station (0.07% of area) had a value exceeding the ERM (Table 3.2-1).

Mercury
Mercury was detected at 180 of the stations and had a mean concentration of 0.113 µg/g (Table 3.2-1). The maximum concentration of 3.11 µg/g occurred in the Estero Americano, California. The only other values >1 µg/g occurred in the Los Angeles Harbor and the Albion River, California, which had concentrations of 2.33 and 1.37 µg/g, respectively. Fifty percent of the area of the West Coast small estuaries had mercury concentrations less than 0.03 µg/g, and 90% of the area had concentrations less than 0.16 µg/g (Figure 3.2-8). Mercury concentrations exceeded the ERL at 25 stations (12.1% of area), while 3 stations (0.1% of area) had values exceeding the ERM (Table 3.2-1).

Nickel
Nickel was detected at all 190 stations and had a mean concentration of 47.6 µg/g (Table 3.2-1). The two highest concentrations, 354 µg/g and 307 µg/g, both occurred in the Smith River, California. Fifty percent of the area of the West Coast small estuaries had nickel concentrations less than 18.6 µg/g, while 90% of the area had concentrations less than 50.0 µg/g (Figure 3.2-9). Nickel concentrations exceeded the ERL at 116

stations (43.7% of area), while 45 stations (9.4% of area) had values exceeding the ERM (Table 3.2-1). Nickel concentrations in relation to the published ERM values should be interpreted cautiously since the ERM value has a low reliability (Long et al., 1995). Because of its unreliability, nickel was excluded from a recent evaluation of sediment quality in southern Puget Sound (Long et al., 2000). Additionally, a study of metal concentrations in cores on the West Coast determined an historical background concentration of nickel in the range of 35 - 70 ppm (Lauenstein et al., 2000), which brackets the value of the ERM (51.6 ppm).

Selenium

Selenium was detected at 78 of the stations and had a mean concentration of 0.107 µg/g (Table 3.2-1). The maximum concentration of 1.6 µg/g occurred in the Los Angeles Harbor. Of the seven other values >0.5 µg/g, six occurred in California and one in Oregon. Approximately 71% of the area of the West Coast small estuaries had non-detectable levels of selenium, and 90% had concentrations less than 0.25 µg/g (Figure 3.2-10). No stations exceeded either the ERL or ERM for selenium.

Silver

Silver was detected at 178 of the stations and had a mean concentration of 0.16 µg/g (Table 3.2-1). The maximum concentration of 1.13 µg/g occurred in the Los Angeles Harbor. The second and third highest values of 0.98 and 0.92 µg/g were found in Grays Bay, Washington, and San Diego Bay, respectively. Fifty percent of the area of the West Coast small estuaries had a silver concentrations less than 0.21 µg/g, while 90% of the area had concentrations less than 0.48 µg/g (Figure 3.2-11). Silver concentrations exceeded the ERL at only 1 station (0.1% of area) (Table 3.2-1), and no stations exceeded the ERM.

Tin

Tin was detected at 130 stations and had a mean concentration of 1.24 µg/g (Table 3.2-1). The maximum concentration of 17.3 µg/g occurred in the Los Angeles Harbor. The only other value greater than 10 µg/g was in the Albion River, California, which had a concentration of 11.6 µg/g. Fifty percent of the area of the West Coast small estuaries had a tin concentration less than 0.99 µg/g, while 90% of the area had concentrations less than 2.67 µg/g (Figure 3.2-12).

Zinc

Zinc was detected at all 190 stations and had a mean concentration of 69.5 µg/g (Table 3.2-1). The maximum concentration of 538 µg/g occurred in the Los Angeles Harbor, while the next highest value, 173 µg/g, was found in both the Santa Barbara Harbor and San Diego Bay. Fifty percent of the area of the West Coast small estuaries had zinc concentrations less than 49 µg/g, while 90% of the area had concentrations less than 117 µg/g (Figure 3.2-13). Zinc concentrations exceeded the ERL at 4 stations (1.2% of area), while 1 station (0.1% of area) had a value exceeding the ERM (Table 3.2-1).

Additional Metals

In addition to the 11 metals discussed above, aluminum, antimony, iron, and manganese were measured in the sediments. The measured concentration and frequency of detection for each of these metals are given in Table 3.2 -1. Each of these four metals was detected at all of the stations, with the exception of antimony, which was detected at 115 stations. Not unexpectedly, aluminum and iron were the two most abundant metals, with mean concentrations of 44631 µg/g and 33642 µg/g, respectively.

Table 3.2-1. Summary statistics for sediment metal concentrations (µg/g) for all stations from West Coast estuaries. The overall mean and the overall standard deviation (SD) were calculated using all the data, including the non-detects which were set to 0. (N = 190, except 189 for antimony and silver). The "mean when present" was calculated using the samples which had detectable concentrations of the compound. ERL and ERM values are from Long et al. (1995).

Metal	Overall Mean Concen-tration	Overall SD	Mean Concen-tration when Present	Min	Max	Frequency of detection	ERL	ERM	>ERL No. Sites	>ERM No. Sites	>ERL Area	>ERM Area
Aluminum	44631	19837	44631	3030	78800	190						
Antimony	0.432	1.24	0.71	0	16.4	115						
Arsenic	6.11	3.05	6.14	0	18.6	189	8.2	70.0	37	0	14.8	0
Cadmium	0.219	0.38	0.254	0	4.3	164	1.2	9.6	2	0	0.1	0
Chromium	128	209	128	9.2	1770	190	81	370	68	10	27	2.5
Copper	26.7	34.8	26.7	2.1	398	190	34	270	54	1	21.2	0.01
Iron	33600	18600	33600	6000	87500	190						
Lead	13.6	22.7	13.6	3.0	293	190	46.7	218.	5	1	1.3	0.07
Manganese	485	278	485	84.8	1390	190						
Mercury	0.113	0.302	0.120	0	3.11	180	0.15	0.71	25	3	12.1	0.1
Nickel	47.6	55.4	47.6	3.3	354	190	20.9*	51.6*	116*	45*	43.7*	9.4*
Selenium	0.107	0.209	0.261	0	1.60	78	2.0	25.0	0	0	0	0
Silver	0.16	0.20	0.17	0	1.13	178	1.0	3.7	1	0	0.1	0
Tin	1.24	1.86	1.81	0	17.3	130						
Zinc	69.5	52.0	69.5	7.9	538	190	150	410	4	1	1.2	0.1

* The ERL and ERM for nickel has low reliability for the West Coast. See text for discussion.

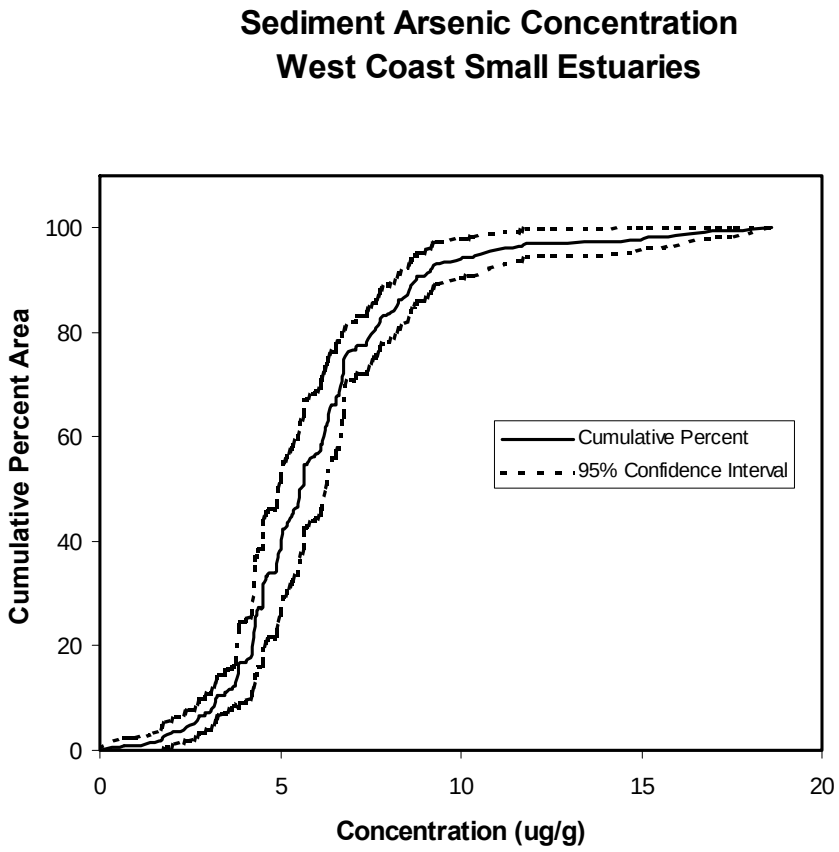

Figure 3.2-3. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of arsenic.

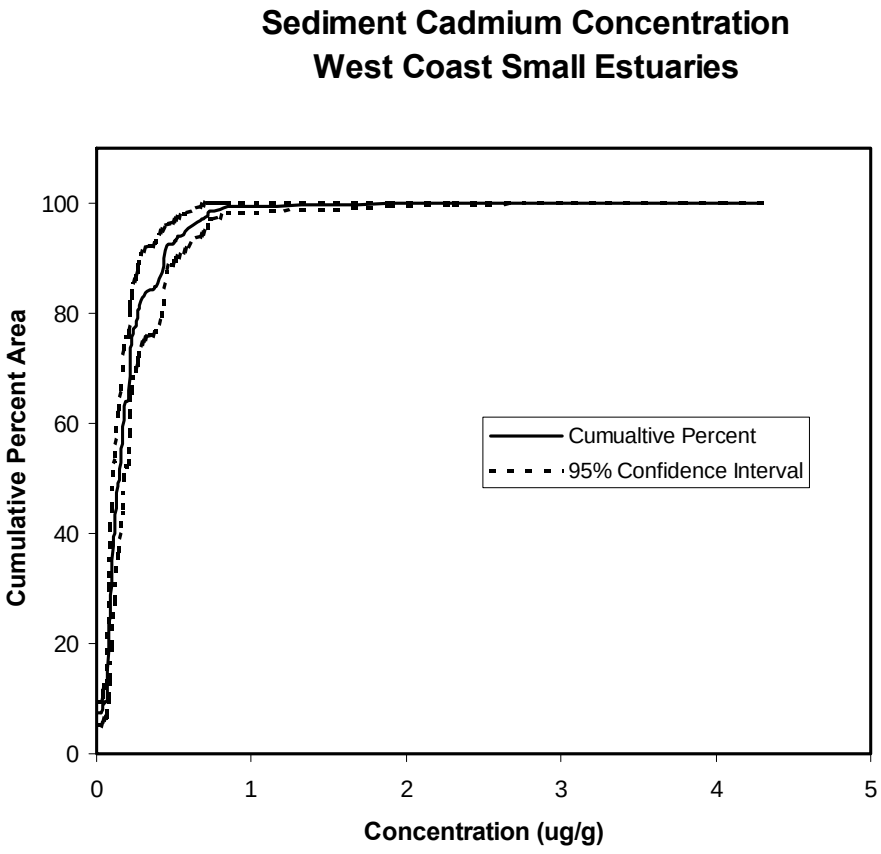

Figure 3.2-4. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of cadmium.

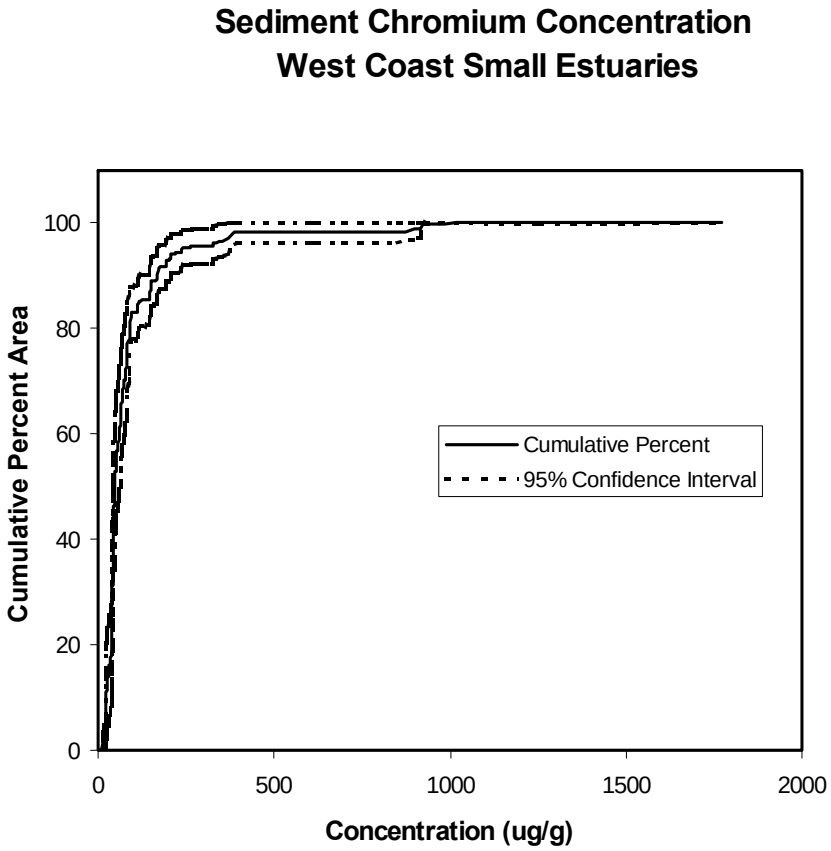

Figure 3.2-5. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of chromium.

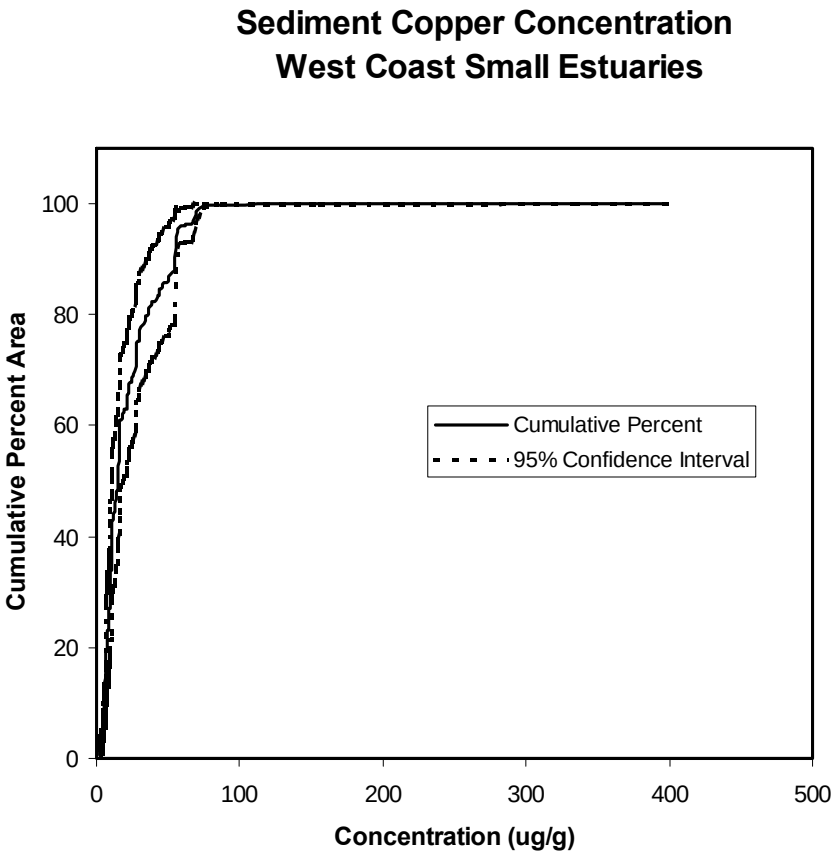

Figure 3.2-6. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of copper.

