EPA 910/9-90-025

Puget Sound Estuary Program

RECONNAISSANCE SURVEY OF CHEMICAL CONTAMINATION AND BIOLOGICAL EFFECTS IN SOUTHERN PUGET SOUND

April 1991

PTI
ENVIRONMENTAL SERVICES
15375 SE 30th Place
Suite 250
Bellevue, Washington 98007

RECONNAISSANCE SURVEY OF CHEMICAL CONTAMINATION AND BIOLOGICAL EFFECTS IN SOUTHERN PUGET SOUND

Prepared for

U.S. Environmental Protection Agency
Region 10, Office of Puget Sound
1200 Sixth Avenue
Seattle, Washington 98101

EPA Contract 68-D8-0085
PTI Contract C744-27

April 1991

CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX TABLES

LIST OF ACRONYMS

ABN	acid/base/neutral
AET	apparent effects threshold
CLP	Contract Laboratory Program
DO	dissolved oxygen
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
HAET	highest apparent effects threshold
HPAH	high molecular weight polycyclic aromatic hydrocarbon
LAET	lowest apparent effects threshold
LC_{50}	concentration lethal to 50 percent of the organisms
LPAH	low molecular weight polycyclic aromatic hydrocarbon
ML	maximum level
MMC	melanin macrophage center
PCB	polychlorinated biphenyl
PSAMP	Puget Sound Ambient Monitoring Program
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance and quality control
SL	screening level

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) Region 10, through the Office of Coastal Waters, has been responsible for the development and implementation of an estuary program for Puget Sound. The present study is a reconnaissance survey of chemical contamination (i.e., of sediments and biota) and associated adverse biological effects in southern Puget Sound. Although several recent studies have provided comprehensive evaluations of chemical contamination and biological effects in central and northern Puget Sound, a similar evaluation has been lacking for southern Puget Sound. The present study serves to fill this gap in the soundwide database.

In the present study, a reconnaissance survey was conducted throughout the embayments of southern Puget Sound using several of the indicators of chemical contamination and biological effects employed in recent surveys conducted in central and northern Puget Sound. Environmental conditions were evaluated in two urban embayments (i.e., Budd Inlet and Oakland Bay), eight nonurban embayments (i.e., Hammersley Inlet, Totten Inlet, Eld Inlet, Henderson Inlet, Case Inlet, Filucy Bay, Carr Inlet, and Wollochet Bay), and three areas off the main channel of the southern sound (i.e., two areas near Steilacoom and one area in Cormorant Passage). In each study area, stations were located in depositional areas where chemical contaminants would be expected to accumulate in sediments. To provide integrative assessments of contamination over relatively large areas, all stations were located away from known contaminant sources.

The indicators used to assess chemical contamination and biological effects were a subset of those used in the recent surveys conducted in central and northern Puget Sound. Chemical contamination was evaluated in the sediments

of Budd Inlet and in five areas outside Budd Inlet (i.e., Eld Inlet, Henderson Inlet, Cormorant Passage, Carr Inlet, and Wollochet Bay). Additional sediment samples were collected for chemical analysis in the other five areas of southern Puget Sound, but were not analyzed because the results of the sediment toxicity tests indicated that the sediments were not toxic. Bioaccumulation of chemical contaminants was evaluated by measuring the concentrations of chemicals in the edible muscle tissue of fish [i.e., English sole (*Parophrys vetulus*) or starry flounder (*Platichthys stellatus*)] throughout the southern sound and in the whole bodies of littleneck clams (*Protothaca staminea*) from Budd Inlet. The primary indicators of biological effects throughout the southern sound were the amphipod mortality toxicity test (using *Rhepoxynius abronius*) and histopathological abnormalities in the livers of English sole. Benthic macroinvertebrate assemblages were sampled in Budd Inlet, but those samples were not analyzed because the results of the sediment toxicity tests indicated that the sediments were not toxic. Although not used explicitly as indicators of chemical contamination, the characteristics of demersal fish and megainvertebrate assemblages captured at all transects were described and compared. Megainvertebrates include large organisms such as crabs, starfish, and sea cucumbers that are collected using an otter trawl.

Field sampling was conducted from 3 to 12 April 1990. Sediment samples for chemical and bioassay analyses were collected at 12 stations in Budd Inlet. Sediment samples were also collected for chemical analysis in 12 areas outside Budd Inlet. Chemical analyses were subsequently conducted for five of these 12 areas (i.e., Eld Inlet, Henderson Inlet, Cormorant Passage, Carr Inlet, and Wollochet Bay). The five areas were selected because they were located in areas that have the potential of being contaminated (i.e., near the heads of embayments or, for Cormorant Passage, near a shoreline discharge). Sediment samples were also collected for bioassay analysis at 12 additional stations outside Budd Inlet. Demersal fish assemblages were sampled for histopathological and bioaccumula-

tion analyses along seven transects throughout southern Puget Sound. Clams were collected for bioaccumulation analysis at two intertidal stations in Budd Inlet.

Because the present study was a reconnaissance survey, the data evaluation focused on comparisons with the results of previous studies in Puget Sound. A limited number of site-specific comparisons were possible by evaluating the historical data collected at stations close to those sampled in the present study. Many of the site-specific comparisons were made with data collected in southern Puget Sound as part of the Puget Sound Ambient Monitoring Program (Tetra Tech 1990). In addition, all results of the present study were placed in the larger context of Puget Sound as a whole by making comparisons with the results obtained for other parts of the sound or with benchmark values based on previous studies throughout the sound. The benchmark values are values derived from information collected throughout the sound for various purposes (e.g., development of sediment quality values, identification of potential health risks). Because they are based on soundwide databases, they can be used to place the results of area-specific studies (such as the present study) in a soundwide perspective.

For sediment contamination, the benchmark values included various sediment quality values such as apparent effects threshold (AET) values (Barrick et al. 1988), the maximum level (ML) and screening level (SL) values developed by the Puget Sound Dredged Disposal Analysis (PSDDA), and numerical sediment quality standards for Puget Sound issued by the Washington Department of Ecology. All of these values are described in the text of this report. Specific AET values used for comparison were the lowest AET (LAET) and highest AET (HAET) values for the four biological indicators having AET values for Puget Sound (i.e., the amphipod mortality, bivalve larvae abnormality, and Microtox® toxicity tests and alterations of benthic macroinvertebrate assemblages). The benchmark values for sediment contamination also included the interim performance standards proposed for reference areas in Puget Sound (Pastorok et al.

1989). For bioaccumulation, the benchmark values included the tissue chemical concentrations of concern in Puget Sound identified by Tetra Tech (1988). For the amphipod mortality toxicity test, the benchmark values included the interim performance standards for Puget Sound reference areas (Pastorok et al. 1989). Although no benchmark values were available for histopathological abnormalities in fishes, the results of the present study were placed in a soundwide context by comparing them with the results obtained in previous studies from a variety of environments throughout the sound.

The remainder of this section summarizes the major results for each of the indicators of chemical contamination and biological effects evaluated in this study.

SEDIMENT CHEMISTRY

Metals

Concentrations of metals in sediments sampled at the 17 stations in southern Puget Sound were relatively low, and few of the existing sediment quality values for the sound were exceeded. No metal concentration exceeded a LAET or HAET value, a numerical sediment quality standard, or a PSDDA ML value. However, several exceedances of PSDDA SL values were found. The SL value for cadmium was exceeded at seven stations in Budd Inlet and at the single stations sampled in Eld Inlet and Carr Inlet. The SL value for mercury was exceeded at two stations in Budd Inlet. The SL values for silver and lead were exceeded at single stations in Budd Inlet. Although several exceedances of PSDDA SL values were found, exceedances of the interim performance standards for metals in reference areas of Puget Sound were relatively small for the nine metals that have interim standards. These results suggest that metals contamination at the 17 stations was not substantial. However, sediments from stations

where SL values were exceeded would require biological testing before they could be dredged and disposed of at unconfined, open-water disposal sites in Puget Sound.

Organic Compounds

All organic compounds were evaluated on the basis of dry-weight normalization, which is the traditional method of expressing concentrations for these compounds. In addition, nonionic organic compounds were evaluated on the basis of organic-carbon normalization, which more accurately assesses the potential bioavailability of these compounds.

The concentrations of most organic compounds in sediments sampled at the 17 stations evaluated in southern Puget Sound were either undetected or relatively low. However, high concentrations of phenol and 4-methylphenol were found at numerous stations in Budd Inlet, and an unusually high concentration of tributyltin (62 μg/kg) was found at a single station in that embayment. Concentrations of four of the organic compounds detected in sediment samples from Budd Inlet exceeded various sediment quality values for Puget Sound. Those compounds included phenol, 4-methylphenol, p,p'-DDD, and indeno(1,2,3-cd)pyrene.

On the basis of dry weight normalization, concentrations of phenol exceeded the HAET value at five stations and exceeded the LAET value at six additional stations. Concentrations of 4-methylphenol at two stations exceeded the LAET value, and concentrations of p,p'-DDD exceeded the HAET value at a single station. On the basis of organic carbon normalization, concentrations of p,p'-DDD exceeded the LAET value at a single station.

The numerical sediment quality standards were exceeded for phenol at 11 stations and for 4-methylphenol at 2 stations.

PSDDA ML values were exceeded for phenol at five stations and for 4-methylphenol at two stations. PSDDA SL values were exceeded for phenol at six stations and for 4-methylphenol at three stations. In addition, the SL value for indeno(1,2,3-cd)pyrene was exceeded at a single station.

Interim performance standards for organic compounds in reference areas in Puget Sound have been developed only for total low molecular weight polycyclic aromatic hydrocarbon (LPAH) compounds, total high molecular weight polycyclic aromatic hydrocarbon (HPAH) compounds, and total polychlorinated biphenyls (PCBs). In the present study, comparisons were made only for total PCBs. Comparisons were not made for total LPAH and total HPAH compounds because most of the individual LPAH and HPAH compounds were not detected in the present study. Although the interim performance standard for total PCBs was exceeded at two stations (i.e., one in Budd Inlet and one in Henderson Inlet), both values were considerably lower than the LAET value (i.e., the concentration at which adverse biological effects would be expected).

The results of the analysis of organic compounds in sediments from the 17 stations evaluated in southern Puget Sound suggest that although the observed concentrations of most compounds were relatively low, phenol and 4-methyl-phenol were present at concentrations that may be associated with adverse biological effects at numerous stations in Budd Inlet. In addition, p,p'-DDD was present at a single station in Budd Inlet at concentrations that may be associated with adverse biological effects.

CHEMICAL CONTAMINANTS IN TISSUE

Fish

Of the total of 94 chemicals evaluated in muscle tissue of English sole and starry flounder, only four metals (i.e, arsenic, copper, lead, and mercury) and four organic compounds (i.e., total PCBs, di-*n*-butyl phthalate, isophorone, and benzoic acid) were detected. The concentrations of all of these detected chemicals, except di-*n*-butyl phthalate, were relatively low. Four of these eight chemicals were identified by Tetra Tech (1988) as having a medium to high priority with respect to potential concerns for health risks to humans through seafood consumption. Those chemicals include two carcinogens (i.e., arsenic and total PCBs) and two noncarcinogens (i.e., lead and mercury).

Although a formal health risk assessment was beyond the scope of the present study, the health implications of the observed tissue concentrations of the four priority chemicals were evaluated qualitatively by comparing them with the results of the risk assessments conducted previously by Tetra Tech (1988). Based on this comparative analysis, the plausible upper limit estimates of excess lifetime cancer risk for the maximum tissue concentrations of arsenic and total PCBs observed in the present study were probably in the range of 10^{-4} to 10^{-5}. The noncarcinogenic risk index values for the maximum tissue concentrations of lead and mercury observed in the present study were probably less than 1.0. To place these risk values in a regulatory perspective, they all were consistent with EPA's Superfund site remediation goals, as contained in the National Contingency Plan, of $\leq 10^{-4}$ for carcinogens and < 1.0 for noncarcinogens (U.S. EPA 1989). This consistency indicates that the observed concentrations of chemical contaminants in fish muscle tissue from the seven transects in southern Puget Sound did not appear to pose an unacceptable health risk to consumers of these organisms.

Clams

Of the total of 94 chemicals evaluated in the whole bodies of littleneck clams, only four metals (i.e, arsenic, copper, lead, and mercury) and no organic compounds were detected at the two stations evaluated in Budd Inlet. The concentrations of all four of the detected metals were relatively low. Three of these four metals were considered by Tetra Tech (1988) to have a medium to high priority with respect to concerns for potential health risks to humans through seafood consumption. Those chemicals included the carcinogen arsenic and the noncarcinogens lead and mercury.

The health implications of the observed tissue concentrations of the three priority metals were evaluated qualitatively by comparing them with the results of the risk assessments conducted previously by Tetra Tech (1988). Based on this comparative analysis, the plausible upper limit estimate of lifetime cancer risk based on the maximum tissue concentrations of arsenic observed in the present study was probably in the range of 10^{-6} to 10^{-7}. The noncarcinogenic risk index values associated with the maximum tissue concentrations of lead and mercury observed in the present study were each probably less than 1.0. These results were consistent with EPA's Superfund site remediation goals, as contained in the National Contingency Plan, of $\leq 10^{-4}$ for carcinogens and < 1.0 for noncarcinogens (U.S. EPA 1989) and indicate that the observed concentrations of chemical contaminants in the whole bodies of littleneck clams from Budd Inlet did not appear to pose an unacceptable health risk to consumers of these organisms.

SEDIMENT TOXICITY

Amphipod mortality at the 24 stations sampled in this study ranged from 1 to 18 percent. All of these values were less than the interim performance standard of 25 percent proposed for Puget Sound reference areas (Pastorok et al.

1989). In addition, all but one mortality value (18 percent, Station 8) were less than the median value of 16.2 percent observed by Pastorok et al. (1989) for 60 samples from Puget Sound reference areas. These results indicate that the toxicity of sediments from all 24 stations sampled in this study was well within the range of conditions found in Puget Sound reference areas, and that elevated sediment toxicity did not appear to be a problem at any of the sites evaluated. However, neither sublethal nor chronic effects of sediment toxicity were evaluated in this study.

FISH ASSEMBLAGES

A total of 9,496 fishes, representing 15 families and 28 species, was sampled in this study. The most abundant family of fishes throughout southern Puget Sound was Pleuronectidae (i.e., righteye flounders), which accounted for 50 percent of the total catch. The most abundant pleuronectids were English sole and starry flounder, the two species selected for histopathological and bioaccumulation analyses.

Although English sole and starry flounder were abundant in southern Puget Sound as a whole, considerable differences were found among individual transects. In general, English sole was most abundant at the two transects located near the mouths of embayments, whereas starry flounder was most abundant at the five transects located at the heads of embayments. The total numbers of species and individuals also showed large differences between transects located in the mouths or heads of embayments, with both variables being considerably lower in the latter environments. The results of this study suggest that habitat differences within the embayments exerted a considerable influence on the characteristics of the resident demersal fish assemblages. Because English sole was relatively rare or absent at the heads of embayments, starry flounder was used for bioaccumulation analysis at those five transects, and histopathological evaluations

were not conducted at those locations. Starry flounder was not used for histopathological evaluations because the historical database for this species is limited.

FISH HISTOPATHOLOGY

Sufficient sample sizes of English sole for histopathological analysis were obtained at only two of the seven transects (i.e., those in Totten and Carr inlets) at which demersal fishes were sampled. The only kinds of liver lesions found at those two transects were nonspecific responses to injury. These lesions generally are not indicative of major adverse biological effects. The three kinds of serious liver lesions found in previous studies of English sole from contaminated environments in Puget Sound (i.e., neoplasms, foci of cellular alteration, and megalocytic hepatosis) were not found in any of the fish collected in this study. In general, the prevalences of nonspecific responses to injury were relatively low (all < 17 percent), and only three of these conditions (i.e., hepatocellular regeneration, mononuclear infiltrates, and parenchymal inflammation) were found in more than 10 percent of the fish from either study area.

The absence of neoplasms, foci of cellular alteration, and megalocytic hepatosis in English sole from Totten and Carr inlets suggests that any potential chemical contamination in those two areas was not high enough to cause serious liver lesions in fishes. Compared with historical data collected in a variety of environments elsewhere in Puget Sound, the absence of serious liver lesions in English sole from Totten and Carr inlets suggests that those two areas were similar to the reference areas used in previous studies in Puget Sound.

CONCLUSIONS

The results of this study suggest that most of the areas sampled in southern Puget Sound were not characterized by substantial levels of chemical contamination or adverse biological effects. However, the concentrations of several organic compounds in one or more sediment samples from Budd Inlet were high enough to potentially result in adverse biological effects. Despite these elevated chemical concentrations, sediment toxicity was not elevated above Puget Sound reference levels at any of the Budd Inlet stations, according to the results of the amphipod mortality toxicity test. Sediment toxicity also was not elevated above reference levels at any of the other stations sampled throughout southern Puget Sound. However, neither sublethal nor chronic effects of sediment toxicity were evaluated in this study. The limited amount of information collected on fish disease suggests that fish evaluated from Totten and Carr inlets were not affected by chemical contamination, as serious histopathological abnormalities were not found in the livers of any of these individuals. However, information on fish disease in Budd Inlet (i.e., the major urban embayment in southern Puget Sound) could not be evaluated because the target species (i.e., English sole) was not found in sufficient abundance there. Finally, the observed concentrations of chemical contaminants in tissue samples from fishes and clams did not appear to pose an unacceptable health risk to consumers of these organisms.

ACKNOWLEDGMENTS

This document was prepared by PTI Environmental Services under the direction of Dr. Scott Becker. The document was prepared for the U.S. Environmental Protection Agency (EPA) in partial fulfillment of Contract No. 68-D8-0085. Dr. Thomas Ginn of PTI Environmental Services was the Program Manager. Dr. John Armstrong of EPA was the Project Monitor. Mr. Joe Cummins of EPA conducted the amphipod mortality toxicity tests. Dr. Marsha Landolt of Landolt, Busch & Associates conducted the histopathological analyses of fish livers. Ms. Ruth Mandapat made the age determinations for the fishes selected for histopathological analysis.

INTRODUCTION

The national program for estuarine studies and pollution abatement (i.e., the National Estuary Program) is implemented through the U.S. Environmental Protection Agency (EPA) regional offices under the guidance of the EPA Office of Marine and Estuarine Protection. EPA Region 10, through the Office of Coastal Waters, has been responsible for the development and implementation of an estuary program for Puget Sound. A component of the program is this reconnaissance survey to evaluate chemical contamination and associated adverse biological effects in southern Puget Sound. Although several recent studies have provided comprehensive evaluations of chemical contamination and biological effects in central and northern Puget Sound (Tetra Tech 1985; PTI and Tetra Tech 1988a,b; Crecelius et al. 1989), a similar evaluation has been lacking for southern Puget Sound. The present study serves to fill this data gap.

STUDY OBJECTIVES AND DESIGN

In the present study, a reconnaissance survey was conducted throughout the embayments of southern Puget Sound using several of the indicators of chemical contamination and biological effects employed in recent surveys conducted in central and northern Puget Sound. The primary objective was to characterize current environmental conditions in southern Puget Sound and compare those conditions with conditions found in other parts of the sound.

Environmental conditions were evaluated in two urban embayments (i.e., Budd Inlet and Oakland Bay), eight nonurban embayments (i.e., Hammersley Inlet, Totten Inlet, Eld Inlet, Henderson Inlet, Case Inlet, Filucy Bay, Carr Inlet,

and Wollochet Bay), and three areas off the main channel of the southern sound (i.e., two areas near Steilacoom and one area in Cormorant Passage). In each study area, stations were located in depositional areas where chemical contaminants would be expected to accumulate in the sediments. To provide integrative assessments of contamination over relatively large areas, all stations were located away from known contaminant sources. The results of this study therefore do not represent the worst-case conditions that may exist in the immediate vicinity of contaminant sources.

A subset of the indicators used to assess chemical contamination and biological effects in the recent surveys conducted in central and northern Puget Sound was selected for the southern Puget Sound survey. Chemical contamination was evaluated in both bottom sediments and animal tissue. However, all sediment samples for chemical analysis outside of Budd Inlet were archived for future analysis, depending on the results of the sediment toxicity tests. Bioaccumulation was evaluated in the edible muscle tissue of English sole (*Parophrys vetulus*) and starry flounder (*Platichthys stellatus*) and in the whole bodies of littleneck clams (*Protothaca staminea*). The primary indicators of biological effects were results of the amphipod mortality toxicity test (using *Rhepoxynius abronius*) and histopathological abnormalities found in the livers of English sole. Benthic macroinvertebrate assemblages were also sampled in Budd Inlet and archived for future analysis, depending on the results of the sediment toxicity tests. Although not used explicitly as indicators of chemical contamination, the characteristics of demersal fish and megainvertebrate assemblages captured at all transects were described and compared. Megainvertebrates include large organisms such as crabs, starfish, and sea cucumbers that are collected using an otter trawl.

METHODS

FIELD COLLECTION

Sampling was conducted from 3 to 12 April 1990 aboard the *RV Kittiwake*. Sediment samples for chemical analysis and sediment toxicity evaluations were collected at 24 stations throughout southern Puget Sound (Figures 1 and 2). Twelve of the 24 stations were located in Budd Inlet, and the remaining 12 stations were distributed throughout southern Puget Sound. Benthic macroinvertebrate assemblages were sampled at each of the 12 stations in Budd Inlet and were archived for possible future analysis. Demersal fish assemblages were sampled for histopathological and bioaccumulation analyses along seven transects (Figures 1 and 2). Two transects were located in each of Budd and Carr inlets, and single transects were located in Oakland Bay, Totten Inlet, and Case Inlet. Clams were collected for bioaccumulation analysis at two intertidal stations in Budd Inlet (Figure 2). All sampling was conducted following the procedures recommended by the Puget Sound Estuary Program (PSEP) (PSEP 1986; 1987; 1989a,b; 1991). Information on the depths and geographic locations of all stations and transects is presented in Appendix E.

Sediment samples for analysis of chemical contaminants, sediment toxicity, and benthic macroinvertebrate assemblages were collected using a 0.1-m^2 stainless steel van Veen bottom grab sampler. For chemical and toxicity analyses, the overlying water of each acceptable grab sample was siphoned off and the top 2 cm of sediment was removed using stainless steel utensils and placed in a stainless steel bowl. The sediment was then homogenized by stirring with a stainless steel spoon until the color and texture were visually uniform. Subsamples for toxicity evaluations were placed in precleaned glass containers and stored

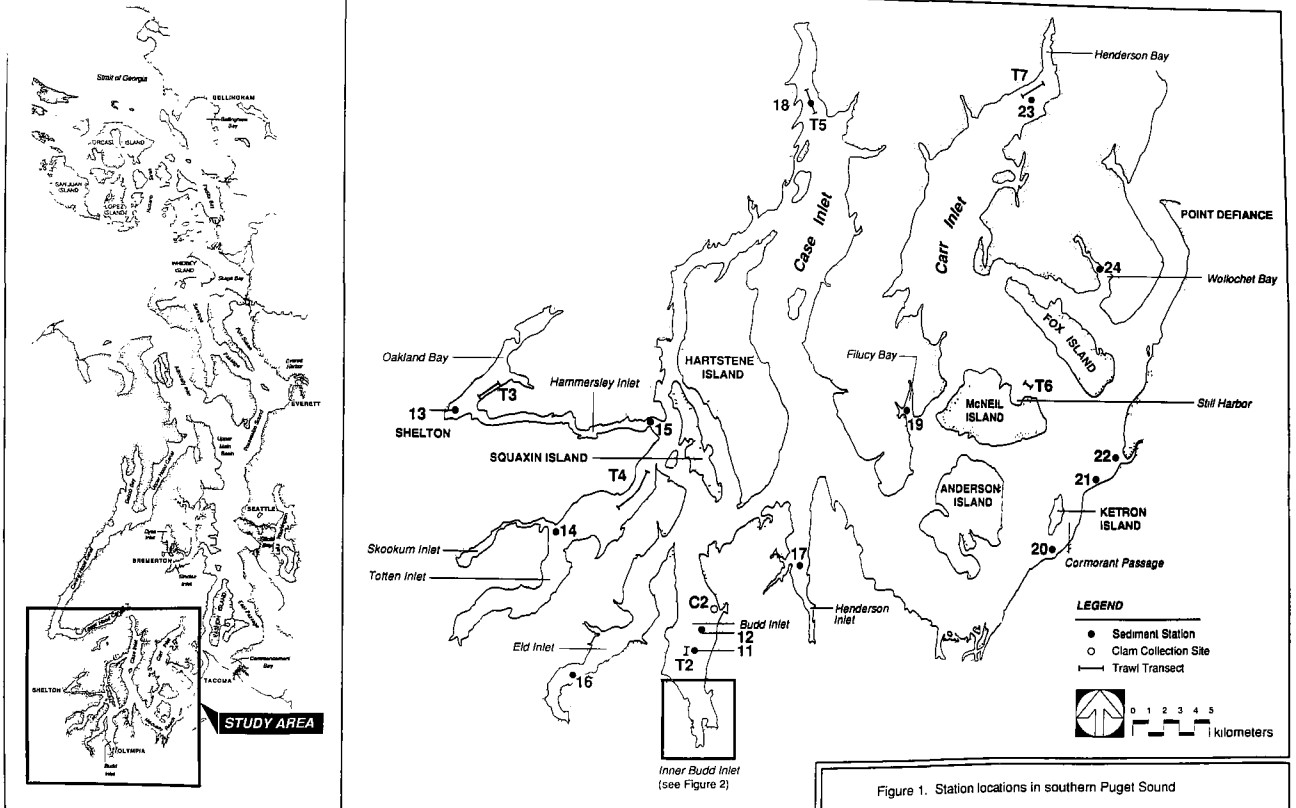

Figure 1. Station locations in southern Puget Sound

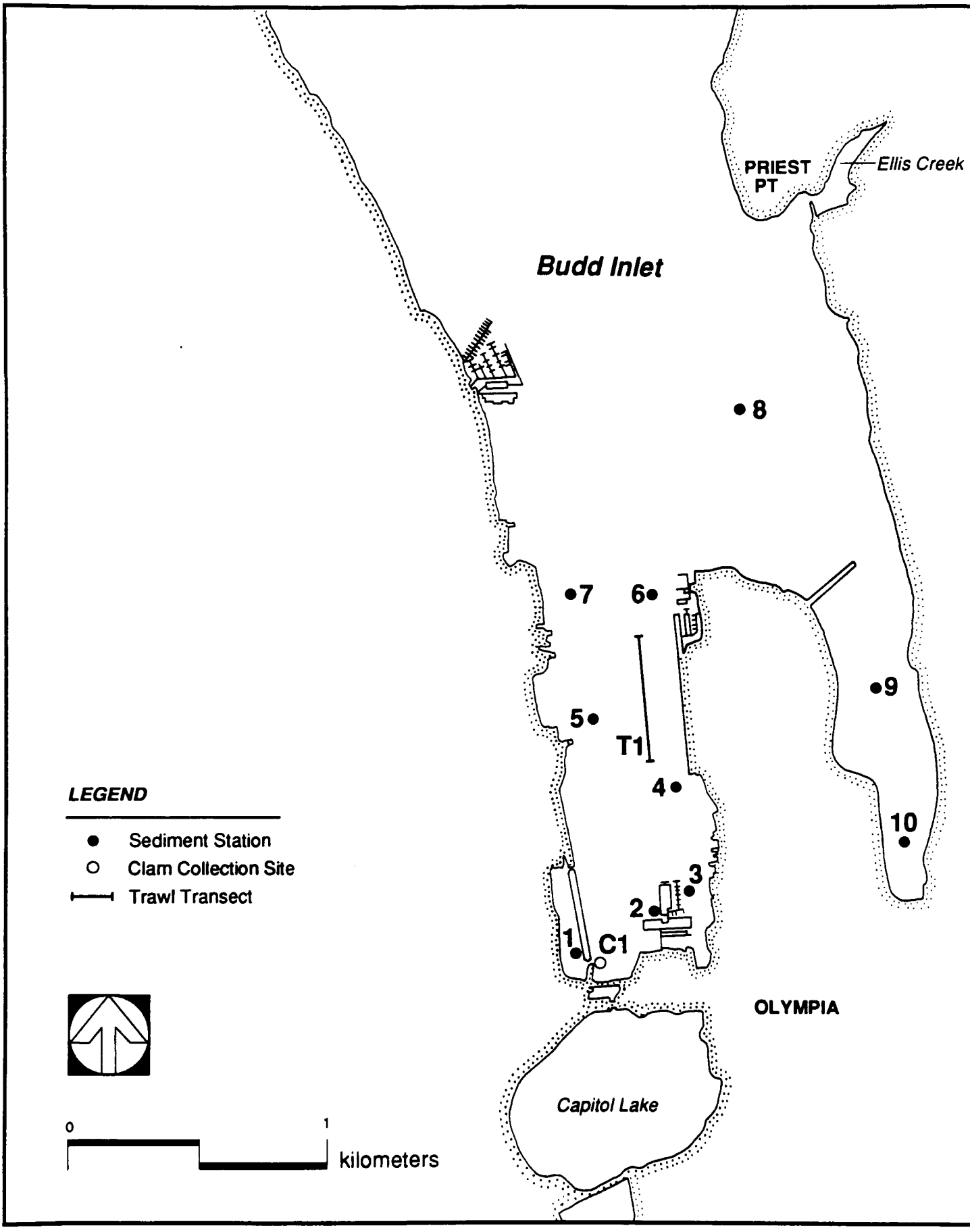

Figure 2. Station locations in inner Budd Inlet

at 4°C until laboratory analysis. Subsamples for chemical analysis were placed in precleaned jars with Teflon® cap liners, stored on ice in the field, and frozen upon return to shore. To prevent cross-station contamination, the grab sampler and all subsampling utensils were rinsed with seawater, acetone, and methylene chloride at the start of sampling at each station. Toxicity tests were conducted on the sediment samples collected from all 24 stations. Chemical analyses were conducted on the 12 samples from Budd Inlet and on 5 samples collected from other areas (i.e., Eld Inlet, Henderson Inlet, Cormorant Passage, Carr Inlet, and Wollochet Bay). The remaining seven samples collected in other parts of southern Puget Sound were not analyzed, because the sediment toxicity tests did not indicate that those sediments were toxic.

For analysis of benthic macroinvertebrate assemblages, five replicate grab samples were collected at each station in Budd Inlet. Each sample was passed through a stainless steel sieve having a mesh size of 1.0 mm. Retained material was transferred to polyethylene jars, fixed with a 10-percent solution of buffered formalin, and stained with rose bengal. In the laboratory, all benthic macroinvertebrate samples were transferred to isopropyl alcohol for long-term storage. These samples were not analyzed as part of the present study, because the results of the sediment toxicity tests indicated that none of the sediments collected from Budd Inlet were toxic.

Demersal fish assemblages were sampled using a 7.6-meter (headrope) Marinovich otter trawl having a body mesh size of 3.2 cm (stretched) and a cod-end liner mesh size of 0.8 cm (stretched). Trawling was conducted along isobaths at a constant vessel speed of approximately 2.5 knots during daylight hours (0730-1900). Transect lengths ranged from 0.2 to 2.0 km, depending on catch size. After each sample was brought on board the vessel, the target species were placed in plastic tubs and the remaining species (both fish and megainvertebrates) were identified, counted, and returned to the sound.

The primary target species for both the histopathological and bioaccumulation analyses in fish was English sole. If adequate sample sizes of English sole were not available at a location, starry flounder was used as an alternate target species for bioaccumulation analysis. Starry flounder was not used for histopathological analysis because the historical database for this species is limited. A target sample size of 60 English sole larger than 23 cm total length was used for histopathological analysis at each transect. A target sample size of 15 English sole or starry flounder greater than 23 cm total length was used for bioaccumulation analysis at each transect. If English sole was used for bioaccumulation analysis, individuals were randomly selected from the individuals used for histopathological analysis. Prior to laboratory analysis, the 15 fish selected for bioaccumulation analysis from each transect were randomly assigned to three groups of five individuals for analysis of tissue composites. For both the histopathological and bioaccumulation analyses, a minimum size limit was specified because prevalences of liver abnormalities and tissue chemical concentrations were expected to be higher in older individuals. This study therefore focused on those fish most likely to be affected by liver abnormalities or bioaccumulation.

For histopathological analysis, each selected fish was killed by a blow to the head, measured to the nearest millimeter total length, and transferred to the shipboard laboratory for liver removal. In the laboratory, the liver of each fish was removed in its entirety, cut into multiple sections, and examined for the presence of grossly visible lesions. If lesions or discontinuities were noted, a subsample was taken from the affected area for histopathological analysis. If the liver appeared normal, a subsample was taken from the center of the organ at its broadest point. Each subsample was fixed in 10-percent buffered formalin. After the liver was removed from each individual, the sex of the fish was noted and the head was removed and stored frozen. On shore, the otoliths (sagittae) were removed from each head and delivered to the laboratory for age determination.

For bioaccumulation analysis, each selected fish was decapitated and eviscerated. The body was then tightly wrapped in precleaned aluminum foil (i.e., rinsed with acetone and methylene chloride), placed in a plastic bag, stored on ice in the field, and frozen upon return to the laboratory. The head of each fish was stored frozen. On shore, the otoliths were removed and delivered to the laboratory for age determination.

The target species for bioaccumulation analysis in clams was the littleneck clam. At each collection site, approximately 30 clams were removed from the sediment by hand, placed on ice in a cooler, and shipped to the analytical laboratory.

