Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall
2005

City of San Diego
Ocean Monitoring Program

Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

THE CITY OF SAN DIEGO

July 1, 2006

Mr. John Robertus
Executive Officer
Regional Water Quality Control Board
San Diego Region
9771 Clairemont Mesa Blvd. Suite B
San Diego, CA 92124

Attention: POTW Compliance Unit

Dear Sir:

Enclosed is the 2005 Annual Receiving Waters Monitoring Report for NPDES Permit No. CA0107409, Order No. R9-2002-0025 for the City of San Diego Point Loma Wastewater Treatment Plant, Point Loma Ocean Outfall. This report contains data summaries and statistical analyses for the various portions of the ocean monitoring program, including oceanographic conditions, microbiology, sediment characteristics, benthic macrofauna, demersal fish and megabenthic invertebrate communities, and bioaccumulation of contaminants in fish tissues.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering information, I certify that the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

ALAN C. LANGWORTHY
Deputy Metropolitan Wastewater Director

DP\dp
Enclosure

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The City of San Diego

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Prepared by:

City of San Diego
Ocean Monitoring Program
Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

June 2006

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Cover photo: M/V Oceanus with Point Loma Wastewater Treatment Plant in background. Photo by Mike Kelly.

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Executive Summary

The ocean monitoring program for the Point Loma Ocean Outfall (PLOO) is conducted in accordance with NPDES permit requirements for the Point Loma Wastewater Treatment Plant (PLWTP) operated by the City of San Diego (NPDES Permit No. CA0107409, Order No. R9-2002-0025). These documents specify the terms and conditions that allow PLWTP effluent to be discharged into the Pacific Ocean via the PLOO. Additionally, Monitoring and Reporting Program (MRP) No. R9-2002-0025 contained within the above permit defines the requirements for monitoring the receiving waters environment, including the sampling plan, compliance criteria, laboratory methods, data analysis, and reporting guidelines. Furthermore, the above MRP was modified effective August 1, 2003 with the adoption of Addendum No. 1 (see City of San Diego 2004).

The main objectives of the Point Loma ocean monitoring program are to provide data that satisfy NPDES permit requirements, demonstrate compliance with the 2001 California Ocean Plan (COP), monitor dispersion of the waste field, and identify any environmental changes that may be associated with wastewater discharge. Specifically, the program was designed to assess the effects of wastewater discharge on ocean water quality, sediment conditions, and the marine biota. The study area is centered around the PLOO discharge site, which is located approximately 7.2 km offshore of the treatment plant at a depth of 94–98 m. Monitoring at sites along the shore extends from Mission Beach southward to the tip of Point Loma. Offshore monitoring is conducted in an adjacent area overlying the coastal continental shelf at sites ranging up to about 116 m in depth.

The receiving waters monitoring effort for the Point Loma region is divided into several major components, each comprising a separate chapter in this report: Oceanographic Conditions, Microbiology, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, and Bioaccumulation of Contaminants in Fish Tissues. Data regarding physical and chemical oceanographic parameters are evaluated to characterize water transport potential in the region. Water quality monitoring along the shore and in offshore waters includes the measurement of bacteriological indicators to assess natural and anthropogenic impacts. Benthic monitoring includes sampling and analysis of soft-bottom macrofaunal communities and associated sediments, while demersal fish and megabenthic invertebrate communities are the focus of trawling activities. The monitoring of fish populations is supplemented by bioaccumulation studies to determine whether or not contaminants are present in the tissues of “local” species.

In addition to the above activities, the City supports other projects relevant to assessing ocean quality in the region. One such project is a remote sensing study of the San Diego/Tijuana coastal region that is jointly funded by the City and the International Boundary and Water Commission (IBWC); results from this study are incorporated herein into the interpretations of oceanographic and microbiological data (see Chapters 2 and 3). A long-term study of the Point Loma kelp forest funded by the City is being conducted by scientists at the Scripps Institution of Oceanography and these data were recently summarized in City of San Diego 2003. Finally, the current MRP includes plans to perform adaptive or special strategic process studies each year as determined by the City in conjunction with the RWQCB and the USEPA. Such studies have included a comprehensive scientific review of the Point Loma ocean monitoring program and a sediment mapping study for both the Point Loma and South Bay coastal regions (see SIO 2004, Stebbins et al. 2004).