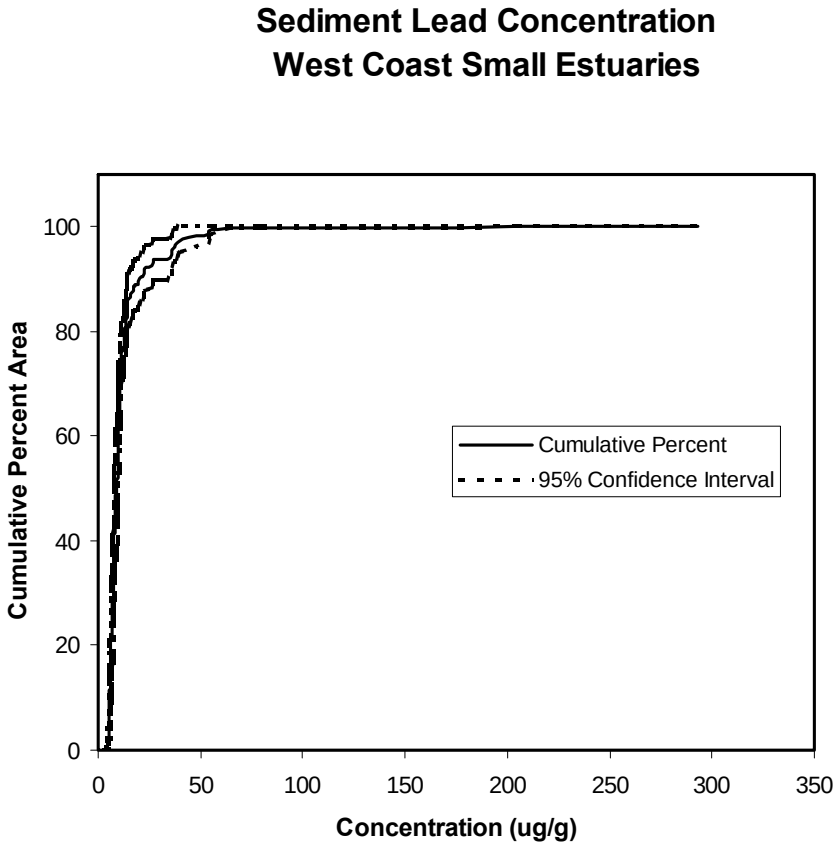

Figure 3.2-7. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of lead.

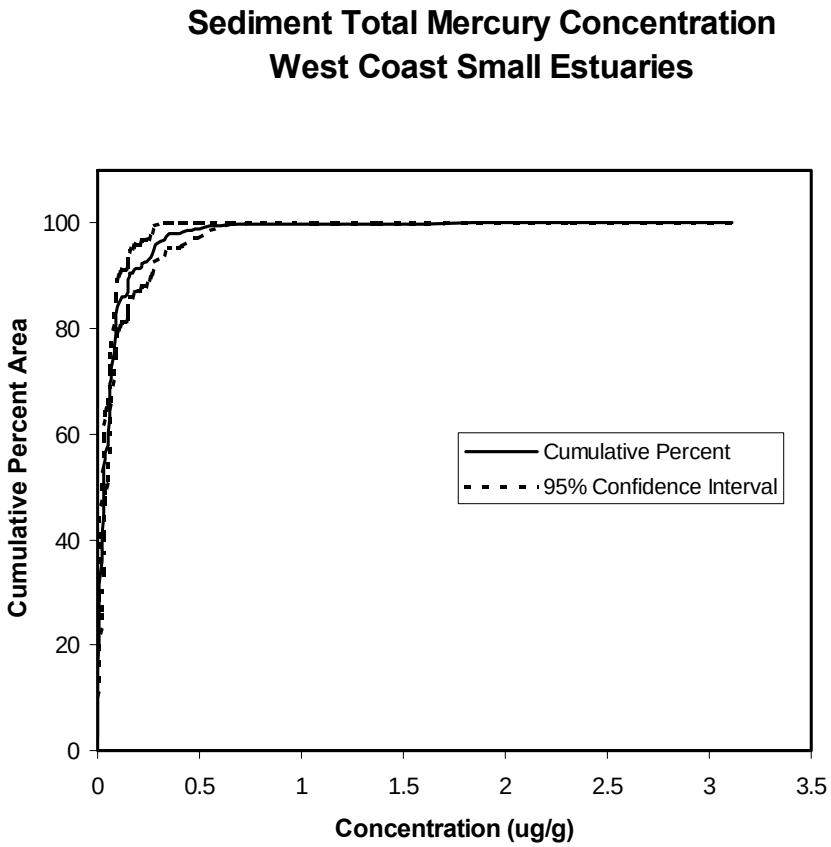

Figure 3.2-8. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of mercury.

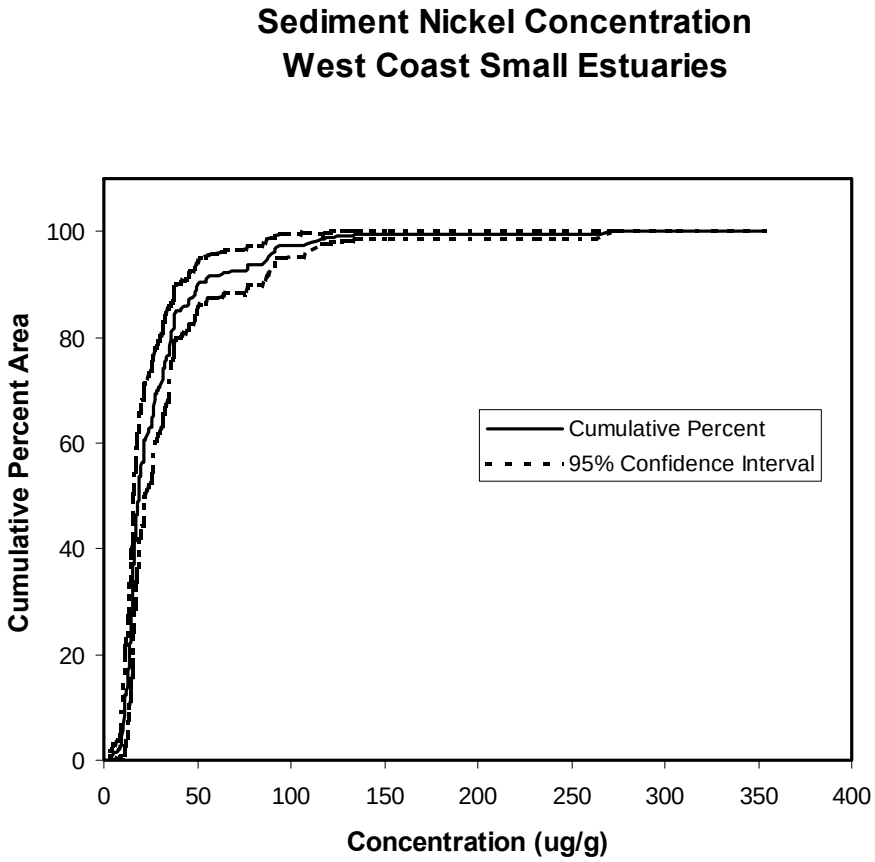

Figure 3.2-9. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of nickel.

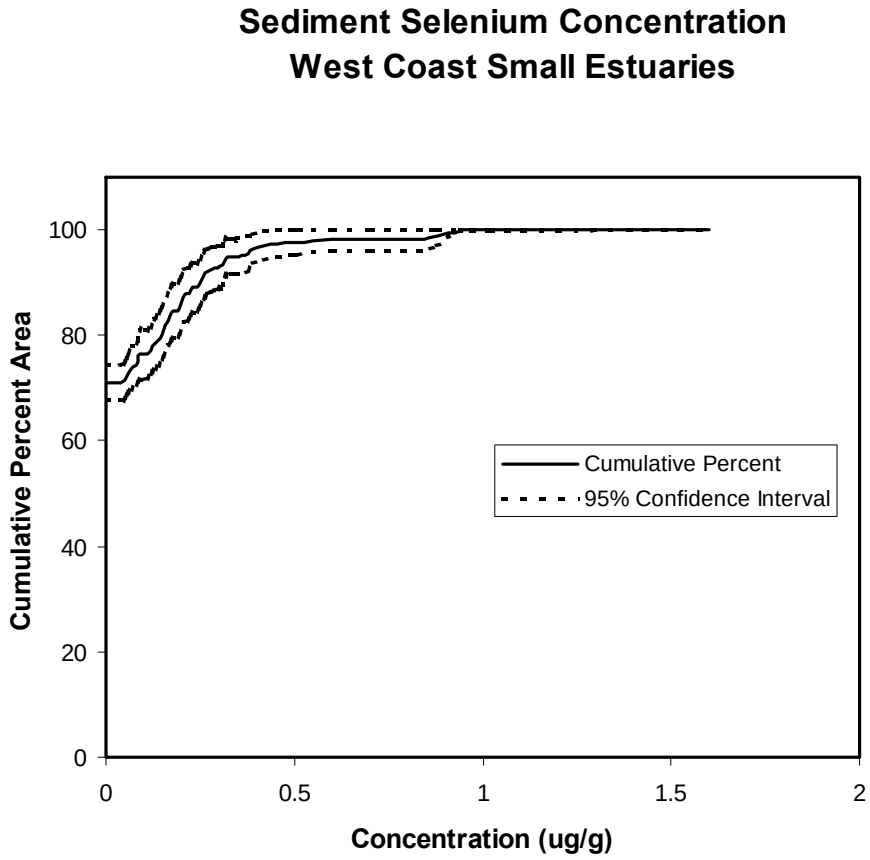

Figure 3.2-10. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of selenium.

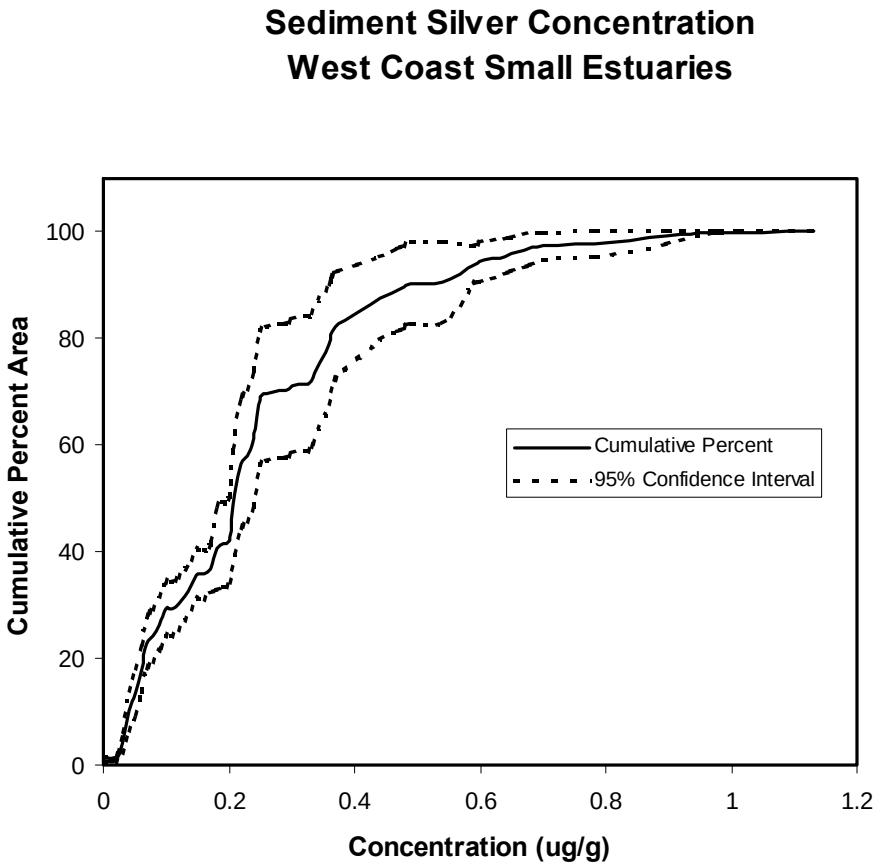

Figure 3.2-11. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of silver.

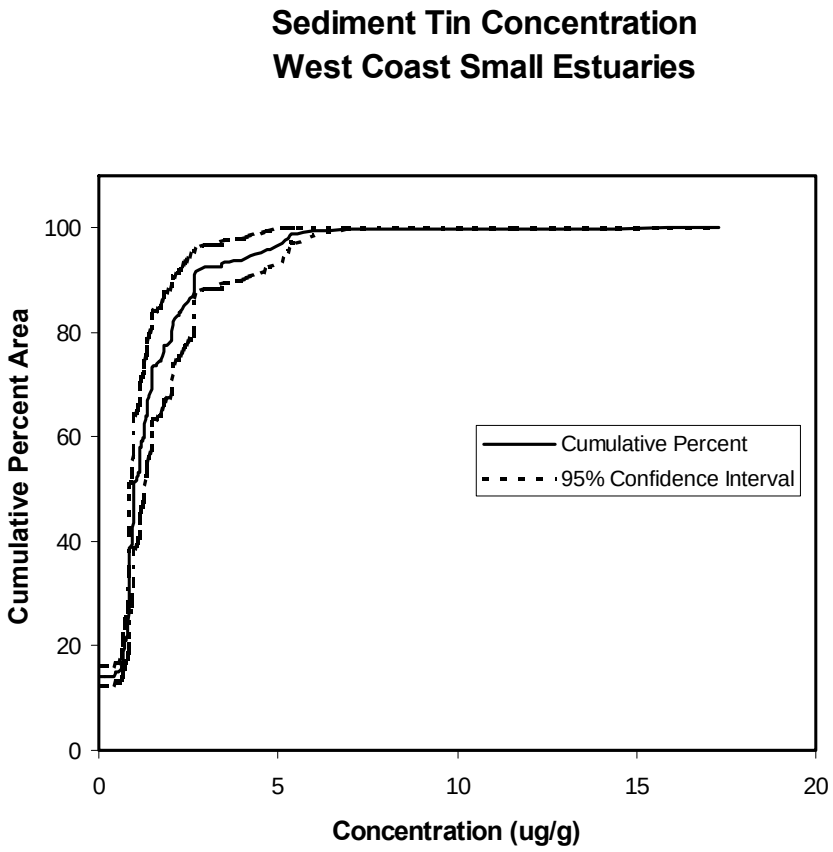

Figure 3.2-12. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of tin.