LABORATORY ANALYSIS

Chemical Analysis

Concentrations of metals and organic compounds (except guaiacols and tributyltin) were determined following modified EPA Contract Laboratory Program (CLP) protocols, as specified by PSEP (1989a,b). Different suites of chemicals were measured for sediment and tissue samples (see *Results* section). Analysis of all conventional sediment variables followed the PSEP protocols (PSEP 1986).

Prior to chemical analysis, tissue samples were resected and composited from fish and clams using decontaminated stainless steel scalpels. Prior to tissue resection, the 15 fish sampled at each transect were randomly assigned to three groups of five individuals so that the mean length of fish did not differ significantly ($P > 0.05$; analysis of variance) among the three groups. The group assignment was reiterated, if necessary, until the length criterion was achieved. Within

each group of fish, an equal weight of tissue was resected from the dorsal muscle of each individual, composited with the tissue samples from the other fish in the group, homogenized mechanically, and subsampled for chemical analysis. For clam samples, all individuals from each station were considered a single group for chemical analysis. The whole bodies of all individuals were removed from the shells, composited, homogenized mechanically, and subsampled for chemical analysis.

Analyses of semivolatile compounds, including acid/base/neutral (ABN) extractable compounds, polychlorinated biphenyl (PCB) mixtures, and pesticides, followed modified CLP protocols that are consistent with PSEP recommendations for analyses with low detection limits. Modifications included a larger sample size (typically 50-100 grams dry weight for sediment and 50 grams for tissue), a smaller final extract volume (e.g., 0.5 mL) for gas chromatography/mass spectrometry analyses, and an adjusted calibration curve. Stable-isotope labeled surrogates specified by the CLP were used to monitor, but not correct for, recovery of ABN compounds. Separate sediment subsamples were used for ABN and pesticide/PCB extractions. Ultrasonic extractions were conducted according to the CLP procedure (analogous to EPA Method 3550). Gel permeation chromatography, an optional step under the CLP analogous to EPA Method 3640, was performed for sediment ABN extracts as necessary to reduce interferences and attain project detection limits. Care was taken by the laboratory to minimize mechanical losses during gel permeation chromatography cleanup. Gas chromatography/mass spectrometry was used to measure semivolatile compounds using the CLP procedure, which is analogous to EPA Method 8270.

Pesticide/PCB analyses were conducted using a slightly modified version of the CLP method. These analyses include extract cleanup by alumina column chromatography (EPA Method 3610) and, when necessary, elemental sulfur cleanup (EPA Method 3660), followed by gas chromatography/electron capture detection analysis. The CLP method for gas chromatography/electron capture

detection is analogous to EPA Method 8080; however, quantification and confirmation analyses were conducted with megabore capillary columns rather than the packed columns used in the CLP. Calibration procedures were consistent with the CLP.

Guaiacol analyses were conducted using the same technique applied to samples from the Everett Harbor Action Program (PTI and Tetra Tech 1988b). Sediment samples were initially acidified and then extracted using acetone and methylene chloride. The extracts were then quantified with selective-ion monitoring. Guaiacol analyses were conducted only at the five stations in Budd Inlet most likely to be affected by pulp-mill wastes.

Protocols for tributyltin used in this study were based on procedures and recommendations discussed in the methods memorandum from EPA Region 10 that resulted from a meeting of the Subcommittee on Organotin Analysis Methods held on 25 September 1987. Sediment samples for tributyltin analyses were frozen at -18°C within 24 hours of collection. Samples were acidified and mixed with Na_2SO_4 prior to extraction with tropolone/dichloromethane. The extracts were concentrated, exchanged into hexane, and treated with a Grignard reagent to form hexyl derivatives. Derivatized extracts were subjected to Florisil column chromatography cleanup and analyzed by gas chromatography/mass selective detector. A standard reference material spiked with roughly 100 μg/kg dry weight tributyltin was also analyzed. Tripropyl tin chloride was spiked in all samples as a surrogate to monitor recovery. Tributyltin analyses were conducted only at the 12 stations in Budd Inlet, because boating activities are greatest in that embayment.

For all metals analyses except those for aluminum, antimony, chromium, and zinc, sediments were subjected to the modified strong-acid digestion described in detail by PSEP (1989a). The strong-acid technique uses nitric and hydrochloric acids and hydrogen peroxide. Puget Sound studies have shown that this modified

CLP procedure yields results for most metals that are comparable with the alternative total metals procedure described by PSEP (1989a). Aluminum, antimony, chromium, and zinc were analyzed by total acid digestion with nitric, hydrochloric, and hydrofluoric acids (PSEP 1989a). Antimony, which is difficult to analyze by any of the recommended techniques (PSEP 1989a), was analyzed using the modified strong-acid digestion. Mercury analyses were conducted according to CLP cold vapor procedures. Metals concentrations in sediment and tissue digestates (except mercury) were determined by graphite furnace atomic absorption spectrometry or flame atomic absorption, as appropriate, to attain the desired detection limits. Cold vapor atomic absorption was used for determination of mercury concentrations.

The grain-size distribution of sediment samples was determined on oxidized samples (using hydrogen peroxide) by standard sieve and pipet techniques (PSEP 1986). After initial wet sieving through a 63-μm mesh, the gravel and sand fractions were separated by dry sieving techniques, and the silt and clay fractions were separated using pipet analysis. The total organic carbon content of each sediment sample was determined by combustion in an elemental analyzer.

Sediment Toxicity

The amphipod mortality toxicity test was conducted according to the protocols described by Swartz et al. (1985) and PSEP (1991). This test measures mortality in adult amphipods exposed for 10 days to bedded test sediment. All testing was conducted within 14 days of field collection of test sediments. Amphipods were collected in the field and acclimated to the test temperature and salinity for 3-4 days prior to testing. Five replicate tests were conducted for each field sample. For each replicate, 20 amphipods were exposed to a 2-cm layer of bedded test sediment in a 1-liter chamber filled with clean seawater. After the 10-day exposure period, the surviving amphipods in each test chamber were

sieved from the sediment and counted. Percent mortality was determined relative to the total of 20 individuals added to each chamber at the beginning of the test. Quality assurance and quality control (QA/QC) procedures included the use of positive controls (cadmium chloride), negative controls (i.e., sediment from West Beach on Whidbey Island), and measurements of water quality conditions (i.e., temperature, salinity, pH, dissolved oxygen) in each test chamber at the beginning and end of the 10-day exposure period.

Fish Histopathology

Histopathological evaluations of the English sole livers were conducted according to the protocols described by PSEP (1987). Each formalin-fixed liver was dehydrated in a graded ethanol series, cleared in xylene, and embedded in paraffin. Embedded livers were sectioned at 5 μm using a rotary microtome and were stained using hematoxylin and eosin. Prepared slides were examined using conventional light microscopy. Each slide was coded, so the pathologist did not know where the corresponding fish was captured. Each slide was first scanned at low magnification (40×) for general form and contour. The entire section was then examined at high magnification (430×) for the presence of pathological abnormalities. A description of each abnormality was recorded on the data sheet, and the identity and severity of each abnormality was coded according to the system used by the National Oceanographic Data Center.

DATA EVALUATION

Because the present study was a reconnaissance survey, data evaluation focused on comparisons with the results of previous studies in Puget Sound. A limited number of site-specific comparisons were possible by evaluating the historical data collected at stations close to those sampled in the present study.

Many of the site-specific comparisons were made with data collected in southern Puget Sound as part of the Puget Sound Ambient Monitoring Program (PSAMP) (Tetra Tech 1990). In addition, all results of the present study were placed in the larger context of Puget Sound as a whole by making comparisons with the results obtained in previous studies in other parts of the sound or with benchmark values based on previous studies throughout the sound. The benchmark values are derived from information collected throughout the sound for various purposes (e.g., development of sediment quality values, identification of potential health risks). Because they are based on soundwide databases, they can be used to place the results of area-specific studies (such as the present study) in a soundwide perspective.

For sediment contamination, the benchmark values included various sediment quality values such as apparent effects threshold (AET) values (Barrick et al. 1988), the maximum level (ML) and screening level (SL) values developed by the Puget Sound Dredged Disposal Analysis (PSDDA) (PSDDA 1989), and numerical sediment quality standards for Puget Sound issued by the Washington Department of Ecology (Ecology) [Washington Administrative Code (WAC) Chapter 173-204]. The benchmark values also included the interim performance standards proposed for reference areas in Puget Sound (Pastorok et al. 1989). Each of these benchmark values is described below:

- AET values—These values are the chemical-specific concentrations above which adverse biological effects are always predicted in the database used to generate the AET values. For Puget Sound, AET values have been developed for three sediment toxicity tests (i.e., amphipod mortality, bivalve larvae abnormality, and Microtox® toxicity tests) and for alterations of *in situ* benthic macroinvertebrate assemblages. The AET values used for comparisons in the present study included the lowest AET (LAET) and the highest AET (HAET) values for the four biological indicators that have AET values for Puget Sound.

- PSDDA SL and ML values—These values were derived for use in regulatory decisionmaking regarding dredged material disposal in Puget Sound. SL values are the chemical-specific concentrations below which there is no reason to believe that unconfined open-water disposal of dredged material would result in unacceptable adverse effects. SL values are used as guidelines for requiring biological testing (i.e., testing may be required if SL values are exceeded for a particular sediment). ML values are the chemical-specific concentrations above which there is reason to believe that sediments would be unacceptable for unconfined open-water disposal. The ML values set the upper limits of chemical concentrations for which biological testing provides a sufficient basis for regulatory decisionmaking.

- Numerical sediment quality standards—These standards are the chemical-specific concentrations used by Ecology to identify sediments that have no adverse effects on biological resources and are determined using available standard techniques.

- Interim performance standards—These standards are the chemical-specific concentrations used by Ecology to evaluate the suitability of candidate reference areas in Puget Sound. At present, interim performance standards are available for nine metals (i.e., arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) and three groups of organic compounds [i.e., low molecular weight polycyclic aromatic hydrocarbon (LPAH), high molecular weight polycyclic aromatic hydrocarbon (HPAH), and total PCBs].

For bioaccumulation, the benchmark values included the tissue chemical concentrations of concern in Puget Sound identified by Tetra Tech (1988). These concentrations of concern were based on a human health risk assessment for

seafood consumption in the sound. For the amphipod mortality toxicity test, the benchmark values included the interim performance standards for Puget Sound reference areas (Pastorok et al. 1989). Although no benchmark values were available for histopathological abnormalities in fishes, the results of the present study were placed in a soundwide context by comparing them with the results obtained in previous studies from a variety of environments throughout the sound.

RESULTS AND DISCUSSION

A summary of the kinds of data collected at each station and transect is presented in Table 1. Prior to analysis, all data were subjected to a QA/QC review. The results of that review are described in PTI (1990). The relationships between sampling stations and sample identification numbers are presented in Appendix E. This information can be used to relate the sample codes used in the QA/QC review to the sampling stations identified in the present report. All data generated during this study are acceptable for characterizing environmental conditions in southern Puget Sound, including those data values that were qualified during QA/QC review. The qualifiers added to specific data values are explained in the text and tables of this report. The remainder of this section presents the results of the study and a discussion of the implications of those results with respect to chemical contamination and biological effects in southern Puget Sound.

SEDIMENT CHEMISTRY

Conventional Variables

Most sediments sampled at the 17 stations evaluated in southern Puget Sound were fine-grained (Table 2). Percent fine-grained sediment (i.e., combined silt and clay fractions) ranged from 26 percent at Station 23 in Carr Inlet to 99 percent at Station 7 in Budd Inlet. The fine-grained character of most of the sediment samples was expected, because stations were located primarily in depositional areas.

TABLE 1. SUMMARY OF SAMPLES COLLECTED DURING THE SOUTHERN PUGET SOUND RECONNAISSANCE SURVEY

Station/ Transect	Location	Sediment Chemistry[a]	Amphipod Bioassay	Benthic Macroinvertebrates	Chemical Contaminants in Tissue	Histopathology
Stations						
1-12	Budd Inlet	X[b]	X	•[c]		
13	Oakland Bay	•	X			
14	Totten Inlet	•	X			
15	Hammersley Inlet	•	X			
16	Eld Inlet	X	X			
17	Henderson Inlet	X	X			
18	Case Inlet	•	X			
19	Filucy Bay	•	X			
20	Cormorant Passage	X	X			
21	Steilacoom Area	•	X			
22	Steilacoom Area	•	X			
23	Carr Inlet	X	X			
24	Wollochet Bay	X	X			
C1	Inner Budd Inlet				X[d]	
C2	Outer Budd Inlet				X[d]	
Transects						
T1	Inner Budd Inlet				X[•]	
T2	Outer Budd Inlet				X[•]	
T3	Oakland Bay				X[•]	
T4	Totten Inlet				X[f]	X[f]
T5	Case Inlet				X[•]	
T6	McNeil Island				X[•]	
T7	Carr Inlet				X[f]	X[f]

[a] Samples from Budd Inlet were analyzed separately from samples from the other areas in southern Puget Sound. The suites of organic compounds analyzed and many of the detection limits differed between the two sets of samples.

[b] X - samples analyzed.

[c] • - samples archived, but not analyzed because sediments were not toxic at the respective stations.

[d] Species - littleneck clams.

[•] Species - starry flounder.

[f] Species - English sole.

TABLE 2. CONCENTRATIONS OF CONVENTIONAL SEDIMENT VARIABLES AT STATIONS SAMPLED DURING THE SOUTHERN PUGET SOUND RECONNAISSANCE SURVEY

Station[b]	Grain-Size Fractions (percent[a])					Percent[a] TOC[d]
	Gravel	Sand	Silt	Clay	Fines[c]	
1	0.40	37	41	21	62	4.4
2	0.40	11	56	33	89	3.4
3	0	3.3	61	36	97	2.6
4	0.30	9.9	53	37	90	3.2
5	2.3	17	48	33	81	5.7
6	0	1.9	58	40	98	2.6
7	0	1.1	63	36	99	3.2
8	0	2.6	62	36	97	3.0
9	0.40	24	56	20	75	3.6
10	0.60	29	56	15	71	2.0
11	0.30	8.9	59	32	91	3.4
12	13	8.8	53	25	78	2.9
16	0.20	20	63	17	80	3.0
17	0.20	64	22	14	36	3.1
20	0	21	66	14	80	1.0
23	1.0	73	23	3.7	26	1.5
24	0	21	71	8.6	79	1.1

[a] Values are based on dry weight.

[b] Stations 1-12 were located in Budd Inlet. Stations 16, 17, 20, 23, and 24 were located in Eld Inlet, Henderson Inlet, Cormorant Passage, Carr Inlet, and Wollochet Bay, respectively.

[c] Fines - fine-grained fraction (i.e., silt plus clay)

[d] TOC - total organic carbon.

Percent total organic carbon at the 17 stations ranged from 1.0 percent at Station 20 in Cormorant Passage to 5.7 percent at Station 5 in Budd Inlet. Although percent total organic carbon and percent fine-grained sediment are usually closely related in marine environments, the correlation between these two variables in the present study (Spearman $r_s = 0.10$) was not significant ($P > 0.05$). The relatively high value of percent total organic carbon at Station 5 may be partly related to the presence of wood debris in the sample, because this station was located in a log-rafting area.

Chemical Contaminants

Metals—The concentrations of metals in the sediments sampled at the 17 stations in southern Puget Sound were relatively low (Tables 3 and 4). The highest concentrations of most metals were found in Budd Inlet at Station 12 (copper, lead, and zinc), Station 6 (aluminum and iron), Station 11 (arsenic and mercury), and Station 10 (silver). The highest concentrations of cadmium, chromium, and nickel were found at Station 16. The highest concentrations of antimony and manganese were found at Stations 17 and 20, respectively. The relatively high concentrations of metals at Stations 11 and 12 in Budd Inlet and Station 16 in Eld Inlet were unexpected, as these stations were located at considerable distances from likely sources of contamination (see Figure 2).

No metal concentration exceeded an HAET or LAET value, a numerical sediment quality standard, or a ML value. However, several exceedances of SL values were found. The SL value for cadmium was exceeded at seven stations in Budd Inlet (Stations 3, 4, 5, 7, 8, 9, and 11) and at the single stations located in Eld Inlet (Station 16) and Carr Inlet (Station 23). The SL value for mercury was exceeded at two stations in Budd Inlet (Stations 11 and 12). The SL values for silver and lead were exceeded at single stations in Budd Inlet (i.e., Stations

TABLE 3. CONCENTRATIONS OF METALS IN SEDIMENT SAMPLES FROM BUDD INLET (mg/kg dry weight)

	Station[a]											
	1	2	3	4	5	6	7	8	9	10	11	12
Aluminum	69,100 E	82,600 E	78,300 E	73,100 E	77,900 E	83,400 E	74,300 E	71,000 E	63,400 E	64,500 E	65,400 E	57,900 E
Antimony	0.390 U	0.400 U	0.390 U	0.390 U	0.400 U	0.390 U	0.400 U	0.390 U	0.390 U	0.400 U	0.710 ZU	1.30 ZU
Arsenic	7.80	8.60	9.20	8.90	8.70	7.60	9.40	11.4	9.90	8.80	16.0	15.7
Cadmium	0.590	0.680	1.00	1.00	0.990	0.610	1.60	1.60	1.50 LM	0.860	1.10	0.870
Chromium (total)	53.6	55.7	54.9	54.3	51.2	51.7	54.9	58.5	58.6	61.2	57.3	54.7
Copper	45.8	63.8	67.7	66.3	58.4	68.6	67.3	61.4	49.9	40.0	62.5	69.1
Iron	28,900	40,300	42,200	41,400	38,000	44,400	41,800	35,600	32,100	29,500	37,200	33,700
Lead	28.8	19.7	21.3	19.7	19.6	16.5	20.6	26.5	39.4	53.2	38.2	78.1
Manganese	480	515	536	528	404	554	504	427	376	393	447	580
Mercury	0.160	0.120	0.160	0.150	0.160	0.110	0.170	0.200	0.170	0.130	0.370	0.330
Nickel	25.3	29.9	30.3	31.2	27.3	33.4	32.6	32.2	27.1	29.9	32.1	31.7
Silver	0.450	0.480	0.690	0.650 T	0.530	0.540	0.630 T	0.850	1.00	1.40	0.720	0.580 T
Zinc	78.2 E	93.0 E	93.7 E	95.5 E	83.4 E	84.3 E	95.4 E	94.5 E	102 E	93.5 E	109 E	114 E

[a]All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

E - Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned *E* qualifiers when one quality assurance and quality control result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limits.
L - Value is less than the maximum shown.
M - Value is a mean.
T - Detected between the limit of detection and the quantification limit shown. These values are acceptable as estimates.
U - Undetected at detection limit shown.
ZU - Value is less than the related detection limit shown because blank contamination was present.

TABLE 4. CONCENTRATIONS OF METALS IN SEDIMENT SAMPLES FROM AREAS OUTSIDE BUDD INLET

(mg/kg dry weight)

Metal	Station[a,b]				
	16	17	20	23	24
Aluminum	64,300 M	62,400	67,800	59,400	51,300
Antimony	0.560 *T*	0.960 *T*	0.930 *T*	0.470 *UW*	0.750 *T*
Arsenic	9.00 *M*	9.80	6.30	7.30	5.90
Cadmium	1.70 *M*	0.770	0.160 *T*	1.60	0.330
Chromium (total)	75.3 *M*	62.7	48.3	70.3	38.8
Copper	47.6 *M*	39.2	28.7	24.0	13.5
Iron	34,600 *M*	30,400	28,600	24,000	16,200
Lead	17.5 *M*	22.7	25.3	14.4	18.1
Manganese	498 *M*	510	807	416	355
Mercury	0.100 *M*	0.110	0.120	0.070	0.050
Nickel	40.1 *M*	36.3	24.8	32.1	20.5
Silver	0.290 *M*	0.300	0.230 *T*	0.220 *T*	0.110 *T*
Zinc	95.2 *M*	92.5	74.9	61.4	42.9

[a] Station 16 - Eld Inlet
Station 17 - Henderson Inlet
Station 20 - Cormorant Passage
Station 23 - Carr Inlet
Station 24 - Wollochet Bay.

[b] All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

M - Value is a mean
T - Detected between the limit of detection and the quantification limit; these values are acceptable as estimates
U - Undetected at detection limit shown
W - Graphite furnace atomic absorption analytical spike recovery >115 percent.

10 and 12, respectively). Although several exceedances of SL values were found, exceedances of the interim performance standards for metals in reference areas of Puget Sound were relatively small for the nine metals that have interim standards (Table 5).

The only metal concentrations found by Tetra Tech (1990) to be elevated in southern Puget Sound relative to other PSAMP stations located throughout the sound were those observed for cadmium at two stations in Budd Inlet, where concentrations were 1.2 mg/kg and 1.8 mg/kg. The concentration of 1.8 mg/kg was the highest value found for cadmium at any of the 50 PSAMP stations. The concentrations of cadmium found at the 17 stations sampled in the present study ranged from 0.16 mg/kg to 1.7 mg/kg, with the highest value found at Station 16 in Eld Inlet and the next highest concentration (i.e., 1.6 mg/kg) found at Stations 7 and 8 in Budd Inlet and Station 23 in Carr Inlet. Tetra Tech (1990) suggested that the apparently elevated levels of cadmium in Budd Inlet were consistent with results of historical studies and may have been the result of operations of a former metal-plating facility located on the western shoreline of the inlet.

In Table 6, the metals concentrations found in the present study are compared with the values found in numerous areas throughout Puget Sound during recent surveys of sediment contamination. In general, the maximum concentrations found in the present study were considerably lower than the values found in the major urban bays, but were within the range of values found in the transitional and reference areas. The apparently elevated levels of cadmium found in Eld, Budd, and Carr inlets (i.e., maximum values = 1.7, 1.6, and 1.6 mg/kg, respectively) were 1-2 orders of magnitude lower than the maximum values found in the major urban bays (7.9-180 mg/kg), and within the range of concentrations found in the transitional areas (0.37-4.6 mg/kg).

TABLE 5. COMPARISONS OF METALS CONCENTRATIONS FOUND IN THIS STUDY WITH THE INTERIM PERFORMANCE STANDARDS PROPOSED FOR REFERENCE AREAS IN PUGET SOUND

Metal	Interim Performance Standard[a] (mg/kg dry weight)	Stations at Which Sediment Samples Exceeded Standard	Range of Exceedances[b]
Arsenic	19	None	--
Cadmium	1.4	7,8,9,16,23	1.07-1.21
Chromium	150	None	--
Copper	58	2,3,4,5,6,7,8,11,12	1.01-1.19
Lead	30	9,10,11,12	1.27-2.60
Mercury	0.19	8,11,12	1.05-1.95
Nickel	65	None	--
Silver	0.78	8,9,10	1.09-1.79
Zinc	110	12	1.04

[a] From Pastorok et al. (1989).

[b] Exceedances are based on ratios to the interim performance standards.

TABLE 6. COMPARISONS OF SEDIMENT CONCENTRATIONS OF SELECTED CHEMICALS IN VARIOUS LOCATIONS IN PUGET SOUND[a]

	Major Urban Bays		
Chemical	Commencement Bay	Elliott Bay	Everett Harbor
Metals (mg/kg dry weight)			
Antimony	0.06–420	0.29 *U*[b]–1,400	1.2–200
Arsenic	5.4–12,000	2.4–580	2.6–690
Cadmium	0.095–180	0.067–17	0.038–7.9
Chromium	5.4–62	33–1,100	50–270
Copper	11–14,000	9.6–2,100	11–1,000
Lead	8.3–6,200	7.2–71,000	4.4–520
Mercury	0.036–52	0.012–29	0.006–0.78
Nickel	6.9–350	19–370	24–69
Silver	0.02–2.4	0.022–8.3	0.007–1.0
Zinc	21–4,200	32–6,000	38–5,900
Organic Compounds (μg/kg dry weight)[c]			
LPAH	45–23,000	7–630,000	36–28,000
HPAH	79–36,000	24–3,200,000	36–23,000
Total PCBs	3–2,000	59–5,800	1 *U*–9,600
Phenol	1.0 *U*–2,100	0.9–1,200	11–2,900
4–Methylphenol	1.0 *U*–96,000	2.0–2,600	3–98,000
p,p'–DDE	0.01 *U*–50 *U*	1.1 *U*–62	1.0 *U*–200 *U*
p,p'–DDD	0.03 *U*–50 *U*	1.7 *U*–140	1.0 *U*–200 *U*
Tributyltin	--[d]	--	--

TABLE 6. (Continued)

Chemical	Transitional Areas[e]			
	Dyes Inlet	Gig Harbor	Oak Harbor	Port Angeles
Metals (mg/kg dry weight)				
Antimony	0.27–1.3	0.54–1.2	0.07–0.28	0.07–0.47
Arsenic	4.1–19	6.9–15	7.5–11	5.7–15
Cadmium	0.93–1.4	0.22–0.37	0.44–0.74	0.02 *U*–4.6
Chromium	100–160	89–130	76–160	66–96
Copper	19–90	31–69	32–48	17–55
Lead	21–79	21–58	12–21	8.0–37
Mercury	0.15–0.79	0.13–0.37	0.067–0.29	0.043–1.3
Nickel	22–62	26–38	27–79	22–37
Silver	0.13–1.2	0.20–0.67	0.13–0.32	0.02–0.17
Zinc	47–170	57–93	74–110	49–480
Organic Compounds (µg/kg dry weight)				
LPAH	150–500	330–9,500	210–1,900	55–140
HPAH	790–2,200	1,900–36,000	210–3,300	190–450
Total PCBs	0.6–9.0	4.0–97	0.1 *U*–8.8	0.1 *U*–8.4
Phenol	75 *U*	75 *U*	75 *U*	75 *U*
4–Methylphenol	12–73 *U*	4–47	12–73 *U*	8–240
p,p'–DDE	0.5 *U*–0.7	0.5 *U*–1.3	0.5 *U*	0.5 *U*
p',p'–DDD	0.5 *U*	0.5 *U*–1.5	0.5 *U*	0.5 *U*–4.9
Tributyltin	3–6	10–15	0.002 *U*–7	0.002 *U*–22

TABLE 6. (Continued)

Chemical	Reference Areas		Present Study	
	Carr Inlet	Port Susan	Budd Inlet	Other Areas
Metals (mg/kg dry weight)				
Antimony	0.1 *U*–0.14	0.92–2.9	39 *U*–1.3 *U*	0.47 *U*–0.96
Arsenic	2.4–3.8	4.6–12	7.6–16	5.9–9.8
Cadmium	0.29–1.5	0.047–0.16	0.59–1.6	0.16–1.7
Chromium	9.6–24	89–260	51–61	39–75
Copper	4.9–8	14–50	40–69	14–48
Lead	4.4–13	5.6–12	17–78	14–25
Mercury	0.01–0.098	0.012–0.13	0.11–0.37	0.05–0.12
Nickel	11–28	41–140	25–33	21–40
Silver	0.1 *U*–0.12	0.02 *U*–0.13	0.45–1.4	0.11–0.30
Zinc	15–24	39–100	78–110	43–95
Organic Compounds (µg/kg dry weight)				
LPAH	2–45	6–19	220–480	24–78
HPAH	22–78	26–74	380–2,000	60–260
Total PCBs	4–7 *U*	50 *U*–220 *U*	5 *U*–43	13–79
Phenol	10 *U*–1,800	3.3 *U*–400	83–3,300	7.4–21
4–Methylphenol	10 *U*–32	2–290	39 *U*–1,600	2.9–10
p,p'–DDE	10 *U*–25 *U*	1 *U*–10 *U*	4.0 *U*–7.1	1.0 *U*–2.0 *U*
p',p'–DDD	10 *U*–25 *U*	1 *U*–33 *U*	4.0 *U*–65	2.0 *U*–5.0 *U*
Tributyltin	--	--	3.1–62	--

[a] Data Sources:

Tetra Tech (1985) - Commencement Bay, Carr Inlet
PTI and Tetra Tech (1988a) - Elliott Bay, Port Susan
PTI and Tetra Tech (1988b) - Everett Harbor, Port Susan
Crecelius et al. (1989) - Dyes Inlet, Gig Harbor, Oak Harbor, Port Angeles
Present Study - Budd Inlet, other areas (i.e., Eld Inlet, Henderson Inlet, Cormorant Passage, Carr Inlet, Wollochet Bay).

[b] *U* - undetected at detection limit shown.

[c] LPAH - low molecular weight polycyclic aromatic hydrocarbon
HPAH - high molecular weight polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl.

[d] -- indicates no data.

[e] Transitional areas are located away from major urban areas, but may be influenced by chemical contamination.

In summary, the results of this study suggest that metals contamination at the stations sampled in southern Puget Sound was not substantial. However, sediments from many of the stations in Budd Inlet would require biological testing before they could be dredged and disposed of at unconfined open-water disposal sites in Puget Sound.

Organic Compounds—The concentrations of most organic compounds in the sediments sampled at the 17 stations in southern Puget Sound were either undetected or relatively low (Tables 7-10). However, relatively high concentrations of phenol and 4-methylphenol were found at numerous stations in Budd Inlet. Because sediments from the Budd Inlet stations (i.e., Stations 1-12) were analyzed separately from sediments from the other areas in southern Puget Sound, the suites of organic compounds and many of the detection limits differed between the two sets of samples. The suite of compounds for the Budd Inlet samples was larger because the laboratory opted to report the results for chemicals that were not included in the statement of work. Lower detection limits were achieved for the samples outside Budd Inlet because the analytical laboratory opted to use more rigorous techniques for those samples. Specifically, the laboratory used a smaller extract volume, demonstrated instrument sensitivity using smaller amounts of standard concentrations, and did not dilute samples.

Tributyltin was detected at all 12 stations in Budd Inlet (Table 11). The concentrations of this compound were generally relatively low, ranging from 3.1 to 16 μg/kg at all stations except Station 4, where an unusually high value of 62 μg/kg was found. A major source of tributyltin to coastal waters is the use of organotin antifouling paint on boat hulls. It is likely that Stations 1-10 in the inner part of Budd Inlet were influenced substantially by boating activities, whereas Stations 11 and 12 in the outer part of Budd Inlet were less affected by these activities. The concentrations of tributyltin observed in this study reflected

TABLE 7. CONCENTRATIONS OF ORGANIC COMPOUNDS IN SEDIMENT SAMPLES FROM BUDD INLET BASED ON DRY WEIGHT NORMALIZATION (μg/kg dry weight)

	Station[a]											
	1	2	3	4	5	6	7	8	9	10	11	12
Low Molecular Weight PAH[b]	220 L	340 L	230 U	390 L	240 L	230 U	240 L	280 L	320 L	480 G	280 U	290 U
Naphthalene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	40 U	39 U	36 UG	47 U	48 U
2-Methylnaphthalene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	36 UG	47 U	48 U
Acenaphthylene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	36 UG	47 U	48 U
Acenaphthene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	36 UG	47 U	48 U
Fluorene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	36 G	47 U	48 U
Phenanthrene	51 T	130	39 U	190	46 T	38 U	49 T	56 T	120	290 G	47 U	48 U
Anthracene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	49 G	47 U	48 U
High Molecular Weight PAH	590 L	690 L	480 L	1,000 L	440 L	380 U	510 L	740 L	990 L	2,000 G	480 U	490 U
Fluoranthene	130	170	92 T	270	79 T	38 U	94 T	150	240	470 G	47 U	48 U
Pyrene	100	140	82 T	240	75 T	38 U	90 T	130	190	410 G	47 U	48 U
Benz(a)anthracene	47 T	49 T	39 U	86 T	39 U	38 U	39 U	59 T	96 T	160 G	54 U	55 U
Chrysene	79 T	85 T	61 T	130	50 T	38 U	60 T	75 T	120	240 G	47 U	48 U
Total benzofluoranthenes (B+K)	90 T	84 L	51 T	120	39 U	76 U	66 T	140	170	350 G	94 U	96 U
Benzo(a)pyrene	40 T	41 U	39 U	44 T	39 U	38 U	39 U	47 U	54 T	170 G	47 U	48 U
Indeno(1,2,3-cd)pyrene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	100 G	47 U	48 U
Dibenzo(a,h)anthracene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	36 UG	47 U	48 U
Benzo(g,h,i)perylene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	73 G	47 U	48 U
Total PCBs[c]	5 U	5 U	5 U	5 U	5 U	5 U	5 U	18 T	5 U	43	5 U	5 U
Phenols and Guaiacols												
Phenol	3,300	1,200	560	660	650	83 E	910	3,000	1,500	1,100 G	2,000	1,300
2-Methylphenol	20 U	32 U	30 U	30 U	30 U	23 U	30 U	38 U	30 U	27 UG	28 U	29 U
2,4-Dimethylphenol	21 U	30 U	30 U	30 U	30 U	20 U	30 U	40 U	30 U	30 UG	30 U	29 U
4-Methylphenol	1,600	360	39 U	39 U	1,400	38 U	43 T	600	530	650 G	120	81
Pentachlorophenol	70 U	100 U	90 U	90 U	90 U	80 U	90 U	150 U	90 U	80 UG	100 U	100 U
Guaiacol	13 U	13 U	NA	14 U	13 U	NA	14 U	NA	NA	NA	NA	NA
4,5-Dichloroguaiacol	26 U	25 U	NA	28 U	25 U	NA	28 U	NA	NA	NA	NA	NA
3,4,5-Trichloroguaiacol	26 U	25 U	NA	28 U	25 U	NA	28 U	NA	NA	NA	NA	NA
4,5,6-Trichloroguaiacol	26 U	25 U	NA	28 U	25 U	NA	28 U	NA	NA	NA	NA	NA
Tetrachloroguaiacol	26 U	25 U	NA	28 U	25 U	NA	28 U	NA	NA	NA	NA	NA
Phthalate Esters												
Bis(2-ethylhexyl)phthalate	160 ZU	670 ZU	400 ZU	800 ZU	770 ZU	180 ZU	700 ZU	120 ZU	1,100 ZU	670 ZU	58 ZU	48 U

TABLE 7. (Continued)

	Station[a]											
	1	2	3	4	5	6	7	8	9	10	11	12
Chlorinated Hydrocarbons												
1,2-Dichlorobenzene	19 U	30 U	28 U	28 U	28 U	21 U	28 U	34 U	28 U	26 UG	27 U	27 U
1,3-Dichlorobenzene	34 U	41 U	39 U	39 U	39 U	38 U	39 U	47 U	39 U	36 UG	47 U	48 U
1,4-Dichlorobenzene	18 U	28 U	26 U	26 U	26 U	20 U	26 U	30 U	26 U	24 UG	25 U	26 U
1,2,4-Trichlorobenzene	22 U	34 U	32 U	32 U	32 U	25 U	32 U	40 U	32 U	29 UG	31 U	32 U
Hexachlorobenzene	39 U	60 U	56 U	57 U	56 U	43 U	57 U	68 U	56 U	52 UG	54 U	58 U
Hexachlorbutadiene	50 U	70 U	60 U	70 U	60 U	50 U	70 U	80 U	80 U	60 UG	70 U	67 U
Chlorinated Pesticides												
p,p'-DDT	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	3.0 U	4.0 U	4.0 U
p,p'-DDE	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	7.1 T
p,p'-DDD	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	65
Heptachlor	23 UE	13 UE	2.0 U	14 UE	8.0 UE	13 UE	12 UE	2.0 U	2.0 U	15 UE	20 UE	20 UE
Heptachlor epoxide	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
α-Chlordane	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	10 T
γ-Chlordane	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	11 T
Methoxychlor	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U
Aldrin	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
Dieldrin	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U
Endrin	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U
Endrin ketone	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U
Toxaphene	300 U	300 U	300 U	300 U	300 U	300 U	300 U	300 U	300 U	300 U	300 U	300 U
Endosulfan sulfate	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U	8.0 U
α-Endosulfan	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
ß-Endosulfan	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U
α-Hexachlorocyclohexane	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
ß-Hexachlorocyclohexane	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
γ-Hexachlorocyclohexane	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
δ-Hexachlorocyclohexane	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U

[a]All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

E - Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned *E* qualifiers when one quality assurance/quality control result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limits.
G - Estimate is greater than value shown.
L - Value is less than the maximum shown.
NA - Not analyzed.
T - Detected between the limit of detection and the quantification limit at the concentration shown. These values are acceptable as estimates.
U - Undetected at detection limit shown.
ZU - Value is less than the related detection limit because blank contamination was present.

[b] Polycyclic aromatic hydrocarbons.

[c] Polychlorinated biphenyls.

TABLE 8. CONCENTRATIONS OF ORGANIC COMPOUNDS IN SEDIMENT SAMPLES FROM AREAS OUTSIDE BUDD INLET BASED ON DRY WEIGHT NORMALIZATION (μg/kg dry weight)

	Station[a,b]									
	16		17		20		23		24	
Low Molecular Weight PAH[c]	78	*L*	65	*E*	48	*L*	57	*L*	24	*L*
Naphthalene	6.4	*E*	8.3	*E*	8.3	*T*	4.6	*E*	3.4	*N*
2-Methylnaphthalene	3.3	*N*	4.5	*N*	4.8	*N*	2.7	*N*	6.8	*U*
Acenaphthylene	15	*U*	3.6	*E*	1.7	*N*	1.5	*N*	0.8	*N*
Fluorene	15	*U*	3.9	*E*	7.8	*U*	10	*U*	1.6	*N*
Phenanthrene	35	*T*	37	*T*	24	*N*	38	*T*	14	*T*
Anthracene	6.2	*E*	12	*E*	6	*E*	2.7	*E*	3.9	*E*
High Molecular Weight PAH	120	*L*	260	*L*	140	*L*	80	*L*	60	*L*
Fluoranthene	32	*N*	100		41	*T*	23	*T*	17	*N*
Pyrene	25	*T*	74	*T*	31	*T*	16	*T*	13	*T*
Benz(a)anthracene	13	*N*	26	*T*	22	*NT*	10	*U*	7.3	*N*
Benzo(a)pyrene	6.9	*N*	17	*N*	13	*N*	5.7	*E*	4.1	*E*
Indeno(1,2,3-c,d)pyrene	15	*N*	15	*N*	13	*N*	8.8	*N*	5.4	*N*
Dibenz(a,h)anthracene	15	*U*	13	*U*	7.8	*U*	5.4	*N*	6.8	*U*
Benzo(g,h,i)perylene	15	*U*	13	*U*	7.8	*U*	10	*U*	6.8	*U*
Total PCBs[d]	16		79		22		21		13	
Phenols										
Phenol	17	*N*	21	*N*	7.4	*N*	12	*N*	7.7	*E*
2-Methylphenol	5	*U*	4.6	*U*	2.7	*U*	3.5	*U*	2.4	*U*
2,4-Dimethylphenol	5.8	*U*	5.3	*U*	3.1	*U*	4	*U*	2.7	*U*
4-Methylphenol	2.9	*N*	13	*U*	7.8	*U*	10	*U*	6.8	*U*
Pentachlorophenol	73	*U*	67	*U*	39	*U*	50	*U*	34	*U*
Phthalate Esters										
Bis(2-ethylhexyl)phthalate	18	*ZU*	18	*ZU*	41	*ZU*	10	*U*	9.6	*ZU*
Chlorinated Hydrocarbons										
1,2-Dichlorobenzene	15	*U*	13	*U*	2.2	*N*	10	*U*	6.8	*U*
1,3-Dichlorobenzene	15	*U*	13	*U*	7.8	*U*	10	*U*	6.8	*U*
1,4-Dichlorobenzene	15	*U*	13	*U*	3.8	*N*	10	*U*	6.8	*U*
1,2,4-Trichlorobenzene	6.1	*U*	5.6	*U*	3.2	*U*	4.2	*U*	2.9	*U*
Hexachlorobenzene	15	*U*	13	*U*	7.8	*U*	10	*U*	6.8	*U*
Hexachlorobutadiene	11	*U*	10	*U*	5.8	*U*	8	*U*	5.1	*U*

TABLE 8. (Continued)

	Station[a,b]				
	16	17	20	23	24
Chlorinated Pesticides					
p,p'-DDT	2.0 *U*	2.0 *U*	2.0 *U*	2.0 *U*	2.0 *U*
p,p'-DDE	1.0 *U*	2.0 *U*	2.0 *U*	2.0 *U*	2.0 *U*
p,p'-DDD	2.0 *U*	2.0 *U*	2.0 *U*	5.0 *U*	2.0 *U*
Heptachlor	0.50 *U*	0.50 *U*	0.50 *U*	0.50 *U*	0.50 *U*
α-Chlordane	1.0 *U*	1.0 *U*	1.0 *U*	1.0 *U*	1.0 *U*
Aldrin	1.0 *U*	3.0 *U*	1.0 *U*	1.5 *U*	1.0 *U*
Dieldrin	1.0 *U*	1.0 *U*	1.0 *U*	5.0 *U*	1.0 *U*
γ-Hexachlorocyclohexane	0.50 *U*	0.50 *U*	0.50 *U*	0.50 *U*	0.50 *U*

[a] Station 16 = Eld Inlet
Station 17 = Henderson Inlet
Station 20 = Cormorant Passage
Station 23 = Carr Inlet
Station 24 = Wollochet Bay.

[b] All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

E - Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned *E* qualifiers when one quality assurance and quality control result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limits.
L Value is less than the maximum shown.
N - Reported analytical results based upon presumptive evidence (i.e., all criteria for compound identification as specified by Contract Laboratory Program protocols were not met).
T Detected between the limit of detection and the quantification limit. These values are acceptable as estimates.
U Undetected at detection limit shown.
ZU - Value is less than the related detection limit because blank contamination was present.

[c] PAH - polycyclic aromatic hydrocarbon.

[d] PCBs - polychlorinated biphenyls.

TABLE 9. CONCENTRATIONS OF NONIONIC ORGANIC COMPOUNDS IN SEDIMENT SAMPLES FROM BUDD INLET BASED ON ORGANIC CARBON NORMALIZATION (μg/kg organic carbon)

	Station[a]											
	1	2	3	4	5	6	7	8	9	10	11	12
Low Molecular Weight PAH[b]	5,000 L	10,000 L	8,800 U	12,000 L	4,200 L	8,800 U	7,500 L	9,400 L	8,900 L	24,000 G	8,200 U	10,000 U
Naphthalene	770 U	1,210 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,300 U	1,100 U	1,800 UG	1,400 U	1,700 U
2-Methylnaphthalene	770 U	1,210 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	1,800 UG	1,400 U	1,700 U
Acenaphthylene	770 U	1,210 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	1,800 UG	1,400 U	1,700 U
Acenaphthene	770 U	1,210 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	1,800 UG	1,400 U	1,700 U
Fluorene	770 U	1,210 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	1,800 G	1,400 U	1,700 U
Phenanthrene	1,200 T	3,820	1,500 U	5,900	800 T	1,500 U	1,500 T	1,900 T	3,300	15,000 G	1,400 U	1,700 U
Anthracene	770 U	1,210 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	2,500 G	1,400 U	1,700 U
High Molecular Weight PAH	13,000 L	20,000 L	18,000 L	31,000 L	7,700 L	570,000 U	16,000 L	25,000 L	28,000 L	100,000 G	14,000 U	17,000 U
Fluoranthene	3,000	5,000	3,500 T	8,400	1,400 T	1,500 U	2,900 T	5,100	6,700	24,000 G	1,400 U	1,700 U
Pyrene	2,300	4,100	3,200 T	7,500	1,300 T	1,500 U	2,800 T	4,400	5,300	21,000 G	1,400 U	1,700 U
Benz(a)anthracene	1,100 T	1,400 T	1,500 U	2,700 T	680 U	1,500 U	1,200 U	2,000 T	2,700 T	8,000 G	1,600 U	1,900 U
Chrysene	1,800 T	2,500 T	2,300 T	4,100	870 T	1,500 U	1,900 T	2,500 T	3,300	12,000 G	1,400 U	1,700 U
Total benzofluoranthenes (B+K)	2,000 T	2,500 L	2,000 T	3,800	680 U	2,900 U	2,100 T	4,700	4,700	18,000 G	2,800 U	3,300 U
Benzo(a)pyrene	910 T	1,200 U	1,500 U	1,400 T	680 U	1,500 U	1,200 U	1,600 U	1,500 T	8,500 G	1,400 U	1,700 U
Indeno(1,2,3-cd)pyrene	770 U	1,200 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	5,000 G	1,400 U	1,700 U
Dibenz(a,h)anthracene	770 U	1,200 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	1,800 UG	1,400 U	1,700 U
Benzo(g,h,i)perylene	770 U	1,200 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	3,700 G	1,400 U	1,700 U
Total PCBs[c]	110 U	150 U	190 U	160 U	87 U	190 U	160 U	610 T	140 U	2,200	150 U	170 U
Phthalate Esters												
Bis(2-ethylhexyl)phthalate	3,600 ZU	20,000 ZU	15,000 ZU	25,000 ZU	13,000 ZU	6,900 ZU	22,000 ZU	4,000 ZU	31,000 ZU	34,000 ZU	1,700 ZU	1,700 U
Chlorinated Hydrocarbons												
1,2-Dichlorobenzene	430 U	880 U	1,100 U	880 U	490 U	810 U	880 U	1,100 U	780 U	1,300 UG	790 U	930 U
1,3-Dichlorobenzene	770 U	1,200 U	1,500 U	1,200 U	680 U	1,500 U	1,200 U	1,600 U	1,100 U	1,800 UG	1,400 U	1,700 U
1,4-Dichlorobenzene	410 U	820 U	1,000 U	810 U	450 U	770 U	810 U	1,000 U	720 U	1,200 UG	740 U	900 U
1,2,4-Trichlorobenzene	500 U	1,000 U	1,200 U	1,000 U	560 U	960 U	1,000 U	1,300 U	890 U	1,500 UG	910 U	1,100 U

TABLE 9. (Continued)

	Station[a]											
	1	2	3	4	5	6	7	8	9	10	11	12
Hexachlorobenzene	890 U	1,800 U	2,200 U	1,800 U	980 U	1,700 U	1,800 U	2,300 U	1,600 U	2,600 UG	1,600 U	2,000 U
Hexachlorobutadiene	1,100 U	2,100 U	2,300 U	2,200 U	1,000 U	1,900 U	2,200 U	2,700 U	2,200 U	3,000 UG	2,100 U	2,300 U
Chlorinated Pesticides												
p,p'-DDT	91 U	120 U	150 U	130 U	70 U	150 U	130 U	130 U	110 U	150 U	120 U	140 U
p,p'-DDE	91 U	120 U	150 U	130 U	70 U	150 U	130 U	130 U	110 U	200 U	120 U	240 T
p,p'-DDD	91 U	120 U	150 U	130 U	70 U	150 U	130 U	130 U	110 U	200 U	120 U	2,200
Heptachlor	520 UE	380 UE	77 U	440 UE	140 UE	500 UE	380 UE	67 U	56 U	750 UE	590 UE	690 UE
Heptachlor epoxide	45 U	59 U	77 U	63 U	35 U	77 U	63 U	67 U	56 U	100 U	59 U	69 U
α-Chlordane	68 U	88 U	120 U	94 U	52 U	120 U	94 U	100 U	83 U	150 U	88 U	340 T
γ-Chlordane	68 U	88 U	120 U	94 U	52 U	120 U	94 U	100 U	83 U	150 U	88 U	380 T
Methoxychlor	180 U	240 U	310 U	250 U	140 U	310 U	250 U	270 U	220 U	400 U	240 U	280 U
Aldrin	45 U	59 U	77 U	63 U	35 U	77 U	63 U	67 U	56 U	100 U	59 U	69 U
Dieldrin	91 U	120 U	150 U	130 U	70 U	150 U	130 U	130 U	110 U	200 U	120 U	140 U
Endrin	91 U	120 U	150 U	130 U	70 U	150 U	130 U	130 U	110 U	200 U	120 U	140 U
Endrin ketone	140 U	180 U	230 U	190 U	100 U	230 U	190 U	200 U	170 U	300 U	180 U	210 U
Toxaphene	6,800 U	8,800 U	12,000 U	9,400 U	5,200 U	12,000 U	9,400 U	10,000 U	8,300 U	15,000 U	8,800 U	10,000 U
Endosulfan sulfate	180 U	240 U	310 U	250 U	140 U	310 U	250 U	270 U	220 U	400 U	240 U	280 U
α-Endosulfan	45 U	59 U	77 U	63 U	35 U	77 U	63 U	67 U	56 U	100 U	59 U	69 U
ß-Endosulfan	91 U	120 U	150 U	130 U	70 U	150 U	130 U	130 U	110 U	200 U	120 U	140 U
α-Hexachlorocyclohexane	45 U	59 U	77 U	63 U	35 U	77 U	63 U	67 U	56 U	100 U	59 U	69 U
ß-Hexachlorocyclohexane	45 U	59 U	77 U	63 U	35 U	77 U	63 U	67 U	56 U	100 U	59 U	69 U
γ-Hexachlorocyclohexane	45 U	59 U	77 U	63 U	35 U	77 U	63 U	67 U	56 U	100 U	59 U	69 U
δ-Hexachlorocyclohexane	68 U	88 U	120 U	94 U	52 U	120 U	94 U	100 U	83 U	150 U	88 U	100 U

[a] All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

E - Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned *E* qualifiers when one quality assurance and quality control result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limits.
G - Estimate is greater than value shown.
L - Value is less than the maximum shown. These values are acceptable as estimates.
T - Detected between the limit of detection and the quantification limit at the concentration shown.
U - Undetected at detection limit shown.
ZU - Value is less than the related detection limit because blank contamination was present.

[b] Polycyclic aromatic hydrocarbons.

[c] Polychlorinated biphenyls.

TABLE 10. CONCENTRATIONS OF NONIONIC ORGANIC COMPOUNDS IN SEDIMENT SAMPLES FROM AREAS OUTSIDE BUDD INLET BASED ON ORGANIC CARBON NORMALIZATION (μg/kg organic carbon)

	Station[a,b]									
	16		17		20		23		24	
Low Molecular Weight PAH[c]	2,600	*L*	2,100	*E*	4,800	*L*	3,800	*L*	2,200	*L*
Naphthalene	210	*E*	270	*E*	830	*T*	310	*E*	310	*N*
2-Methylnaphthalene	110	*N*	150	*N*	480	*N*	180	*N*	620	*U*
Acenaphthylene	500	*U*	120	*E*	170	*N*	100	*N*	73	*N*
Fluorene	500	*U*	130	*E*	780	*U*	670	*U*	150	*N*
Phenanthrene	1,200	*T*	1,200	*T*	2,400	*N*	2,500	*T*	1,300	*T*
Anthracene	210	*E*	390	*E*	600	*E*	180	*E*	350	*E*
High Molecular Weight PAH	4,100	*L*	8,000	*L*	14,000	*L*	5,300	*L*	5,500	*L*
Fluoranthene	1,100	*N*	3,200		4,100	*T*	1,500	*T*	1,500	*N*
Pyrene	830	*T*	2,400	*T*	3,100	*T*	1,100	*T*	1,200	*T*
Benz(a)anthracene	430	*N*	840	*T*	2,200	*NT*	670	*U*	660	*N*
Benzo(a)pyrene	230	*N*	230	*N*	1,300	*N*	380	*E*	370	*E*
Indeno(1,2,3-c,d)pyrene	500	*N*	480	*N*	1,300	*N*	590	*N*	490	*N*
Dibenz(a,h)anthracene	500	*U*	420	*U*	780	*U*	360	*N*	620	*U*
Benzo(g,h,i)perylene	500	*U*	420	*U*	780	*U*	670	*U*	620	*U*
Total PCBs[d]	530		2,500		2,200		1,400		1,200	
Phthalate Esters										
Bis(2-ethylhexyl)phthalate	600	*ZU*	580	*ZU*	4,100	*ZU*	670	*U*	870	*ZU*
Chlorinated Hydrocarbons										
1,2-Dichlorobenzene	500	*U*	420	*U*	220	*N*	670	*U*	620	*U*
1,3-Dichlorobenzene	500	*U*	420	*U*	780	*U*	670	*U*	620	*U*
1,4-Dichlorobenzene	500	*U*	420	*U*	380	*N*	670	*U*	620	*U*
1,2,4-Trichlorobenzene	200	*U*	180	*U*	320	*U*	280	*U*	260	*U*
Hexachlorobenzene	500	*U*	420	*U*	780	*U*	670	*U*	620	*U*
Hexachlorobutadiene	370	*U*	320	*U*	580	*U*	530	*U*	460	*U*
Chlorinated Pesticides										
p,p'-DDT	67	*U*	65	*U*	200	*U*	130	*U*	180	*U*
p,p'-DDE	33	*U*	65	*U*	200	*U*	130	*U*	180	*U*
p,p'-DDD	67	*U*	65	*U*	200	*U*	330	*U*	180	*U*
Heptachlor	17	*U*	16	*U*	50	*U*	33	*U*	45	*U*
α-Chlordane	33	*U*	32	*U*	100	*U*	67	*U*	91	*U*
Aldrin	33	*U*	97	*U*	100	*U*	100	*U*	91	*U*
Dieldrin	33	*U*	32	*U*	100	*U*	330	*U*	91	*U*
γ-Hexachlorocyclohexane	17	*U*	16	*U*	50	*U*	33	*U*	45	*U*

TABLE 10. (Continued)

[a] Station 16 = Eld Inlet
Station 17 = Henderson Inlet
Station 20 = Cormorant Passage
Station 23 = Carr Inlet
Station 24 = Wollochet Bay.

[b] All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

- *E* - Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned *E* qualifiers when one quality assurance and quality control result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limits.
- *L* - Value is less than the maximum shown.
- *N* Reported analytical results based upon presumptive evidence (i.e., all criteria for compound identification as specified by Contract Laboratory Program protocols were not met).
- *T* - Detected between the limit of detection and the quantification limit. These values are acceptable as estimates.
- *U* Undetected at detection limit shown.
- *ZU* Value is less than the related detection limit because blank contamination was present.

[c] PAH - polycyclic aromatic hydrocarbon.

[d] PCBs - polychlorinated biphenyls.

TABLE 11. CONCENTRATIONS OF TRIBUTYLTIN IN SEDIMENT SAMPLES FROM BUDD INLET

Station	Tributyltin (µg/kg dry weight)
1	16
2	15
3	12
4	62
5	11
6	7.3
7	15
8	21
9	8.4
10	5.9
11	4.9
12	3.1

those patterns. Tributyltin was not evaluated in samples outside Budd Inlet, because boating activities are not as extensive outside that embayment.

The highest concentrations of LPAH and HPAH compounds were found at Station 10 in Budd Inlet. The highest concentration of total PCBs was found at Station 17 in Henderson Inlet. As noted above, phenol and 4-methylphenol were detected at numerous stations. The highest concentrations of both compounds were found at Station 1 in Budd Inlet. Guaiacols (evaluated at 5 of the 12 stations in Budd Inlet most likely to be affected by pulp-mill wastes) were not detected at any station. Chlorinated hydrocarbons were detected only at very low concentrations at Station 20 in Cormorant Passage. The only chlorinated pesticides detected were p,p'-DDE, p,p'-DDD, α-chlordane, and γ-chlordane at Station 12 in Budd Inlet.

Concentrations of four of the organic compounds detected in sediment samples from Budd Inlet exceeded various sediment quality values for Puget Sound. Those compounds included phenol, 4-methylphenol, p,p'-DDD, and indeno(1,2,3-cd)pyrene.

On the basis of dry weight normalization, LAET values were exceeded for phenol, 4-methylphenol, and p,p'-DDD. Concentrations of phenol exceeded the HAET value at five stations (Stations 1, 8, 9, 11, and 12), and exceeded the LAET value at six additional stations (Stations 2, 3, 4, 5, 7, and 10). Concentrations of 4-methylphenol exceeded the LAET value at two stations (Stations 1 and 5). Concentrations of p,p'-DDD exceeded the HAET value at Station 12. On the basis of organic carbon normalization, concentrations of p,p'-DDD exceeded the LAET value at Station 12.

The numerical sediment quality standards were exceeded for phenol at 11 stations and for 4-methylphenol at 2 stations.

ML values were exceeded for phenol at Stations 1, 8, 9, 11, and 12 and for 4-methylphenol at Stations 1 and 5. SL values were exceeded for phenol at Stations 2, 3, 4, 5, 7, and 10 and for 4-methylphenol at Stations 8, 9, and 10. In addition, SL values were exceeded for indeno(1,2,3-cd)pyrene at Station 10.

The concentrations of LPAH and HPAH found in the present study were not compared with the interim performance standards for reference areas in Puget Sound, because most of the individual compounds included in those total values were not detected in the present study. The interim performance standard for total PCBs (30 μg/kg) was exceeded at two stations (Station 10 in Budd Inlet and Station 17 in Henderson Inlet). Although the value observed at Station 10 (43 μg/kg) exceeded the interim performance standard by a relatively small amount, the value observed at Station 17 (79 μg/kg) was over 2.5 times higher than the interim standard. However, the value observed at Station 17 was a little over half the LAET value of 130 μg/kg, suggesting that although the observed concentration was higher than the level expected in a reference area, it was considerably lower than the level at which adverse biological effects might be expected.

Concentrations of LPAH and HPAH compounds were relatively low at the two PSAMP stations sampled in Budd Inlet, as well as the other six PSAMP stations sampled in southern Puget Sound (Tetra Tech 1990). For example, all concentrations of total LPAH and HPAH compounds were less than 100 μg/kg and 500 μg/kg (respectively) at the eight PSAMP stations sampled in southern Puget Sound. Malins et al. (1982) also found relatively low concentrations of total LPAH (54-210 μg/kg) and HPAH (350-690 μg/kg) compounds in sediments from three stations in Budd Inlet.

In Table 6, the concentrations of the primary organic compounds detected in the present study are compared with the values found in numerous areas throughout Puget Sound during other recent surveys of sediment contamination. In many

cases, the maximum concentrations found in the present study were considerably lower than the values found in the major urban bays, but were within the range of values found in the transitional or reference areas. However, major exceptions to this pattern were apparent for the maximum concentrations of phenol, 4-methylphenol, p,p'-DDD, and tributyltin found in Budd Inlet. Each of these exceptions is described below:

- The maximum concentration of phenol in Budd Inlet (3,300 μg/kg) was greater than the range of maximum values found in the major urban bays (1,200-2,900 μg/kg).

- The maximum concentration of 4-methylphenol in Budd Inlet (1,600 μg/kg) was less than the range of maximum values found in the major urban bays (2,600-98,000 μg/kg), but considerably greater than the range of maximum values found in the transitional areas (47-240 μg/kg) and reference areas (32-290 μg/kg).

- The maximum concentration of p,p'-DDD in Budd Inlet (65 μg/kg) was within the range of maximum values found in the major urban bays (50*U*-140 μg/kg), and considerably greater than the range of maximum values found in the transitional areas (0.5*U*-4.9 μg/kg) and the reference areas (25*U*-33*U*).

- The maximum concentration of tributyltin in Budd Inlet (62 μg/kg) was considerably greater than the range of maximum values found in the transitional areas (6-22 μg/kg). No information on tributyltin concentrations was available for the major urban bays or reference areas.

In summary, the results of this study suggest that although the observed concentrations of most organic compounds in sediments were relatively low at the 17 stations evaluated in southern Puget Sound, phenol and 4-methylphenol were

present at multiple locations in Budd Inlet at concentrations that may be associated with adverse biological effects (although sediments from these stations were not considered toxic based on the results of the amphipod mortality toxicity tests). In addition, p,p'-DDD was present at a single station in Budd Inlet at concentrations that may be associated with adverse biological effects.

CHEMICAL CONTAMINANTS IN TISSUE

Fish

Of the total of 94 chemicals evaluated in muscle tissue samples from English sole (Transects T4 and T6) and starry flounder (Transects T1, T2, T3, T5, and T7), only four metals (i.e, arsenic, copper, lead, and mercury) and four organic compounds (i.e., total PCBs, di-*n*-butyl phthalate, isophorone, and benzoic acid) were detected (Table 12). However, the concentrations of all of these detected chemicals, except di-*n*-butyl phthalate, were relatively low.

The four metals were found in fish from all seven transects. The highest concentrations of arsenic were found in English sole from Transects T4 (6.3 mg/kg; Totten Inlet) and T6 (9.8 mg/kg; Carr Inlet). The highest concentrations of mercury were found in English sole from Transect T4 (0.12 mg/kg), and in starry flounder from Transects T2 (0.13 mg/kg; outer Budd Inlet) and T7 (0.10 mg/kg; Carr Inlet). Concentrations of copper and lead were generally similar among all transects, with overall ranges of 0.20-0.31 and 0.02-0.04 mg/kg, respectively.

One or more of the four organic compounds were detected in fish from all seven transects. PCBs were detected in fish from five of the seven transects. The highest concentrations of total PCBs were found in starry flounder from

TABLE 12. CHEMICAL CONCENTRATIONS IN TISSUE SAMPLES OF ENGLISH SOLE AND STARRY FLOUNDER FROM SOUTHERN PUGET SOUND

	Transect [a,b,c]						
	T1	T2	T3	T4	T5	T6	T7
Metals (mg/kg, wet weight)							
Arsenic	0.53TE - 1.10S	0.51TE - 0.75TM	1.4T - 1.8	3.9 - 6.3	1.1T - 1.3T	1.70M - 9.80	2.8E - 3.1
Copper	0.21 - 0.28	0.22M - 0.31	0.22 - 0.29	0.25 - 0.29	0.21 - 0.26	0.25 - 0.28	0.20 - 0.23
Lead	0.02T - 0.03T	0.02U - 0.04T	0.02U	0.02T - 0.04T	0.02UE	0.02T - 0.04T	0.02UE
Mercury	0.04T - 0.05	0.07 - 0.13EM	0.02TE - 0.07E	0.02T - 0.12	0.02TE - 0.04E	0.05 - 0.06	0.07E - 0.10E
Organic Compounds (µg/kg, wet weight)							
Low Molecular Weight PAH[d]							
Naphthalene	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
2-Methlynaphthalene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 32U	36U - 41U	33U
Acenaphthylene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 33U	36U - 41U	33U
Acenaphthene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 33U	36U - 41U	33U
Fluorene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 33U	36U - 41U	33U
Phenanthrene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 33U	36U - 41U	33U
Anthracene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	33U - 32U	36U - 41U	33U
High Molecular Weight PAH							
Fluoranthene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 32U	36U - 41U	33U
Pyrene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 32U	36U - 41U	33U
Benz(a)anthracene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 32U	36U - 41U	33U
Chrysene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 32U	36U - 41U	33U
Total benzofluoranthenes (B + K)	62U - 64U	64U - 80U	86U - 90U	90U - 120U	64U - 66U	72U - 82U	66U
Benzo(a)pyrene	31U - 32U	32U - 40U	43U - 45U	45U - 310U	32U - 33U	36U - 41U	33U
Indeno(1,2,3-cd)pyrene	31UE - 32UE	32UE - 40UE	43UE - 45UE	45UE - 62UE	32UE - 33UE	36UE - 41UE	33UE
Dibenz(a,h)anthracene	31U - 32U	32U - 40U	43U, 45U	45U - 62U	32U - 33U	36U - 41U	33U
Benzo(g,h,i)perylene	31U - 32U	32U - 40U	43U, 45U	45U - 62U	32U - 33U	36U - 41U	33U
Total PCBs[e]	24T - 34T	15T - 45T	5U - 18E	5U	5U	5U - 28T	5U - 40

TABLE 12. (Continued)

	Transect [a,b,c]						
	T1	T2	T3	T4	T5	T6	T7
Phenols and Substituted Phenols							
Phenol	63U - 65U	64U - 80U	86U - 91U	90U - 120U	64 - 66U	70U - 80U	66U
2-Methylphenol	19U	18U - 26U	24U - 25U	27U - 37U	18U	21U - 25U	18U - 26U
4-Methylphenol	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
2,4-Dimethylphenol	56U - 58U	19U - 64U	25U - 26U	80U - 110U	19U	60U - 70U	19U - 28U
2-Chlorophenol	31U - 32U	32U - 40U	43U - 45U	450U - 62U	32U - 33U	36U - 41U	33U
2,4-Dichlorophenol	90U - 100U	97U - 120U	130U - 140U	140U - 190U	97U - 100U	110U - 120U	99U - 100U
4-Chloro-3-methylphenol	63U - 65U	64U - 80U	86U - 91U	90U - 120U	64U - 66U	70U - 80U	66U
2,4,5-Trichlorophenol	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
2,4,6-Trichlorophenol	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
2-Nitrophenol	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
2,4-Dinitrophenol	310U - 320U	320U - 400U	430U - 450U	450U - 620U	320U - 330U	360U - 410U	330U
4-Nitrophenol	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
2-Methyl-4,6-dinitrophenol	310U - 320U	320U - 400U	430U - 450U	450U - 620U	320U - 330U	360U - 410U	330U
Pentachlorophenol	90U - 100U	100U - 130U	130U - 140U	140U - 190U	100U	110U - 120U	100U
Phthalate Esters							
Dimethyl phthalate	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Diethyl phthalate	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Di-*n*-butyl phthalate	31U - 32U	33U - 160U	43U - 45U	45U - 890	32U - 33U	36U - 41U	33U
Butyl benzyl phthalate	31U - 32U	33U - 160U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Bis(2-ethylhexyl)phthalate	31U - 220UZ	32U - 40U	43U - 45U	45U - 310UZ	32U - 33U	36U - 41U	33U
Di-*n*-octyl phthalate	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Chlorinated Hydrocarbons							
1,2-Dichlorobenzene	18U	18U - 25U	23U - 24U	26U - 35U	17U - 18U	20U - 24U	18U - 25U
1,3-Dichlorobenzene	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
1,4-Dichlorobenzene	17U	16U - 22U	21U - 22U	24U - 33U	16U	19U - 22U	16U - 23U
1,2,4-Trichlorobenzene	21U	21U - 26U	27U - 29U	30U - 41U	20U - 21U	24U - 27U	21U - 28U
2-Chloronaphthalene	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U

TABLE 12. (Continued)

	Transect [a,b,c]						
	T1	T2	T3	T4	T5	T6	T7
Hexachlorobenzene	36U - 37U	39U - 56U	60U - 63U	51U - 70U	45U - 47U	41U - 47U	46U - 47U
Hexachlorobutadiene	44U - 45U	46U - 56U	60U - 63U	60U - 90U	45U - 47U	50U - 60U	46U - 57U
Hexachloroethane	63U - 65U	64U - 80U	86U - 91U	90U - 120U	64U - 66U	70U - 80U	66U
Hexachlorocyclopentadiene	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
Halogenated Ethers							
Bis(2-chloroethyl)ether	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Bis(2-chloroisopropyl)ether	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Bis(2-chloroethoxy)methane	31U - 32U	32U - 40U	43U - 45U	45U - 62U	33U - 33U	36U - 41U	33U
4-Chlorophenyl phenyl ether	31U - 32U	32U - 40U	43U - 45U	45U - 62U	33U - 33U	36U - 41U	33U
4-Bromophenyl phenyl ether	31U - 32U	32U - 40U	43U - 45U	45U - 62U	33U - 33U	36U - 41U	33U
Miscellaneous Oxygenated Compounds							
Benzyl alcohol	40U	40U - 50U	50U - 60U	50U - 70U	40U - 42U	40U - 50U	41U - 48U
Benzoic acid	160U - 190T	160U - 200U	220U - 320	230U - 310U	160U - 180	190 - 260	170
Dibenzofuran	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Organonitrogen Compounds							
Aniline	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
Nitrobenzene	31U - 32U	32U - 40U	43U - 45U	46U - 62U	32U - 33U	36U - 41U	33U
N-nitrosodi-*n*-propylamine	31U - 32U	32U - 40U	43U - 45U	46U - 62U	32U - 33U	36U - 41U	33U
N-nitrosodimethylamine	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
1,2-Diphenylhydrazine	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
Carbazole	31U - 32U	32U - 40U	43U - 45U	45U - 62U	32U - 33U	36U - 41U	33U
4-Chloroaniline	94U - 97U	97U - 120U	130U - 140U	140U - 190U	96U - 100U	110U - 120U	99U - 100U
2-Nitroaniline	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
3-Nitroaniline	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
4-Nitroaniline	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
2,6-Dinitrotoluene	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
2,4-Dinitrotoluene	160U	160U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 210U	160U - 170U
N-nitrosodiphenylamine	16U - 17U	16U - 23U	25U - 26U	23U - 32U	19U	18U - 21U	19U

TABLE 12. (Continued)

	Transect [a,b,c]						
	T1	T2	T3	T4	T5	T6	T7
Benzidine	1,600U	1,600U - 2,000U	2,200U - 2,300U	2,300U - 3,100U	160U - 1,700U	1,800U - 2,100U	1,600U - 1,700U
3,3'-Dichlorobenzidine	160U	32U - 200U	220U - 230U	230U - 310U	160U - 170U	180U - 2,100U	160U - 170U
Chlorinated Pesticides							
p,p'-DDT	4U	4U	4U	4U	4U	4U	4U
p,p'-DDD	4U	4U	4U	4U	4U	4U	4U
p,p'-DDE	4U	4U	4U	4U	4U	4U	4U
Heptachlor	2U	2U	2U	2U	2U	2U	2U - 14U
Heptachlor epoxide	2U	2U	2U	2U	2U	2U	2U
α-Chlordane	3U	3U	3U	3U	3U	3U	3U
γ-Chlordane	3U	3U	3U	3U	3U	3U	3U
Methoxychlor	8U	8U	8U	8U	8U	8U	8U
Aldrin	2U	2U	2U	2U	2U	2U	2U
Dieldrin	4U	4U	4U	4U	4U	4U	4U
Endrin	4U	4U	4U	4U	4U	4U	4U
Endrin ketone	6U	6U	6U	6U	6U	6U	6U
Isophorone	150 - 170	32U - 180	110 - 300	62U - 83T	71T - 120	36U - 41U	73T - 200
Toxaphene	300U	300U	300U	300U	300U	300U	300U
Endosulfan sulfate	8U	8U	8U	8U	8U	8U	8U
α-Endosulfan	2U	2U	2U	2U	2U	2U	2U
ß-Endosulfan	4U	4U	4U	4U	4U	4U	4U
α-Hexachlorocyclohexane	2U	2U	2U	2U	2U	2U	2U
ß-Hexachlorocyclohexane	2U	2U	2U	2U	2U	2U	2U

TABLE 12. (Continued)

	Transect [a,b,c]						
	T1	T2	T3	T4	T5	T6	T7
γ-Hexachlorocyclohexane	2U	2U	2U	2U	2U	2U	2U
δ-Hexachlorocyclohexane	3U	3U	3U	3U	3U	3U	3U
Lipid Content (percent)	0.23 - 0.27	0.24 - 0.41	0.39 - 0.65	0.32 - 0.51	0.33 - 0.47	0.28 - 0.35	0.30 - 0.37

[a] Transect locations and species evaluated are:

T1 - Inner Budd Inlet - starry flounder
T2 - Outer Budd Inlet - starry flounder
T3 - Oakland Bay - starry flounder
T4 - Totten Inlet - English sole
T5 - Case Inlet - starry flounder
T6 - McNeil Island - English sole
T7 - Carr Inlet - starry flounder.