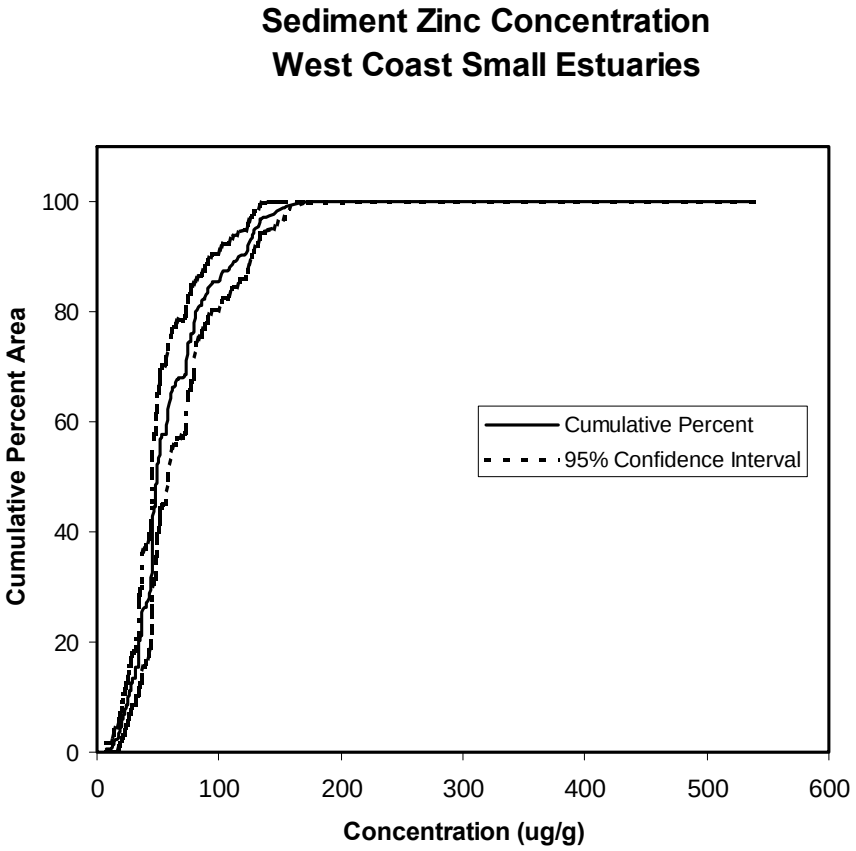

Figure 3.2-13. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of zinc.

3.2.2.2 Sediment Organics

An overall mean concentration was calculated for sediment organics using all the samples (N=190) with the non-detects set to 0. "Mean concentrations when present" were also calculated using the subset of samples in which the compounds were detected (Table 3.2-2)

Total PAHs

PAHs were detected at 112 of the stations. One laboratory replicate from a sediment sample from Martin Slough in the Columbia River had individual PAH concentrations 3 to 690 times greater than in the other three replicates from the same sample. Total PAH concentration for this sample was 59,878 ng/g if the high laboratory replicate was included, but 2427 ng/g if it was excluded. The order-of-magnitude higher concentrations in this replicate could be due to a drop of creosote. Because the sample appears to be an outlier relative to the other laboratory replicates at the station, this sample was not included in the total PAH analysis.

Total PAHs had an overall mean concentration of 263 ng/g dry weight (Table 3.2-2). The highest concentration, 22,982 ng/g, occurred in the Los Angeles Harbor. The compounds 2,6-Dimethylnaphthalene, 2,3,5-Trimethylnaphthalene, and 1-Methylphenanthrene constituted 61% of the total PAHs at the Los Angeles Harbor site. Fifty percent of the area of the West Coast small estuaries had a total PAH concentration less than 25 ng/g, and 90% of the area had a concentration less than 435 ng/g (Figure 3.2-14). On the average, low molecular weight (LMW) PAHs constituted 57 % of the total PAHs, while high molecular weight (HMW) PAHs constituted 43 % of the total PAHs (Table 3.2-2). Four stations exceeded the ERL for both HMW (0.2 % of area; Figure 3.2-15) and LMW PAHs (0.9 % of area; Figure 3.2-16), and two stations exceeded the ERL (0.2 % of area) for total PAHs. The ERM was exceeded only for LMW PAHs at two stations (Table 3.2-2).

Total PCBs

PCBs were detected at 78 of the stations, and total PCBs had an overall mean concentration of 3.72 ng/g dry weight (Table 3.2-2). The maximum concentration of 86.5 ng/g dry weight occurred in San Diego Bay, while the second highest concentration of 66.2 ng/g occurred in the Los Angeles Harbor. Seventy-three percent of the area of the West Coast small estuaries had non-detectable levels of PCBs, while 90% of the area had concentrations less than 7.5 ng/g (Figure 3.2-17). PCB18 was the most abundant PCB conger and made up 18% of the total PCBs on average. The next most abundant congener was PCB52, which made up 11% of the total PCBs. PCB18 and PCB52 were also the most frequently detected PCB congeners, occurring in 69 and 68 of the stations, respectively. The ERL for total PCBs was exceeded at 7 stations (2.2% of area), while no stations exceeded the ERM (Table 3.2-2).

Total DDT

DDT or one of its metabolites was detected at 28 of the stations, including 13 in California, 3 in Oregon and 9 in Washington. Total DDT had an overall mean concentration of 3.29 and a maximum concentration of 301 ng/g dry weight in the Channel Island Harbor in Southern California (Table 3.2-2). The only two other values >50 ng/g were the 99 and 50 ng/g concentrations in the Long Beach Harbor and the Los Angeles Harbor, respectively. Eighty-eight percent of the area of the small estuaries had non-detectable levels of DDTs, while 90% of the area had total DDT concentrations less than 0.31 ng/g (Figure 3.2-18). The most abundant form was 4,4'-DDD, constituting 77% of the total DDT on average (Table 3.2-2). The concentration of 4,4'-DDD exceeded the ERL at 15 stations (6.1% of area), and exceeded the ERM at 3 stations (1.6% of area) (Table 3.2-2). The ERL for total DDT was exceeded at 17 stations (6.2% of area), while the ERM was exceeded at 3 stations (0.1% of area) (Table 3.2-2).

Additional Pesticides

Besides DDT, an additional 12 pesticides were measured in the sediments in all three states (Table 3.2-2). Of these Dieldrin, Endosulfan II and Mirex were never detected at any station. The other pesticides occurred in 3 to 11 of the 190 sediment samples. An overall mean concentration was calculated for each of these pesticides using all the samples (N=190) with the non-detects set to 0. Because of their low frequency of detection, means were also calculated for these pesticides using just the samples in which the pesticides were detected. Endrin had the highest concentrations, with an overall mean concentration of 0.36 ng/g and a mean of 7.50 ng/g at the sites where it was detected. All nine sites where endrin was detected had concentrations which exceeded the ERL but not the ERM. Trans-nonachlor was the second most abundant of the additional pesticides, with an overall mean of 0.21 ng/g and a mean of 5.70 ng/g where detected. There was an insufficient number of detects to calculate CDFs for any of the additional pesticides.

Table 3.2-2. Mean sediment concentrations (ng/g dry weight) and frequency of detection of the PAHs, PCBs and pesticides measured in all three states. The overall mean and the overall standard deviation (SD) were calculated using all the data including the non-detects, which were set to 0. The "mean when present" was calculated using the samples which had detectable concentrations of the compound. N = 190. ERL and ERM values are from Long et al. (1995). NA - not analyzed, see text.

Analyte	Overall mean concentration ng/g dry wt	Overall SD	Mean concentration when present	Min	Max	Frequency of detection	ERL	ERM	>ERL No. Sites	>ERM No. Sites	>ERL Area %	>ERM Area %
HMW PAHs	112	371.2	199	0	2918	107	1700	9600	4	0	0.2	0
LMW PAHs	151	1460	398	0	20064	72	552	3160	4	2	0.9	0.1
Total PAHs	263	1700	446	0	22982	112	4022	44792	2	0	0.2	0
Total PCBs	3.72	9.57	9.05	0	86.5	78	22.7	180	7	0	2.2	0
2,4'-DDD	0.089	0.79	4.21	0	9.20	4						
2,4'-DDE	0.183	1.20	4.97	0	13.6	7						
2,4'-DDT	0.190	2.62	36.1	0	36.1	1						
4,4'-DDD	0.285	2.12	5.42	0	26.7	10						
4,4'-DDE	2.53	17.7	17.1	0	224	28	2.2	27.0	15	3	6.1	1.6
4,4'-DDT	0.015	0.20	2.80	0	2.80	1						
Total DDT	3.29	23.6	22.3	0	301	28	1.58	46.1	17	3	6.2	0.1
Aldrin	0.022	0.22	1.38	0	2.90	3						
Alpha-chlordane	0.067	0.42	2.54	0	3.50	5						
Dieldrin	0.000	0.00	0.000	0	0.00	0	0.02	8	0	0	NA	NA
Endosulfan I	0.020	0.28	3.80	0	3.80	1						
Endosulfan II	0.000	0.00	0.00	0	0.00	0						
Endosulfan Sulfate	0.053	0.40	2.54	0	3.60	4						
Endrin	0.355	1.60	7.50	0	7.50	9	0.02	45	9	0	NA	NA
Heptachlor	0.131	0.58	2.26	0	3.70	11						
Heptachlor Epoxide	0.053	0.54	5.00	0	6.70	2						
Lindane (gamma-BHC)	0.005	0.07	1.00	0	1.00	1						
Mirex	0.000	0.00	0.00	0	0.00	0						
Trans-nonachlor	0.210	1.31	5.70	0	12.7	7						

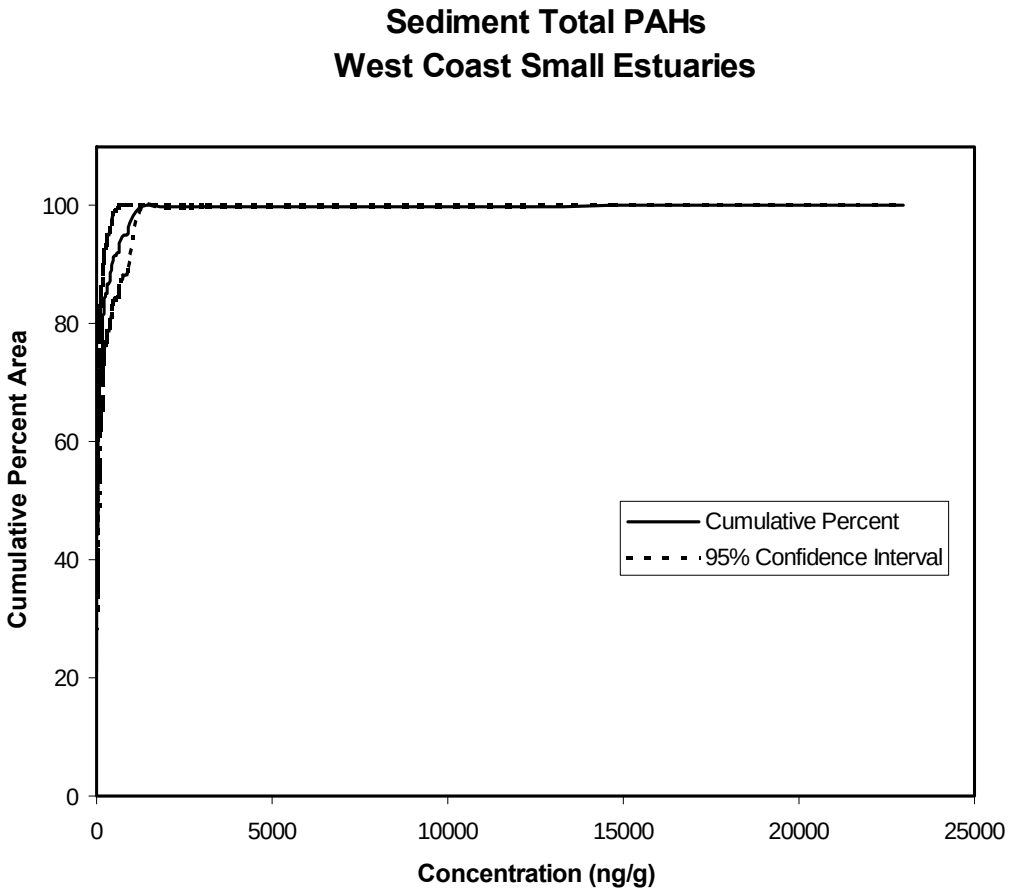

Figure 3.2-14. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of total PAHs.

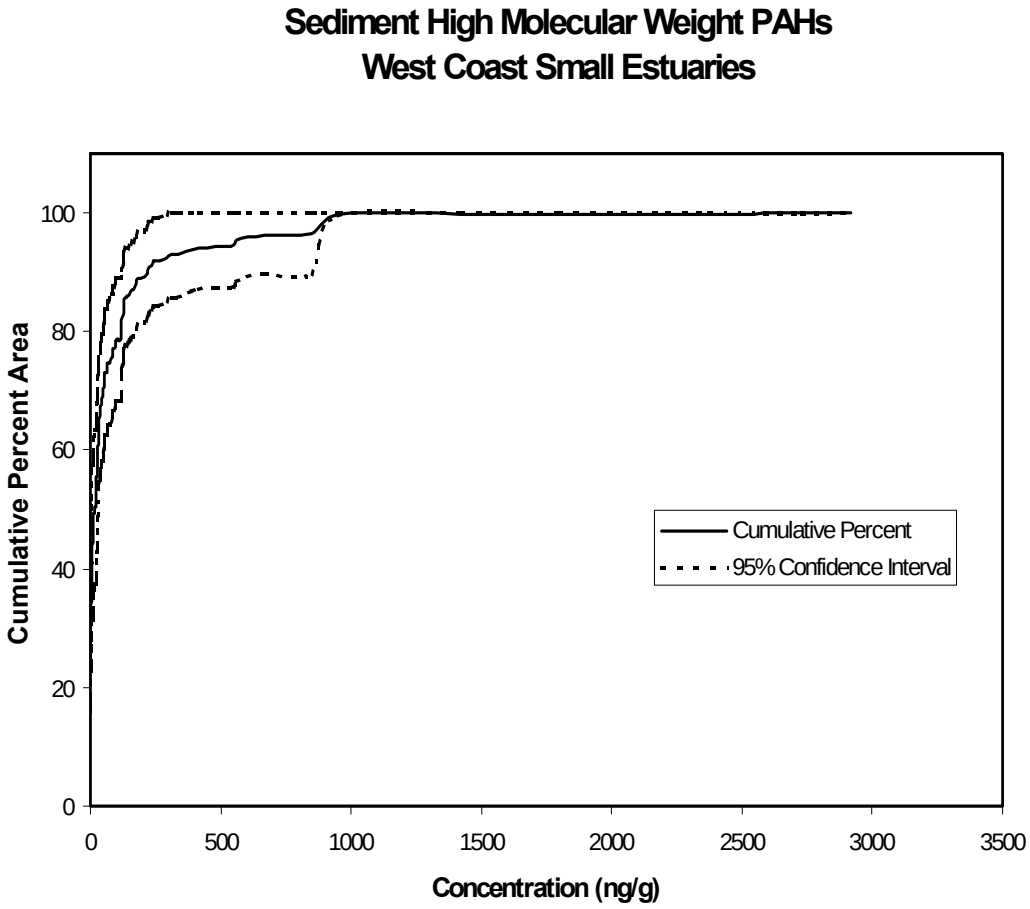

Figure 3.2-15. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of high molecular weight PAHs.