[b] Concentrations are presented as the range of values found for the three replicate composite samples at each transect. If all values are equal for the three samples, a single concentration is presented in the table. Mean values were not calculated because most chemicals were not detected. Values for each composite sample at each transect are presented in Appendix B.

[c] All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

E - Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned *E* qualifiers when one quality assurance and quality control result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limits.
M - Value is a mean.
S - Value determined by method of standard additions; the value is reliable and should not be considered an estimate.
T - Detected between the limit of detection and the quantification limit at the concentration shown. These values are acceptable as estimates.
U - Undetected at detection limit shown.

[d] Polycyclic aromatic hydrocarbon.

[e] Polychlorinated biphenyls.

Transects T2 (45 μg/kg) and T7 (40 μg/kg). Di-*n*-butyl phthalate was found only in fish from Transect T4 at a maximum concentration of 890 μg/kg. Benzoic acid was found in fish from five transects, with the highest concentration observed in starry flounder from Transect T3 (320 μg/kg). Isophorone was found in fish from all transects except Transect T6, with the highest concentration found in starry founder from Transect T3 (300 μg/kg).

Four of the eight chemicals found in fish tissue during the present study were considered in Tetra Tech (1988) to have a medium to high priority with respect to concerns for potential health risks to humans through seafood consumption. Those chemicals include two carcinogens (i.e., arsenic and total PCBs) and two noncarcinogens (i.e., lead and mercury).

Although a formal health risk assessment was beyond the scope of the present study, the health implications of the observed tissue concentrations of the four priority chemicals were evaluated qualitatively by comparing them with the results of the risk assessments conducted previously by Tetra Tech (1988). To place the risk values in a regulatory perspective, values $\leq 10^{-4}$ for carcinogens and risk index values < 1.0 for noncarcinogens were consistent with EPA's Superfund site remediation goals, as contained in the National Contingency Plan (U.S. EPA 1989). Therefore, the values were indicative of the absence of unacceptable risks to human health. Based on those criteria, it is unlikely that any of the four priority chemicals posed an unacceptable health risk at the tissue concentrations measured in the present study.

For the carcinogens, the maximum concentration of arsenic observed in the present study (9.8 mg/kg) was comparable to the mean value of 6.4 mg/kg found for fish in Commencement Bay by Tetra Tech (1988). The plausible upper limit estimate of excess lifetime cancer risk associated with the Commencement Bay value was estimated as 2×10^{-5} for the average fish consumption rate assumed for Puget Sound (12.3 grams/day) (Tetra Tech 1988). The maximum value of total

PCBs found in the present study (i.e., 45 μg/kg) was comparable to the mean value of 51 μg/kg found for fish at Point No Point (located off the central basin in northern Puget Sound) by Tetra Tech (1988). The plausible upper limit estimate of excess lifetime cancer risk associated with the value found at Point No Point was estimated as 7×10^{-5} for the average fish consumption rate (Tetra Tech 1988).

For the noncarcinogens, the maximum value of lead observed in the present study (0.04 mg/kg) was comparable to the mean value of 0.03 mg/kg found for fish in Elliott Bay by Tetra Tech (1988). The noncarcinogenic risk index associated with the Elliott Bay value was estimated as 3×10^{-3} for the average consumption rate (Tetra Tech 1988). The maximum value of mercury found in the present study (0.13 mg/kg) was comparable to the mean value of 0.15 mg/kg found for fish from Anacortes by Tetra Tech (1988). The noncarcinogenic risk index associated with the value found at Anacortes was estimated as 9×10^{-2} for the average fish consumption rate (Tetra Tech 1988).

In Table 13, the tissue concentrations of metals and total PCBs found in the present study are compared with the values found in the muscle tissue of flatfishes collected from numerous areas throughout Puget Sound during other recent surveys of tissue contamination in fishes. The following chemical-specific patterns were apparent:

- Arsenic—In most cases, the concentrations of arsenic found in the present study were below or within the range of mean values found for reference areas. An exception was the maximum value of 9.8 mg/kg observed off McNeil Island, which was within the range of mean values found in transitional areas.

- Copper—In most cases, the concentrations of copper found in the present study were within the range of mean values found for reference areas. An exception was the maximum value of

TABLE 13. COMPARISONS OF TISSUE CONCENTRATIONS OF SELECTED CHEMICALS IN VARIOUS FLATFISHES COLLECTED FROM VARIOUS LOCATIONS IN PUGET SOUND

Embayment	Data Source[c]	Species[d]	Chemical[a,b] Arsenic	Copper	Lead	Mercury	Total PCBs
Major Urban Bays							
Bellingham Bay	1	ES	3.8	0.23	0.04 *U*[e]	--[f]	13 *U*
Commencement Bay	2	ES	3.3	0.14	0.20	0.059	210
Elliott Bay	1,3	ES	--, 6.4	--, 0.22	--, 0.05	0.07, 0.065	39, 260
Everett Harbor	1,4	ES	--, 4.5	--, 0.22	--, 0.05	0.05, 0.042	23, 26
Sinclair Inlet	1, 5	ES, ES	8.7, 6.7	0.27, 0.29	0.07, 0.55	0.07, 0.09	102, 32
Transitional Areas[g]							
Dyes Inlet	5	ES	5.2	0.20	0.29	0.004 *U*	24
Gig Harbor	5	ES	10	0.17	0.63	0.072	56
Lake Washington Ship Canal	5	ES	3.4	0.32	0.35	0.038	36
Liberty Bay	5	RS	4.5	0.14	0.14	0.082	16
Oak Harbor	5	SF	2.5	0.29	0.25	0.12	16
Port Angeles	5	SD	3.5	0.15	0.18	0.19	12
Port Gamble	5	ES	3.2	0.43	0.18	0.036	28
Port Townsend	1, 5	ES, ES	5.0, 3.1	0.19, 0.22	0.06, 0.18	--, 0.004 *U*	9.1 *U*, 15
Quartermaster Harbor	5	ES	9.4	0.35	0.23	0.12	23

TABLE 13. (Continued)

Embayment	Data Source[c]	Species[d]	Chemical[a,b] Arsenic	Copper	Lead	Mercury	Total PCBs
Reference Areas							
Carr Inlet	2	ES	7.9	0.038 *U*	0.22	0.055	36
Discovery Bay	1	ES	6.7	0.22	0.07	--	12 *U*
Hood Canal	1	ES	4.7	0.21	0.04 *U*	0.06	6.7 *U*
Port Susan	4, 5	ES, ES	--, 3.0	--, 0.25	--, 0.21	0.067, 0.052	8.3, 16
Richmond Beach	5	ES	3.6	0.18	0.13	0.046	14
Skagit Bay	5	SF	2.0	0.29	0.20	0.038	10
Strait of Georgia	1	ES	3.4	0.23	0.05	0.06	8.4 *U*
Present Study							
Budd Inlet	6	SF	0.51–1.1	0.21–0.31	0.02 *U*–0.04	0.04–0.13	15–45
Carr inlet	6	SF	2.8–3.1	0.20–0.23	0.02 *U*	0.07–0.10	5 *U*–40
Case inlet	6	SF	1.1–1.3	0.21–0.26	0.02 *U*	0.02–0.04	5 *U*
McNeil Island	6	ES	1.7–9.8	0.25–0.28	0.02–0.04	0.05–0.06	5 *U*–28
Oakland Bay	6	SF	1.4–1.8	0.22–0.29	0.02 *U*	0.02–0.07	5 *U*–18
Totten Inlet	6	ES	3.9–6.3	0.25–0.29	0.02–0.04	0.02–0.12	5 *U*

[a] Concentrations for metals - mg/kg (wet weight)
Concentrations for total PCBs - µg/kg (wet weight).

[b] Concentrations for all studies other than the present study are mean values. Where data are presented from two sources, species names and mean concentrations are presented in the same order as the two sources. Concentrations for the present study are ranges unless all values at a station were the same.

TABLE 13. (Continued)

[c] Sources:

1 - O'Neill and Schmitt (1991).
2 - Tetra Tech (1985).
3 - PTI and Tetra Tech (1988a).
4 - PTI and Tetra Tech (1988b).
5 - Crecelius et al. (1989). Concentrations for this study were originally reported on a dry weight basis. Conversion of concentrations to a wet-weight basis were made by dividing each dry-weight concentration by 5.0 (i.e., it was assumed that each tissue was 20 percent dry weight).
6 - Present study.

[d] ES - English sole *(Parophrys vetulus)*.
SF - Starry flounder (*Platichthys stellatus*)
RS - Rock sole (*Lepidopsetta bilineata)*.
SD - Sanddab (*Citharichthys* sp.).

[e] *U* - undetected at detection limit shown.

[f] -- indicates no data.

[g] Transitional areas are located away from major urban areas, but may be influenced by chemical contamination.

0.31 mg/kg observed in Budd Inlet, which was within the range of mean values found in transitional areas.

- Lead—The concentrations of lead found in the present study were at the lower end of the range of values found in reference areas.

- Mercury—In many cases, the concentrations of mercury found in the present study were within the range of mean values found for reference areas. Major exceptions to that pattern were the maximum concentrations observed in Carr Inlet (0.10 mg/kg), Totten Inlet (0.12 mg/kg), and Budd Inlet (0.13 mg/kg), which were within the range of mean values found in transitional areas.

- Total PCBs—In most cases, the concentrations of total PCBs found in the present study were within the range of mean values found for reference areas. Exceptions to that pattern were the maximum concentrations observed in Carr Inlet (40 μg/kg) and Budd Inlet (45 μg/kg), which were within the range of mean values found in transitional areas.

Tetra Tech (1985) measured the concentrations of di-*n*-butyl phthalate and isophorone in the muscle tissue of English sole from Carr Inlet and Commencement Bay. The ranges of concentrations of di-*n*-butyl phthalate in Carr Inlet and Commencement Bay were 10*U*-120 μg/kg and 10*U*-4,000 μg/kg, respectively. Isophorone was not detected in any fish from either Carr Inlet or Commencement Bay at a detection limit of 10 μg/kg.

In summary, concentrations of the 94 chemical contaminants evaluated in fish muscle tissue were relatively low at all of the seven transects sampled in the present study. Although several chemicals capable of posing a human health risk were detected at all seven transects, it is unlikely that any of the tissue concentra-

tions observed in the present study were high enough to pose an unacceptable health risk through seafood consumption.

Clams

Of the total of 94 chemicals evaluated in the whole bodies of littleneck clams, only four metals (i.e, arsenic, copper, lead, and mercury) and no organic compounds were detected at the two stations evaluated in Budd Inlet (Table 14). However, the concentrations of all four metals were relatively low.

All four metals were detected in clams from Station C1, and all but lead were detected in clams from Station C2. The concentrations of arsenic, copper, and mercury were similar between the two stations, whereas the concentration of lead was higher at Station C1 (0.08 mg/kg) than at Station C2 (undetected at a detection limit of 0.02 mg/kg).

Three of the four metals found in clam tissue during the present study were considered in Tetra Tech (1988) to have a medium to high priority with respect to concerns for potential health risks to humans through seafood consumption. Those chemicals included the carcinogen arsenic and the noncarcinogens lead and mercury. Although a formal health risk assessment was beyond the scope of the present study, the health implications of the observed tissue concentrations of the three priority metals were evaluated qualitatively by comparing them with the results of the risk assessments conducted previously by Tetra Tech (1988). To place the risk values in a regulatory perspective, values $\leq 10^{-4}$ for carcinogens and risk index values < 1.0 for noncarcinogens were consistent with EPA's Superfund site remediation goals, as contained in the National Contingency Plan (U.S. EPA 1989). Therefore, the values were indicative of the absence of unacceptable risks to human health. Based on those criteria, it is unlikely that

TABLE 14. CHEMICAL CONCENTRATIONS IN TISSUE SAMPLES OF LITTLENECK CLAMS FROM BUDD INLET

	Station[a,b]	
	C1	C2
Metals (mg/kg wet weight)		
Arsenic	2.10S	1.90S
Copper	1.40	1.30
Lead	0.08S	0.02U
Mercury	0.01TE	0.02TE
Organic Compounds (μg/kg, wet weight)		
Low Molecular Weight PAH[c]		
Naphthalene	160U	160U
2-Methlynaphthalene	160U	160U
Acenaphthylene	160U	160U
Acenaphthene	160U	160U
Fluorene	160U	160U
Phenanthrene	160U	160U
Anthracene	160U	160U
High Molecular Weight PAH		
Fluoranthene	160U	160U
Pyrene	160U	160U
Benz(a)anthracene	160U	160U
Chrysene	160U	160U
Total benzofluoranthenes (B + K)	320U	320U
Benzo(a)pyrene	160U	160U
Indeno(1,2,3-cd)pyrene	160UE	160UE
Dibenz(a,h)anthracene	160U	160U
Benzo(g,h,i)perylene	160U	160U
Total PCBs[d]	5U	5U

TABLE 14. (Continued)

	Station[a,b]	
	C1	C2
Phenols and Substituted Phenols		
Phenol	320U	320U
2-Methylphenol	130U	130U
4-Methylphenol	160U	160U
2,4-Dimethylphenol	130U	130U
2-Chlorophenol	160U	160U
2,4-Dichlorophenol	490U	480U
4-Chloro-3-methylphenol	320U	320U
2,4,5-Trichlorophenol	810U	810U
2,4,6-Trichlorophenol	810U	810U
2-Nitrophenol	810U	810U
2,4-Dinitrophenol	1600U	1600U
4-Nitrophenol	810U	810U
2-Methyl-4,6-dinitrophenol	1,600U	1,600U
Pentachlorophenol	490U	480U
Phthalate Esters		
Dimethyl phthalate	160U	160U
Diethyl phthalate	160U	160U
Di-*n*-butyl phthalate	160U	160U
Butyl benzyl phthalate	160U	160U
Bis(2-ethylhexyl)phthalate	360ZU	160U
Di-*n*-octyl phthalate	160U	160U
Chlorinated Hydrocarbons		
1,2-Dichlorobenzene	120U	120U
1,3-Dichlorobenzene	160U	160U
1,4-Dichlorobenzene	110U	110U
1,2,4-Trichlorobenzene	140U	140U
2-Chloronaphthalene	160U	160U
Hexachlorobenzene	230U	230U
Hexachlorobutadiene	280U	280U
Hexachloroethane	320U	320U
Hexachlorocyclopentadiene	810U	810U

TABLE 14. (Continued)

	Station[a,b]	
	C1	C2
Halogenated Ethers		
Bis(2-chloroethyl)ether	160U	160U
Bis(2-chloroisopropyl)ether	160U	160U
Bis(2-chloroethoxy) methane	160U	160U
4-Chlorophenyl phenyl ether	160U	160U
4-Bromophenyl phenyl ether	160U	160U
Miscellaneous Oxygenated Compounds		
Benzyl alcohol	230U	230U
Benzoic acid	810U	810U
Dibenzofuran	160U	160U
Organonitrogen Compounds		
Aniline	810U	810U
Nitrobenzene	160U	160U
N-nitroso-di-*n*-propylamine	160U	160U
N-nitroso-dimethylamine	810U	810U
1,2-Diphenylhydrazine	160U	160U
Carbazole	160U	160U
4-Chloroaniline	480U	490U
2-Nitroaniline	810U	810U
3-Nitroaniline	810U	810U
4-Nitroaniline	810U	810U
2,6-Dinitrotoluene	810U	810U
2,4-Dinitrotoluene	810U	810U
N-Nitrosodiphenylamine	90U	90U
Benzidine	8,100U	8,100U
3,3'-Dichlorobenzidine	810U	810U
Pesticides		
p,p'-DDT	4U	4U
p,p'-DDD	4U	4U
p,p'-DDE	4U	4U
Heptachlor	14U	14U
Heptachlor epoxide	2U	2U

TABLE 14. (Continued)

	Station[a,b]	
	C1	C2
α-Chlordane	3U	3U
γ-Chlordane	3U	3U
Methoxychlor	8U	8U
Aldrin	2U	2U
Dieldrin	4U	4U
Endrin	4U	4U
Endrin ketone	6U	6U
Isophorone	160U	170U
Toxaphene	300U	300U
Endosulfan sulfate	8U	8U
α-Endosulfan	2U	2U
ß-Endosulfan	4U	4U
α-Hexachlorocyclohexane	2U	2U
ß-Hexachlorocyclohexane	2U	2U
γ-Hexachlorocyclohexane	2U	2U
δ-Hexachlorocyclohexane	3U	3U
Lipid Content (percent)	0.80	0.92

[a] Station C1 is located in inner Budd Inlet and Station C2 is located in outer Budd Inlet.

[b] All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

E - Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned *E* qualifiers when one quality assurance and quality control result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limit.

S - Value determined by method of standard additions; the value is reliable and should not be considered an estimate.

T - Detected between the limit of detection and the quantification limit at the concentration shown

U - Undetected at detection limit shown. These values are acceptable as estimates.

Z - Blank-corrected, still above detection limit

ZU - Value is less than the related detection limit because blank contamination was present.

[c] PAH - Polycyclic aromatic hydrocarbon.

[d] PCB - Polychlorinated biphenyl.

any of the three priority chemicals posed an unacceptable health risk at the tissue concentrations measured in the present study.

For the carcinogen arsenic, the maximum concentration observed in the present study (2.1 mg/kg) was comparable to the mean value of 2.3 mg/kg found for shellfish in Birch Bay (i.e., a nonurban bay near the U.S./Canada border) by Tetra Tech (1988). The plausible upper limit estimate of excess lifetime cancer risk associated with the Birch Bay value is estimated as 5×10^{-7} for the average shellfish consumption rate assumed for Puget Sound (1.1 grams/day) (Tetra Tech 1988).

For the noncarcinogens, the maximum value of lead observed in the present study (0.08 mg/kg) was identical to the mean value found in shellfish off Mukilteo by Tetra Tech (1988). The noncarcinogenic risk index associated with the Mukilteo value was estimated as 9×10^{-4} for the average shellfish consumption rate (Tetra Tech 1988). The maximum value of mercury found in the present study (0.02 mg/kg) was identical to the mean value found in shellfish from Quartermaster Harbor (on Vashon Island) by Tetra Tech (1988). The noncarcinogenic risk index associated with the value found at Quartermaster Harbor was estimated as 1×10^{-3} for the average shellfish consumption rate (Tetra Tech 1988).

In Table 15, the tissue concentrations of arsenic, copper, lead, and mercury found in the present study are compared with the values found in littleneck clams collected from numerous locations in Puget Sound during a recent survey conducted by EPA and the Washington Department of Social and Health Services (Faigenblum 1988). One station sampled during that survey was located near Station C2 off Priest Point in Budd Inlet.

For all four metals, the ranges of concentrations found in the present study were similar to the ranges found in the reference areas by Faigenblum (1988).

TABLE 15. COMPARISONS OF TISSUE CONCENTRATIONS OF SELECTED METALS IN LITTLENECK CLAMS FROM VARIOUS LOCATIONS IN PUGET SOUND[a]

	Chemical[b]			
Location	Arsenic	Copper	Lead	Mercury
Major Urban Bays				
Everett Harbor	1.3-2.4	1.0-2.2	0.04*U*[c]-0.05	0.02*U*
Sinclair Inlet	2.0-3.6	1.3-2.4	0.12-0.18	0.03
Budd Inlet	2.1-4.1	0.6*U*-1.6	0.04*U*-0.10	0.02*U*
Transitional Areas[d]				
Alki Point	2.1-3.5	0.6*U*-2.3	0.4*U*-0.12	0.02*U*
Quartermaster Harbor	2.8-4.0	0.8-1.5	0.04*U*-0.14	0.02*U*-0.03
Reference Areas				
Birch Bay	2.1-3.2	0.6*U*-1.6	0.04*U*	0.02*U*
Dash Point	1.9-3.7	0.9-1.8	0.09-0.10	0.02*U*
Present Study	1.9-2.1	1.3-1.4	0.02-0.08	0.01-0.02

[a] All data, except those from the present study, are from Faigenblum (1988).

[b] Concentrations are mg/kg dry weight; concentrations are ranges, unless all values at a location were the same.

[c] *U* - undetected at detection limit shown.

[d] Transitional areas are located away from major urban areas, but may be influenced by chemical contamination.

The concentrations of copper, lead, and mercury found at Station C2 were similar to the ranges of concentrations found off Priest Point in Budd Inlet by Faigenblum (1988). The concentration of arsenic found at Station C2 was slightly lower than the range of values found off Priest Point by Faigenblum (1988).

In summary, bioaccumulation of chemical contaminants in the whole bodies of littleneck clams was not substantial at either of the two stations sampled in Budd Inlet. Although several chemicals capable of posing a human health risk were detected at both stations, it is unlikely that any of the tissue concentrations observed in the present study were high enough to pose an unacceptable health risk through seafood consumption.

SEDIMENT TOXICITY

The detailed results for individual bioassay samples are presented in Appendix C. Amphipod mortality at the 24 stations sampled in this study ranged from 1 to 18 percent (Table 16). All of these values are less than the interim performance standard of 25 percent proposed for Puget Sound reference areas (Pastorok et al. 1989). In addition, all values but one (18 percent at Station 8) are less than the median value of 16.2 percent observed for 60 samples from Puget Sound reference areas by Pastorok et al. (1989). These results indicate that 1) the toxicity of sediments from all 24 stations sampled in this study is well within the range of conditions found in Puget Sound reference areas, and 2) elevated sediment toxicity does not appear to be a problem at any of the sites evaluated. However, neither sublethal nor chronic effects of sediment toxicity were evaluated in this study.

The AET values specific to the amphipod mortality test (Barrick et al. 1988) were exceeded for phenol (amphipod AET = 1,200 μg/kg) at five stations and for p,p'-DDD (amphipod AET = 43 μg/kg) at a single station. These results

TABLE 16. AMPHIPOD MORTALITY IN SOUTHERN PUGET SOUND

Station	Location	Percent Mortality[a,b]	
1	Budd Inlet	15	(6.1)
2	Budd Inlet	7	(2.7)
3	Budd Inlet	1	(2.2)
4	Budd Inlet	5	(5.0)
5	Budd Inlet	6	(6.5)
6	Budd Inlet	13	(7.6)
7	Budd Inlet	12	(9.1)
8	Budd Inlet	18	(5.7)
9	Budd Inlet	5	(3.5)
10	Budd Inlet	10	(9.4)
11	Budd Inlet	9	(2.2)
12	Budd Inlet	13	(2.7)
13	Oakland Bay	5	(5.0)
14	Totten Inlet	4	(4.2)
15	Hammersley Inlet	9	(9.6)
16	Eld Inlet	10	(7.9)
17	Henderson Inlet	11	(5.5)
18	Case Inlet	4	(4.2)
19	Filucy Bay	5	(8.7)
20	Cormorant Passage	10	(11.7)
21	Steilacoom Area	5	(3.5)
22	Steilacoom Area	5	(6.1)
23	Carr Inlet	4	(2.2)
24	Wollochet Bay	6	(6.5)

[a] Each value represents the mean of 5 replicates. The standard deviation of each mean is given in parentheses.

[b] Mean percent mortality in the negative controls was 3 percent for Stations 1–12 (i.e., first sample batch), and 1 percent for Stations 13–24 (i.e., second sample batch).

suggest that the amphipod AET may be increased for those two compounds if the results of this study are included in the AET database.

Although sediment toxicity was not a problem at any of the 24 stations evaluated in this study, the values of mortality at stations in Budd Inlet (i.e., range = 1-18 percent, mean = 9.5 percent) were generally higher than the values observed at stations in the other parts of southern Puget Sound (i.e., range = 4-11 percent, mean = 6.5 percent). The somewhat elevated values of mortality in parts of Budd Inlet may have been related to increased levels of chemical contamination in the sediments of that embayment, because the results of chemical analyses showed that several chemicals exceeded HAET or LAET values at stations in Budd Inlet. Alternatively, the somewhat elevated values of mortality in parts of Budd Inlet could have been related to the relatively high percentage of fine-grained material that characterized many of the sites (i.e., values >85 percent were found at 7 of the 12 stations). DeWitt et al. (1988) found that amphipod mortality can increase in reference sediments in response to increasing percentages of fine-grained sediment. Two of the five values of percent fine-grained sediment at the five stations evaluated outside Budd Inlet (i.e., 26 and 36 percent) were lower than the range of values found in Budd Inlet (i.e., 71-99 percent) suggesting that sediment grain-size distribution may have been partly responsible for the small differences in amphipod mortality between the two sets of samples. A third possibility is that the amphipods used to test the 12 samples from Budd Inlet (which were tested as a single batch) were more sensitive to chemical toxicity than the amphipods used to test the remaining 12 samples (which were tested as a separate batch). This third possibility is feasible because the amphipods used to test the samples from Budd Inlet exhibited an LC_{50} value of 0.85 mg/L in the positive controls, compared to the LC_{50} value of 1.4 mg/L exhibited by the amphipods used to test the remaining samples. The lower LC_{50} value for the Budd Inlet samples indicates that the test organisms were more sensitive to the reference toxicant (and potentially chemical toxicity

in general) than were the test organisms used to evaluate the samples from outside Budd Inlet.

Previous studies of amphipod mortality have been conducted in Budd Inlet (Tetra Tech 1990), Oakland Bay (Tetra Tech 1990), Case Inlet (Battelle 1986; Tetra Tech 1990), and Carr Inlet (Tetra Tech 1985, 1990; PTI 1988, 1989), although station locations differed from those used in the present study. In Budd Inlet, the 4-5 percent values of mortality found at two stations sampled in the previous studies were within the range of values (i.e., 1-18 percent) found in the present study. In Oakland Bay, the value of 4 percent mortality at one station sampled in the previous studies was nearly identical to the value of 5 percent found in the present study. In Carr Inlet, values of mortality ranged from 2 to 16 percent at six stations sampled in the previous studies, and were consistent with the value of 4 percent observed in the present study. In Case Inlet, mortality ranged from 2 to 43 percent at five stations sampled in the previous studies. The single value of 2 percent found in Case Inlet by Tetra Tech (1990) was similar to the value of 4 percent observed in the present study. However, the values of 28 to 43 percent found at four stations by Battelle (1986) were considerably higher than the values found by Tetra Tech (1990) and the present study. Because the water depths of the stations sampled in Case Inlet by Battelle (i.e., 21-40 meters) were greater than the depth of 11 meters sampled in the present study, it is possible that the sediments collected previously were more fine-grained than those collected in the present study. If that is the case, differences in sediment grain-size distribution may partially account for the observed differences in mortality values between the two studies. An additional factor that may have contributed to the differences observed between the two studies is that the results found by Battelle were based on a sediment sample composited over the top 10 cm of sediment, whereas the results found by Tetra Tech (1990) and the present study were based on samples composited over the top 2 cm of sediment.

FISH ASSEMBLAGES

A total of 9,496 fishes, representing 15 families and 28 species, were sampled in this study (Table 17). The most abundant family of fishes collected by otter trawl throughout southern Puget Sound was Pleuronectidae, which accounted for 50 percent of the total catch. The most abundant pleuronectids were English sole and starry flounder, the two species selected for histopathological and bioaccumulation analyses.

Although English sole and starry flounder were abundant in southern Puget Sound as a whole, considerable differences were found among the areas sampled. In general, English sole was most abundant at the two transects located near the mouths of embayments (i.e., the transects in Totten and Carr inlets), whereas starry flounder was most abundant at the five transects located at the heads of embayments (i.e., the transects in Budd Inlet, Oakland Bay, Case Inlet, and Carr Inlet). The total numbers of species and individuals also showed large differences between the transects located in the mouths and the heads of embayments; both variables were considerably lower in the latter environments. Total number of species ranged from 5 to 10 at the heads of embayments, whereas 23 species were collected at each of the transects located in the mouth of an embayment. Total number of individuals ranged from 36 to 63 fish/km at the heads of embayments, compared to a range of 316 to 1,590 fish/km in the mouths of embayments.

The results of this study suggest that habitat differences within the embayments exerted a considerable influence on the characteristics of the resident demersal fish assemblages. Because English sole was relatively rare or absent at the heads of embayments, starry flounder was used for bioaccumulation analyses at those five transects. Histopathological evaluations were not conducted on starry flounder from those locations because the historical database for this species is limited.