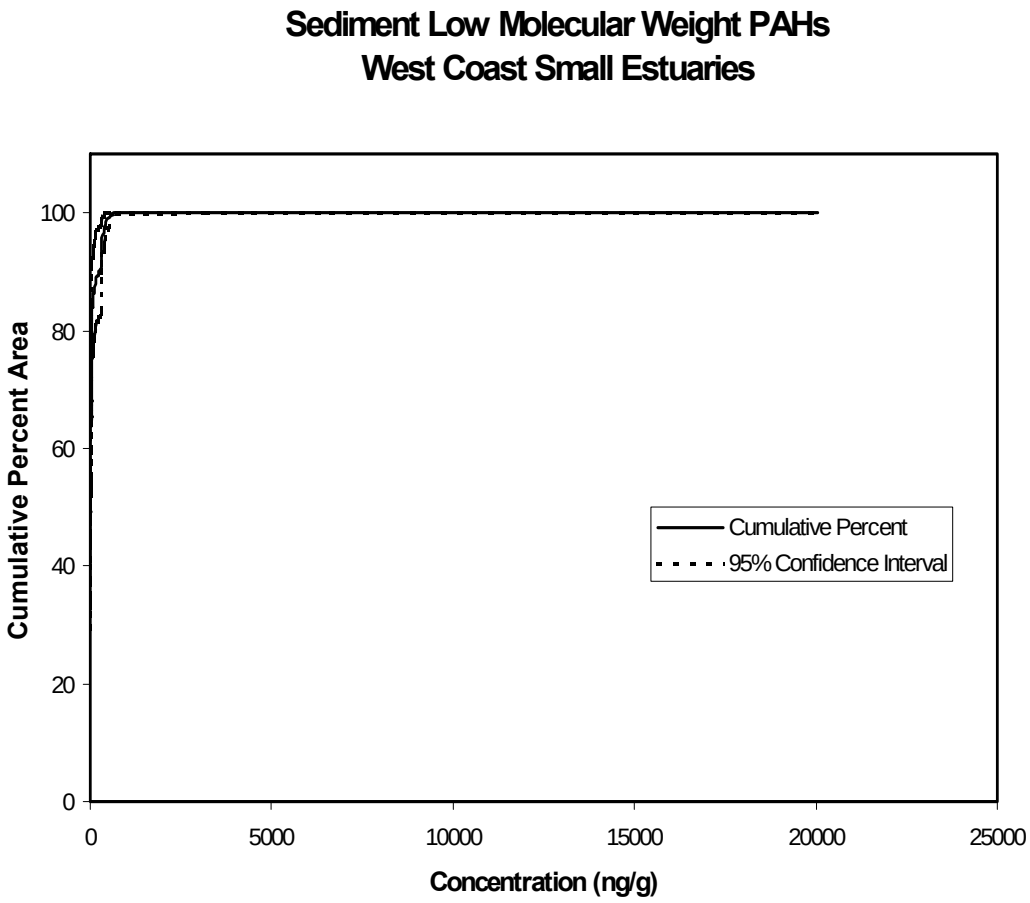

Figure 3.2-16. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of low molecular weight PAHs.

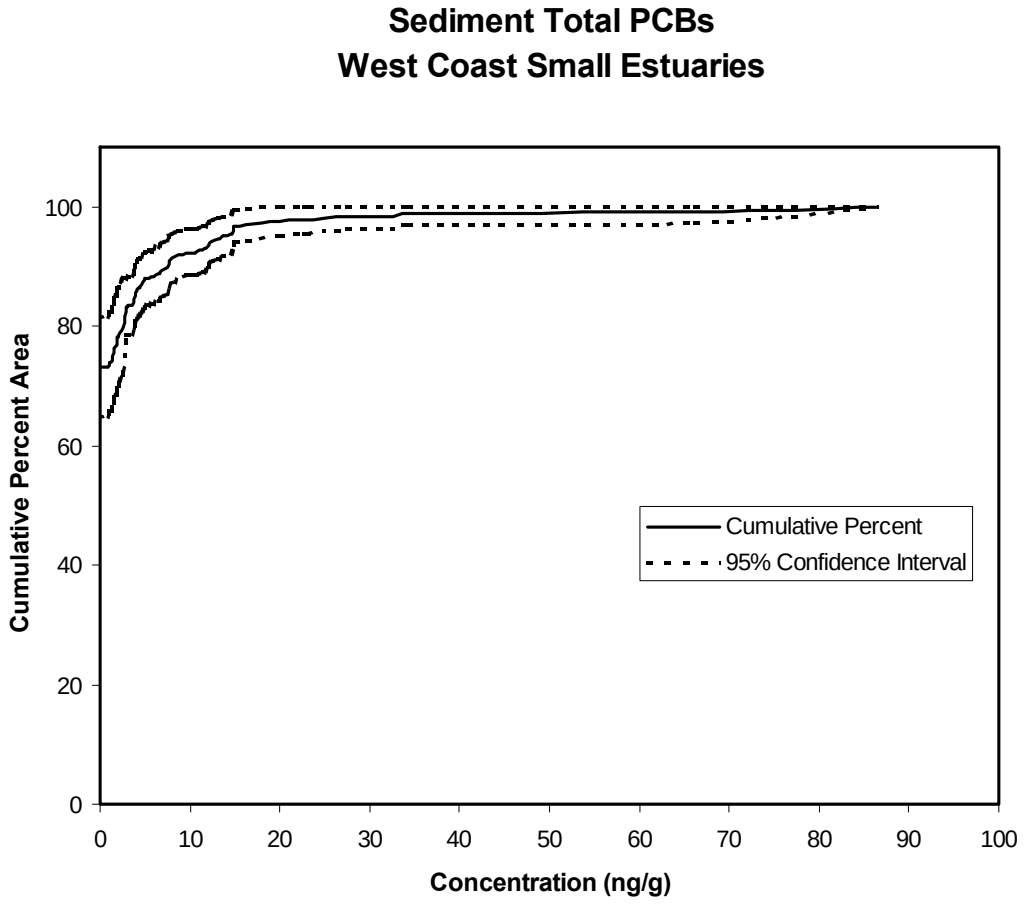

Figure 3.2-17. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of total PCBs.

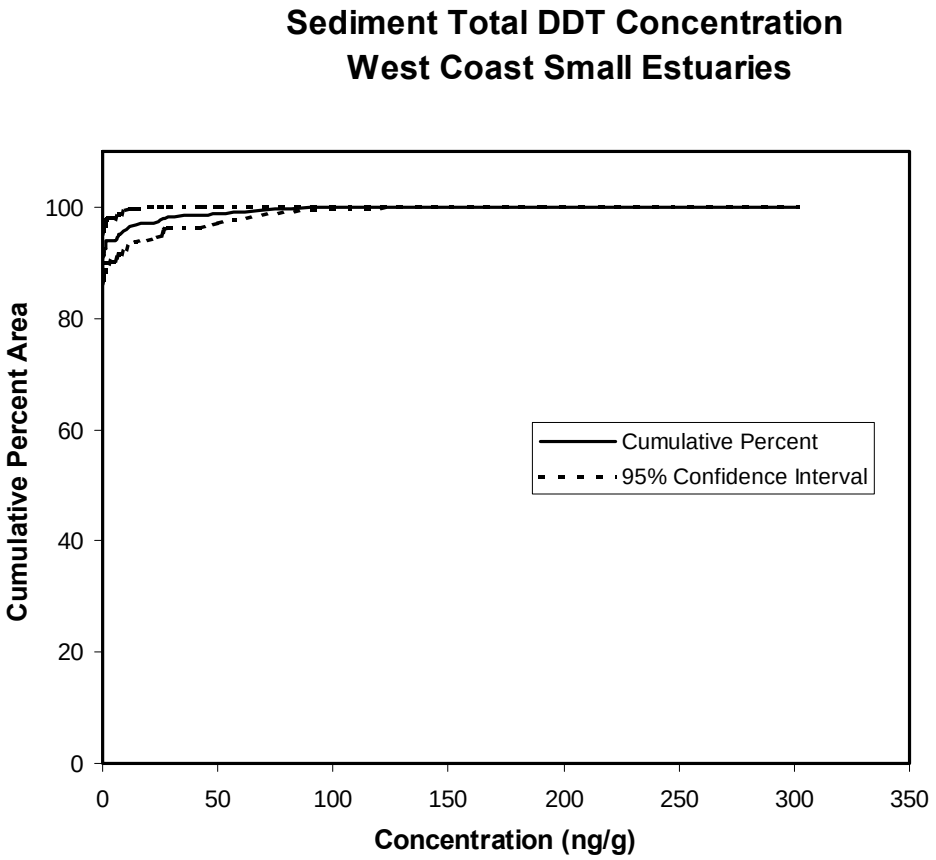

Figure 3.2-18. Percent area (and 95% C.I.) of West Coast small estuaries vs. sediment concentration of total DDT.

3.2.3 Sediment Toxicity

3.2.3.1 *Ampelisca abdita*

Sediment toxicity tests with the amphipod *Ampelisca abdita* were conducted on a total of 190 sediment samples, 41 in Washington, 76 in Oregon, and 73 in California. Control conditions for a successful toxicity test with this species require a mean of 90% survival in the five replicates in control sediments, with no replicate less than 80%. If the amphipods do not survive at acceptable levels in control replicates, it may be possible that they were unduly stressed due to shipping or laboratory holding conditions and that their response to test sediments may be compromised. The quality control requirements were not met in 24 of the 190 samples, and these samples were excluded from the CDF analysis, leaving 166 samples for analysis. The stations that were excluded included 7 in Washington, 6 in Oregon and 11 in California.

The control-corrected survivorship of *Ampelisca abdita* in bioassays of sediments collected in West Coast small estuaries (Figure 3.2 -19) ranged from 0 % to 109.9 % across the 166 stations that were included in the analysis. Approximately 9.2 % of the area of West Coast small estuaries (represented by 12 sites) had control-corrected survivorship of *Ampelisca abdita* in sediment bioassays < 80%. Over 19 % of area had control-corrected survivorship > 100 %, indicating better survival of amphipods in test sediments than in controls.

Four stations in Washington, one in Oregon and seven stations in California had mean survival in test sediments less than 80%. Only four stations had mean survival in test sediments less than 60%; these included two sites in the Smith River, one site in the Los Angeles River in California, and one site in Grays Bay, Washington. Of the 12 sites with survival less than 80%, five sites showed evidence of high levels of sediment contaminants.

3.2.3.2 *Arbacia punctulata*

Sediment porewater toxicity tests with sea urchins, *Arbacia punctulata*, were conducted on 41 sites in Washington, 36 base stations in Oregon, and 47 base stations in California, for a total of 124 samples. No sediments from the intensification sites in northern California or Tillamook Bay, Oregon, were tested with *Arbacia*. Five test sediments from Oregon (OR99-0018,..20,..24,..25,..26) and thirteen from California (CA99-0014,..15,..16,..17,..20, ..21,..22,..23,..25,..26,..28,..29,..30) arrived at the testing laboratory at temperatures that exceeded the acceptable temperature criterion. Since it is not known what effect the elevated temperatures may have on porewater toxicity, test results from those sediment samples were excluded from the CDF analysis. As described in Section 2.4.2.2.2, the designation of toxicity for *Arbacia* bioassays utilized two statistical test criteria for individual samples, rather than using a single survival standard as was done with the *Ampelisca* bioassays. The statistical test criteria in practice translate to a control corrected standard of approximately 85% fertilization success or embryonic survival in the CDF based analysis of data.

The control corrected mean percent fertilization of *A. punctulata* eggs in the 100% of the water quality adjusted (WQA) porewater treatment ranged from 0.2 % to 106 %, across the 97 stations that were included in the analysis (Figure 3.2-20). Approximately 7.4 % of the area of the West Coast small estuaries (12 sites) had control corrected mean percent fertilization of < 86 %, and thus would be considered to have toxic sediments based on this bioassay. For the 50 % of WQA porewater treatment, the range of mean percent fertilization was 5 % to 106 %, while 2.3% of estuarine area (6 sites) had values < 86% fertilization (Figure 3.2-21). For the 25 % of WQA porewater treatment, the range of mean percent fertilization was 50 % to 106 %, while 0.8 % of estuarine area (4 sites) had values < 85% fertilization (Figure 3.2-22).

The control corrected mean percent successful development of *A. punctulata* embryos in the 100 % of WQA porewater treatment ranged from 0 % to 103 %, across the 97 stations that were included in the analysis (Figure 3.2-23). Approximately 45 % of the area of the West Coast small estuaries (52 sites) had control corrected mean percent embryo development success of $\leq$ 87 %, and thus would be considered to have toxic sediments based on this bioassay. For the 50 % of WQA porewater treatment, the range of mean percent embryo development success was 0 % to 103 %, while 19.7 % of estuarine area (27 sites) had values < 85 % embryo development success (Figure 3.2-24). For the 25 % of WQA porewater treatment, the range of mean percent embryo development success was 0 % to 103 %, while 2.5 % of estuarine area (6 sites) had values < 86 % embryo development success (Figure 3.2-25).

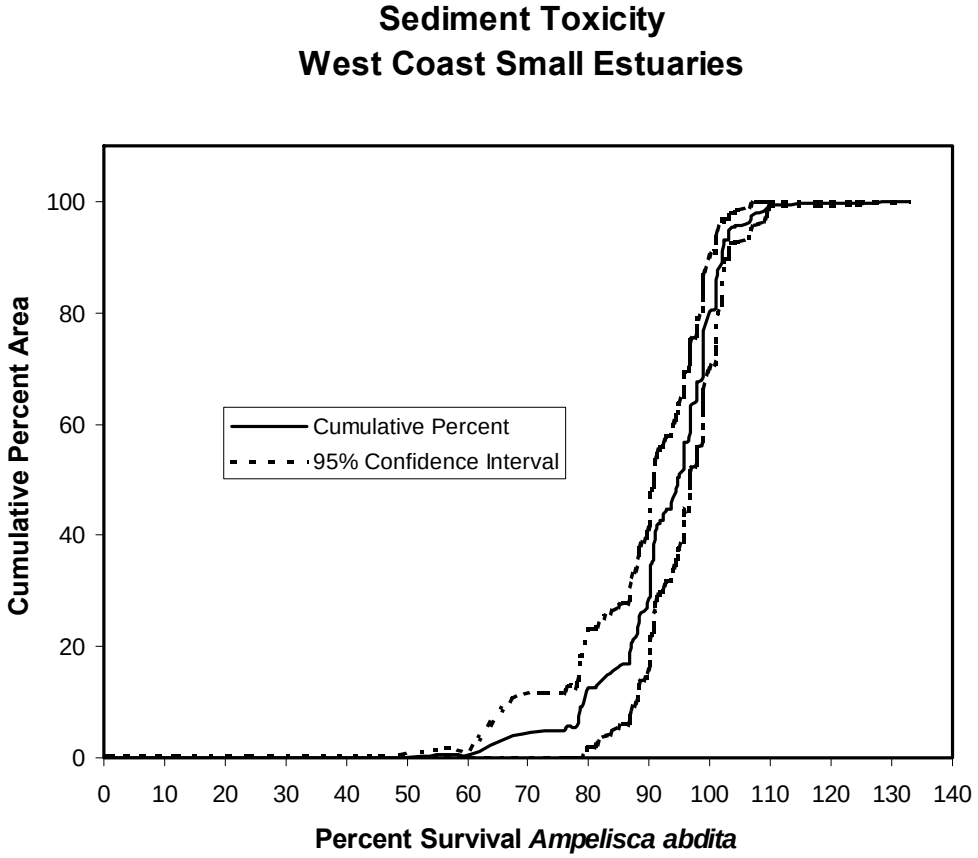

Figure 3.2-19. Percent area (and 95% C.I.) of West Coast small estuaries vs. percent control-corrected survivorship of *Ampelisca abdita*.