TABLE 17. RELATIVE ABUNDANCES OF FISHES CAPTURED IN SOUTHERN PUGET SOUND

Family	Species	Common Name	Relative Abundance at Each Transect (percent)						
			T1	T2	T3	T4	T5	T6	T7
Rajidae	*Raja binoculata*	big skate	2.1	--[a]	2.9	[b]	--	[b]	1.0
Clupeidae	*Clupea harengus pallasi*	Pacific herring	42.7	--	4.3	2.8	21.0	[b]	1.0
Batrachoididae	*Porichthys notatus*	plainfin midshipman	--	--	--	[b]	--	[b]	--
Gadidae	*Microgadus proximus*	Pacific tomcod	--	--	--	9.8	2.0	6.1	--
Zoarcidae	*Lycodopsis pacificus*	blackbelly eelpout	--	--	--	--	[b]	4.6	--
Gasterosteidae	*Aulorhynchus flavidus*	tube-snout	--	--	--	[b]	--	0.1	--
Embiotocidae	*Cymatogaster aggregata*	shiner perch	2.1	--	--	4.7	4.0	3.5	--
	Embiotoca lateralis	striped seaperch	--	--	--	0.3	--	--	--
	Rhacochilus vacca	pile perch	--	--	--	2.3	--	[b]	--
Bathymasteridae	*Ronquilus jordani*	northern ronquil	--	--	--	[b]	--	[b]	--
Stichaeidae	*Lumpenus sagitta*	snake prickleback	1.0	--	1.4	3.4	--	0.9	--
Scorpaenidae	*Sebastes caurinus*	copper rockfish	--	--	--	--	--	[b]	--
Hexagrammidae	*Zaniolepis latipinnis*	longspine combfish	--	--	--	--	--	[b]	--
Cottidae	*Chitonotus pugetensis*	roughback sculpin	--	--	--	[b]	--	--	--
	Enophrys bison	buffalo sculpin	--	1.5	--	8.1	--	[b]	--
	Leptocottus armatus	Pacific staghorn sculpin	2.1	4.6	--	15.9	1.0	23.9	1.0
	Myxocephalus polyacanthocephalus	great sculpin	--	--	--	[b]	--	--	--
Agonidae	*Agonus aciperserinus*	sturgeon poacher	--	--	--	1.1	--	1.2	--
	Odontopyxis trispinosa	pygmy poacher	--	--	--	1.1	--	1.2	--

TABLE 17. (Continued)

Family	Species	Common Name	Relative Abundance at Each Transect (percent)						
			T1	T2	T3	T4	T5	T6	T7
Bothidae	*Citharichthys sordidus*	Pacific sanddab	--	--	--	1.1	1.0	[b]	--
	Citharichthys stigmaeus	speckled sanddab	--	--	--	0.9	3.0	11.4	33.3
Pleuronectidae	*Lepidopsetta bilineata*	rock sole	1.0	1.5	1.4	13.8	--	6.2	2.9
	Lyopsetta exilis	slender sole	--	--	--	--	--	[b]	--
	Microstomus pacificus	Dover sole	--	--	--	--	--	[b]	--
	Parophrys vetulus	English sole	--	--	--	19.4	4.0	40.5	1.0
	Platichthys stellatus	starry flounder	37.5	66.7	84.3	13.6	41.4	[b]	53.9
	Pleuronichthys coenosus	C-O sole	--	--	--	[b]	--	--	--
	Psettichthys melanostictus	sand sole	11.5	25.8	5.7	1.7	22.0	--	5.6
		Total catch (per km)	38	36	38	316	63	1,590	55

[a] -- = species not captured at this transect.

[b] <0.1 percent of catch.

The otter trawl used to sample demersal fishes in this study is not a quantitative sampling device for megainvertebrates (i.e., the relatively large invertebrates collected using an otter trawl). However, the megainvertebrates collected incidentally in the trawl samples were counted to provide a qualitative estimate of their abundances at the various transects (Table 18). Megainvertebrates were collected at all transects except Transect T7. The absence of megainvertebrates at Transect T7 may have been an accurate estimate of their abundance or an artifact of the unreliable sampling efficiency of an otter trawl for those organisms. The most abundant megainvertebrates were the sea anemone *Metridium senile* and the graceful crab *Cancer gracilis*.

FISH HISTOPATHOLOGY

A total of 119 English sole was evaluated for histopathological abnormalities in liver tissue. Fifty-nine individuals were collected at Transect T4 in Totten Inlet, and 60 individuals were sampled at Transect T6 off McNeil Island in Carr Inlet. English sole was not sufficiently numerous at the remaining five transects to provide adequate sample sizes for histopathological evaluation. Detailed descriptions of the field and laboratory observations made for each fish are presented in Appendix D.

The histopathological evaluations focused on idiopathic liver lesions (i.e., those having no apparent association with an infectious agent) to identify the lesions potentially related to chemical contamination. Four kinds of idiopathic lesions were evaluated: neoplasms, foci of cellular alteration, megalocytic hepatosis, and nonspecific responses to injury. The first three kinds of lesions, which are considered serious abnormalities, have been found in English sole collected from many contaminated areas of Puget Sound (e.g., Malins et al. 1984; Becker et al. 1987; Myers et al. 1987). Briefly, neoplasms include both benign and malignant tumors. Foci of cellular alteration are discrete clusters of altered

TABLE 18. ABUNDANCES OF MEGAINVERTEBRATES CAPTURED IN SOUTHERN PUGET SOUND

Taxon	Abundance at Each Transect (individuals/km)						
	T1	T2	T3	T4	T5	T6	T7
Metridium senile (sea anemone)	4.8	13.5	0	0.5	19.7	1.4	0
Nudibranchia (sea slug)	0	0	0	0	0	0.5	0
Cancer gracilis (graceful crab)	3.2	3.8	1.1	0.5	0.6	0	0
Asteroidea (starfish)	0	0.5	0	0	0	9.0	0
Parastichopus californicus (sea cucumber)	0	1.6	0	1.6	0	0	0

cells that have specific staining characteristics and are suspected of being preneoplastic. Megalocytic hepatosis is a specific degenerative condition characterized by a marked increase in both nuclear and cellular diameters in the absence of cellular inflammatory responses. Myers et al. (1987) suggested that megalocytic hepatosis, foci of cellular alteration, and neoplasms are sequentially related in the progression toward neoplasia in English sole. By contrast with the three kinds of serious liver lesions, nonspecific responses to injury generally are not associated with major adverse biological effects but may be indicative of exposure to toxic chemicals.

The only kinds of liver lesions found in English sole in Totten and Carr inlets were nonspecific responses to injury (Table 19). Neoplasms, foci of cellular alteration, and megalocytic hepatosis were not found in any of the fish collected in this study. In general, the prevalences of nonspecific responses to injury were relatively low (i.e., all were < 17 percent), and only three of these conditions (i.e., hepatocellular regeneration, mononuclear infiltrates, and parenchymal inflammation) were found in more than 10 percent of the fish from either study area.

The mean ages of fish evaluated for liver lesions did not differ significantly ($P > 0.05$; *t*-test) between the two study areas. The mean age of the fish from Totten Inlet was 3.6 years (standard deviation = 0.98), compared with the mean age of 3.7 years (standard deviation = 0.84) for the fish from Carr Inlet. It therefore is unlikely that fish age contributed substantially to any differences in the prevalences of liver lesions between the two study areas.

In Table 20, the prevalences of serious liver lesions (i.e., neoplasms, foci of cellular alteration, and megalocytic hepatosis) found in previous studies in Puget Sound are compared with the values of zero percent found in the present study. In general, the highest prevalences of all three conditions have been found in major urban bays that are substantially influenced by chemical contamination.

TABLE 19. PREVALANCES OF HEPATIC LESIONS IN ENGLISH SOLE FROM TOTTEN AND CARR INLETS[a]

Hepatic Lesions	Totten Inlet (n = 59)	Carr Inlet (n = 60)
Hepatocellular necrosis	10.2	3.3
Hepatocellular pyknosis	0	5.0
Hepatocellular regeneration	1.7	0
Spongiosis hepatis	0	1.7
Nonuniforn vaculolation	1.7	3.3
Hyperpigmented MMC[b]	8.5	3.3
Mononuclear infiltrates	11.9	16.7
Parenchymal fibrosis	0	1.7
Parenchymal inflammation	0	15.0
Pancreatic necrosis	1.7	0

[a] Values are percentages of the total number of fish collected at each site.

[b] MMC - melanin macrophage centers.

TABLE 20. COMPARISONS OF PREVALENCES OF HEPATIC LESIONS IN ENGLISH SOLE COLLECTED FROM VARIOUS LOCATIONS IN PUGET SOUND

Embayment	Data Source[a]	Sample Size	Prevalence (percent)		
			Neoplasms	Foci of Cellular Alteration	Megalocytic Hepatosis
Major Urban Bays					
Commencement Bay	1	853	2	13	11
Elliott Bay	2	637	6	25	33
Everett Harbor	3	538	2	11	2
Sinclair Inlet	4	60	0	10	0
Transitional Areas[b]					
Lake Washington Ship Canal	5	60	8	13	5
Gig Harbor	5	31	3	3	0
Dyes Inlet	5	60	0	2	0
Reference Areas					
Carr Inlet	1	120	0	6	1
Case Inlet	4	30	3	3	0
Nisqually Delta	6	88	0	2	0
Point Pulley	2	60	0	7	3
Port Susan	3	56	0	7	0
Eliza Island	4	28	0	0	0
Present Study					
Totten Inlet	7	59	0	0	0
Carr Inlet	7	60	0	0	0

[a] 1 - Tetra Tech (1985)
2 - PTI and Tetra Tech (1988a)
3 - PTI and Tetra Tech (1988b)
4 - Battelle (1986)
5 - Crecelius et al. (1989)
6 - Myers (8 April 1991, *personal communication*)
7 - Present study

[b] Transitional areas are located away from major urban areas, but may be influenced by chemical contamination.

Prevalences of the three types of lesions have also been relatively high in selected transitional areas. By contrast, prevalences of all three types of lesion have been very low in Puget Sound reference areas. The only area having a complete absence of the three lesions (other than the areas sampled in the present study) was the area near Eliza Island in northern Puget Sound.

The absence of neoplasms, foci of cellular alteration, and megalocytic hepatosis in English sole from Totten and Carr inlets suggests that any potential chemical contamination in those two areas was not high enough to cause serious liver lesions in fishes. Compared with the data presented in Table 20, the absence of serious liver lesions in English sole from Totten and Carr inlets suggests that those two areas were similar to the reference areas used in previous studies in Puget Sound.

CONCLUSIONS

The results of this study suggest that most of the areas sampled in southern Puget Sound were not characterized by substantial levels of chemical contamination or adverse biological effects. However, the concentrations of several organic compounds in one or more sediment samples from Budd Inlet were high enough to potentially result in adverse biological effects. Despite these elevated chemical concentrations, sediment toxicity was not elevated above Puget Sound reference levels at any of the Budd Inlet stations based on the results of the amphipod mortality toxicity test. Sediment toxicity also was not elevated at any of the other stations sampled throughout southern Puget Sound. However, neither sublethal nor chronic effects of sediment toxicity were evaluated in this study. The limited amount of information collected on fish disease suggests that the fish evaluated from Totten and Carr inlets were not affected by chemical contamination, as serious histopathological abnormalities were not found in the livers of any of these individuals. However, information on fish disease in Budd Inlet (i.e., the major urban embayment in southern Puget Sound) could not be evaluated because the target species (i.e., English sole) was not sufficiently abundant there. Finally, the observed concentrations of chemical contaminants in tissue samples from fishes and clams did not appear to pose an unacceptable health risk to consumers of these organisms.

REFERENCES

Barrick, R.C., D.S. Becker, L.B. Brown, et al. 1988. Sediment quality values refinement: 1988 update and evaluation of Puget Sound AET. Volume I. Final Report. Prepared for Tetra Tech, Inc. and U.S. Environmental Protection Agency. PTI Environmental Services, Bellevue, WA.

Battelle. 1986. Reconnaissance survey of eight bays in Puget Sound. Final Report. Prepared for U.S. Environmental Protection Agency. Battelle Pacific Northwest Laboratory, Sequim, WA.

Becker, D.S., T.C. Ginn, M.L. Landolt, et al. 1987. Hepatic lesions in English sole (*Parophrys vetulus*) from Commencement Bay, Washington (USA). Mar. Environ. Res. 23:153-173.

Crecelius, E.A., D.L. Woodruff, and M.S. Myers. 1989. 1988 reconnaissance survey of environmental conditions in 13 Puget Sound locations. Final Report. Prepared for U.S. Environmental Protection Agency. Battelle Ocean Sciences, Duxbury, MA.

DeWitt, T.H., G.R. Ditsworth, and R.C. Swartz. 1988. Effects of natural sediment features on survival of the phoxocephalid amphipod, *Rhepoxynius abronius*. Mar. Environ. Res. 25:99-124.

Faigenblum, J. 1988. Chemicals and bacteriological organisms in recreational shellfish. U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA.

Malins, D.C., B.B. McCain, D.W. Brown, et al. 1982. Chemical contaminants and abnormalities in fish and invertebrates from Puget Sound. NOAA Technical Memorandum OMPA-19. National Oceanic and Atmospheric Administration, Rockville, MD.

Malins, D.C., B.B. McCain, D.W. Brown, et al. 1984. Chemical pollutants in sediments and diseases of bottom-dwelling fish in Puget Sound, WA. Environ. Sci. Technol. 18:705-713.

Myers, M.S. 8 April 1991. Personal Communication (telephone conversation with D.S. Becker, PTI Environmental Services, Bellevue, WA). National Oceanic and Atmospheric Administration, Seattle, WA.

Myers, M.S., L.D. Rhodes, and B.B. McCain. 1987. Pathologic anatomy and patterns of occurrence of hepatic neoplasms, putative preneoplastic lesions, and other idiopathic hepatic conditions in English sole (*Parophrys vetulus*) from Puget Sound, Washington. J. Natl. Cancer Inst. 78:333-363.

O'Neill, S.M. and C.C. Schmitt. 1991. What contaminants are in our fish. Paper presented at Puget Sound Research '91, 4-5 January 1991, Washington Department of Fisheries, Olympia, WA.

Pastorok, R.A., R. Sonnerup, J.J. Greene, et al. 1989. Interim performance standards for Puget Sound reference areas. Final Report. Prepared for Washington Department of Ecology. PTI Environmental Services, Bellevue, WA.

PSDDA. 1989. Draft management plan report (DMPR) - unconfined, open-water disposal of dredged material, Phase II (north and south Puget Sound). Puget Sound Dredged Disposal Analysis. Seattle, WA.

PSEP. 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Final Report. Prepared by U.S. Environmental Protection Agency, Seattle, WA.

PSEP. 1987. Recommended protocols for fish pathology studies in Puget Sound. Final Report. Prepared by U.S. Environmental Protection Agency, Seattle, WA.

PSEP. 1989a. Recommended protocols for measuring metals in Puget Sound water, sediment and tissue samples. Final Report. Prepared by U.S. Environmental Protection Agency, Seattle, WA.

PSEP. 1989b. Recommended guidelines for measuring organic compounds in Puget Sound sediment and tissue samples. Final Report. Prepared by U.S. Environmental Protection Agency, Seattle, WA.

PSEP. 1991. Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Final Report. Prepared by U.S. Environmental Protection Agency, Seattle, WA.

PTI. 1990. South Puget Sound reconnaissance survey quality assurance reports for chemical analyses. Final Report. Prepared for U.S. Environmental Protection Agency. PTI Environmental Services, Bellevue, WA.

PTI and Tetra Tech 1988a. Elliott Bay Action Program: analysis of toxic problem areas. Final Report. Prepared for U.S. Environmental Protection Agency. PTI Environmental Services and Tetra Tech, Inc., Bellevue, WA.

PTI and Tetra Tech 1988b. Everett Harbor Action Program: analysis of toxic problem areas. Final Report. Prepared for U.S. Environmental Protection Agency. PTI Environmental Services and Tetra Tech, Inc., Bellevue, WA.

Swartz, R.C., W.A. DeBen, J.K. Phillips, et al. 1985. Phoxocephalid amphipod bioassay for marine sediment toxicity. pp. 284-307. In: Aquatic Toxicology and Hazard Assessment: Seventh Symposium. R.D. Cardwell, R. Purdy, and R. Bahner (eds). ASTM STP 854. American Society for Testing and Materials, Philadelphia, PA.

Tetra Tech. 1985. Commencement Bay nearshore/tideflats remedial investigation. Prepared for Washington Department of Ecology. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1988. Health risk assessment of chemical contamination in Puget Sound seafood. Final Report. Prepared for U.S. Environmental Protection Agency. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1990. Puget Sound ambient monitoring program 1989: marine sediment monitoring. Final Report. Prepared for Washington Department of Ecology. Tetra Tech, Inc., Bellevue, WA.

U.S. EPA. 1989. Risk assessment guidance for Superfund, Volume I: human health evaluation manual. Interim final report. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC.

Appendix A

Puget Sound Sediment Quality Values

TABLE A-1. SUMMARY OF VARIOUS SEDIMENT QUALITY VALUES FOR CHEMICAL CONTAMINANTS IN PUGET SOUND BASED ON DRY WEIGHT NORMALIZATION

Chemical	LAET	HAET	Numerical Sediment Quality Standard	PSDDA SL	PSDDA ML
Metals					
Antimony	150	200	--	20	200
Arsenic	57	700	57	57	700
Cadmium	5.1	9.6	5.1	0.96	9.6
Chromium	260	270	260	--	--
Copper	390	1,300	390	81	810
Lead	450	660	450	66	660
Mercury	0.41	2.1	0.41	0.21	2.1
Nickel	--	140	--	140	--
Silver	6.1	6.1	6.1	1.2	6.1
Zinc	410	1,600	410	160	1,600
Organic Compounds (µg/kg dry weight; ppb)					
Low molecular weight PAH[a]	5,200	24,000	--	610	6,100
Naphthalene	2,100	2,700	--	210	2,100
Acenaphthylene	1,300	1,300	--	64	640
Acenaphthene	500	2,000	--	63	6,300
Fluorene	540	3,600	--	64	6,400
Phenanthrene	1,500	6,900	--	320	3,200
Anthracene	960	13,000	--	130	1,300
High molecular weight PAH	12,000	69,000	--	1,800	51,000
Fluoranthene	1,700	30,000	--	630	6,300
Pyrene	2,600	16,000	--	430	7,300
Benzo(a)anthracene	1,300	5,100	--	450	4,500
Chrysene	1,400	9,200	--	670	6,700
Benzofluoranthenes	3,200	9,900	--	800	8,000
Benzo(a)pyrene	1,600	3,600	--	680	6,800
Indeno(1,2,3-c,d)pyrene	600	2,600	--	69	5,200
Dibenz(a,h)anthracene	230	970	--	120	1,200
Benzo(g,h,i)perylene	670	2,600	--	540	5,400
Chlorinated benzenes					
1,2-Dichlorobenzene	35	110	--	19	350
1,3-Dichlorobenzene	170	170	--	170	--
1,4-Dichlorobenzene	110	120	--	26	260
1,2,4-Trichlorobenzene	31	64	--	6.4	64
Hexachlorobenzene (HCB)	22	230	--	23	230
Total PCBs[b]	130	3,100	--	130	2,500

TABLE A-1. (Continued)

Chemical	LAET	HAET	Numerical Sediment Quality Standard	PSDDA SL	PSDDA ML
Phthalates					
Dimethyl phthalate	71	1,400	--	160	--
Diethyl phthalate	200	1,200	--	97	--
Di-*n*-butyl phthalate	1,400	5,100	--	1,400	--
Butyl benzyl phthalate	63	900	--	470	--
Bis(2-ethylhexyl)phthalate	1,300	3,100	--	3,100	--
Di-*n*-octyl phthalate	25	6,200	--	6,200	--
Phenols					
Phenol	420	1,200	420	120	1,200
2-Methylphenol	63	72	63	10	72
4-Methylphenol	670	3,600	670	120	1,200
2,4-Dimethylphenol	29	210	29	10	50
Pentachlorophenol	360	690	360	69	690
Miscellaneous extractables					
2-Methylnaphthalene	670	1,900	--	67	670
Benzyl alcohol	57	870	--	10	73
Benzoic acid	650	760	--	216	690
Dibenzofuran	540	1,700	--	54	540
Hexachlorobutadiene	11	270	--	29	290
N-nitrosodiphenylamine	28	130	--	22	220
Volatile Organics					
Tetrachloroethene	57	210	--	14	210
Ethylbenzene	10	50	--	10	50
Total xylenes	40	160	--	12	160
Pesticides					
p,p'-DDE	9.0	15	--	--	--
p,p'-DDD	16	43	--	--	--
p,p'-DDT	34	270	--	--	--

[a] PAH - polycyclic aromatic hydrocarbon.

[b] PCB - polychlorinated biphenyl.

TABLE A-2. SUMMARY OF VARIOUS SEDIMENT QUALITY VALUES FOR NONIONIC ORGANIC COMPOUNDS IN PUGET SOUND BASED ON ORGANIC CARBON NORMALIZATION

Chemical	LAET	HAET	Numerical Sediment Quality Standard
Nonionic Organic Compounds (mg/kg organic carbon; ppm)			
Low molecular weight PAH[a]	370	2,200	370
Naphthalene	99	220	99
Acenaphthylene	66	66	66
Acenaphthene	16	200	16
Fluorene	23	360	23
Phenanthrene	120	690	100
Anthracene	220	1,200	220
High molecular weight PAH	960	7,600	960
Fluoranthene	160	3,000	160
Pyrene	1,000	1,400	1,000
Benz(a)anthracene	110	650	110
Chrysene	110	850	110
Benzofluoranthenes	230	1,500	230
Benzo(a)pyrene	99	210	99
Indeno(1,2,3-c,d)pyrene	34	900	34
Dibenz(a,h)anthracene	12	89	12
Benzo(g,h,i)perylene	31	78	31
Chlorinated benzenes			
1,2-Dichlorobenzene	2.3	2.3	2.3
1,3-Dichlorobenzene	--	--	--
1,4-Dichlorobenzene	3.1	16	3.1
1,2,4-Trichlorobenzene	0.81	2.7	0.81
Hexachlorobenzene (HCB)	0.38	9.6	0.38
Total PCBs[b]	12	190	12
Phthalates			
Dimethyl phthalate	53	53	53
Diethyl phthalate	61	61	61
Di-*n*-butyl phthalate	220	1,700	220

TABLE A-2. (Continued)

Chemical	LAET	HAET	Numerical Sediment Quality Standard
Phthalates (continued)			
Butyl benzyl phthalate	4.9	64	4.9
Bis(2-ethylhexyl)phthalate	47	78	47
Di-*n*-octyl phthalate	58	4,500	58
Miscellaneous extractables			
2-Methylnaphthalene	38	64	38
Dibenzofuran	15	58	15
Hexachlorobutadiene	3.9	11	3.9
N-nitrosodiphenylamine	11	11	11
Pesticides			
p,p'-DDD	0.31	2.2	--
p,p'-DDE	0.81	2.2	--
p,p'-DDT	3.7	3.7	--

[a] PAH - polycyclic aromatic hydrocarbon.

[b] PCB - polychlorinated biphenyl.

Appendix B

Bioaccumulation Data

TABLE B-1. SUMMARY OF CHEMICAL CONCENTRATIONS IN TISSUE SAMPLES COLLECTED FROM SOUTHERN PUGET SOUND[1]

Location	Site/ Transect	Composite	1,2-Dichloro-benzene	1,2-Diphenyl-hydrazine	1,2,4-Tri-chlorobenzene	1,3-Dichloro-benzene	1,4-Dichloro-benzene	2-Chloro-naphthalene	2-Chloro-phenol	2-Methyl-naphthalene	2-Methyl-phenol
Budd Inlet	C1	A	120 U	160 U	140 U	160 U	110 U	160 U	160 U	160 U	130 U
Budd Inlet	C2	A	120 U	160 U	140 U	160 U	110 U	160 U	160 U	160 U	130 U
Inner Budd Inlet	T1	A	18 U	31 U	21 U	31 U	17 U	31 U	31 U	31 U	19 U
Inner Budd Inlet	T1	B	18 U	32 U	21 U	32 U	17 U	32 U	32 U	32 U	19 U
Inner Budd Inlet	T1	C	18 U	32 U	21 U	32 U	17 U	32 U	32 U	32 U	19 U
Outer Budd Inlet	T2	A	25 U	32 U	26 U	32 U	22 U	32 U	32 U	32 U	26 U
Outer Budd Inlet	T2	B	22 U	40 U	25 U	40 U	20 U	40 U	40 U	40 U	22 U
Outer Budd Inlet	T2	C	18 U	33 U	21 U	33 U	16 U	33 U	33 U	33 U	18 U
Shelton	T3	A	24 U	44 U	28 U	44 U	21 U	44 U	44 U	44 U	24 U
Shelton	T3	B	23 U	43 U	27 U	43 U	21 U	43 U	43 U	43 U	24 U
Shelton	T3	C	24 U	45 U	29 U	45 U	22 U	45 U	45 U	45 U	25 U
Totten Inlet	T4	A	35 U	62 U	41 U	62 U	33 U	62 U	62 U	62 U	37 U
Totten Inlet	T4	B	26 U	46 U	30 U	46 U	24 U	46 U	46 U	46 U	28 U
Totten Inlet	T4	C	26 U	45 U	30 U	45 U	24 U	45 U	45 U	45 U	27 U
Case Inlet	T5	A	18 U	33 U	21 U	33 U	16 U	33 U	33 U	33 U	18 U
Case Inlet	T5	B	17 U	32 U	20 U	32 U	16 U	32 U	32 U	32 U	18 U
Case Inlet	T5	C	18 U	32 U	20 U	32 U	16 U	32 U	32 U	32 U	18 U
McNeil Island	T6	A	20 U	36 U	24 U	36 U	19 U	36 U	36 U	36 U	21 U
McNeil Island	T6	B	23 U	41 U	27 U	41 U	22 U	41 U	41 U	41 U	25 U
McNeil Island	T6	C	24 U	41 U	27 U	41 U	22 U	41 U	41 U	41 U	25 U
Carr Inlet	T7	A	18 U	33 U	21 U	33 U	16 U	33 U	33 U	33 U	18 U
Carr Inlet	T7	B	18 U	33 U	21 U	33 U	16 U	33 U	33 U	33 U	18 U
Carr Inlet	T7	C	25 U	33 U	28 U	33 U	23 U	33 U	33 U	33 U	26 U

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	2-Nitro-aniline	2-Nitro-phenol	2,4-Dichloro-phenol	2,4-Dimethyl-phenol	2,4-Dinitro-phenol	2,4-Dinitro-toluene	2,4,5-Tri-chlorophenol	2,4,6-Tri-chlorophenol	2,6-Dinitro-toluene	Dibenzo(a,h) anthracene
Budd Inlet	C1	A	810 U	810 U	490 U	130 U	1600 U	810 U	810 U	810 U	810 U	160 U
Budd Inlet	C2	A	810 U	810 U	480 U	130 U	1600 U	810 U	810 U	810 U	810 U	160 U
Inner Budd Inlet	T1	A	160 U	160 U	90 U	56 U	310 U	160 U	160 U	160 U	160 U	31 U
Inner Budd Inlet	T1	B	160 U	160 U	100 U	58 U	320 U	160 U	160 U	160 U	160 U	32 U
Inner Budd Inlet	T1	C	160 U	160 U	90 U	57 U	310 U	160 U	160 U	160 U	160 U	32 U
Outer Budd Inlet	T2	A	160 U	160 U	97 U	64 U	320 U	160 U	160 U	160 U	160 U	32 U
Outer Budd Inlet	T2	B	200 U	200 U	120 U	23 U	400 U	200 U	200 U	200 U	200 U	40 U
Outer Budd Inlet	T2	C	170 U	170 U	99 U	19 U	330 U	170 U	170 U	170 U	170 U	33 U
Shelton	T3	A	220 U	220 U	131 U	25 U	440 U	220 U	220 U	220 U	220 U	44 U
Shelton	T3	B	220 U	220 U	129 U	25 U	430 U	220 U	220 U	220 U	220 U	43 U
Shelton	T3	C	230 U	230 U	136 U	26 U	450 U	230 U	230 U	230 U	230 U	45 U
Totten Inlet	T4	A	310 U	310 U	190 U	110 U	620 U	310 U	310 U	310 U	310 U	62 U
Totten Inlet	T4	B	230 U	230 U	140 U	83 U	460 U	230 U	230 U	230 U	230 U	46 U
Totten Inlet	T4	C	230 U	230 U	135 U	80 U	450 U	230 U	230 U	230 U	230 U	45 U
Case Inlet	T5	A	170 U	170 U	100 U	19 U	330 U	170 U	170 U	170 U	170 U	33 U
Case Inlet	T5	B	160 U	160 U	96 U	19 U	320 U	160 U	160 U	160 U	160 U	32 U
Case Inlet	T5	C	160 U	160 U	97 U	19 U	320 U	160 U	160 U	160 U	160 U	32 U
McNeil Island	T6	A	180 U	180 U	110 U	60 U	360 U	180 U	180 U	180 U	180 U	36 U
McNeil Island	T6	B	200 U	200 U	120 U	70 U	410 U	200 U	200 U	200 U	200 U	41 U
McNeil Island	T6	C	210 U	210 U	120 U	70 U	410 U	210 U	210 U	210 U	210 U	41 U
Carr Inlet	T7	A	160 U	160 U	99 U	19 U	330 U	160 U	160 U	160 U	160 U	33 U
Carr Inlet	T7	B	170 U	170 U	99 U	19 U	330 U	170 U	170 U	170 U	170 U	33 U
Carr Inlet	T7	C	170 U	170 U	100 U	28 U	330 U	170 U	170 U	170 U	170 U	33 U

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	2-Methyl-4,6-Dinitrophenol	Di-n-octyl-phthalate	3-Nitro-aniline	3,3'-Dichloro-benzidine	4-Bromophenyl-phenyl ether	4-Chloro-3-methylphenol	4-Chloro-aniline	4-Chlorophenyl phenyl ether	4-Methyl-phenol
Budd Inlet	C1	A	1600 U	160 U	810 U	810 U	160 U	320 U	490 U	160 U	160 U
Budd Inlet	C2	A	1600 U	160 U	810 U	810 U	160 U	320 U	480 U	160 U	160 U
Inner Budd Inlet	T1	A	310 U	31 U	160 U	160 U	31 U	63 U	94 U	31 U	31 U
Inner Budd Inlet	T1	B	320 U	32 U	160 U	160 U	32 U	65 U	97 U	32 U	32 U
Inner Budd Inlet	T1	C	310 U	32 U	160 U	160 U	32 U	63 U	95 U	32 U	32 U
Outer Budd Inlet	T2	A	320 U	32 U	160 U	32 U	32 U	64 U	97 U	32 U	32 U
Outer Budd Inlet	T2	B	400 U	40 U	200 U	200 U	40 U	80 U	120 U	40 U	40 U
Outer Budd Inlet	T2	C	330 U	33 U	170 U	170 U	33 U	66 U	99 U	33 U	33 U
Shelton	T3	A	440 U	44 U	220 U	220 U	44 U	88 U	131 U	44 U	44 U
Shelton	T3	B	430 U	43 U	220 U	220 U	43 U	86 U	129 U	43 U	43 U
Shelton	T3	C	450 U	45 U	230 U	230 U	45 U	91 U	136 U	45 U	45 U
Totten Inlet	T4	A	620 U	62 U	310 U	310 U	62 U	120 U	190 U	62 U	62 U
Totten Inlet	T4	B	460 U	46 U	230 U	230 U	46 U	92 U	138 U	46 U	46 U
Totten Inlet	T4	C	450 U	45 U	230 U	230 U	45 U	90 U	140 U	45 U	45 U
Case Inlet	T5	A	330 U	33 U	170 U	170 U	33 U	66 U	100 U	33 U	33 U
Case Inlet	T5	B	320 U	32 U	160 U	160 U	32 U	64 U	96 U	32 U	32 U
Case Inlet	T5	C	320 U	32 U	160 U	160 U	32 U	65 U	97 U	32 U	32 U
McNeil Island	T6	A	360 U	36 U	180 U	180 U	36 U	70 U	110 U	36 U	36 U
McNeil Island	T6	B	410 U	41 U	200 U	200 U	41 U	80 U	120 U	41 U	41 U
McNeil Island	T6	C	410 U	41 U	210 U	2100 U	41 U	80 U	120 U	41 U	41 U
Carr Inlet	T7	A	330 U	33 U	160 U	160 U	33 U	66 U	99 U	33 U	33 U
Carr Inlet	T7	B	330 U	33 U	170 U	170 U	33 U	66 U	99 U	33 U	33 U
Carr Inlet	T7	C	330 U	33 U	170 U	170 U	33 U	66 U	100 U	33 U	33 U

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	4-Nitro-aniline	4-Nitro-phenol	Pentachloro-phenol	Hexachlorocyclo-hexane -alpha	Hexachlorocyclo-hexane - Beta	Hexachlorocyclo-hexane - delta	Hexachlorocyclo-hexane - gamma	Hexachloro-benzene	Hexachloro-butadiene
Budd Inlet	C1	A	810 *U*	810 *U*	490 *U*	2 *U*	2 *U*	3 *U*	2 *U*	230 *U*	280 *U*
Budd Inlet	C2	A	810 *U*	810 *U*	480 *U*	2 *U*	2 *U*	3 *U*	2 *U*	230 *U*	280 *U*
Inner Budd Inlet	T1	A	160 *U*	160 *U*	94 *U*	2 *U*	2 *U*	3 *U*	2 *U*	36 *U*	44 *U*
Inner Budd Inlet	T1	B	160 *U*	160 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	37 *U*	45 *U*
Inner Budd Inlet	T1	C	160 *U*	160 *U*	90 *U*	2 *U*	2 *U*	3 *U*	2 *U*	36 *U*	44 *U*
Outer Budd Inlet	T2	A	160 *U*	160 *U*	130 *U*	2 *U*	2 *U*	3 *U*	2 *U*	39 *U*	53 *U*
Outer Budd Inlet	T2	B	200 *U*	200 *U*	120 *U*	2 *U*	2 *U*	3 *U*	2 *U*	56 *U*	56 *U*
Outer Budd Inlet	T2	C	170 *U*	170 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	46 *U*	46 *U*
Shelton	T3	A	220 *U*	220 *U*	130 *U*	2 *U*	2 *U*	3 *U*	2 *U*	61 *U*	61 *U*
Shelton	T3	B	220 *U*	220 *U*	130 *U*	2 *UE*	2 *UE*	3 *UE*	2 *UE*	60 *U*	60 *U*
Shelton	T3	C	230 *U*	230 *U*	140 *U*	2 *U*	2 *U*	3 *U*	2 *U*	63 *U*	63 *U*
Totten Inlet	T4	A	310 *U*	310 *U*	190 *U*	2 *UE*	2 *UE*	3 *UE*	2 *UE*	70 *U*	90 *U*
Totten Inlet	T4	B	230 *U*	230 *U*	140 *U*	2 *U*	2 *U*	3 *U*	2 *U*	52 *U*	64 *U*
Totten Inlet	T4	C	230 *U*	230 *U*	140 *U*	2 *U*	2 *U*	3 *U*	2 *U*	51 *U*	60 *U*
Case Inlet	T5	A	170 *U*	170 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	47 *U*	47 *U*
Case Inlet	T5	B	160 *U*	160 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	45 *U*	45 *U*
Case Inlet	T5	C	160 *U*	160 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	45 *U*	45 *U*
McNeil Island	T6	A	180 *U*	180 *U*	110 *U*	2 *U*	2 *U*	3 *U*	2 *U*	41 *U*	50 *U*
McNeil Island	T6	B	200 *U*	200 *U*	120 *U*	2 *U*	2 *U*	3 *U*	2 *U*	47 *U*	60 *U*
McNeil Island	T6	C	210 *U*	210 *U*	120 *U*	2 *U*	2 *U*	3 *U*	2 *U*	47 *U*	60 *U*
Carr Inlet	T7	A	160 *U*	160 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	46 *U*	46 *U*
Carr Inlet	T7	B	170 *U*	170 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	46 *U*	46 *U*
Carr Inlet	T7	C	170 *U*	170 *U*	100 *U*	2 *U*	2 *U*	3 *U*	2 *U*	47 *U*	57 *U*

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	Hexachlorocyclo-pentadiene	Hexachloro-ethane	Acenapthene	Acenaphthylene	Aldrin	Aniline	Anthracene	Arsenic	Bis(2-chloro-ethyl) ether	Bis(2-chloro-isopropyl) ether
Budd Inlet	C1	A	810 *U*	320 *U*	160 *U*	160 *U*	2 *U*	810 *U*	160 *U*	2.10	160 *U*	160 *U*
Budd Inlet	C2	A	810 *U*	320 *U*	160 *U*	160 *U*	2 *U*	810 *U*	160 *U*	1.90	160 *U*	160 *U*
Inner Budd Inlet	T1	A	160 *U*	63 *U*	31 *U*	31 *U*	2 *U*	160 *U*	31 *U*	0.530 *TE*	31 *U*	31 *U*
Inner Budd Inlet	T1	B	160 *U*	65 *U*	32 *U*	32 *U*	2 *U*	160 *U*	32 *U*	0.560 *TE*	32 *U*	32 *U*
Inner Budd Inlet	T1	C	160 *U*	63 *U*	32 *U*	32 *U*	2 *U*	160 *U*	32 *U*	1.10	32 *U*	32 *U*
Outer Budd Inlet	T2	A	160 *U*	64 *U*	32 *U*	32 *U*	2 *U*	160 *U*	32 *U*	0.510 *TE*	32 *U*	32 *U*
Outer Budd Inlet	T2	B	200 *U*	80 *U*	40 *U*	40 *U*	2 *U*	200 *U*	40 *U*	0.740 *T*	40 *U*	40 *U*
Outer Budd Inlet	T2	C	170 *U*	66 *U*	33 *U*	33 *U*	2 *U*	170 *U*	33 *U*	0.750 *TM*	33 *U*	33 *U*
Shelton	T3	A	220 *U*	88 *U*	44 *U*	44 *U*	2 *U*	220 *U*	44 *U*	1.60 *T*	44 *U*	44 *U*
Shelton	T3	B	220 *U*	86 *U*	43 *U*	43 *U*	2 *UE*	220 *U*	43 *U*	1.80	43 *U*	43 *U*
Shelton	T3	C	230 *U*	91 *U*	45 *U*	45 *U*	2 *U*	230 *U*	45 *U*	1.40 *T*	45 *U*	45 *U*
Totten Inlet	T4	A	310 *U*	120 *U*	62 *U*	62 *U*	2 *UE*	310 *U*	62 *U*	6.30	62 *U*	62 *U*
Totten Inlet	T4	B	230 *U*	92 *U*	46 *U*	46 *U*	2 *U*	230 *U*	46 *U*	5.70	46 *U*	46 *U*
Totten Inlet	T4	C	230 *U*	90 *U*	45 *U*	45 *U*	2 *U*	230 *U*	45 *U*	3.90	45 *U*	45 *U*
Case Inlet	T5	A	170 *U*	66 *U*	33 *U*	33 *U*	2 *U*	170 *U*	33 *U*	1.10 *T*	33 *U*	33 *U*
Case Inlet	T5	B	160 *U*	64 *U*	32 *U*	32 *U*	2 *U*	160 *U*	32 *U*	0.880 *T*	32 *U*	32 *U*
Case Inlet	T5	C	160 *U*	65 *U*	32 *U*	32 *U*	2 *U*	160 *U*	32 *U*	1.30 *T*	32 *U*	32 *U*
McNeil Island	T6	A	180 *U*	70 *U*	36 *U*	36 *U*	2 *U*	180 *U*	36 *U*	10.7 *M*	36 *U*	36 *U*
McNeil Island	T6	B	200 *U*	80 *U*	41 *U*	41 *U*	2 *U*	200 *U*	41 *U*	9.80	41 *U*	41 *U*
McNeil Island	T6	C	210 *U*	80 *U*	41 *U*	41 *U*	2 *U*	210 *U*	41 *U*	8.00	41 *U*	41 *U*
Carr Inlet	T7	A	160 *U*	66 *U*	33 *U*	33 *U*	2 *U*	160 *U*	33 *U*	3.10	33 *U*	33 *U*
Carr Inlet	T7	B	170 *U*	66 *U*	33 *U*	33 *U*	2 *U*	170 *U*	33 *U*	2.90	33 *U*	33 *U*
Carr Inlet	T7	C	170 *U*	66 *U*	33 *U*	33 *U*	2 *U*	170 *U*	33 *U*	2.80 *E*	33 *U*	33 *U*

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	Bis(2-ethylhexyl) phthalate	Benz(a)-anthracene	Benzo(a)-pyrene	Bis(2-chloro-ethoxy) methane	Benzoic Acid	Benzyl Alcohol	Benzo(g,h,i) perylene	Butyl benzyl phthalate	Benzidine	Carbazole
Budd Inlet	C1	A	360 *UZ*	160 *U*	160 *U*	160 *U*	810 *U*	230 *U*	160 *U*	160 *U*	8100 *U*	160 *U*
Budd Inlet	C2	A	160 *U*	160 *U*	160 *U*	160 *U*	810 *U*	230 *U*	160 *U*	160 *U*	8100 *U*	160 *U*
Inner Budd Inlet	T1	A	31 *U*	31 *U*	31 *U*	31 *U*	160 *U*	40 *U*	31 *U*	31 *U*	1600 *U*	31 *U*
Inner Budd Inlet	T1	B	220 *UZ*	32 *U*	32 *U*	32 *U*	160 *U*	40 *U*	32 *U*	32 *U*	1600 *U*	32 *U*
Inner Budd Inlet	T1	C	32 *U*	32 *U*	32 *U*	32 *U*	190	40 *U*	32 *U*	32 *U*	1600 *U*	32 *U*
Outer Budd Inlet	T2	A	32 *U*	32 *U*	32 *U*	32 *U*	160 *U*	50 *U*	32 *U*	160 *U*	1600 *U*	32 *U*
Outer Budd Inlet	T2	B	40 *U*	40 *U*	40 *U*	40 *U*	200 *U*	50 *U*	40 *U*	40 *U*	2000 *U*	40 *U*
Outer Budd Inlet	T2	C	33 *U*	33 *U*	33 *U*	33 *U*	180	40 *U*	33 *U*	33 *U*	1700 *U*	33 *U*
Shelton	T3	A	44 *U*	44 *U*	44 *U*	44 *U*	320	60 *U*	44 *U*	44 *U*	2200 *U*	44 *U*
Shelton	T3	B	43 *U*	43 *U*	43 *U*	43 *U*	220 *U*	50 *U*	43 *U*	43 *U*	2200 *U*	43 *U*
Shelton	T3	C	45 *U*	45 *U*	45 *U*	45 *U*	230 *U*	60 *U*	45 *U*	45 *U*	2300 *U*	45 *U*
Totten Inlet	T4	A	310 *UZ*	62 *U*	62 *U*	62 *U*	310 *U*	70 *U*	62 *U*	62 *U*	3100 *U*	62 *U*
Totten Inlet	T4	B	240 *UZ*	46 *U*	46 *U*	46 *U*	230 *U*	50 *U*	46 *U*	46 *U*	2300 *U*	46 *U*
Totten Inlet	T4	C	45 *U*	45 *U*	45 *U*	45 *U*	230 *U*	50 *U*	45 *U*	45 *U*	2300 *U*	45 *U*
Case Inlet	T5	A	33 *U*	33 *U*	33 *U*	33 *U*	180	42 *U*	33 *U*	33 *U*	1700 *U*	33 *U*
Case Inlet	T5	B	32 *U*	32 *U*	32 *U*	32 *U*	160 *U*	40 *U*	32 *U*	32 *U*	1600 *U*	32 *U*
Case Inlet	T5	C	32 *U*	32 *U*	32 *U*	32 *U*	170	41 *U*	32 *U*	32 *U*	1600 *U*	32 *U*
McNeil Island	T6	A	36 *U*	36 *U*	36 *U*	36 *U*	190	40 *U*	36 *U*	36 *U*	1800 *U*	36 *U*
McNeil Island	T6	B	41 *U*	41 *U*	41 *U*	41 *U*	200 *U*	50 *U*	41 *U*	41 *U*	2000 *U*	41 *U*
McNeil Island	T6	C	41 *U*	41 *U*	41 *U*	41 *U*	260	50 *U*	41 *U*	41 *U*	2100 *U*	41 *U*
Carr Inlet	T7	A	33 *U*	33 *U*	33 *U*	33 *U*	170	41 *U*	33 *U*	33 *U*	1600 *U*	33 *U*
Carr Inlet	T7	B	33 *U*	33 *U*	33 *U*	33 *U*	170 *U*	42 *U*	33 *U*	33 *U*	1700 *U*	33 *U*
Carr Inlet	T7	C	33 *U*	33 *U*	33 *U*	33 *U*	170 *U*	48 *U*	33 *U*	33 *U*	1700 *U*	33 *U*

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	Alpha Chlordane	Gamma Chlordane	Chrysene	Copper	Diethyl phthalate	Dibenzofuran	Dieldrin	Di-n-butyl-phthalate	Dimethyl phthalate	Alpha Endosulfan	Beta Endosulfan
Budd Inlet	C1	A	3 *U*	3 *U*	160 *U*	1.40	160 *U*	160 *U*	4 *U*	160 *U*	160 *U*	2 *U*	4 *U*
Budd Inlet	C2	A	3 *U*	3 *U*	160 *U*	1.30	160 *U*	160 *U*	4 *U*	160 *U*	160 *U*	2 *U*	4 *U*
Inner Budd Inlet	T1	A	3 *U*	3 *U*	31 *U*	0.260	31 *U*	31 *U*	4 *U*	31 *U*	31 *U*	2 *U*	4 *U*
Inner Budd Inlet	T1	B	3 *U*	3 *U*	32 *U*	0.280	32 *U*	32 *U*	4 *U*	32 *U*	32 *U*	2 *U*	4 *U*
Inner Budd Inlet	T1	C	3 *U*	3 *U*	32 *U*	0.210	32 *U*	32 *U*	4 *U*	32 *U*	32 *U*	2 *U*	4 *U*
Outer Budd Inlet	T2	A	3 *U*	3 *U*	32 *U*	0.310	32 *U*	32 *U*	4 *U*	160 *U*	32 *U*	2 *U*	4 *U*
Outer Budd Inlet	T2	B	3 *U*	3 *U*	40 *U*	0.290	40 *U*	40 *U*	4 *U*	40 *U*	40 *U*	2 *U*	4 *U*
Outer Budd Inlet	T2	C	3 *U*	3 *U*	33 *U*	0.215 *M*	33 *U*	33 *U*	4 *U*	33 *U*	33 *U*	2 *U*	4 *U*
Shelton	T3	A	3 *U*	3 *U*	44 *U*	0.220	44 *U*	44 *U*	4 *U*	44 *U*	44 *U*	2 *U*	4 *U*
Shelton	T3	B	3 *UE*	3 *UE*	43 *U*	0.240	43 *U*	43 *U*	4 *UE*	43 *U*	43 *U*	2 *UE*	4 *UE*
Shelton	T3	C	3 *U*	3 *U*	45 *U*	0.290	45 *U*	45 *U*	4 *U*	45 *U*	45 *U*	2 *U*	4 *U*
Totten Inlet	T4	A	3 *UE*	3 *UE*	62 *U*	0.290	62 *U*	62 *U*	4 *UE*	62 *U*	62 *U*	2 *UE*	4 *UE*
Totten Inlet	T4	B	3 *U*	3 *U*	46 *U*	0.250	46 *U*	46 *U*	4 *U*	890	46 *U*	2 *U*	4 *U*
Totten Inlet	T4	C	3 *U*	3 *U*	45 *U*	0.260	45 *U*	45 *U*	4 *U*	45 *U*	45 *U*	2 *U*	4 *U*
Case Inlet	T5	A	3 *U*	3 *U*	33 *U*	0.260	33 *U*	33 *U*	4 *U*	33 *U*	33 *U*	2 *U*	4 *U*
Case Inlet	T5	B	3 *U*	3 *U*	32 *U*	0.210	32 *U*	32 *U*	4 *U*	32 *U*	32 *U*	2 *U*	4 *U*
Case Inlet	T5	C	3 *U*	3 *U*	32 *U*	0.230	32 *U*	32 *U*	4 *U*	32 *U*	32 *U*	2 *U*	4 *U*
McNeil Island	T6	A	3 *U*	3 *U*	36 *U*	0.245 *M*	36 *U*	36 *U*	4 *U*	36 *U*	36 *U*	2 *U*	4 *U*
McNeil Island	T6	B	3 *U*	3 *U*	41 *U*	0.280	41 *U*	41 *U*	4 *U*	41 *U*	41 *U*	2 *U*	4 *U*
McNeil Island	T6	C	3 *U*	3 *U*	41 *U*	0.250	41 *U*	41 *U*	4 *U*	41 *U*	41 *U*	2 *U*	4 *U*
Carr Inlet	T7	A	3 *U*	3 *U*	33 *U*	0.200	33 *U*	33 *U*	4 *U*	33 *U*	33 *U*	2 *U*	4 *U*
Carr Inlet	T7	B	3 *U*	3 *U*	33 *U*	0.220	33 *U*	33 *U*	4 *U*	33 *U*	33 *U*	2 *U*	4 *U*
Carr Inlet	T7	C	3 *U*	3 *U*	33 *U*	0.230	33 *U*	33 *U*	4 *U*	33 *U*	33 *U*	2 *U*	4 *U*

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	Endosulfan Sulfate	Endrin	Endrin Ketone	Fluoranthene	Fluorene	Heptachlor Epoxide	Heptachlor	Indeno(1,2,3-cd) pyrene	Isophorone	Lead
Budd Inlet	C1	A	8 *U*	4 *U*	6 *U*	160 *U*	160 *U*	2 *U*	14 *U*	160 *UE*	170	0.080
Budd Inlet	C2	A	8 *U*	4 *U*	6 *U*	160 *U*	160 *U*	2 *U*	14 *U*	160 *UE*	160 *U*	0.020 *U*
Inner Budd Inlet	T1	A	8 *U*	4 *U*	6 *U*	31 *U*	31 *U*	2 *U*	2 *U*	31 *UE*	170	0.020 *T*
Inner Budd Inlet	T1	B	8 *U*	4 *U*	6 *U*	32 *U*	32 *U*	2 *U*	2 *U*	32 *UE*	150	0.030 *T*
Inner Budd Inlet	T1	C	8 *U*	4 *U*	6 *U*	32 *U*	32 *U*	2 *U*	2 *U*	32 *UE*	150	0.030 *T*
Outer Budd Inlet	T2	A	8 *U*	4 *U*	6 *U*	32 *U*	32 *U*	2 *U*	2 *U*	32 *UE*	32 *U*	0.040 *T*
Outer Budd Inlet	T2	B	8 *U*	4 *U*	6 *U*	40 *U*	40 *U*	2 *U*	2 *U*	40 *UE*	90 *T*	0.020 *U*
Outer Budd Inlet	T2	C	8 *U*	4 *U*	6 *U*	33 *U*	33 *U*	2 *U*	2 *U*	33 *UE*	180	0.018 *UM*
Shelton	T3	A	8 *U*	4 *U*	6 *U*	44 *U*	44 *U*	2 *U*	2 *U*	44 *UE*	300	0.020 *UE*
Shelton	T3	B	8 *UE*	4 *UE*	6 *UE*	43 *U*	43 *U*	2 *UE*	2 *UE*	43 *UE*	120	0.020 *UE*
Shelton	T3	C	8 *U*	4 *U*	6 *U*	45 *U*	45 *U*	2 *U*	2 *U*	45 *UE*	110	0.020 *U*
Totten Inlet	T4	A	8 *UE*	4 *UE*	6 *UE*	62 *U*	62 *U*	2 *UE*	2 *UE*	62 *UE*	62 *U*	0.040 *T*
Totten Inlet	T4	B	8 *U*	4 *U*	6 *U*	46 *U*	46 *U*	2 *U*	2 *U*	46 *UE*	72 *T*	0.020 *T*
Totten Inlet	T4	C	8 *U*	4 *U*	6 *U*	45 *U*	45 *U*	2 *U*	2 *U*	45 *UE*	83 *T*	0.040 *T*
Case Inlet	T5	A	8 *U*	4 *U*	6 *U*	33 *U*	33 *U*	2 *U*	2 *U*	33 *UE*	71 *T*	0.020 *UE*
Case Inlet	T5	B	8 *U*	4 *U*	6 *U*	32 *U*	32 *U*	2 *U*	2 *U*	32 *UE*	120	0.020 *UE*
Case Inlet	T5	C	8 *U*	4 *U*	6 *U*	32 *U*	32 *U*	2 *U*	2 *U*	32 *UE*	79 *T*	0.020 *UE*
McNeil Island	T6	A	8 *U*	4 *U*	6 *U*	36 *U*	36 *U*	2 *U*	2 *U*	36 *UE*	36 *U*	0.018 *UM*
McNeil Island	T6	B	8 *U*	4 *U*	6 *U*	41 *U*	41 *U*	2 *U*	2 *U*	41 *UE*	41 *U*	0.020 *T*
McNeil Island	T6	C	8 *U*	4 *U*	6 *U*	41 *U*	41 *U*	2 *U*	2 *U*	41 *UE*	41 *U*	0.040 *T*
Carr Inlet	T7	A	8 *U*	4 *U*	6 *U*	33 *U*	33 *U*	2 *U*	14 *U*	33 *UE*	200	0.020 *UE*
Carr Inlet	T7	B	8 *U*	4 *U*	6 *U*	33 *U*	33 *U*	2 *U*	3 *U*	33 *UE*	78 *T*	0.020 *UE*
Carr Inlet	T7	C	8 *U*	4 *U*	6 *U*	33 *U*	33 *U*	2 *U*	2 *U*	33 *UE*	73 *T*	0.020 *UE*

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	Mercury	Methoxychlor	Naphthalene	Nitrobenzene	N-nitroso-dimethylamine	N-nitroso-di-n-propylamine	N-nitroso-diphenylamine	PCB-1221	PCB-1232	PCB-1248
Budd Inlet	C1	A	0.010 *TE*	8 *U*	160 *U*	160 *U*	810 *U*	160 *U*	90 *U*	5 *U*	5 *U*	5 *U*
Budd Inlet	C2	A	0.020 *TE*	8 *U*	160 *U*	160 *U*	810 *U*	160 *U*	90 *U*	5 *U*	5 *U*	5 *U*
Inner Budd Inlet	T1	A	0.050	8 *U*	31 *U*	31 *U*	160 *U*	31 *U*	16 *U*	5 *U*	5 *U*	5 *U*
Inner Budd Inlet	T1	B	0.060	8 *U*	32 *U*	32 *U*	160 *U*	32 *U*	17 *U*	5 *U*	5 *U*	5 *U*
Inner Budd Inlet	T1	C	0.040 *T*	8 *U*	32 *U*	32 *U*	160 *U*	32 *U*	16 *U*	5 *U*	5 *U*	5 *U*
Outer Budd Inlet	T2	A	0.070	8 *U*	32 *U*	32 *U*	160 *U*	32 *U*	16 *U*	5 *U*	5 *U*	5 *U*
Outer Budd Inlet	T2	B	0.075 *E*	8 *U*	40 *U*	40 *U*	200 *U*	40 *U*	23 *U*	5 *U*	5 *U*	5 *U*
Outer Budd Inlet	T2	C	0.130 *EM*	8 *U*	33 *U*	33 *U*	170 *U*	33 *U*	19 *U*	5 *U*	5 *U*	5 *U*
Shelton	T3	A	0.020 *TE*	8 *U*	44 *U*	44 *U*	220 *U*	44 *U*	25 *U*	5 *U*	5 *U*	5 *U*
Shelton	T3	B	0.070 *E*	8 *UE*	43 *U*	43 *U*	220 *U*	43 *U*	25 *U*	5 *UE*	5 *UE*	5 *UE*
Shelton	T3	C	0.050 *E*	8 *U*	45 *U*	45 *U*	230 *U*	45 *U*	26 *U*	5 *U*	5 *U*	5 *U*
Totten Inlet	T4	A	0.120	8 *UE*	62 *U*	62 *U*	310 *U*	62 *U*	32 *U*	5 *UE*	5 *UE*	5 *UE*
Totten Inlet	T4	B	0.040 *T*	8 *U*	46 *U*	46 *U*	230 *U*	46 *U*	23 *U*	5 *U*	5 *U*	5 *U*
Totten Inlet	T4	C	0.020 *T*	8 *U*	45 *U*	45 *U*	230 *U*	45 *U*	23 *U*	5 *U*	5 *U*	5 *U*
Case Inlet	T5	A	0.040 *E*	8 *U*	33 *U*	33 *U*	170 *U*	33 *U*	19 *U*	5 *U*	5 *U*	5 *U*
Case Inlet	T5	B	0.020 *TE*	8 *U*	32 *U*	32 *U*	160 *U*	32 *U*	19 *U*	5 *U*	5 *U*	5 *U*
Case Inlet	T5	C	0.030 *TE*	8 *U*	32 *U*	32 *U*	160 *U*	32 *U*	19 *U*	5 *U*	5 *U*	5 *U*
McNeil Island	T6	A	0.056 *M*	8 *U*	36 *U*	36 *U*	180 *U*	36 *U*	18 *U*	5 *U*	5 *U*	5 *U*
McNeil Island	T6	B	0.050	8 *U*	41 *U*	41 *U*	200 *U*	41 *U*	21 *U*	5 *U*	5 *U*	5 *U*
McNeil Island	T6	C	0.060	8 *U*	41 *U*	41 *U*	210 *U*	41 *U*	21 *U*	5 *U*	5 *U*	5 *U*
Carr Inlet	T7	A	0.080 *E*	8 *U*	33 *U*	33 *U*	160 *U*	33 *U*	19 *U*	5 *U*	5 *U*	5 *U*
Carr Inlet	T7	B	0.070 *E*	8 *U*	33 *U*	33 *U*	170 *U*	33 *U*	19 *U*	5 *U*	5 *U*	5 *U*
Carr Inlet	T7	C	0.100 *E*	8 *U*	33 *U*	33 *U*	170 *U*	33 *U*	19 *U*	5 *U*	5 *U*	5 *U*

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	PCB-1254	PCB-1260	PCB-1016/ PCB-1242	Phenanthrene	Phenol	P,P'-DDD	P,P'-DDE	P,P'-DDT	Pyrene	Total Benzofluoranthene	Toxaphene
Budd Inlet	C1	A	5 *U*	5 U	5 *U*	160 *U*	320 *U*	4 *U*	4 *U*	4 *U*	160 *U*	320 *U*	300 *U*
Budd Inlet	C2	A	5 *U*	5 U	5 *U*	160 *U*	320 *U*	4 *U*	4 *U*	4 *U*	160 *U*	320 *U*	300 *U*
Inner Budd Inlet	T1	A	13 *T*	13 T	5 *U*	31 *U*	63 *U*	4 *U*	4 *U*	4 *U*	31 *U*	62 *U*	300 *U*
Inner Budd Inlet	T1	B	18 *T*	16 T	5 *U*	32 *U*	65 *U*	4 *U*	4 *U*	4 *U*	32 *U*	64 *U*	300 *U*
Inner Budd Inlet	T1	C	13 *T*	11 T	5 *U*	32 *U*	63 *U*	4 *U*	4 *U*	4 *U*	32 *U*	64 *U*	300 *U*
Outer Budd Inlet	T2	A	27 *T*	18 T	5 *U*	32 *U*	64 *U*	4 *U*	4 *U*	4 *U*	32 *U*	64 *U*	300 *U*
Outer Budd Inlet	T2	B	5 *U*	15 T	5 *U*	40 *U*	80 *U*	4 *U*	4 *U*	4 *U*	40 *U*	80 *U*	300 *U*
Outer Budd Inlet	T2	C	15 *T*	17 T	5 *U*	33 *U*	66 *U*	4 *U*	4 *U*	4 *U*	33 *U*	66 *U*	300 *U*
Shelton	T3	A	5 *U*	5 U	5 *U*	44 *U*	88 *U*	4 *U*	4 *U*	4 *U*	44 *U*	88 *U*	300 *U*
Shelton	T3	B	5 *UE*	18 E	5 *UE*	43 *U*	86 *U*	4 *UE*	4 *UE*	4 *UE*	43 *U*	86 *U*	300 *UE*
Shelton	T3	C	5 *U*	5 U	5 *U*	45 *U*	91 *U*	4 *U*	4 *U*	4 *U*	45 *U*	90 *U*	300 *U*
Totten Inlet	T4	A	5 *UE*	5 UE	5 *UE*	62 *U*	120 *U*	4 *UE*	4 *UE*	4 *UE*	62 *U*	124 *U*	300 *UE*
Totten Inlet	T4	B	5 *U*	5 U	5 *U*	46 *U*	92 *U*	4 *U*	4 *U*	4 *U*	46 *U*	92 *U*	300 *U*
Totten Inlet	T4	C	5 *U*	5 U	5 *U*	45 *U*	90 *U*	4 *U*	4 *U*	4 *U*	45 *U*	90 *U*	300 *U*
Case Inlet	T5	A	5 *U*	5 U	5 *U*	33 *U*	66 *U*	4 *U*	4 *U*	4 *U*	33 *U*	66 *U*	300 *U*
Case Inlet	T5	B	5 *U*	5 U	5 *U*	32 *U*	64 *U*	4 *U*	4 *U*	4 *U*	32 *U*	64 *U*	300 *U*
Case Inlet	T5	C	5 *U*	5 U	5 *U*	32 *U*	65 *U*	4 *U*	4 *U*	4 *U*	32 *U*	64 *U*	300 *U*
McNeil Island	T6	A	5 *U*	5 U	5 *U*	36 *U*	70 *U*	4 *U*	4 *U*	4 *U*	36 *U*	72 *U*	300 *U*
McNeil Island	T6	B	5 *U*	5 U	5 *U*	41 *U*	80 *U*	4 *U*	4 *U*	4 *U*	41 *U*	82 *U*	300 *U*
McNeil Island	T6	C	14 *T*	14 T	5 *U*	41 *U*	80 *U*	4 *U*	4 *U*	4 *U*	41 *U*	82 *U*	300 *U*
Carr Inlet	T7	A	5 *U*	5 U	5 *U*	33 *U*	66 *U*	4 *U*	4 *U*	4 *U*	33 *U*	66 *U*	300 *U*
Carr Inlet	T7	B	5 *U*	15 *T*	5 *U*	33 *U*	66 *U*	4 *U*	4 *U*	4 *U*	33 *U*	66 *U*	300 *U*
Carr Inlet	T7	C	5 *U*	40	5 *U*	33 *U*	66 *U*	4 *U*	4 *U*	4 *U*	33 *U*	66 *U*	300 *U*

TABLE B-1. (Continued)

Location	Site/ Transect	Composite	Percent Lipid
Budd Inlet	C1	A	0.92
Budd Inlet	C2	A	0.80
Inner Budd Inlet	T1	A	0.23
Inner Budd Inlet	T1	B	0.27
Inner Budd Inlet	T1	C	0.25
Outer Budd Inlet	T2	A	0.41
Outer Budd Inlet	T2	B	0.31
Outer Budd Inlet	T2	C	0.24
Shelton	T3	A	0.43
Shelton	T3	B	0.65
Shelton	T3	C	0.39
Totten Inlet	T4	A	0.51
Totten Inlet	T4	B	0.32
Totten Inlet	T4	C	0.44
Case Inlet	T5	A	0.47
Case Inlet	T5	B	0.37
Case Inlet	T5	C	0.33
McNeil Island	T6	A	0.28
McNeil Island	T6	B	0.29
McNeil Island	T6	C	0.35
Carr Inlet	T7	A	0.33
Carr Inlet	T7	B	0.30
Carr Inlet	T7	C	0.37

[1] Tissues used were littleneck clams (sites C1 and C2), English sole (Transects T4 and T6), and starry flounder (Transects T1, T2, T3, T5, and T7).

[2] All of the chemical concentrations presented in this table pass PSEP (1989a,b) guidelines and are considered acceptable for characterizing environmental conditions in southern Puget Sound. The following qualifiers provide additional information for specific values:

E = Estimated value. These values have a greater degree of uncertainty than unqualified data. Data are generally assigned E qualifiers when one QA/QC result (i.e., matrix spike, matrix duplicate, etc.) falls outside of the control limits.

M = Value is a mean.

T = Detected between the limit of detection and the quantification limit at the detection limit shown. These values are acceptable as estimates.

U = Undetected at detection limit shown.

Z = Value is above the detection limit shown after blank correction.