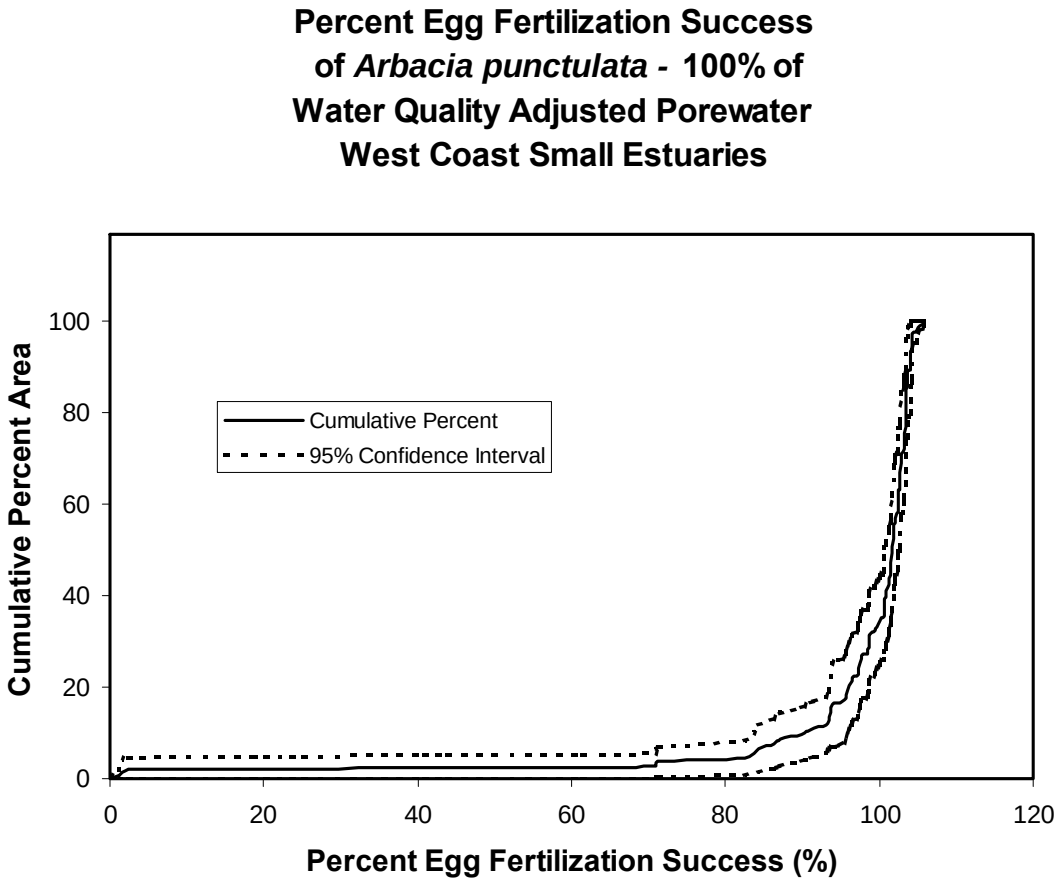

Figure 3.2-20. Percent area (and 95% C.I.) of West Coast small estuaries vs. percent fertilization of *Arbacia punctulata* eggs for the 100% water quality adjusted porewater concentration.

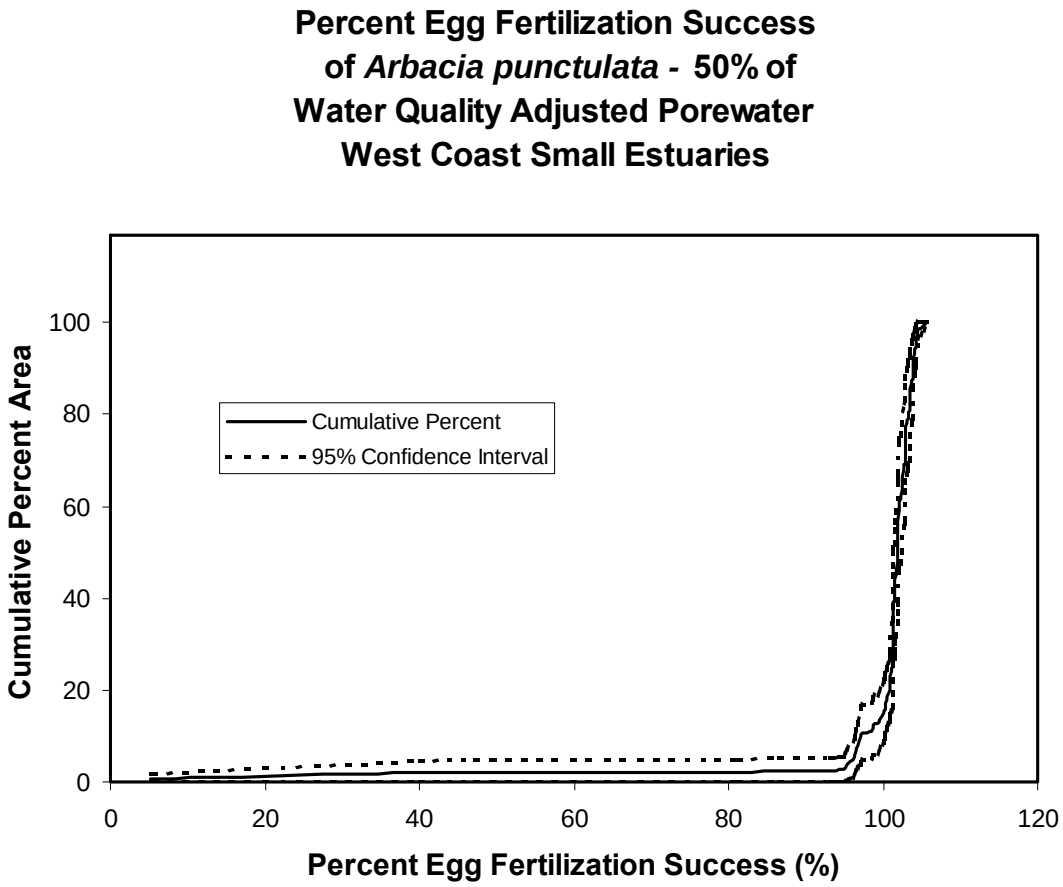

Figure 3.2-21. Percent area (and 95% C.I.) of West Coast small estuaries vs. percent fertilization of *Arbacia punctulata* eggs for the 50% water quality adjusted porewater concentration.

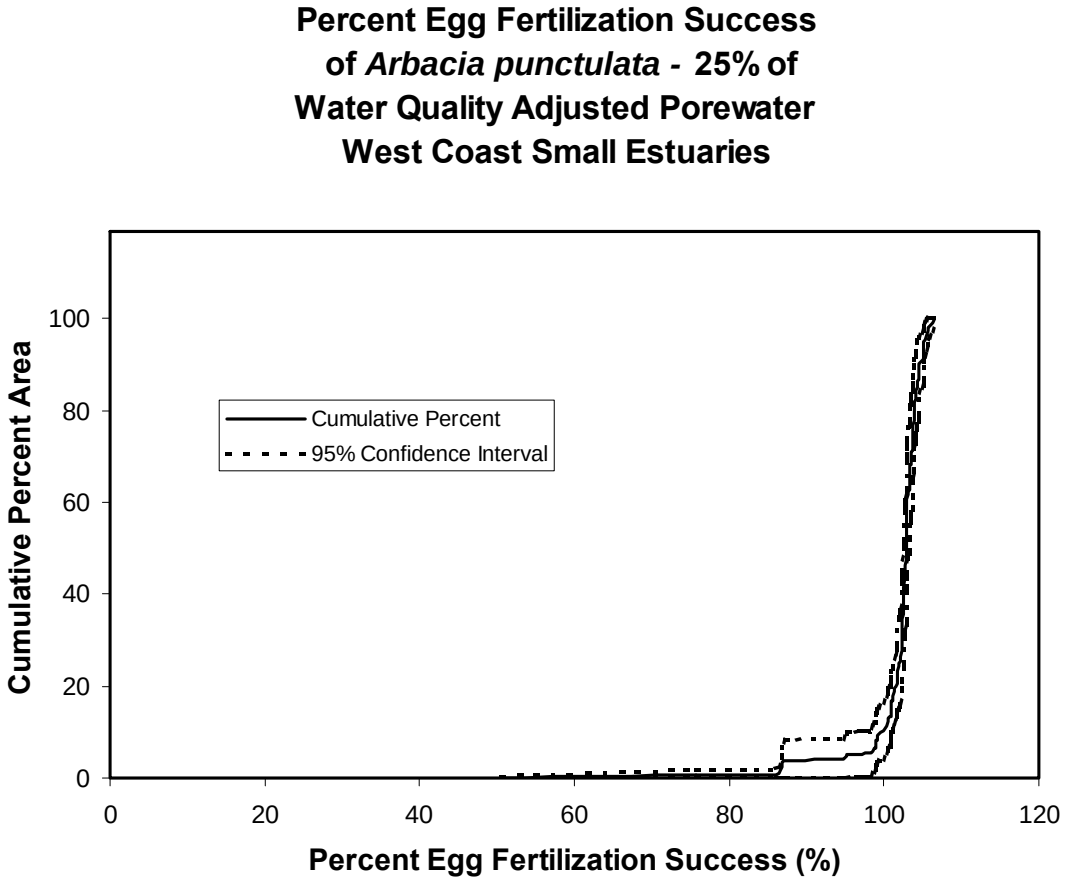

Figure 3.2-22. Percent area (and 95% C.I.) of West Coast small estuaries vs. percent fertilization of *Arbacia punctulata* eggs for the 25% water quality adjusted porewater concentration.

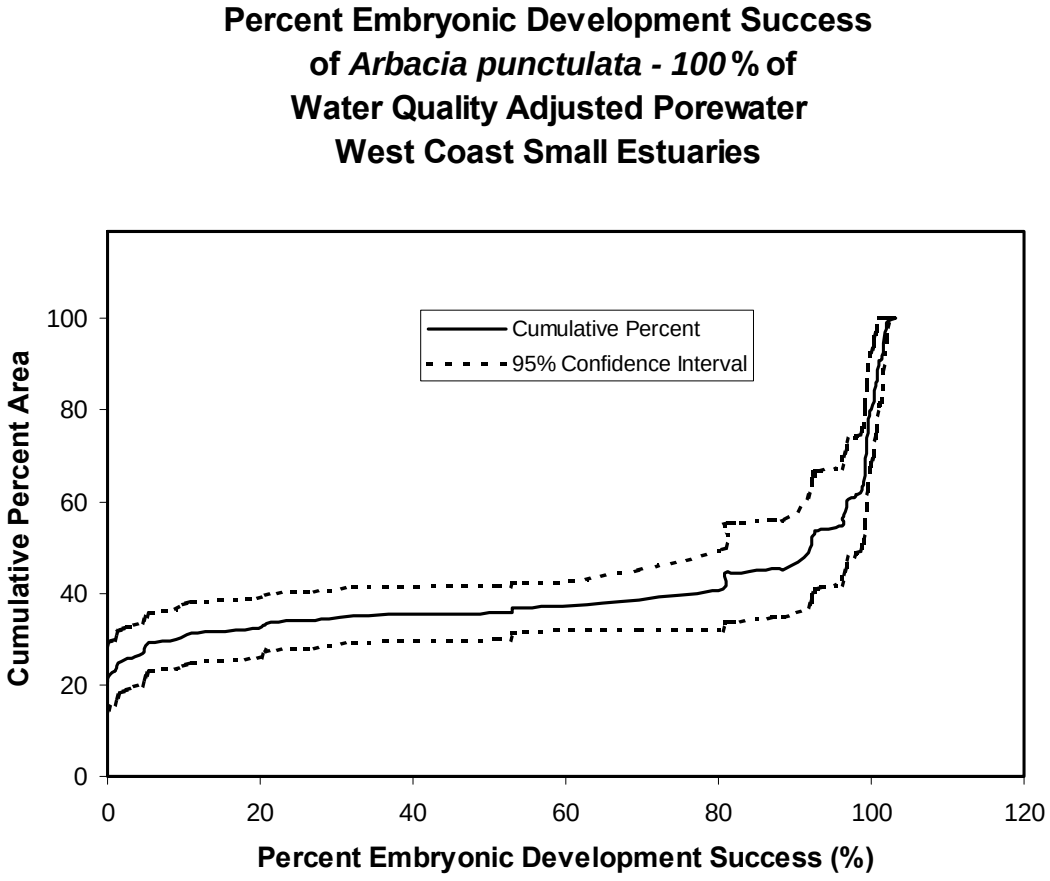

Figure 3.2-23. Percent area (and 95% C.I.) of West Coast small estuaries vs. percent successful embryonic development of *Arbacia punctulata* for the 100% water quality adjusted porewater concentration.