TABLE B-2. SUMMARY OF LENGTHS AND AGES OF FISH USED FOR BIOACCUMULATION ANALYSES

Location	Transect	Date	Composite	Fish Number	Species	Length (mm)	Age (years)
Inner Budd Inlet	T1	04/10/90	B	1	Starry flounder	490	9
Inner Budd Inlet	T1	04/10/90	A	2	Starry flounder	378	5
Inner Budd Inlet	T1	04/10/90	B	3	Starry flounder	368	12
Inner Budd Inlet	T1	04/10/90	C	4	Starry flounder	386	14
Inner Budd Inlet	T1	04/10/90	A	5	Starry flounder	340	6
Inner Budd Inlet	T1	04/10/90	A	6	Starry flounder	346	11
Inner Budd Inlet	T1	04/10/90	A	7	Starry flounder	374	12
Inner Budd Inlet	T1	04/10/90	C	8	Starry flounder	365	12
Inner Budd Inlet	T1	04/10/90	B	9	Starry flounder	433	10
Inner Budd Inlet	T1	04/10/90	C	10	Starry flounder	347	12
Inner Budd Inlet	T1	04/10/90	C	11	Starry flounder	340	8
Inner Budd Inlet	T1	04/10/90	B	12	Starry flounder	333	11
Inner Budd Inlet	T1	04/10/90	B	13	Starry flounder	297	7
Inner Budd Inlet	T1	04/10/90	C	14	Starry flounder	274	5
Inner Budd Inlet	T1	04/10/90	A	15	Starry flounder	298	6
Outer Budd Inlet	T2	04/10/90	B	16	Starry flounder	310	9
Outer Budd Inlet	T2	04/10/90	B	17	Starry flounder	330	15
Outer Budd Inlet	T2	04/10/90	C	18	Starry flounder	320	13
Outer Budd Inlet	T2	04/10/90	C	19	Starry flounder	310	7
Outer Budd Inlet	T2	04/10/90	C	20	Starry flounder	335	10
Outer Budd Inlet	T2	04/10/90	A	21	Starry flounder	375	7
Outer Budd Inlet	T2	04/10/90	A	22	Starry flounder	350	5
Outer Budd Inlet	T2	04/10/90	B	23	Starry flounder	345	8
Outer Budd Inlet	T2	04/10/90	B	24	Starry flounder	335	14
Outer Budd Inlet	T2	04/10/90	C	25	Starry flounder	340	14
Outer Budd Inlet	T2	04/10/90	A	26	Starry flounder	330	10
Outer Budd Inlet	T2	04/10/90	C	27	Starry flounder	315	7
Outer Budd Inlet	T2	04/10/90	A	28	Starry flounder	315	8
Outer Budd Inlet	T2	04/10/90	B	29	Starry flounder	320	8
Outer Budd Inlet	T2	04/10/90	A	30	Starry flounder	310	7
Shelton	T3	04/09/90	C	1	Starry flounder	440	10
Shelton	T3	04/09/90	C	2	Starry flounder	405	8
Shelton	T3	04/09/90	C	3	Starry flounder	420	9
Shelton	T3	04/09/90	A	4	Starry flounder	350	6
Shelton	T3	04/09/90	B	5	Starry flounder	425	8
Shelton	T3	04/09/90	A	6	Starry flounder	400	7
Shelton	T3	04/09/90	B	7	Starry flounder	400	7
Shelton	T3	04/09/90	A	8	Starry flounder	370	6
Shelton	T3	04/09/90	B	9	Starry flounder	340	10
Shelton	T3	04/09/90	C	10	Starry flounder	350	6
Shelton	T3	04/09/90	A	11	Starry flounder	330	8
Shelton	T3	04/09/90	B	12	Starry flounder	410	9
Shelton	T3	04/09/90	B	13	Starry flounder	400	7
Shelton	T3	04/09/90	C	14	Starry flounder	415	6
Shelton	T3	04/09/90	A	15	Starry flounder	390	7
Totten Inlet	T4	04/09/90	C	1	English Sole	280	4
Totten Inlet	T4	04/09/90	C	2	English Sole	255	2
Totten Inlet	T4	04/09/90	A	3	English Sole	260	4
Totten Inlet	T4	04/09/90	A	4	English Sole	255	4
Totten Inlet	T4	04/09/90	C	5	English Sole	230	3
Totten Inlet	T4	04/09/90	C	6	English Sole	230	2
Totten Inlet	T4	04/09/90	A	7	English Sole	240	4
Totten Inlet	T4	04/09/90	B	8	English Sole	240	3
Totten Inlet	T4	04/09/90	C	9	English Sole	230	3

TABLE B-2. (Continued)

Location	Transect	Date	Composite	Fish Number	Species	Length (mm)	Age (years)
Totten Inlet	T4	04/09/90	B	10	English Sole	265	4
Totten Inlet	T4	04/09/90	A	11	English Sole	295	5
Totten Inlet	T4	04/09/90	B	12	English Sole	265	4
Totten Inlet	T4	04/09/90	A	13	English Sole	320	5
Totten Inlet	T4	04/09/90	B	14	English Sole	265	3
Totten Inlet	T4	04/09/90	B	15	English Sole	300	5
Case Inlet	T5	04/10/90	B	1	Starry flounder	280	4
Case Inlet	T5	04/10/90	B	2	Starry flounder	315	8
Case Inlet	T5	04/10/90	A	3	Starry flounder	310	5
Case Inlet	T5	04/10/90	A	4	Starry flounder	310	5
Case Inlet	T5	04/10/90	C	5	Starry flounder	320	5
Case Inlet	T5	04/10/90	C	6	Starry flounder	310	5
Case Inlet	T5	04/10/90	A	7	Starry flounder	305	8
Case Inlet	T5	04/10/90	C	8	Starry flounder	300	5
Case Inlet	T5	04/10/90	B	9	Starry flounder	340	7
Case Inlet	T5	04/10/90	C	10	Starry flounder	300	14
Case Inlet	T5	04/10/90	A	11	Starry flounder	320	8
Case Inlet	T5	04/10/90	B	12	Starry flounder	365	10
Case Inlet	T5	04/10/90	B	13	Starry flounder	340	8
Case Inlet	T5	04/10/90	C	14	Starry flounder	335	5
Case Inlet	T5	04/10/90	A	15	Starry flounder	380	11
McNeil Island[1]	T6	04/11/90	C	61	English Sole	340	5
McNeil Island	T6	04/11/90	B	62	English Sole	270	4
McNeil Island	T6	04/11/90	C	63	English Sole	275	4
McNeil Island	T6	04/11/90	A	64	English Sole	230	3
McNeil Island	T6	04/11/90	C	65	English Sole	250	4
McNeil Island	T6	04/11/90	C	66	English Sole	260	5
McNeil Island	T6	04/11/90	B	67	English Sole	245	3
McNeil Island	T6	04/11/90	A	68	English Sole	240	4
McNeil Island	T6	04/11/90	B	69	English Sole	250	4
McNeil Island	T6	04/11/90	C	70	English Sole	240	4
McNeil Island	T6	04/11/90	A	71	English Sole	260	4
McNeil Island	T6	04/11/90	A	72	English Sole	260	4
McNeil Island	T6	04/11/90	B	73	English Sole	240	4
McNeil Island	T6	04/11/90	A	74	English Sole	245	3
McNeil Island	T6	04/11/90	B	75	English Sole	235	3
Carr Inlet	T7	04/11/90	A	1	Starry flounder	400	8
Carr Inlet	T7	04/11/90	B	2	Starry flounder	315	9
Carr Inlet	T7	04/11/90	C	3	Starry flounder	340	7
Carr Inlet	T7	04/11/90	B	4	Starry flounder	390	8
Carr Inlet	T7	04/11/90	B	5	Starry flounder	300	6
Carr Inlet	T7	04/11/90	A	6	Starry flounder	300	6
Carr Inlet	T7	04/11/90	A	7	Starry flounder	320	7
Carr Inlet	T7	04/11/90	C	8	Starry flounder	345	12
Carr Inlet	T7	04/11/90	C	9	Starry flounder	320	8
Carr Inlet	T7	04/11/90	A	10	Starry flounder	295	9
Carr Inlet	T7	04/11/90	C	11	Starry flounder	305	10
Carr Inlet	T7	04/11/90	B	12	Starry flounder	230	7
Carr Inlet	T7	04/11/90	B	13	Starry flounder	325	10
Carr Inlet	T7	04/11/90	A	14	Starry flounder	330	13
Carr Inlet	T7	04/11/90	C	15	Starry flounder	310	5

[1] Located off of McNeil Island in Carr Inlet.

Appendix C

Sediment Bioassay Data

TABLE C-1. CHARACTERISTICS OF SEDIMENTS COLLECTED AT STATIONS 1-12 IN SOUTHERN PUGET SOUND

Sampling Station	Interstitial Water Salinity (°/°°)	pH	Wet Weight (grams) per 2-cm Sediment Layer Tested	General Observations
West Beach Control	28	7.02	253	Fine, beige, clean sand.
1	25	7.03	214	Fine, light brown sediment with thick consistency and slight fishy odor.
2	28	7.01	191	Fine, light brown sediment with watery consistency and "dirt" odor.
3	27.5	7.03	189	Same as Station 2.
4	26	7.10	192	Same as Station 2.
5	27.5	7.07	190	Same as Station 2.
6	28	7.04	190	Same as Station 2.
7	27.5	7.11	190	Same as Station 2.
8	28	7.17	190	Same as Station 2.
9	28	7.39	199	Brown sediment with thick consistency and sweet odor.
10	25	7.15	204	Brown sediment with thick consistency and "dirt" odor.
11	28	7.22	197	Same as Station 10.
12	28	7.44	197	Light brown sediment with thick consistency and "dirt" odor.

TABLE C-2. RESPONSES OF *RHEPOXYNIUS ABRONIUS* TO TEST SEDIMENTS FROM STATIONS 1-12

Sampling Station	Replicate Number	Amphipod Response: 10-Day Amphipod Emergence	Amphipod Response: 10-Day Amphipod Survival: No. of Survivors	Amphipod Response: 10-Day Amphipod Survival: Mean %	Amphipod Response: Survivors Not Reburying
West Beach Control	1	5	19		0
	2	1	20		0
	3	6 $\bar{x}$ = 4.0	20 $\bar{x}$ = 19.4	97.0	0 $\bar{x}$ = 0.0
	4	4 Sx = 1.9	19 Sx = 0.55		0 Sx = 0
	5	4	19		0
1	1	14	17		0
	2	8	15		0
	3	4 $\bar{x}$ = 6.0	18 $\bar{x}$ = 17.0	85.0	0 $\bar{x}$ = 0.0
	4	1 Sx = 5.1	18 Sx = 1.2		0 Sx = 0
	5	3	17		0
2	1	1	19		0
	2	2	18		0
	3	8 $\bar{x}$ = 3.4	19 $\bar{x}$ = 18.6	93.0	0 $\bar{x}$ = 0.0
	4	5 Sx = 3.0	18 Sx = 0.55		0 Sx = 0
	5	1	19		0
3	1	2	20		0
	2	0	20		0
	3	1 $\bar{x}$ = 1.2	20 $\bar{x}$ = 19.8	99.0	0 $\bar{x}$ = 0.0
	4	2 Sx = 0.8	20 Sx = 0.45		0 Sx = 0
	5	1	19		0
4	1	5	18		0
	2	2	18		0
	3	3 $\bar{x}$ = 2.6	20 $\bar{x}$ = 19.0	95.0	0 $\bar{x}$ = 0.0
	4	1 Sx = 1.5	20 Sx = 1.0		0 Sx = 0
	5	2	19		0
5	1	6	19		0
	2	4	17		1
	3	2 $\bar{x}$ = 2.4	18 $\bar{x}$ = 18.8	94.0	0 $\bar{x}$ = 0.2
	4	0 Sx = 2.6	20 Sx = 1.3		0 Sx =0.4
	5	0	20		0
6	1	2	18		0
	2	0	17		0
	3	6 $\bar{x}$ = 3.0	18 $\bar{x}$ = 17.4	87.0	0 $\bar{x}$ = 0.0
	4	3 Sx = 2.2	15 Sx = 1.5		0 Sx = 0
	5	4	19		0

TABLE C-2. (Continued)

Sampling Station	Replicate Number	Amphipod Response: 10-Day Amphipod Emergence	Amphipod Response: 10-Day Amphipod Survival: No. of Survivors	Amphipod Response: 10-Day Amphipod Survival: Mean %	Amphipod Response: Survivors Not Reburying
7	1	6	16	88.0	0
	2	8	17		0
	3	1 $\bar{x}$ = 4.4	20 $\bar{x}$ = 17.6		0 $\bar{x}$ = 0.0
	4	3 Sx = 2.7	16 Sx = 1.8		0 Sx = 0
	5	4	19		0
8	1	2	16	82.0	0
	2	2	17		0
	3	0 $\bar{x}$ = 1.0	15 $\bar{x}$ = 16.4		0 $\bar{x}$ = 0.0
	4	1 Sx = 1.0	18 Sx = 1.1		0 Sx = 0
	5	0	16		0
9	1	5	19	95.0	0
	2	4	18		0
	3	3 $\bar{x}$ = 4.6	20 $\bar{x}$ = 19.0		0 $\bar{x}$ = 0.0
	4	9 Sx = 2.7	19 Sx = 0.71		0 Sx = 0
	5	2	19		0
10	1	5	19	90.0	0
	2	8	18		0
	3	0 $\bar{x}$ = 4.0	20 $\bar{x}$ = 18.0		0 $\bar{x}$ = 0.2
	4	4 Sx = 2.9	15 Sx = 1.9		1 Sx=0.45
	5	3	18		0
11	1	0	18	91.0	0
	2	0	19		0
	3	1 $\bar{x}$ = 0.8	18 $\bar{x}$ = 18.2		0 $\bar{x}$ = 0.0
	4	3 Sx = 1.3	18 Sx = 0.45		0 Sx = 0
	5	0	18		0
12	1	2	17	87.0	0
	2	0	18		0
	3	0 $\bar{x}$ = 0.6	17 $\bar{x}$ = 17.4		0 $\bar{x}$ = 0.0
	4	0 Sx = 0.9	17 Sx = 0.55		0 Sx = 0
	5	1	18		0

TABLE C-3. OBSERVATIONS OF AMPHIPOD EMERGENCE DURING TESTING OF SEDIMENTS FROM STATIONS 1-12

Treatment	Replicate Number	No. of Amphipods Out of Sediment Floating, Swimming, or on Sediment Surface — Days 1	2	3	4	5	6	7	8	9	10	Total Emergence	10-Day Treatment Summary
West Beach Control	1	0	0	0	0	1	1	0	1	1	1	5	
	2	0	0	0	0	0	0	1	0	0	0	1	
	3	1	1	0	1	1	1	1	0	0	0	6	$\bar{x}$ = 4.0
	4	0	1	2	1	0	0	0	0	0	0	4	Sx = 1.9
	5	0	0	0	0	0	1	1	1	0	1	4	
1	1	1	1	3	2	3	2	1	0	0	1	14	
	2	0	2	0	1	1	1	0	1	0	2	8	
	3	0	0	0	0	1	0	0	1	0	2	4	$\bar{x}$ = 6.0
	4	0	0	0	0	0	0	0	0	0	1	1	Sx = 5.1
	5	1	0	0	0	0	0	0	1	0	1	3	
2	1	0	0	0	0	0	0	1	0	0	0	1	
	2	1	0	0	0	0	0	0	1	0	0	2	
	3	0	3	0	5	0	0	0	0	0	0	8	$\bar{x}$ = 3.4
	4	1	1	2	1	0	0	0	0	0	0	5	Sx = 3.0
	5	0	0	0	1	0	0	0	0	0	0	1	
3	1	0	0	0	0	0	1	0	0	0	1	2	
	2	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	1	0	0	0	1	$\bar{x}$ = 1.2
	4	0	1	0	1	0	0	0	0	0	0	2	Sx = 0.8
	5	0	1	0	0	0	0	0	0	0	0	1	
4	1	0	2	1	0	0	0	0	0	0	2	5	
	2	0	2	0	0	0	0	0	0	0	0	2	
	3	0	0	0	0	0	0	0	2	1	0	3	$\bar{x}$ = 2.6
	4	0	1	0	0	0	0	0	0	0	0	1	Sx = 1.5
	5	0	0	0	0	0	0	0	0	0	2	2	
5	1	2	0	3	0	0	0	0	0	0	1	6	
	2	0	1	0	0	0	0	0	1	1	1	4	
	3	0	0	0	0	0	0	0	1	0	1	2	$\bar{x}$ = 2.4
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 2.6
	5	0	0	0	0	0	0	0	0	0	0	0	
6	1	1	0	0	1	0	0	0	0	0	0	2	
	2	0	0	0	0	0	0	0	0	0	0	0	
	3	0	1	2	1	0	0	0	0	1	1	6	$\bar{x}$ = 3.0
	4	0	0	1	1	0	0	0	0	0	1	3	Sx = 2.2
	5	1	1	0	0	0	0	1	0	0	1	4	

TABLE C-3. (Continued)

Treatment	Replicate Number	No. of Amphipods Out of Sediment Floating, Swimming, or on Sediment Surface — Days 1	2	3	4	5	6	7	8	9	10	Total Emergence	10-Day Treatment Summary
	1	0	0	1	1	1	1	0	1	0	1	6	
	2	0	3	1	0	0	1	2	1	0	0	8	
7	3	0	0	0	0	0	0	0	1	0	0	1	$\bar{x}$ = 4.4
	4	0	0	1	1	0	0	0	1	0	0	3	Sx = 2.7
	5	0	2	0	0	0	0	0	2	0	0	4	
	1	0	1	0	0	1	0	0	0	0	0	2	
	2	0	0	0	0	0	1	0	0	1	0	2	
8	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 1.0
	4	0	0	0	0	1	0	0	0	0	0	1	Sx = 1.0
	5	0	0	0	0	0	0	0	0	0	0	0	
	1	0	0	2	2	0	1	0	0	0	0	5	
	2	1	2	1	0	0	0	0	0	0	0	4	
9	3	0	0	2	0	0	0	0	0	0	1	3	$\bar{x}$ = 4.6
	4	0	1	0	0	3	2	1	1	0	1	9	Sx = 2.7
	5	0	1	0	0	0	0	0	1	0	0	2	
	1	1	0	0	0	0	0	0	1	1	2	5	
	2	2	0	1	0	1	1	1	1	0	1	8	
10	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 4.0
	4	0	2	2	0	0	0	0	0	0	0	4	Sx = 2.9
	5	0	0	0	0	0	0	1	1	0	1	3	
	1	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	0	0	0	
11	3	0	0	0	0	1	0	0	0	0	0	1	$\bar{x}$ = 0.8
	4	0	0	0	0	0	0	0	2	1	0	3	Sx = 1.3
	5	0	0	0	0	0	0	0	0	0	0	0	
	1	0	0	1	0	0	0	0	0	0	1	2	
	2	0	0	0	0	0	0	0	0	0	0	0	
12	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 0.6
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 0.9
	5	0	0	0	0	0	0	0	1	0	0	1	

TABLE C-4. SELECTED WATER QUALITY CHARACTERISTICS MEASURED AT THE BEGINNING (DAY 0) AND END (DAY 10) OF TESTING FOR STATIONS 1-12

	Day 0				Day 10			
Sampling Station	pH	DO[a] (mg/L)	Temperature (°C)	Salinity (°/°°)	pH	DO[a] (mg/L)	Temperature (°C)	Salinity (°/°°)
West Beach Control	7.97	8.3	15.3	28	7.94	7.7	15.0	28
1	7.87	8.3	15.2	28	8.01	7.6	15.4	28
2	7.84	8.2	15.3	28	8.11	8.1	15.2	28
3	7.89	8.3	15.3	28	8.08	7.8	15.3	28
4	7.88	8.2	15.2	28	8.04	8.1	15.0	28
5	7.87	8.1	15.3	28	7.94	7.8	15.2	28
6	7.87	8.3	15.2	28	7.99	8.1	15.0	28
7	7.86	8.3	15.3	28	7.92	8.0	15.2	28
8	7.92	8.3	15.3	28	7.89	7.8	15.0	28
9	7.88	8.2	15.3	28	7.93	7.8	15.1	28
10	7.92	8.3	15.3	28	7.94	8.2	15.0	28
11	7.94	8.2	15.3	28	7.93	8.0	15.0	28
12	7.97	8.3	15.3	28	ND[a]	7.8	14.8	28

[a] DO - dissolved oxygen
[b] ND - no data

TABLE C-5. CHARACTERISTICS OF SEDIMENTS COLLECTED AT STATIONS 13-24 IN SOUTHERN PUGET SOUND

Sampling Station	Interstitial Water Salinity (°/°°)	pH	Wet Weight (grams) per 2-cm Sediment Layer Tested	General Observations
West Beach Control	28	6.86	267	Fine, beige, clean sand.
13	25.5	7.66	194	Fine, charcoal brown sediment with pourable consistency, "dirt" odor.
14	27	7.43	195	Same as Station 13.
15	28	7.64	251	Coarse, brown sediment with rotten oyster odor.
16	28	7.32	199	Same as Station 13.
17	28	7.27	193	Same as Station 13.
18	28	7.36	273	Same as Station 15, but less rotten odor.
19	30	7.20	204	Same as Station 13, but thicker.
20	28	7.46	219	Same as Station 13, but thicker.
21	30	7.66	297	Same as Station 15, but less rotten odor.
22	30	7.15	296	Same as Station 15, but sandier with less rotten odor.
23	30	7.25	194	Same as Station 13.
24	30	7.21	213	Medium-grained, charcoal brown sediment, with a slight rotten odor.

TABLE C-6. RESPONSES OF *RHEPOXYNIUS ABRONIUS* TO TEST SEDIMENTS FROM STATIONS 13-24

Sampling Station	Replicate Number	Amphipod Response: 10-Day Amphipod Emergence	Amphipod Response: 10-Day Amphipod Survival: No. of Survivors	Amphipod Response: 10-Day Amphipod Survival: Mean %	Amphipod Response: Survivors Not Reburying
West Beach Control	1	1	20		0
	2	0	20		0
	3	0 $\bar{x}$ = 2.2	20 $\bar{x}$ = 19.8	99.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 4.4	20 Sx = 0.4		0 Sx = 0
	5	10	19		0
13	1	3	20		0
	2	0	18		0
	3	0 $\bar{x}$ = 0.6	19 $\bar{x}$ = 19.0	95.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 1.3	20 Sx = 1.0		0 Sx = 0
	5	0	18		0
14	1	0	19		0
	2	0	20		0
	3	2 $\bar{x}$ = 0.6	20 $\bar{x}$ = 19.2	96.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 0.9	19 Sx = 0.8		0 Sx = 0
	5	1	18		0
15	1	1	20		0
	2	2	19		0
	3	1 $\bar{x}$ = 2.8	18 $\bar{x}$ = 18.2	91.0	0 $\bar{x}$ = 0.2
	4	4 Sx = 2.2	19 Sx = 1.9		0 Sx =0.4
	5	6	15		1
16	1	1	16		0
	2	0	20		0
	3	1 $\bar{x}$ = 0.6	19 $\bar{x}$ = 18.0	90.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 0.5	18 Sx = 1.6		0 Sx = 0
	5	1	17		0
17	1	9	18		0
	2	1	16		0
	3	0 $\bar{x}$ = 2.0	19 $\bar{x}$ = 17.8	89.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 3.9	18 Sx = 1.1		0 Sx = 0
	5	0	18		0
18	1	12	18		0
	2	0	20		0
	3	1 $\bar{x}$ = 2.6	19 $\bar{x}$ = 19.2	96.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 5.3	19 Sx = 0.8		0 Sx = 0
	5	0	20		0

TABLE C-6. (Continued)

Sampling Station	Replicate Number	Amphipod Response: 10-Day Amphipod Emergence	Amphipod Response: 10-Day Amphipod Survival: No. of Survivors	Amphipod Response: 10-Day Amphipod Survival: Mean %	Amphipod Response: Survivors Not Reburying
	1	14	19		0
	2	0	16		0
19	3	1 $\bar{x}$ = 3.6	20 $\bar{x}$ = 19.0	95.0	0 $\bar{x}$ = 0.0
	4	1 Sx = 5.9	20 Sx = 1.7		0 Sx = 0
	5	2	20		0
	1	0	20		0
	2	1	16		0
20	3	0 $\bar{x}$ = 0.8	19 $\bar{x}$ = 18.0	90.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 1.3	20 Sx = 2.3		0 Sx = 0
	5	3	15		0
	1	0	19		0
	2	0	19		0
21	3	1 $\bar{x}$ = 0.4	18 $\bar{x}$ = 19.0	95.0	0 $\bar{x}$ = 0.0
	4	1 Sx = 0.5	19 Sx = 0.7		0 Sx = 0
	5	0	20		0
	1	0	20		0
	2	0	17		0
22	3	0 $\bar{x}$ = 0.0	19 $\bar{x}$ = 19.0	95.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 0	19 Sx = 1.2		0 Sx = 0
	5	0	20		0
	1	0	20		0
	2	0	19		0
23	3	0 $\bar{x}$ = 0.6	19 $\bar{x}$ = 19.2	96.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 1.3	19 Sx = 0.4		0 Sx = 0
	5	3	19		0
	1	3	18		0
	2	1	19		0
24	3	0 $\bar{x}$ = 0.8	17 $\bar{x}$ = 18.8	94.0	0 $\bar{x}$ = 0.0
	4	0 Sx = 1.3	20 Sx = 1.3		0 Sx = 0
	5	0	20		0

TABLE C-7. OBSERVATIONS OF AMPHIPOD EMERGENCE DURING TESTING OF SEDIMENTS FROM STATIONS 13-24

Treatment	Replicate Number	No. of Amphipods Out of Sediment Floating, Swimming, or on Sediment Surface — Days 1	2	3	4	5	6	7	8	9	10	Total Emergence	10-Day Treatment Summary
West Beach Control	1	0	0	0	0	0	0	0	0	0	1	1	
	2	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 2.2
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 4.4
	5	1	1	1	1	1	1	1	1	1	1	10	
13	1	0	0	1	1	1	0	0	0	0	0	3	
	2	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 0.6
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 1.3
	5	0	0	0	0	0	0	0	0	0	0	0	
14	1	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	0	1	1	0	2	$\bar{x}$ = 0.6
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 0.9
	5	0	0	0	0	0	0	0	0	0	1	1	
15	1	0	0	0	0	0	0	0	0	0	1	1	
	2	0	0	0	0	1	1	0	0	0	0	2	
	3	0	0	0	0	0	0	0	0	0	1	1	$\bar{x}$ = 2.8
	4	0	0	0	0	0	0	0	1	1	2	4	Sx = 2.2
	5	0	0	0	0	0	0	1	1	1	3	6	
16	1	0	0	0	0	0	0	0	0	0	1	1	
	2	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	0	0	0	1	1	$\bar{x}$ = 0.6
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 0.5
	5	0	0	0	0	0	0	0	0	0	1	1	
17	1	0	1	1	1	1	1	1	1	1	1	9	
	2	0	1	0	0	0	0	0	0	0	0	1	
	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 2.0
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 3.9
	5	0	0	0	0	0	0	0	0	0	0	0	
18	1	1	2	1	1	1	1	1	1	2	1	12	
	2	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	0	0	0	1	1	$\bar{x}$ = 2.6
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 5.3
	5	0	0	0	0	0	0	0	0	0	0	0	

TABLE C-7. (Continued)

Treatment	Replicate Number	No. of Amphipods Out of Sediment Floating, Swimming, or on Sediment Surface — Days 1	2	3	4	5	6	7	8	9	10	Total Emergence	10-Day Treatment Summary
	1	1	0	2	1	2	1	1	2	2	2	14	
	2	0	0	0	0	0	0	0	0	0	0	0	
19	3	0	0	0	0	0	0	1	0	0	0	1	$\bar{x}$ = 3.6
	4	0	0	0	0	0	0	0	1	0	0	1	Sx = 5.9
	5	0	0	0	0	0	0	0	1	0	1	2	
	1	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	1	0	0	1	
20	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 0.8
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 1.3
	5	0	0	1	1	1	0	0	0	0	0	3	
	1	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	0	0	0	
21	3	0	0	0	0	1	0	0	0	0	0	1	$\bar{x}$ = 0.4
	4	0	0	0	1	0	0	0	0	0	0	1	Sx = 0.5
	5	0	0	0	0	0	0	0	0	0	0	0	
	1	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	0	0	0	
22	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 0.0
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 0
	5	0	0	0	0	0	0	0	0	0	0	0	
	1	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	0	0	0	
23	3	0	0	0	0	0	0	0	0	0	0	0	
	4	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 0.6
	5	0	0	0	0	0	0	0	1	1	1	3	Sx = 1.3
	1	1	0	0	1	1	0	0	0	0	0	3	
	2	0	1	0	0	0	0	0	0	0	0	1	
24	3	0	0	0	0	0	0	0	0	0	0	0	$\bar{x}$ = 0.8
	4	0	0	0	0	0	0	0	0	0	0	0	Sx = 1.3
	5	0	0	0	0	0	0	0	0	0	0	0	

TABLE C-8. SELECTED WATER QUALITY CHARACTERISTICS MEASURED AT THE BEGINNING (DAY 0) AND END (DAY 10) OF TESTING FOR STATIONS 13-24

	Day 0				Day 10			
Sampling Station	pH	DO[a] (mg/L)	Temperature (°C)	Salinity (°/°°)	pH	DO[a] (mg/L)	Temperature (°C)	Salin (°/°
West Beach Control	7.98	7.6	14.7	28	7.97	8.3	14.8	28
13	7.97	7.8	14.7	28	7.95	8.6	14.9	28
14	7.99	7.5	14.7	28	7.96	8.7	14.8	28
15	7.98	7.5	14.7	28	7.97	8.4	14.8	28
16	8.01	7.8	14.6	28	7.95	8.6	14.8	28
17	8.00	7.4	15.0	28	7.97	8.0	14.8	28
18	7.99	7.8	15.2	28	8.08	8.2	14.9	28
19	7.95	7.5	14.8	28	8.03	8.2	15.0	28
20	7.96	7.6	15.0	28	8.02	8.3	15.0	28
21	7.97	7.1	14.7	28	8.04	8.3	15.0	28
22	8.04	7.4	14.8	28	8.15	8.2	14.8	28
23	7.98	7.5	14.8	28	8.03	8.3	15.3	28
24	8.04	7.5	15.0	28	8.15	7.8	15.0	28

[a] DO - dissolved oxygen

TABLE C-9. RESPONSES OF *RHEPOXYNIUS ABRONIUS* TO THE REFERENCE TOXICANT $CdCl_2$[a]

Controls for Stations 1–12: 96-hour Cadmium LC_{50}[b] Determination

Nominal Cadmium Concentration (mg/L)	Amphipod Survival (percent) Replicates 1	2	3	4	Mean Percent Survival
0.0	100	100	100	90	97.5
0.25	100	90	80	100	92.5
0.50	100	80	70	80	82.5
1.0	30	40	70	10	37.5
2.0	0	0	0	0	0
4.0	0	0	0	0	0

Controls for Stations 13–24: 96-hour Cadmium LC_{50}[c] Determination

Nominal Cadmium Concentration (mg/L)	Amphipod Survival (percent) Replicates 1	2	3	4	Mean Percent Survival
0.0	100	100	100	100	100
0.25	100	80	90	100	92.5
0.50	90	100	100	100	97.5
1.0	70	60	90	90	77.5
2.0	20	30	50	50	37.5
4.0	0	0	0	0	0

[a] EPA, EMSL-Cinn #784.

[b] 96-hour LC_{50} = 0.85 mg Cd/L, (95 percent confidence limits, 0.71–0.98 mg Cd/L).

[c] 96-hour LC_{50} = 1.4 mg Cd/L (significant heterogeneity).

Appendix D

Histopathology Data

TABLE D-1. SUMMARY OF SHIPBOARD OBSERVATIONS MADE ON ENGLISH SOLE SAMPLED FOR HISTOPATHOLOGICAL ANALYSIS FROM TOTTEN INLET

LBA ACC. NUMBER (1)	STATION CODE	SPECIES CODE (2)	LENGTH (MM)	SEX (3)	GROSS EXTERNAL LESIONS (DESCRIPTIVE OBSERVATIONS)	LIVER COLOR (4)	GROSS LIVER LESIONS (DESCRIPTIVE OBSERVATIONS)
1	T-4	1	280	2	Philometra	1	NVL
2	T-4	1	255	2	Papillomas (2) & Philometra	1	NVL
3	T-4	1	260	2	Philometra	1	NVL
4	T-4	1	255	2	Scar on Blind Side	1	NVL
5	T-4	1	230	2	Philometra	2	NVL
6	T-4	1	230	2	NVL	2	NVL
7	T-4	1	240	2	Philometra	1	NVL
8	T-4	1	240	2	Philometra	1	NVL
9	T-4	1	230	2	Philometra	2	NVL
10	T-4	1	265	2	Philometra	1	Parasite on Surface
11	T-4	1	295	2	Philometra	1	Bile Staining
12	T-4	1	265	2	Philometra	1	NVL
13	T-4	1	320	2	Philometra	1	Parasite on Surface
14	T-4	1	265	2	Philometra	1	NVL
15	T-4	1	300	2	Philometra & Fin Erosion	1	NVL
16	T-4	1	280	2	Philometra	1	White Cysts on Surface
17	T-4	1	260	2	Philometra	1	NVL
18	T-4	1	250	2	Philometra	1	White Cyst on Surface
19	T-4	1	230	2	Philometra	1	Parasite on Surface
20	T-4	1	255	2	Philometra	1	NVL
21	T-4	1	230	2	Philometra	1	NVL
22	T-4	1	250	2	Philometra	1	NVL
23	T-4	1	320	2	Philometra	2	NVL
24	T-4	1	280	2	Philometra	1	NVL
25	T-4	1	240	1	Philometra	1	Parasite on Surface
26	T-4	1	230	2	Philometra	2	NVL
27	T-4	1	265	2	Philometra	1	NVL
28	T-4	1	260	1	Philometra	1	Parasite on Surface
29	T-4	1	270	2	Philometra	1	NVL
30	T-4	1	245	2	Parasites Between Fin Rays	1	Parasite on Surface
31	T-4	1	230	2	Philometra	2	NVL
32	T-4	1	280	2	Philometra & Scoliosis	1	NVL
33	T-4	1	230	2	Philometra	2	NVL
34	T-4	1	250	2	Philometra	1	NVL
35	T-4	1	280	2	Philometra	1	NVL
36	T-4	1	250	2	Philometra	1	Bile Staining
37	T-4	1	260	2	Philometra	2	NVL
38	T-4	1	330	2	Philometra	1	Large Parasite Cysts
39	T-4	1	260	2	Philometra	2	NVL
40	T-4	1	240	2	Philometra	1	Extensive Parasites
41	T-4	1	240	2	Philometra	1	One White Cyst
42	T-4	1	230	2	Philometra	2	NVL
43	T-4	1	235	2	Philometra	2	NVL
44	T-4	1	245	2	Philometra	1	NVL
45	T-4	1	265	2	Philometra	2	NVL
46	T-4	1	260	2	Philometra	1	Bile Staining
47	T-4	1	250	2	Philometra	1	NVL
48	T-4	1	290	2	Philometra	1	NVL
49	T-4	1	315	2	Philometra & Fin Erosion	1	White Cyst
50	T-4	1	310	2	Philometra	1	Parasites
51	T-4	1	370	2	Philometra	2	NVL
52	T-4	1	295	2	Philometra	1	NVL
53	T-4	1	270	2	Philometra	1	NVL
54	T-4	1	255	2	Philometra	1	NVL
55	T-4	1	295	2	Philometra	2	NVL
56	T-4	1	230	1	Philometra	2	NVL
57	T-4	1	260	2	Philometra	2	NVL
58	T-4	1	250	2	Philometra	1	NVL
59	T-4	1	230	2	Philometra	1	NVL
60		No Sample					

TABLE D-2. SUMMARY OF SHIPBOARD OBSERVATIONS MADE ON ENGLISH SOLE SAMPLED FOR HISTOPATHOLOGICAL ANALYSIS FROM CARR INLET

LBA ACC. NUMBER (1)	STATION CODE	SPECIES CODE (2)	LENGTH (MM)	SEX (3)	GROSS EXTERNAL LESIONS (DESCRIPTIVE OBSERVATIONS)	LIVER COLOR (4)	GROSS LIVER LESIONS (DESCRIPTIVE OBSERVATIONS)
61	T-6	1	340	2	Philometra & Fin Erosion	2	NVL
62	T-6	1	270	2	Philometra	1	NVL
63	T-6	1	275	2	Philometra	1	White Cyst
64	T-6	1	230	2	Philometra	1	NVL
65	T-6	1	250	1	Philometra	2	Extensive Parasites
66	T-6	1	260	2	Philometra	1	Parasites
67	T-6	1	245	2	Philometra	1	NVL
68	T-6	1	240	1	Philometra	2	Parasites
69	T-6	1	250	2	Philometra	1	Parasites
70	T-6	1	240	2	Philometra	1	Parasite
71	T-6	1	260	2	Philometra	2	Extensive Parasites
72	T-6	1	260	1	Philometra	2	NVL
73	T-6	1	240	2	Philometra	2	NVL
74	T-6	1	245	2	Philometra	1	White Spots
75	T-6	1	235	2	Philometra	2	NVL
76	T-6	1	275	2	Philometra	3	NVL
77	T-6	1	260	1	Philometra	3	Parasite
78	T-6	1	255	2	Philometra	1	NVL
79	T-6	1	230	1	Philometra	2	White Cyst
80	T-6	1	235	2	Philometra	2	NVL
81	T-6	1	230	1	Philometra	2	White Cyst
82	T-6	1	230	2	Philometra	1	NVL
83	T-6	1	230	2	Philometra	1	NVL
84	T-6	1	230	2	NVL	2	NVL
85	T-6	1	270	2	Philometra	1	Yellow Cyst
86	T-6	1	255	2	Philometra	2	NVL
87	T-6	1	240	2	Philometra	1	NVL
88	T-6	1	245	1	Philometra	2	NVL
89	T-6	1	280	2	Philometra	1	NVL
90	T-6	1	235	2	Philometra	2	NVL
91	T-6	1	240	2	Philometra	2	White Parasites
92	T-6	1	235	2	Philometra	2	NVL
93	T-6	1	270	1	Philometra	3	Large White Parasites
94	T-6	1	230	2	Philometra	1	NVL
95	T-6	1	230	2	Philometra	2	NVL
96	T-6	1	230	1	Philometra	2	Yellow Cysts
97	T-6	1	270	2	Philometra	1	Long Yellow Parasites
98	T-6	1	300	2	Philometra	1	Yellow Cysts
99	T-6	1	270	2	Philometra	2	Short Yellow Worm
100	T-6	1	260	2	Philometra	1	NVL
101	T-6	1	230	2	Philometra	2	NVL
102	T-6	1	250	2	Philometra	2	Long Parasite
103	T-6	1	235	1	Philometra	3	NVL
104	T-6	1	240	1	Philometra & Fin Erosion	2	NVL
105	T-6	1	260	1	NVL	3	NVL
106	T-6	1	230	2	Philometra & Fin Base Hemorrhage	1	NVL
107	T-6	1	230	1	Philometra & Fin Erosion	2	NVL
108	T-6	1	240	2	Philometra	2	NVL
109	T-6	1	240	1	Fin Erosion	2	Yellow Cysts
110	T-6	1	230	2	NVL	2	White Cyst
111	T-6	1	230	2	Philometra	1	NVL
112	T-6	1	260	2	Philometra	3	NVL
113	T-6	1	260	2	Philometra	3	Yellow Parasite
114	T-6	1	240	2	Philometra	2	NVL
115	T-6	1	230	2	Philometra	2	NVL
116	T-6	1	255	2	Philometra	1	White Worm
117	T-6	1	245	2	Philometra & Fin Erosion	3	White Cyst
118	T-6	1	235	2	Philometra	2	NVL
119	T-6	1	240	2	Philometra	1	NVL
120	T-6	1	230	2	Philometra	1	White & Yellow Parasites

TABLE D-3. SUMMARY OF LABORATORY OBSERVATIONS MADE ON LIVERS OF ENGLISH SOLE FROM TOTTEN INLET

LBA ACC. NUMBER (1)	HISTOLOGICAL LIVER LESIONS and SEVERITY (ABBREVIATED DESCRIPTIVE OBSERVATIONS)	NODC HISTOLOGICAL LESION CODE				
1	Vac-2/Serositis-1/Paren Nema-1/	14 -482	12 -200	14 -116		
2	Vac-1/Myx-1	14 -482	18 - 68			
3	Vac-1/Myx-1	14 -482	18 - 68			
4	Vac-1/Ser Nema-1/Coccidia-1	14 -482	12 -116	14 - 58		
5	Vac-3/Myx-1/Ser Nema-1	14 -482	18 - 68	12 -116		
6	Vac-3/Non-Uni Vac-1	14 -482	14 -483			
7	Vac-1/Coccidia-1	14 -482	14 - 58			
8	Vac-2/Serositis-2/MMC's-1/Mono Infil-1/Ser Nema-2	14 -482	12 -200	103 -726	14 -234	12 -116
9	Vac-2/Myx-1	14 -482	18 - 68			
10	Vac-1/Serositis-2/Ser Nema-2/Coccidia-1/Mono Infil-1	14 -482	12 -200	12 -116	14 - 58	14 -234
11	Vac-1/Serositis-1/Ser Nema-1/MMC's-1/Regen-1	14 -482	12 -200	12 -116	103 -726	14 -734
12	Vac-1/Myx-1/Serositis-1	14 -482	18 - 68	12 -200		
13	Vac-1/Serositis-2/MMC's-1/Myx-1/Ser Nema-2	14 -482	12 -200	103 -726	18 - 68	12 -116
14	Vac-1/Myx-1	14 -482	18 - 68			
15	Vac-1/Myx-1/Foc Nec-1/Mono Infil-1	14 -482	18 - 68	14 -308	14 -234	
16	Vac-1/Serositis-2/Ser Nema-2/Paren Myx-1	14 -482	12 -200	12 -116	14 - 68	
17	Vac-1	14 -482				
18	Vac-1/Myx-1/Serositis-2	14 -482	18 - 68	12 -200		
19	Vac-2/Myx-1/Serositis-1	14 -482	18 - 68	12 -200		
20	Vac-2	14 -482				
21	Vac-1	14 -482				
22	Vac-1/Myx-1	14 -482	18 - 68			
23	Vac-1/Serositis-2/Ser Nema-1/Paren Gran-1	14 -482	12 -200	12 -116	73 -219	
24	Vac-1/Coccidia-1/Serositis-1	14 -482	14 - 58	12 -200		
25	Vac-1/Paren Nema-1/Myx-1/Ser Nema-2/Serositis-1	14 -482	14 -116	18 - 68	12 -116	12 -200
26	Vac-2/Myx-1/Foc Nec-1	14 -482	18 - 68	14 -308		
27	Vac-1/Mono Infil-1/Myx-1	14 -482	14 -234	18 - 68		
28	Vac-1/Serositis-2/Ser Nema-2/Myx-1	14 -482	12 -200	12 -116	18 - 68	
29	Vac-1/Myx-1/Foc Nec-1	14 -482	18 - 68	14 -308		
30	Vac-1/Myx-1/Foc Nec-1	14 -482	18 - 68	14 -308		
31	Vac-1/Myx-1	14 -482	18 - 68			
32	Vac-1/Myx-1/Coccidia-1	14 -482	18 - 68	14 - 58		
33	Vac-1	14 -482				
34	Vac-1	14 -482				
35	Vac-1/Myx-1/Mono Infil-1	14 -482	18 - 68	14 -234		
36	Vac-1/Myx-1	14 -482	18 - 68			
37	Vac-2/Serositis-1/Myx-1	14 -482	12 -200	18 - 68		
38	Vac-2/Serositis-3/Ser Nema-3/Myx-1/Coccidia-1	14 -482	12 -200	12 -116	18 - 68	14 - 58
39	Vac-1/Myx-1/Paren Gran-2/MMC's-1	14 -482	18 - 68	73 -219	103 -726	
40	Vac-1/Serositis-1/Myx-1/Mono Infil-1/Foc Nec-1	14 -482	12 -200	18 - 68	14 -234	14 -308
41	Vac-2/Myx-1	14 -482	18 - 68			
42	Vac-1	14 -482				
43	Vac-1/Myx-1	14 -482	18 - 68			
44	Vac-1/Foc Nec-1/Serositis-1	14 -482	14 -308	12 -200		
45	Vac-1/Mono Infil-2/Myx-1/Panc Nec-1/MMC's-1	14 -482	14 -234	18 - 68	74 -308	103 -726

TABLE D-3. (Continued)

LBA ACC. NUMBER (1)	HISTOLOGICAL LIVER LESIONS and SEVERITY (ABBREVIATED DESCRIPTIVE OBSERVATIONS)	NODC HISTOLOGICAL LESION CODE					
46	Vac-1	14 -482					
47	Vac-2/Coccidia-1	14 -482	14 - 58				
48	Vac-1/Myx-1	14 -482	18 - 68				
49	Vac-1/Myx-1/Ser Nema-1	14 -482	18 - 68	12 -116			
50	Vac-2/Ser Gran-1/Paren Nema-1/Coccidia-1/Paren Gran-1/Foc Nec-1	14 -482	12 -219	14 -116	14 - 58	73 -219	14 -308
51	Vac-1/Myx-1	14 -482	18 - 68				
52	Vac-1/Myx-1	14 -482	18 - 68				
53	Vac-1/Ser Gran-1	14 -482	12 -219				
54	Vac-1/Coccidia-1/Myx-1	14 -482	14 - 58	18 - 68			
55	Vac-1/Foc Pyk-1/Foc Nec-1/Myx-1	14 -482	14 -404	14 -308	18 - 68		
56	Vac-1/Myx-1/Mono Infil-1	14 -482	18 - 68	14 -234			
57	Vac-1/Myx-2/Duc Inflam-2	14 -482	18 - 68	18 -200			
58	Vac-1/MNC's-1/Myx-1/Foc Pyk-1	14 -482	103 -726	18 - 68	14 -404		
59	Vac-1/Serositis-2/Ser Nema-1	14 -482	12 -200	12 116			
60	(NO SPECIMEN)						

TABLE D-4. SUMMARY OF LABORATORY OBSERVATIONS MADE ON LIVERS OF ENGLISH SOLE FROM CARR INLET

LBA ACC. NUMBER (1)	HISTOLOGICAL LIVER LESIONS and SEVERITY (ABBREVIATED DESCRIPTIVE OBSERVATIONS)	NOOC HISTOLOGICAL LESION CODE					
1	Vac-1	14 -482					
2	Vac-1/Foc Inflam-1	14 -482	14 -200				
3	Vac-1/Serositis-1/Myx-1	14 -482	12 -200	18 - 68			
4	Vac-1/Mono Infil-1/Myx-1	14 -482	14 -234	18 - 68			
5	Vac-1/Myx-1/Ser Nema-1	14 -482	18 - 68	12 -116			
6	Vac-1/Mono Infil-1/Myx-1/Foc Nec-1	14 -482	14 -234	18 - 68	14 -308		
7	Vac-1/Serositis-1	14 -482	12 -200				
8	Vac-1/Serositis-2/Ser Nema-2/Mono Infil-1	14 -482	12 -200	12 -116	14 -234		
9	Vac-1/Foc Inflam-1	14 -482	14 -200				
10	Vac-1/Myx-1/Coccidia-1	14 -482	18 - 68	14 - 58			
11	Vac-1/Myx-1/Foc Inflam-1/Ser Nema-1	14 -482	18 - 68	14 -200	12 -116		
12	Vac-2/Myx 1	14 -482	18 - 68				
13	Vac-1/Myx-1/Mono Infil-1	14 -482	18 - 68	14 -234			
14	Vac-1/Spong Hep-1/Myx-1/Mono Infil-1/Serositis-1	14 -482	14 -720	18 - 68	14 -234	12 -200	
15	Vac-1/Myx-1	14 -482	18 - 68				
16	Vac-1/Myx-1	14 -482	18 - 68				
17	Vac-1/Coccidia-1/Myx-1/Ser Nema-1/Mono Infil-1	14 -482	14 - 58	18 - 68	12 -116	14 -234	
18	Vac-1/Myx-1	14 -482	18 - 68				
19	Vac-1/MMC's-1/Ser Nema-1/Non-Uni Vac-1	14 -482	103 -726	12 -116	14 -483		
20	Vac-1/Serositis-1/Myx-1/Coccidia-1/Fibrosis-1	14 -482	12 -200	18 - 68	14 - 58	14 -261	
21	Vac-1/Myx-1/Foc Inflam-1/Foc Pyk-1	14 -482	18 - 68	14 -200	14 -404		
22	Vac-1/Coccidia-1/Myx-1	14 -482	14 - 58	18 - 68			
23	Vac-1	14 -482					
24	Vac-1/Mono Infil-1/Myx-1	14 -482	14 -234	18 - 68			
25	Vac-1/Serositis-1	14 -482	12 -200				
26	Vac-1	14 -482					
27	Vac-1/Myx-1	14 -482	18 - 68				
28	Vac-1/Coccidia-1	14 -482	14 - 58				
29	Vac-1/Coccidia-1	14 -482	14 - 58				
30	Vac-1/Myx-1/Paren Nema-1	14 -482	18 - 68	18 -116			
31	Vac-1/Myx-1	14 -482	18 - 68				
32	Vac-1/Myx-1	14 -482	18 - 68				
33	Vac-1/Myx-1/Foc Pyk-1/Mono Infil-1/Foc Inflam-1/Paren Gran-1/Serositis-1/Ser Nema-1	14 -482	18 - 68 12 -200	14 -404 12 -116	14 -234	14 -200	73 -219
34	Vac-1	14 -482					
35	Vac-1	14 -482					
36	Vac-1/Serositis-1	14 -482	12 -200				
37	Vac-1/Ser Nema-2/Serositis-1	14 -482	12 -116	12 -200			
38	Vac-1/Myx-1	14 -482	18 - 68				
39	Vac-1/Myx-1/Foc Inflam-1	14 -482	18 - 68	14 -200			
40	Vac-1	14 -482					
41	Vac-1/Foc Inflam-1/Myx-2/Foc Nec-1	14 -482	14 -200	18 - 68	14 -308		
42	Vac-1/Myx-1/Foc Inflam-1/Paren Nema-1	14 -482	18 - 68	14 -200	12 -116		
43	Vac-1/Myx-1/Ser Nema-1	14 -482	18 - 68	12 -116			
44	Vac-1/Myx-1	14 -482	18 - 68				
45	Vac-1/MMC's-3	14 -482	103 -726				

TABLE D-4. (Continued)

LBA ACC. NUMBER (1)	HISTOLOGICAL LIVER LESIONS and SEVERITY (ABBREVIATED DESCRIPTIVE OBSERVATIONS)	NODC HISTOLOGICAL LESION CODE				
46	Vac-1/Myx-1	14 -482	18 - 68			
47	Vac-1	14 -482				
48	Vac-1/Myx-1	14 -482	18 - 68			
49	Vac-1	14 -482				
50	Vac-1/Ser Nema-1/Foc Pyk-1	14 -482	12 -116	14 -404		
51	Vac-1/Ser Nema-1/Serositis-1/Myx-1	14 -482	12 -116	12 -200	18 - 68	
52	Vac-2/Myx-1/Foc Inflam-1/Sporozoan-1	14 -482	18 - 68	14 -200	18 - 75	
53	Vac-1/Serositis-1/Coccidia-1/Mono Infil-1/Myx-1	14 -482	12 -200	14 - 58	14 -234	18 - 68
54	Vac-1/Myx-1	14 -482	18 - 68			
55	Vac-1/Mono Infil-1/Myx-1/Coccidia-1	14 -482	14 -234	18 - 68	14 - 58	
56	Vac-1/Ser Nema-1	14 -482	12 -116			
57	Vac-1/Non-Uni Vac-1/Myx-1	14 -482	14 -483	18 - 68		
58	Vac-1/Myx-1	14 -482	18 - 68			
59	Vac-1	14 -482				
60	Vac-1/Ser Nema-1	14 -482	12 -116			

TABLE D-5. SUMMARY OF LESION CODES USED IN TABLES D-3 AND D-4

LESION SEVERITY CODES

Mild (1)
Moderate (2)
Severe (3)

LESION CODES

12-116	Serosal nematodes
12-200	Serosal inflammation
14-58	Coccidian parasite
14-68	Myxidium in parenchymal tissue
14-116	Parenchymal nematodes
14-200	Parenchymal inflammation
14-234	Mononuclear cell infiltration into parenchymal tissue
14-261	Parenchymal fibrosis
14-308	Focal hepatocellular necrosis
14-404	Hepatocellular pyknosis
14-482	Degree of hepatocellular vacuolation (coded as minimal=1, moderate=2, heavy=3). This is not a lesion, but rather a variation in physiological condition.
14-483	Non-uniform hepatcellular vacuolation
14-720	Spongiosis hepatis
14-734	Hepatocellular regeneration
18-68	Myxidium in bile ducts
18-75	Unidentified sporozoan parasite in bile duct
18-116	Nematodes in bile ducts
73-219	Parenchymal granuloma
74-308	Pancreatic necrosis
103-726	Increase in size, number or pigmentation of melanin macrophage centers

TABLE D-6. SUMMARY OF LENGTHS AND AGES OF ENGLISH SOLE USED FOR HISTOPATHOLOGICAL ANALYSES

Location	Transect	Date	Fish Number	Length (mm)	Age (years)
Totten Inlet	T4	04/09/90	1	280	4
Totten Inlet	T4	04/09/90	2	255	2
Totten Inlet	T4	04/09/90	3	260	4
Totten Inlet	T4	04/09/90	4	255	4
Totten Inlet	T4	04/09/90	5	230	3
Totten Inlet	T4	04/09/90	6	230	2
Totten Inlet	T4	04/09/90	7	240	4
Totten Inlet	T4	04/09/90	8	240	3
Totten Inlet	T4	04/09/90	9	230	3
Totten Inlet	T4	04/09/90	10	265	4
Totten Inlet	T4	04/09/90	11	295	5
Totten Inlet	T4	04/09/90	12	265	4
Totten Inlet	T4	04/09/90	13	320	5
Totten Inlet	T4	04/09/90	14	265	3
Totten Inlet	T4	04/09/90	15	300	5
Totten Inlet	T4	04/09/90	16	280	5
Totten Inlet	T4	04/09/90	17	260	3
Totten Inlet	T4	04/09/90	18	250	3
Totten Inlet	T4	04/09/90	19	230	3
Totten Inlet	T4	04/09/90	20	255	3
Totten Inlet	T4	04/09/90	21	230	3
Totten Inlet	T4	04/09/90	22	250	4
Totten Inlet	T4	04/09/90	23	320	6
Totten Inlet	T4	04/09/90	24	280	4
Totten Inlet	T4	04/09/90	25	240	6
Totten Inlet	T4	04/09/90	26	230	3
Totten Inlet	T4	04/09/90	27	265	4
Totten Inlet	T4	04/09/90	28	260	7
Totten Inlet	T4	04/09/90	29	270	5
Totten Inlet	T4	04/09/90	30	245	3
Totten Inlet	T4	04/09/90	31	230	3
Totten Inlet	T4	04/09/90	32	280	4
Totten Inlet	T4	04/09/90	33	230	3
Totten Inlet	T4	04/09/90	34	250	3
Totten Inlet	T4	04/09/90	35	280	3
Totten Inlet	T4	04/09/90	36	250	3
Totten Inlet	T4	04/09/90	37	260	3
Totten Inlet	T4	04/09/90	38	330	5
Totten Inlet	T4	04/09/90	39	260	3
Totten Inlet	T4	04/09/90	40	240	3
Totten Inlet	T4	04/09/90	41	240	3
Totten Inlet	T4	04/09/90	42	230	3
Totten Inlet	T4	04/09/90	43	235	3
Totten Inlet	T4	04/09/90	44	245	3
Totten Inlet	T4	04/09/90	45	265	3
Totten Inlet	T4	04/09/90	46	260	3
Totten Inlet	T4	04/09/90	47	250	3
Totten Inlet	T4	04/09/90	48	290	4
Totten Inlet	T4	04/09/90	49	315	4
Totten Inlet	T4	04/09/90	50	310	4
Totten Inlet	T4	04/09/90	51	370	5
Totten Inlet	T4	04/09/90	52	295	4

TABLE D-6. (Continued)

Location	Transect	Date	Fish Number	Length (mm)	Age (years)
Totten Inlet	T4	04/09/90	53	270	4
Totten Inlet	T4	04/09/90	54	255	3
Totten Inlet	T4	04/09/90	55	295	4
Totten Inlet	T4	04/09/90	56	230	3
Totten Inlet	T4	04/09/90	57	260	3
Totten Inlet	T4	04/09/90	58	250	3
Totten Inlet	T4	04/09/90	59	230	3
McNeil Island[1]	T6	04/11/90	61	340	5
McNeil Island	T6	04/11/90	62	270	4
McNeil Island	T6	04/11/90	63	275	4
McNeil Island	T6	04/11/90	64	230	3
McNeil Island	T6	04/11/90	65	250	4
McNeil Island	T6	04/11/90	66	260	5
McNeil Island	T6	04/11/90	67	245	3
McNeil Island	T6	04/11/90	68	240	4
McNeil Island	T6	04/11/90	69	250	4
McNeil Island	T6	04/11/90	70	240	4
McNeil Island	T6	04/11/90	71	260	4
McNeil Island	T6	04/11/90	72	260	4
McNeil Island	T6	04/11/90	73	240	4
McNeil Island	T6	04/11/90	74	245	3
McNeil Island	T6	04/11/90	75	235	3
McNeil Island	T6	04/11/90	76	275	4
McNeil Island	T6	04/11/90	77	260	4
McNeil Island	T6	04/11/90	78	255	4
McNeil Island	T6	04/11/90	79	230	7
McNeil Island	T6	04/11/90	80	235	3
McNeil Island	T6	04/11/90	81	230	3
McNeil Island	T6	04/11/90	82	230	5
McNeil Island	T6	04/11/90	83	230	3
McNeil Island	T6	04/11/90	84	230	2
McNeil Island	T6	04/11/90	85	270	4
McNeil Island	T6	04/11/90	86	255	4
McNeil Island	T6	04/11/90	87	240	3
McNeil Island	T6	04/11/90	88	245	3
McNeil Island	T6	04/11/90	89	280	4
McNeil Island	T6	04/11/90	90	235	3
McNeil Island	T6	04/11/90	91	240	4
McNeil Island	T6	04/11/90	92	235	3
McNeil Island	T6	04/11/90	93	270	5
McNeil Island	T6	04/11/90	94	230	3
McNeil Island	T6	04/11/90	95	230	3
McNeil Island	T6	04/11/90	96	230	4
McNeil Island	T6	04/11/90	97	270	4
McNeil Island	T6	04/11/90	98	300	5
McNeil Island	T6	04/11/90	99	270	4
McNeil Island	T6	04/11/90	100	260	4
McNeil Island	T6	04/11/90	101	230	3
McNeil Island	T6	04/11/90	102	250	4
McNeil Island	T6	04/11/90	103	235	3
McNeil Island	T6	04/11/90	104	240	4
McNeil Island	T6	04/11/90	105	260	5

TABLE D-6. (Continued)

Location	Transect	Date	Fish Number	Length (mm)	Age (years)
McNeil Island	T6	04/11/90	106	230	3
McNeil Island	T6	04/11/90	107	230	4
McNeil Island	T6	04/11/90	108	240	3
McNeil Island	T6	04/11/90	109	240	3
McNeil Island	T6	04/11/90	110	230	3
McNeil Island	T6	04/11/90	111	230	3
McNeil Island	T6	04/11/90	112	260	3
McNeil Island	T6	04/11/90	113	260	5
McNeil Island	T6	04/11/90	114	240	3
McNeil Island	T6	04/11/90	115	230	3
McNeil Island	T6	04/11/90	116	255	5
McNeil Island	T6	04/11/90	117	245	3
McNeil Island	T6	04/11/90	118	235	4
McNeil Island	T6	04/11/90	119	240	3
McNeil Island	T6	04/11/90	120	230	4

[1] Station located off of McNeil Island in Carr Inlet.

APPENDIX E

Sample Codes and Station Locations and Depths

TABLE E-1. STATION, SAMPLE AND FISH IDENTIFICATION CODES FOR SOUTH SOUND RECONNAISSANCE SURVEY

SURVEY	STATION	SAMPLING DATE	SAMPLE ID	FISH ID	SAMPLE TYPE	DATA TYPE
SSRECON	BUD-1	04/04/90	C00010	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-2	04/04/90	C00007	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-3	04/04/90	C00008	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-4	04/03/90	C00004	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-5	04/04/90	C00006	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-6	04/04/90	C00009	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-7	04/04/90	C00005	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-8	04/03/90	C00003	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-9	04/03/90	C00001	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-10	04/05/90	C00002	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-11	04/05/90	C00011	N/A	SEDIMENT	SEDCHEM
SSRECON	BUD-12	04/05/90	C00012	N/A	SEDIMENT	SEDCHEM
SSRECON	ELD-16	04/05/90	C00013	N/A	SEDIMENT	SEDCHEM
SSRECON	HEND-17	04/05/90	C00014	N/A	SEDIMENT	SEDCHEM
SSRECON	CORM-20	04/05/90	C00024	N/A	SEDIMENT	SEDCHEM
SSRECON	CR-23	04/05/90	C00029	N/A	SEDIMENT	SEDCHEM
SSRECON	WOLL-24	04/05/90	C00021	N/A	SEDIMENT	SEDCHEM
SSRECON	C-1	05/02/90	BIWBABC	BIWB-A,-B,-C	CLAM	BIOACCM
SSRECON	C-2	05/01/90	BIGHABC	BIGH-A,-B,-C	CLAM	BIOACCM
SSRECON	IBUD-T1	04/10/90	T1-A	F00039,42,43,44,52	FISH	BIOACCM
SSRECON	IBUD-T1	04/10/90	T1-B	F00038,40,46,49,50	FISH	BIOACCM
SSRECON	IBUD-T1	04/10/90	T1-C	F00041,45,47,48,51	FISH	BIOACCM
SSRECON	OBUD-T2	04/10/90	T2-A	F00036,37,71,73,75	FISH	BIOACCM
SSRECON	OBUD-T2	04/10/90	T2-B	F00031,32,68,69,74	FISH	BIOACCM
SSRECON	OBUD-T2	04/10/90	T2-C	F00033,34,35,70,72	FISH	BIOACCM
SSRECON	SHEL-T3	04/09/90	T3-A	F00019,21,23,26,30	FISH	BIOACCM
SSRECON	SHEL-T3	04/09/90	T3-B	F00020,22,24,27,28	FISH	BIOACCM
SSRECON	SHEL-T3	04/09/90	T3-C	F00016,17,18,25,29	FISH	BIOACCM
SSRECON	TOT-T4	04/09/90	T4-A	F00003,4,7,11,13	FISH	BIOACCM
SSRECON	TOT-T4	04/09/90	T4-B	F00008,10,12,14,15	FISH	BIOACCM
SSRECON	TOT-T4	04/09/90	T4-C	F00001,2,5,6,9	FISH	BIOACCM
SSRECON	CASE-T5	04/10/90	T5-A	F00078,79,82,86,65	FISH	BIOACCM
SSRECON	CASE-T5	04/10/90	T5-B	F00076,77,84,87,88	FISH	BIOACCM
SSRECON	CASE-T5	04/10/90	T5-C	F00080,81,83,85,89	FISH	BIOACCM
SSRECON	GERT-T6	04/11/90	T6-A	F00093,97,100,101,103	FISH	BIOACCM
SSRECON	GERT-T6	04/11/90	T6-B	F00091,96,98,102,104	FISH	BIOACCM
SSRECON	GERT-T6	04/11/90	T6-C	F00090,92,94,95,99	FISH	BIOACCM
SSRECON	CARR-T7	04/11/90	T7-A	F00105,110,111,114,118	FISH	BIOACCM
SSRECON	CARR-T7	04/11/90	T7-B	F00106,108,109,116,117	FISH	BIOACCM
SSRECON	CARR-T7	04/11/90	T7-C	F00107,112,113,115,119	FISH	BIOACCM

TABLE E-2. LOCATIONS AND DEPTHS OF STATIONS SAMPLED FOR SEDIMENT CHEMISTRY, SEDIMENT TOXICITY, AND BENTHIC MACROINVERTEBRATE ASSEMBLAGES

Station[a]	Loran C Coordinates	North Longitude	West Latitude	DEPTH (m)
2	27898.2, 42149.7	47 02.69'	122 54.47'	11
3	27897.9, 42150.3	47 02.76'	122 54.31'	8
4	27899.4, 42150.5	47 02.99'	122 54.33'	15
5	27901.4, 42149.9	47 03.14'	122 54.60'	4
6	27902.7, 42150.9	47 03.47'	122 54.44'	12
7	21903.5, 42150.3	47 03.48'	122 54.64'	5
8	27904.1, 42152.0	47 03.85'	122 54.21'	6
9	27898.8, 42152.5	47 03.26'	122 53.77'	6
10	27896.2, 42152.2	47 02.87'	122 53.70'	3
11	27916.2, 42153.3	47 05.61'	122 54.54'	10
12	27919.5, 42154.6	47 06.25'	122 54.38'	11
13	28000.7. 42131.5	47 12.58'	123 05.03'	8
14	27959.9, 42139.7	47 08.81'	122 00.63'	9
15	27968.3, 42154.0	47 --[b]	122 --	6
16	27930.7, 42137.2	47 04.71'	122 59.69'	8
17	27913.2, 42169.1	47 07.91'	122 50.20'	7
18	28004.4, 42192.6	47 22.29'	122 49.21'	11
19	27922.4, 42190.2	47 12.47'	122 45.20'	9
20	27867.0, 42203.8	47 08.16'	122 38.32'	10
21	27872.8, 42212.1	47 10.25'	122 36.49'	9
22	27874.0, 42216.9	47 11.18'	122 35.31'	7
23	27961.1, 42223.4	47 21.99'	122 38.83'	19
24	27916.0, 42223.4	47 17.00'	122 36.16'	11

[a] Station 1 was an intertidal station, and geographic coordinates were not determined.

[b] -- indicates no information.

TABLE E-3. LOCATIONS AND DEPTHS OF STATIONS SAMPLED FOR EVALUATIONS OF TISSUE CONTAMINATION AND HISTOPATHOLOGICAL ABNORMALITIES IN FISHES

Transect[a]	Loran C Coordinates Start Trawl	Loran C Coordinates End Trawl	Heading	Distance (nm)	Depth (m)
T1-1	27900.5, 42150.6	27903.6, 42150.9	330 C	0.45	14 - 14
T1-2	27900.6, 42150.4	27903.2, 42150.8	330 C	0.40	13 - 14
T1-3	27900.4, 42150.6	27903.7, 42151.0	330 C	0.50	12 - 12
T2-1	27916.3, 42153.1	27913.9, 42152.1	175 C	0.50	07 - 09
T2-2	27915.7, 42152.9	27913.5, 42151.6	170 C	0.50	07 - 08
T3-1	27997.8, 42132.9	--[b] --	120 C	0.30	12 - 22
T3-2	28001.6, 42133.3	28001.9, 42134.7	025 C	0.35	12 - 15
T3-3	28000.8, 42135.1	27998.8, 42133.7	190 C	0.50	05 - 06
T3-4	27999.0, 42134.0	27999.9, 42135.8	010 C	0.50	05 - 06
T4-1	27959.9, 42153.1	-- --	155 C	0.60	
T4-2	27954.4, 42150.7	27954.9, 42148.9	210 C	0.40	18 - 25
T4-3	27954.2, 42149.9	27954.9, 42151.4	020 C	0.40	18 - 25
T4-4	27953.8, 42151.5	27954.2, 42150.0	210 C	0.35	18 - 24
T4-5	27957.8, 42152.7	27955.5, 42151.2	175 C	0.55	24 - 28
T4-6	27955.0, 42151.7	27955.7, 42148.6	190 C	0.70	20 - 36
T4-7	27953.5, 42147.9	27952.6, 42149.7	045 C	0.40	23 - 25
T5-1	28000.1, 42192.2	27997.3, 42191.9	150 C	0.35	13 - 20
T5-2	27991.3, 42191.8	27987.4, 42191.4	150 C	0.50	24 - 24
T5-3	27982.6, 42191.2	27980.0, 42189.9	170 C	0.50	30 - 30
T5-4	27978.8, 42184.1	27976.6, 42182.7	175 C	0.50	35 - 44
T6-1	27905.0, 42207.3	27900.5, 42208.6	115 C	0.50	22 - 40
T6-2	27901.4, 42208.4	27910.2, 42206.1	275 C	1.00	30 - 55
T6-3	27907.5, 42207.2	27911.8, 42205.9	275 C	0.50	50 - 53
T6-4	27907.1, 42207.2	27910.6, 42206.1	280 C	0.40	38 - 42
T6-5	27907.9, 42207.2	27910.5, 42206.3	280 C	0.30	50 - 52
T7-1	27961.5, 42219.3	27959.3, 42217.8	185 C	0.50	25 - 27
T7-2	27959.3, 42216.0	27956.6, 42215.0	170 C	0.45	35 - 43
T7-3	27960.4, 42211.7	27960.6, 42209.5	200 C	0.50	53 - 54
T7-4	27963.9, 42210.8	27963.9, 42212.1	030 C	0.25	40 - 40
T7-5	27962.8, 42224.3	27964.6, 42221.9	220 C	0.50	15 - 17

[a] Numerals following transect numbers are replicate-haul numbers.

[b] -- indicates no information.