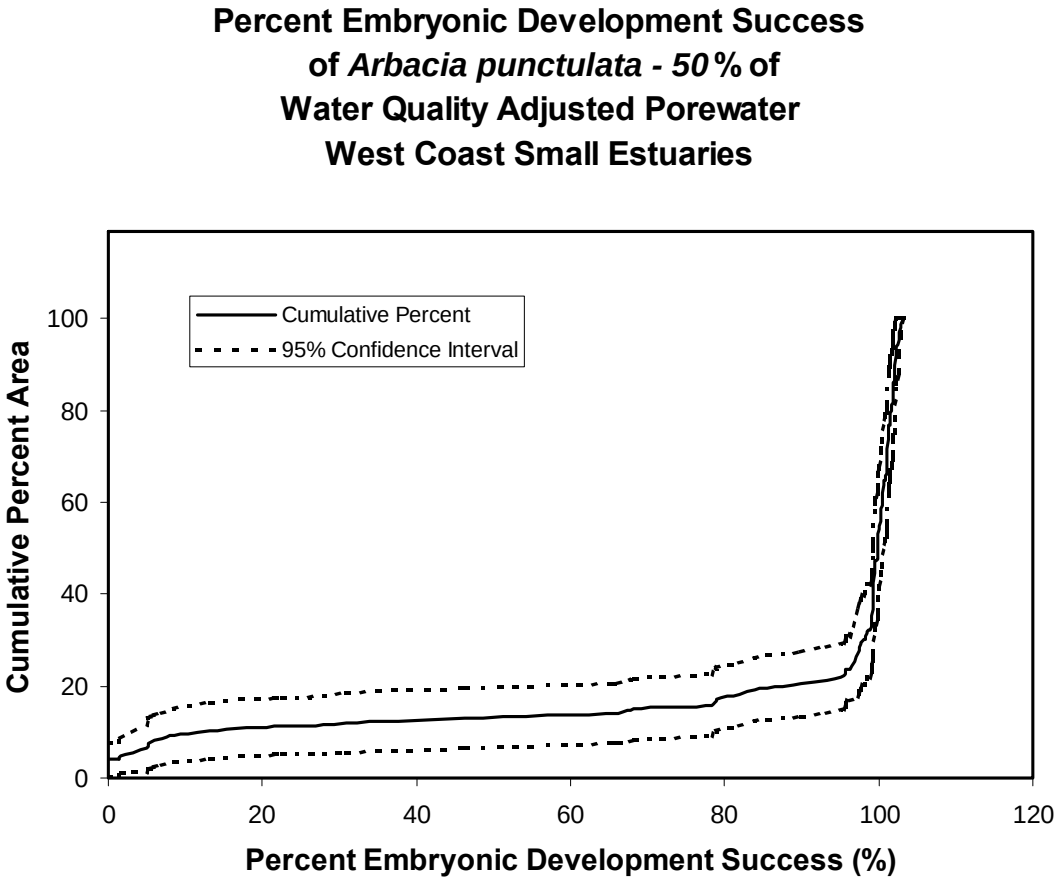

Figure 3.2-24. Percent area (and 95% C.I.) of West Coast small estuaries vs. percent successful embryonic development of *Arbacia punctulata* for the 50% water quality adjusted porewater concentration.

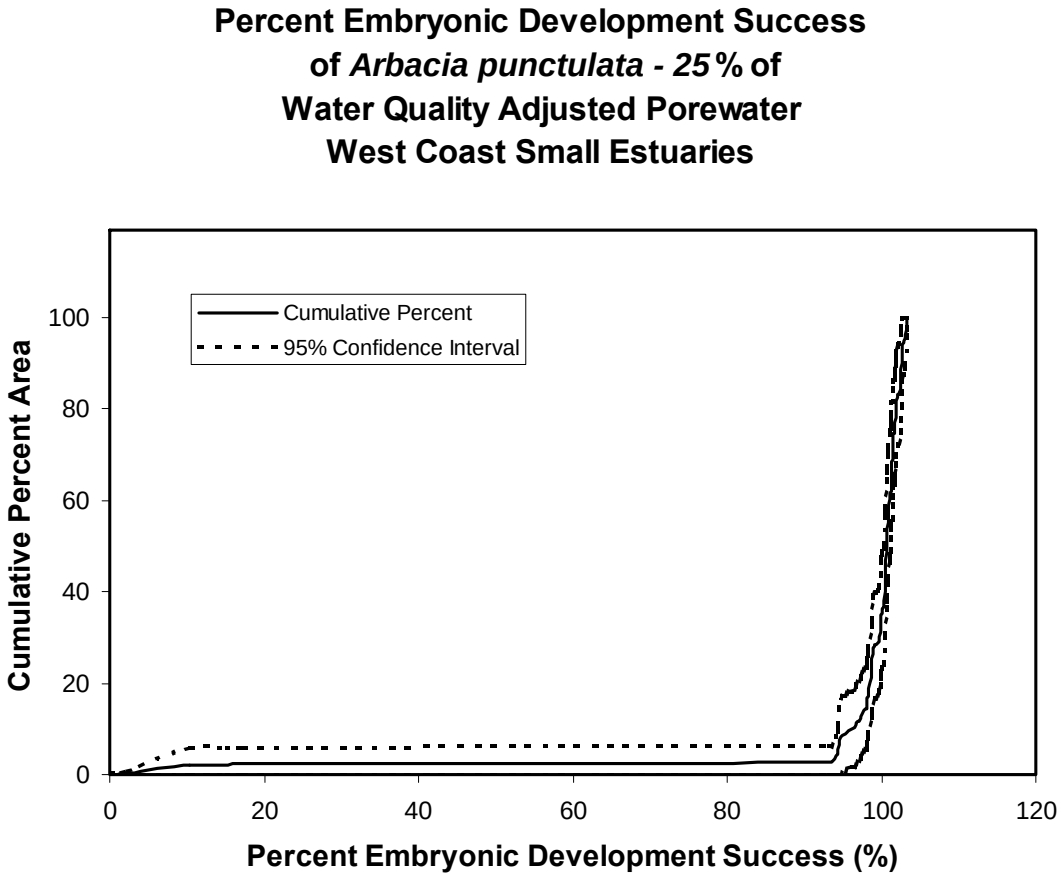

Figure 3.2-25. Percent area (and 95% C.I.) of West Coast small estuaries vs. percent successful embryonic development of *Arbacia punctulata* for the 25% water quality adjusted porewater concentration.

3.2.4 Tissue Contaminants

Residues of a suite of metals, PCBs, and pesticides were measured in the whole bodies of fish (see Table 2-5 for list of compounds). Flatfish (pleuronectiformes) were the designated target species, while various perch-like species (perciformes) were the secondary target group when flatfish were not captured. If neither flatfish nor perch-like species were present, whatever abundant species was captured at the site was utilized as an "other" group. Twelve of the fifteen sites with residues measured on the "other" species occurred in the Northern California intensive sites. The specific fish species in each group and their relative abundance are given in Table 3.2-3. Combined across all three states, fish residues were measured at 145 to 152 sites, depending upon the analyte, with flatfish measured at 112 to 119 of these sites (Tables 3.2 -4 and 3.2 -5). Because it is not clear that the sites without any fish captured for residue analysis were distributed randomly, and due to the uncertainties associated with mixing different guilds of fish species, the fish residue data are presented as summary statistics rather than as CDFs to estimate areas.

Fish tissue residues of the 11 metals measured in all three states are summarized for all fish species combined and for each fish group in Table 3.2 -4. Aluminum, with an average concentration of 122 µg/g for all fish species, had a residue about seven-times greater than zinc, the metal with the second highest concentration. Silver, mercury, cadmium, and lead had the lowest residues, with all four having a mean concentration <0.1 µg/g when averaged for all species. The concentrations of the various metals were generally similar among the three fish groups. The greatest difference was with nickel, which had mean values of 0.38 µg/g and 0.11 µg/g in the flatfish and perches, respectively, compared to an average of 2.07 µg/g in the "other" group. Though the mean values were similar, the sample site location of the maximum tissue residues varied for each of the metals. For example, all the mercury residues >0.05 µg/g occurred in California, and the two residues >0.1 µg/g occurred in San Diego Bay and in the Albion River in Northern California. In comparison, the two highest arsenic concentrations occurred in Discovery Bay, Washington; the highest lead value occurred in Willapa Bay, Washington; and the highest copper residues occurred in Tillamook Bay, Oregon.

Fish tissue residues of total PCBs, total DDT, and other pesticides are summarized in Table 3.2 -5. Total DDT had the highest residue of all the neutral organic contaminants, averaging about 44.7 ng/g when averaged over all the fish species. 4,4'-DDE constituted 83% to 91% of the total DDT in all three fish groups. In contrast to the metals, total DDT showed a considerable difference among the fish groups, ranging from 1.92 ng/g in the "other" group to 245 ng/g in the perciform species. Total PCBs had the second highest residue of the neutral organics, averaging about 17 ng/g for all fish species combined. PCB138 and PCB153 were the two most abundant PCB congeners, making up 34% to 60% of the total PCBs in the three fish groups. As with total DDT, total PCBs showed a considerable difference among the fish groups, ranging from about 1 ng/g in the "other" group to 83 ng/g in the perciform species. It is possible that these differences among fish groups are largely a result of where the different types

of fish species were collected rather than an inherent difference in bioaccumulation by the fish groups. *Genyonemus lineatus* (white croaker) was the most abundant species in the perciform group, and all the white croaker used for fish residues were obtained from either the Los Angeles Harbor or the Long Beach Harbor. These two industrialized harbors were the sites for the maximum fish residues for both total PCBs and total DDT and had relatively high total PCB and total DDT sediment concentrations. In comparison, most of the individuals making up the "other" group were captured in the non-industrialized, small, Northern California estuaries.

The residues of the thirteen additional pesticides were considerably lower than that of total DDT (Table 3.2 -5). Endosulfan sulfate had the highest residue of the other pesticides, with a concentration of 1.24 ng/g when averaged over all the fish species. No other pesticide was >1 ng/g when averaged over all the fish species, though Trans-nonachlor averaged 3.08 ng/g in the perciform species. Mirex and Toxaphene were never detected in any fish. The three fish groups showed several differences in the mean residues of these pesticides. None of the thirteen additional pesticides were detected in the "other" fish group. The primary differences between the flatfish and perch-like species were the absence of detectable levels of Endosulfan sulfate and the higher residues of Trans-nonachlor in the perch-like species. As mentioned above, differences in where the various species groups were collected may have contributed to these among-group differences in residue patterns.

Tissue residues of certain organic pollutants (e.g., DDT and PCBs) and organometals (e.g., mercury) tend to increase in larger organisms. It is not possible to directly evaluate this effect using the EMAP data because different size fish were composited into single analytical samples. It is possible, however, to assess whether there is any relationship between the average size of the individuals in a composite and the composite residue. Using mercury as the test compound, a significant positive linear relationship was observed between average wet weight of the individuals and mercury concentration when all fish species were combined as well as with *Pleuronectes vetulus*. These preliminary results suggest that residues for the organic pollutants and organometals would tend to be higher in larger fish in the small estuaries of the Pacific Coast.

Table 3.2-3. The species composition and relative abundance of the three fish groups used in the tissue residue analysis. The percent within a group is the relative abundance of the species within the group in which it is included. The overall percent is the relative abundance of the species when all the fish species are combined.

Fish Group	Number	Percent within Group	Overall Percent
Pleuronectiformes			
Pleuronectes vetulus	47	37.0	29.4
Platichthys stellatus	43	33.9	26.9
Citharichthys stigmaeus	21	16.5	13.1
Paralichthys californicus	10	7.87	6.25
Psettichthys melanostictus	3	2.36	1.88
Citharichthys sordidus	1	0.79	0.63
Pleuronectes isolepis	1	0.79	0.63
Symphurus atricauda	1	0.79	0.63
Perciformes			
Genyonemus lineatus	6	33.3	3.75
Cymatogaster aggregata	5	27.8	3.13
Paralabrax nebulifer	3	16.7	1.88
Gasterosteus aculeatus	2	11.1	1.25
Embiotoca lateralis	1	5.56	0.63
Paralabrax maculatofasciatus	1	5.56	0.63
"Other"			
Leptocottus armatus	12	80.0	7.50
Oligocottus rimensis	2	13.3	1.25
Atherinops affinis	1	6.67	0.63

Table 3.2-4. Fish tissue residues of metals measured in all three states. The "All Fish" group is the overall average combining all species. The species compositions of the pleuronectiform, perciform, and "other" groups are given in Table 3.2 -3.

Metal	Mean (µg/g wet)	SD	Minimum	Maximum	Number Samples
All Fish					
Aluminum	122	110	3.36	569	145
Arsenic	0.60	0.63	0.00	3.77	146
Cadmium	0.03	0.04	0.00	0.31	145
Chromium	1.11	3.48	0.07	36.5	145
Copper	1.25	1.04	0.00	7.77	145
Lead	0.06	0.10	0.00	0.84	145
Mercury	0.02	0.02	0.00	0.11	149
Nickel	0.52	1.74	0.00	15.1	145
Selenium	0.37	0.14	0.00	0.83	147
Silver	0.01	0.02	0.00	0.27	145
Zinc	17.7	7.09	7.84	39.1	145
Pleuronectiformes					
Aluminum	116	110	3.36	568	112
Arsenic	0.61	0.70	0	3.77	113
Cadmium	0.03	0.05	0	0.31	112
Chromium	1.00	3.47	0.07	36.5	112
Copper	1.21	1.12	0	7.77	112
Lead	0.05	0.10	0	0.84	112
Mercury	0.02	0.02	0	0.09	116
Nickel	0.38	1.30	0	13.2	112
Selenium	0.35	0.13	0	0.63	114
Silver	0.01	0.03	0	0.27	112
Zinc	18.8	6.95	7.9	39.1	112
Perciformes					
Aluminum	117	82.2	15.2	266	18
Arsenic	0.76	0.29	0.30	1.27	18
Cadmium	0.01	0.01	0.00	0.04	18
Chromium	0.46	0.59	0.12	2.66	18
Copper	1.30	0.86	0.68	4.44	18
Lead	0.10	0.10	0.00	0.37	18
Mercury	0.05	0.02	0.01	0.11	18
Nickel	0.11	0.16	0.00	0.53	18
Selenium	0.52	0.17	0.17	0.83	18
Silver	0.01	0.01	0.00	0.04	18
Zinc	15.06	7.56	7.84	37.0	18
"Other"					
Aluminum	174	127	46.1	485	15
Arsenic	0.33	0.08	0.23	0.50	15
Cadmium	0.01	0.01	0.00	0.03	15

Table continued on next page

Chromium	2.73	5.02	0.27	19.8	15
Copper	1.51	0.42	1.01	2.39	15
Lead	0.06	0.05	0.00	0.17	15
Mercury	0.03	0.02	0.00	0.10	15
Nickel	2.07	3.84	0.06	15.1	15
Selenium	0.39	0.09	0.22	0.56	15
Silver	0.01	0.00	0.00	0.01	15
Zinc	13.0	4.73	9.46	29.0	15

Table 3.2-5. Fish tissue residues of total PCBs, total DDT and the additional pesticides measured in all three states. The "All Fish" group is the overall average combining all species. The species composition of the pleuronectiform, perciform, and "other" groups are given in Table 3.2 -3.

Compound	Mean (ng/g wet)	SD	Minimum	Maximum	Number Samples
All Fish					
Total PCBs	17	47.9	0.00	331	152
Aldrin	0.04	0.28	0.00	2.40	149
Alpha-chlordane	0.18	1.07	0.00	11.5	149
Total DDT	44.7	219	0.00	2509	148
Dieldrin	0.05	0.24	0.00	1.40	149
Endosulfan Sulfate	1.24	3.34	0.00	21.4	151
Endosulfan I	0.10	0.63	0.00	5.17	150
Endosulfan II	0.05	0.26	0.00	2.09	149
Endrin	0.10	0.43	0.00	3.81	149
Heptachlor	0.45	1.44	0.00	9.80	149
Heptachlor Epoxide	0.02	0.16	0.00	1.26	149
Lindane (gamma-BHC)	0.01	0.13	0.00	1.62	149
Mirex	0.00	0.00	0.00	0.00	149
Trans-nonachlor	0.58	2.60	0.00	27.1	149
Toxaphene	0.00	0.00	0.00	0.00	149
Pleuronectiformes					
Total PCBs	8.89	21.5	0	133	119
Aldrin	0.05	0.32	0	2.40	116
Alpha-chlordane	0.08	0.38	0	3.55	116
Total DDT	19.0	45.9	0	311	115
Dieldrin	0.07	0.27	0	1.40	116
Endosulfan Sulfate	1.59	3.71	0	21.4	118
Endosulfan I	0.13	0.71	0	5.17	117
Endosulfan II	0.05	0.26	0	2.09	116
Endrin	0.12	0.48	0	3.81	116
Heptachlor	0.58	1.61	0	9.80	116
Heptachlor Epoxide	0.02	0.14	0	1.16	116
Lindane (gamma-BHC)	0.01	0.15	0	1.62	116
Mirex	0.00	0.00	0	0.00	116
Trans-nonachlor	0.26	0.76	0	4.57	116
Toxaphene	0.00	0.00	0	0.00	116
Perciformes					
Total PCBs	83.5	109	0.00	331	18
Aldrin	0.00	0.00	0.00	0.00	18
Alpha-chlordane	0.98	2.88	0.00	11.50	18
Total DDT	245	593	0.00	2509	18
Dieldrin	0.00	0.00	0.00	0.00	18
Endosulfan Sulfate	0.00	0.00	0.00	0.00	18

Table continued on next page

Endosulfan I	0.00	0.00	0.00	0.00	18
Endosulfan II	0.08	0.36	0.00	1.51	18
Endrin	0.06	0.24	0.00	1.01	18
Heptachlor	0.00	0.00	0.00	0.00	18
Heptachlor Epoxide	0.07	0.30	0.00	1.26	18
Lindane (gamma-BHC)	0.00	0.00	0.00	0.00	18
Mirex	0.00	0.00	0.00	0.00	18
Trans-nonachlor	3.08	6.87	0.00	27.1	18
Toxaphene	0.00	0.00	0.00	0.00	18
“Other”					
Total PCBs	1.08	1.89	0.00	4.70	15
Aldrin	0.00	0.00	0.00	0.00	15
Alpha-chlordane	0.00	0.00	0.00	0.00	15
Total DDT	1.92	3.22	0.00	9.00	15
Dieldrin	0.00	0.00	0.00	0.00	15
Endosulfan Sulfate	0.00	0.00	0.00	0.00	15
Endosulfan I	0.00	0.00	0.00	0.00	15
Endosulfan II	0.00	0.00	0.00	0.00	15
Endrin	0.00	0.00	0.00	0.00	15
Heptachlor	0.00	0.00	0.00	0.00	15
Heptachlor Epoxide	0.00	0.00	0.00	0.00	15
Lindane (gamma-BHC)	0.00	0.00	0.00	0.00	15
Mirex	0.00	0.00	0.00	0.00	15
Trans-nonachlor	0.00	0.00	0.00	0.00	15
Toxaphene	0.00	0.00	0.00	0.00	15

3.3 Biotic Condition Indicators

A total of 187 0.1-m^2 benthic samples (grabs or combined cores) were collected in the three states: 47 in the base stations in California, 25 in the intensive stations in Northern California, 49 in the base stations in Oregon, 29 in the intensive stations in Tillamook, Oregon, and 37 in the base stations in Washington. Average penetration of the 187 samples was 10.3 cm, although five grabs and six core samples had a penetration less than 5 cm. These eleven samples had an average benthic density about one-third greater than the three-state average and so were included in the analysis.

3.3.1 Infaunal Species Richness and Diversity

A total of 841 benthic taxa, plus an additional 26 colonial species growing on hard substrates (e.g., bryozoans on shell hash), were found in the 187 benthic samples. Due to difficulties in standardizing the count of colonial species, such species were excluded from the estimates of abundance and the count of number of species per sample. Insects were included as a single taxon in the current analyses. Species richness averaged 22.2 species per sample (0.1-m^2) in the three states, while average species richness among the states ranged from a low of 14.3 species per sample in Oregon to a high of 28.6 in California (Table 3.3-1). The Northern California intensive sites tended to have a lower species richness, and without inclusion of these sites, the species richness increased in the base California sites to an average of 38.2 species per sample. Across the three states, species richness ranged from 1 to 157 species per grab (0.1-m^2). Of the five benthic samples that only had one species, two occurred in California, two in Oregon, and one in Washington. Four of these stations with low species richness occurred at stations with bottom salinities <1 psu, while the fifth occurred at a station with a bottom salinity of 13.9 psu. Of the three stations with >100 species per sample, two occurred in Discovery Bay and the other in Freshwater Bay, both in the Strait of Juan de Fuca, Washington. All these stations with high species richness had bottom salinities >30 psu.

On an areal basis, approximately 50% of the area of the West Coast small estuaries had a species richness of $\leq$ 17 species per sample, and 90% of the area had a species richness less than 62 species per sample (Figure 3.3-1). Because of the small area of the Northern California estuaries compared to rest of the coast, exclusion of the Northern California intensive sites had an inconsequential effect on these areal estimates.

The diversity index H′ (log base 2 derived) averaged 2.33 in the three states and ranged from 0 to 5.93 (Table 3.3-1). Across the states, average H′ ranged from a low of 1.88 in Oregon to a high of 2.68 in California. H′ tended to be lower in small Northern California estuaries, and for comparison, the exclusion of these intensive sites increased the average for the California base station to 3.33. The stations with an H′ of 0 were the five stations with a single species per sample mentioned above. The maximum H′ (5.93) occurred in the Discovery Bay, Washington, sample that contained 147 species.

On an areal basis, 50% of the area of the West Coast small estuaries had an H′ less than 2.80, and 90% of the area had an H′ less than 4.18 (Figure 3.2 -2). As with species richness, exclusion of the Northern California stations had almost no effect on these areal estimates.

3.3.2 Infaunal Abundance and Taxonomic Composition

Benthic density averaged 1378.9 individuals per sample in the three states and ranged from 1 to 41,582 individuals per sample (Table 3.3-1). Average density across the states ranged from a low of 482.5 individuals per sample in Washington to a high of 2620.7 individuals per sample in California (Table 3.3-1). Benthic density in the Northern California intensive sites tended to be higher than the rest of the state, and if these small estuarine systems are excluded, benthic density averaged 1033.0 individuals per sample in the base stations in California (Table 3.3-1). Across the three states, six stations had densities <10 individuals/sample. Three of these low-density stations occurred at sites with a salinity <0.5 psu, while the other three occurred at sites with salinities ranging from about 1 to 9 psu. The two stations with the greatest benthic densities, 41,582 and 32,285 individuals per sample, both occurred in the Smith River in Northern California. The only other station with >20,000 individuals/sample occurred in the Little River, also in Northern California. The amphipods *Americorophium spinicorn*e and *A. salmonis* constituted between 89% and 98% of the individuals at these stations. Salinity at these Smith River stations was 8-10 psu, while salinity at the Little River station was 31.2 psu.

On an areal basis, 50% of the area of the West Coast small estuaries had a benthic density less than 151 individuals/sample, and 90% of the area had a density less than 1157 individuals/sample (Figure 3.3-3). As with species richness and H′ diversity, exclusion of the Northern California stations had an inconsequential effect on the these areal estimates.

The abundance, taxonomic grouping, and classification of the 10 most abundant benthic species from the three states are given in Table 3.3-2. These ten numerically dominant species made up 75% of the total fauna. The amphipods *Americorophium spinicorne* and *A. salmonis* were the two most abundant species, making up 54% of the total fauna. Oligochaetes were the third most abundant taxon, making up 7% of the total fauna, as well as being the most frequently captured taxon. Of the remaining seven numerically abundant species, six were polychaetes and one was an amphipod. The maximum abundances of six of the numerically dominant species, including all three amphipod species, occurred in the small estuaries of Northern California. With their high densities and small area, the Northern California intensive sites have a disproportionate impact on the three-state summary statistics. Therefore, the summary statistics for the three states are also presented for the 10 most abundant benthic species excluding the Northern California intensive sites (Table 3.3-3). *Americorophium spinicorne* and *A. salmonis* were still the two most abundant species in the three states, although their densities were only about 15% to 30% of their values when Northern California was included. Another difference when the Northern California stations are excluded is that the polychaete *Owenia fusiformis* and the amphipod *Grandidierella japonica* were included among the numerically dominant species while *Neanthes* and *Eogammarus* drop out.

Tables 3.3-2 and 3.3-3 list the classification of the numerically dominant species as native, nonindigenous, cryptogenic, or indeterminate. Cryptogenic species are species of uncertain geographic origin (Carlton, 1996), while indeterminate taxa are those taxa not identified to a sufficiently low level to classify as native, nonindigenous, or

cryptogenic (Lee et al., 2003). Of the 10 numerically dominant species (Table 3.3-2), five were native, two were indeterminate, two were nonindigenous, and one was classified as cryptogenic. These three nonindigenous and cryptogenic species constituted less than 6% of the total benthic abundance. When the Northern California sites are excluded, the ten numerically dominant species in the three states are composed of three natives, two indeterminate taxa, three nonindigenous species, and two cryptogenic species (Table 3.3-3). The relative abundance of the combined, numerically dominant nonindigenous and cryptogenic species was 15.3% (Table 3.3-3) when the Northern California sites were excluded. This contribution to total abundance was more than twice the relative abundance (5.7%, Table 3.3-2) calculated when the Northern California sites were included.

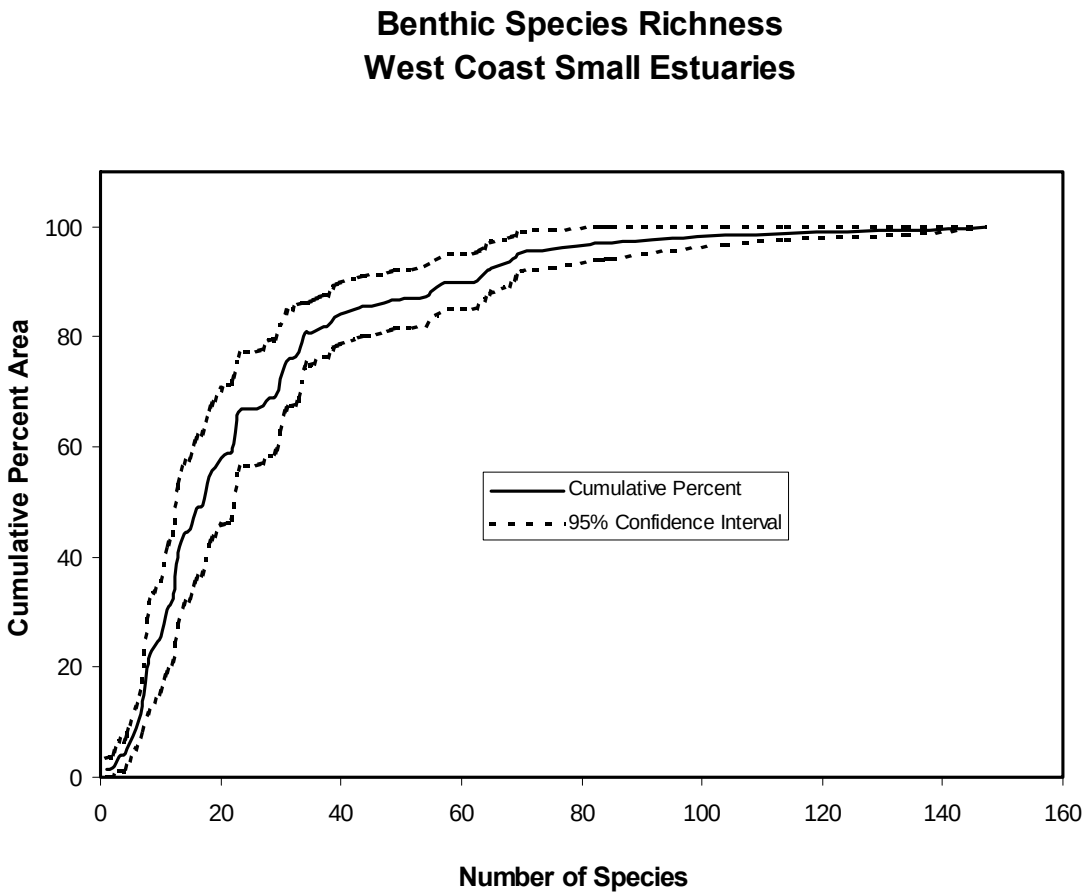

Figure 3.3-1. Percent area (and 95% C.I.) of West Coast small estuaries vs. benthic infaunal species richness.

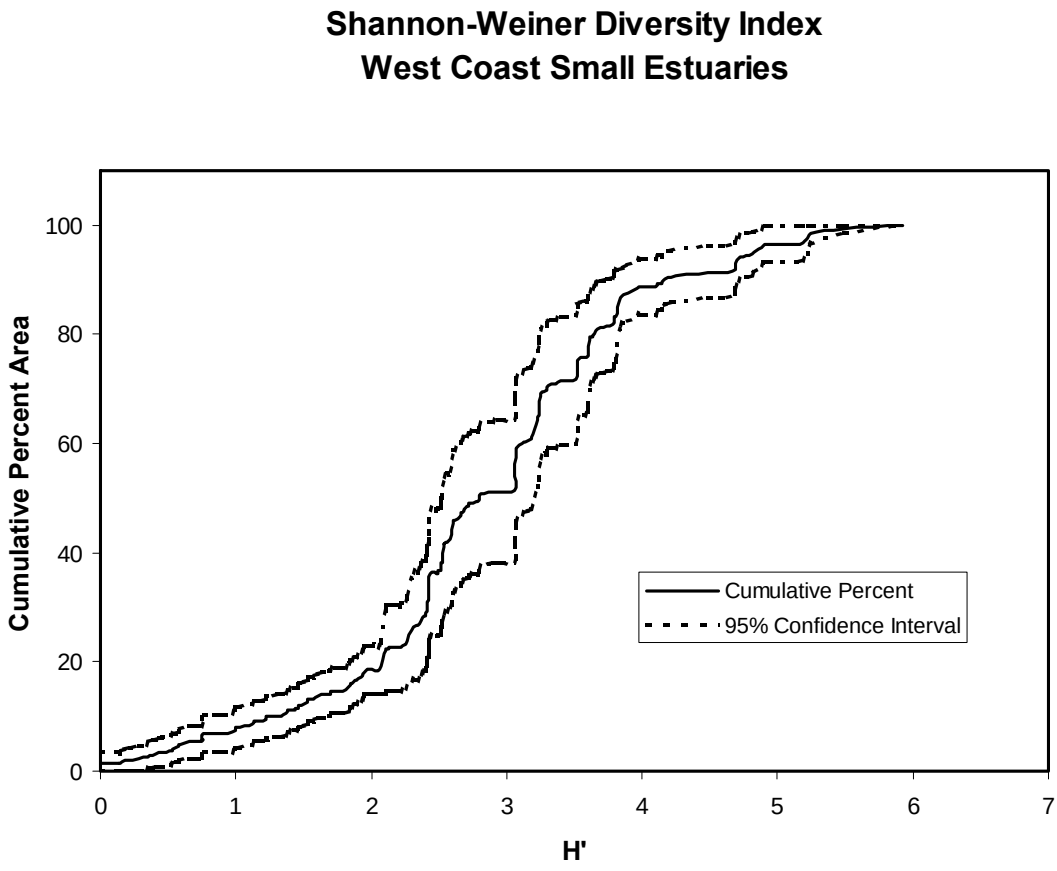

Figure 3.3-2. Percent area (and 95% C.I.) of West Coast small estuaries vs. benthic infaunal H′ diversity.

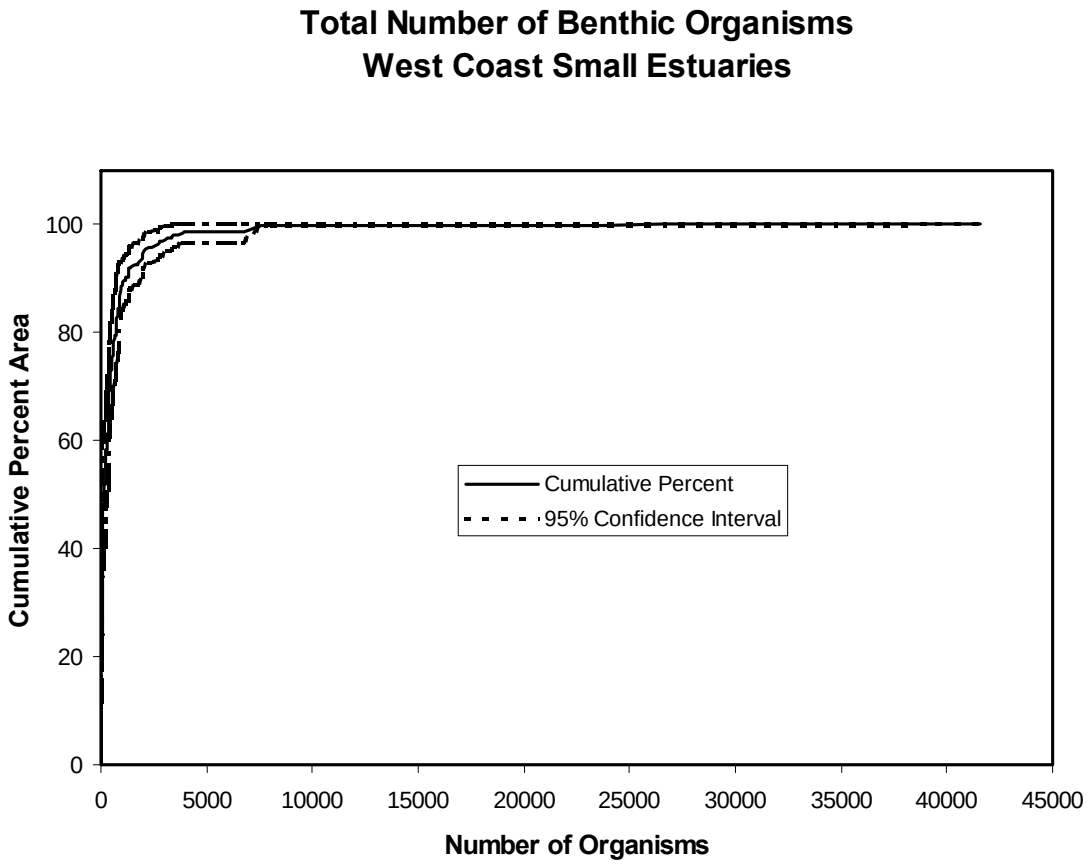

Figure 3.3-3. Percent area (and 95% C.I.) of West Coast small estuaries vs. benthic infaunal total abundance.

Table 3.3-1. Summary statistics for benthic abundance, number of species per benthic sample, and H′. All values are calculated per 0.1 m^2 benthic sample. The 3-State values include the base and intensive stations from California, Oregon and Washington (N=187). The California values are calculated both for the base stations with the intensive stations in Northern California included (N=72), and for the base stations without the California intensive sites (N=47). The Oregon values are calculated for the base stations with the intensive stations in Tillamook Bay (N=78). The Washington values are calculated for the base stations (N=37).

Location:Parameter	Mean	SD	Min	Max
3-State: Individuals/sample	1378.9	4264.8	3	41,582
3-State: Spp/sample	22.2	23.5	1	147
3-State: H′	2.33	1.26	0	5.93
CA: Individuals/sample	2620.7	6580.3	7	41,582
CA: Spp/sample	28.6	23.7	1	95
CA: H′	2.68	1.35	0	5.24
CA base wo/N. CA: Individuals/sample	1033.0	1442.3	12	7383
CA base wo/N. CA: Spp/sample	38.2	23.6	5	95
CA base wo/N. CA: H′	3.33	1.13	1.34	5.24
OR: Individuals/sample	657.7	1191.4	7	8118
OR: Spp/sample	14.3	11.6	1	65
OR: H′	1.88	0.96	0	4.10
WA: Individuals/sample	482.5	710.1	3	3106
WA: Spp/sample	26.5	34.9	1	147
WA: H′	2.58	1.37	0	5.93

Table 3.3-2. Abundance, taxonomic grouping, and classification of the ten most abundant benthic species in the three states including the intensification sites in Northern California and Tillamook, Oregon (N=187). * = maximum value occurred in the Northern California intensification sites. Taxonomic groupings: A = amphipod, O = oligochaete, P = polychaete. Classification of the species: Native, NIS = nonindigenous, Crypto. = cryptogenic, Indeter. = indeterminate taxa (see text for definitions).

	Taxon	Class	Mean	SD	Max	Min	Percent Abundance	Percent Frequency
Americorophium spinicorne	A	Native	524.2	3389.8	39,700*	0	38.0	27.8
Americorophium salmonis	A	Native	220.9	1257.7	14,728*	0	16.0	34.8
Oligochaeta	O	Indeter.	96.7	343.1	3,219*	0	7.0	56.7
Eogammarus confervicolus Complex	A	Native	35.4	198.5	1953*	0	2.6	19.8
Streblospio benedicti	P	NIS	29.2	189.8	1889	0	2.1	13.9
Mediomastus sp	P	Indeter.	28.0	86.3	668	0	2.0	39.6
Mediomastus californiensis	P	Native	26.4	120.9	1162	0	1.9	22.5
Pygospio elegans	P	Crypto.	25.9	202.5	1963	0	1.9	14.4
Pseudopolydora paucibranchiata	P	NIS	23.4	216.3	2772	0	1.7	16.0
Neanthes limnicola	P	Native	19.7	94.7	1004*	0	1.4	29.4

Table 3.3-3. Abundance, taxonomic grouping, and classification of the ten most abundant benthic species in the three states excluding the Northern California intensification stations (N=162). Taxonomic groupings: A = amphipod, O = oligochaete, P = polychaete. Classification of the species: Native, NIS = nonindigenous, Crypto. = cryptogenic, Indeter. = indeterminate taxa (see text for definitions).

	Taxon	Class	Mean	SD	Max	Min	Percent Abundance	Percent Frequency
Americorophium spinicorne	A	Native	77.4	515.5	6147	0	10.7	19.8
Americorophium salmonis	A	Native	67.8	261.8	2598	0	9.3	34.0
Oligochaeta	O	Indeter.	59.1	232.9	2393	0	8.1	53.1
Mediomastus sp	P	Indeter.	32.3	92.0	668	0	4.4	45.1
Mediomastus californiensis	P	Native	30.5	129.5	1162	0	4.2	24.7
Pygospio elegans	P	Crytpo.	29.6	217.4	1963	0	4.1	13.6
Pseudopolydora paucibranchiata	P	NIS	26.9	232.2	2772	0	3.7	16.7
Streblospio benedicti	P	NIS	25.2	174.2	1889	0	3.5	14.8
Owenia fusiformis	P	Crypto.	16.0	154.7	1890	0	2.2	9.3
Grandidierella japonica	A	NIS	13.2	69.3	637	0	1.82	24.7

3.3.3 Demersal Species Richness and Abundance

To measure abundance and composition, fish were sampled with 16-foot bottom otter trawls in all three states. There was a total of 144 successful trawls of at least 5 minute duration across the three states, with 37 in the base stations in California, 2 in the intensive stations in Northern California, 43 in the base stations in Oregon, 28 in the intensive stations in Tillamook, Oregon, and 34 in Washington. Trawls were pulled at an average speed of 1.7 knots for an average duration of 9.9 minutes (Table 3.3-4). Due to the number of stations without successful trawls, the analysis of the fish trawl data is limited to summary statistics and species composition, and no CDFs are presented.

Table 3.3-5 shows the mean number of individuals and species captured per trawl for the three states combined and in each of the individual states. The number of individuals per trawl averaged 33.7 fish per trawl, with a low of 13.9 in Oregon and a high of 68.0 in California. Species richness averaged 3.53 fish species per trawl, with a low of 2.63 in Oregon and a high of 5.46 in California. A total of 77 fish species were identified from the base stations in the three states, and no additional fish species were collected from the additional trawls in the small Northern California estuaries and Tillamook Bay. However, two additional species, *Oligocottus maculosus* and *Salmo clarkii*, were captured in beach seines at a station in Washington that was too shallow to pull the otter trawl. The results from these seines are not included in the summary statistics.

The 10 most abundant fish species across the entire coast are given in Table 3.3-6. These 10 numerically dominant species constituted 81% of the total fauna. *Pleuronectes vetulus,* the English sole, was both the most abundant and frequently collected species along the West Coast. *Citharichthys stigmaeus*, the speckled sanddab, was the second most abundant fish. These two flatfish made up more than 50% of the individuals captured in the three states and were among the top five most abundant species in all three states (Table 3.3-7). Oregon and Washington had similar species composition and shared four of the five numerically dominant species (Table 3.3-7). Two of the abundant species in California, *Genyonemus lineatus* and *Seriphus politus,* were not found in the other states.

Table 3.3-4. Trawl duration and speed averaged across California, Oregon, and Washington (N=141) and in each individual state. SD = standard deviation. Durations are given in minutes and fractions of minutes. Trawls with durations less than 5 minutes were not use in the analysis and are not included in the table.

Location:Parameter	Mean	SD	Maximum	Minimum
3-State: Trawl duration (Min.)	9.9	1.18	15.0	5.0
3-State: Trawl speed (Knots)	1.7	0.41	3.1	0.9
CA: Trawl duration (Min.)	9.8	1.06	12.0	5.0
CA: Trawl speed (Knots)	2.0	0.27	3.1	1.0
OR: Trawl duration (Min.)	9.8	1.25	13.0	5.0
OR: Trawl speed (Knots)	1.6	0.39	2.4	0.9
WA: Trawl duration (Min.)	10.0	1.20	15.0	7.0
WA: Trawl speed (Knots)	1.3	0.17	1.6	1.0

Table 3.3-5. Mean number of fish captured per trawl and mean number of fish species per trawl averaged across California, Oregon, and Washington (N=144) and for each individual state. SD = standard deviation.

Location:Parameter	Mean	SD	Minimum	Maximum	Percent Frequency (%)
3-State: Individuals/trawl	33.7	72.9	0	496	99.3
3-State: Species/trawl	3.53	2.68	0	17	99.3
CA: Individuals/trawl	68.0	111.0	0	496	97.4
CA: Species/trawl	5.46	3.77	0	17	97.4
OR: Individuals/trawl	13.9	18.2	1	111	100
OR: Species/trawl	2.63	1.38	1	6	100
WA: Individuals/trawl	35.5	76.6	1	336	100
WA: Species/trawl	3.18	2.10	1	10	100

Table 3.3-6. Ten numerically dominant fish species averaged across California, Oregon, and Washington, including both the base and intensive stations (N=144). Relative abundance is the percentage the species makes up of the total abundance. Frequency is the number (or percent) of trawls in which each species was captured in the three states.

Scientific Name	Common Name	Mean Individuals/ Trawl	SD Individuals/ Trawl	Max Individuals/ Trawl	Relative Abundance (%)	Frequency (% Frequency)
Pleuronectes vetulus	English sole	10.40	34.63	256	30.9	67 (46.5%)
Citharichthys stigmaeus	Speckled sanddab	6.75	23.96	194	20.0	46 (31.9%)
Cymatogaster aggregata	Shiner perch	2.83	17.08	193	8.4	35 (24.3%)
Platichthys stellatus	Starry flounder	1.98	4.90	33	5.9	53 (36.8%)
Genyonemus lineatus	White croaker	1.07	7.71	76	3.2	9 (6.3%)
Microgadus proximus	Pacific tomcod	0.90	8.72	104	2.7	7 (4.9%)
Ophiodon elongatus	Lingcod	0.89	4.66	40	2.6	13 (9.0%)
Spirinchus thaleichthys	Longfin smelt	0.88	7.55	79	2.6	4 (2.8%)
Leptocottus armatus	Pacific staghorn sculpin	0.88	2.22	13	2.6	41 (28.5%)
Seriphus politus	Queenfish	0.83	8.24	97	2.4	3 (2.1%)

Table 3.3-7. Mean and standard deviation of the five most numerically abundant fish species in California, Oregon, and Washington. The California and Oregon values include both the base and intensive stations. Frequency is the number (or percent) of trawls in which each species was captured within the state. N = 39 in California; N = 71 in Oregon; N = 34 in Washington.

California Species	California Mean/Trawl (SD)	California Frequency	Oregon Species	Oregon Mean/Trawl (SD)	Oregon Frequency	Washington Species	Washington Mean/Trawl (SD)	Washington Frequency
Citharichthys stigmaeus	19.3 (42.1)	17 (43.6%)	*Pleuronectes vetulus*	3.9 (6.6)	38 (53.5%)	*Pleuronectes vetulus*	16.6 (47.8)	18 (52.3%)
Pleuronectes vetulus	16.9 (47.9)	11 (28.2%)	*Platichthys stellatus*	2.7 (5.1)	37 (52.1%)	*Cymatogaster aggregata*	6.4 (33.0)	7 (21.3%)
Genyonemus lineatus	3.9 (14.6)	9 (23.1%)	*Cymatogaster aggregata*	1.7 (4.9)	22 (31.0%)	*Citharichthys stigmaeus*	3.8 (12.5)	12 (35.3%)
Ophiodon elongatus	3.1 (8.6)	9 (23.1%)	*Microgadus proximus*	1.6 (12.4)	2 (2.8%)	*Platichthys stellatus*	2.6 (6.6)	13 (38.2%)
Seriphus politus	3.1 (15.8)	3 (7.7%)	*Citharichthys stigmaeus*	1.3 (3.7)	17 (23.9%)	*Spirinchus thaleichthys*	1.3 (7.7)	1 (2.9%)

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