This report focuses on the results of the ocean monitoring activities conducted off Point Loma during the calendar year 2005. A general overview and summary of the main findings for each major monitoring component are included below.

Analysis of the receiving waters monitoring data off San Diego indicates that the PLOO discharge has had only a limited effect on the local marine environment after 12 years of wastewater discharge at the present location. For example, despite heavy rainfall that periodically affected nearshore water quality during 2005, water samples collected at sites within the Point Loma kelp bed were over 90% compliant with COP bacterial water-contact standards. The few incidences of non-compliance occurred in January and were related to stormwater runoff during periods of heavy rainfall, not to the intrusion of the wastewater plume. In addition, there is no evidence that the waste field from the outfall has affected any shoreline sampling site since the outfall was extended in 1993. Elevated bacterial concentrations that could be attributable to wastewater discharge were limited primarily at depths of 60 m or below. Finally, no evidence of change in any physical or chemical water quality parameter (e.g., dissolved oxygen, pH) has been found that can be attributed to the discharge of wastewater off Point Loma.

Similar to previous years, the benthic conditions off Point Loma in 2005 continued to show some changes that may be expected near large ocean outfalls, although these were restricted to a relatively small, localized region near the discharge site. For example, sediment quality data have indicated slight increases over time in terms of sulfide and BOD concentrations at sites nearest the Zone of Initial Dilution (ZID), as well as the accumulation of coarse sediment particles. However, other potential indicators of environmental impact such as concentrations of sediment contaminants (e.g., trace metals, pesticides) showed no patterns related to wastewater discharge. For example, although metal concentrations in Point Loma sediments increased from the previous year, the increases were regionwide and likely related to sources other than the PLOO (City of San Diego 2006). In addition, descriptors of macrobenthic community structure (e.g., abundance, diversity) or indicators of environmental disturbance (e.g., brittle star populations) have shown temporal differences between reference areas and those nearest the ZID. However, calculations of environmental disturbance indices (i.e., BRI, ITI) used to evaluate the condition of benthic assemblages relative to threshold values suggest that the macrobenthic communities in the Point Loma region remain characteristic of natural conditions. Analyses of demersal fish and invertebrate communities also reveal no spatial or temporal patterns that can be attributed to effects of the PLOO. The paucity of pathological evidence from local fishes and the bioaccumulation of contaminants in liver or muscle tissues also suggest that the local fish community remains healthy and not adversely affected by wastewater discharge or other anthropogenic inputs. Consequently, there is currently no evidence of significant long-term impacts on either sediment quality or biotic communities in the coastal waters off San Diego.

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Chapter 1
General Introduction

Chapter 1. General Introduction

INTRODUCTION

Treated effluent from the City of San Diego E.W. Blom Point Loma Wastewater Treatment Plant (PLWTP) is discharged to the Pacific Ocean through the Point Loma Ocean Outfall (PLOO) according to requirements set forth in Order No. R9-2002-0025, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0107409. The above Order and associated Monitoring and Reporting Program (MRP No. R9-2002-0025) were adopted by the San Diego Regional Water Quality Control Board (RWQCB) on April 10, 2002. During 2003, the monitoring and reporting requirements for the Point Loma region were further modified with the adoption of Addendum No. 1 to the above Order and NPDES Permit (see City of San Diego 2004). The provisions established in Addendum No. 1 became effective August 1, 2003, thus superceding and replacing all prior receiving waters monitoring requirements for the PLWTP.

The MRP for Point Loma defines the requirements for monitoring the receiving water environment around the PLOO, including the sampling plan, compliance criteria, laboratory analyses, statistical analyses and reporting guidelines. The main objectives of the ocean monitoring program are to provide data that satisfy the requirements of the NPDES permit, demonstrate compliance with the 2001 California Ocean Plan (COP), detect movement and dispersion of the wastewater field, and identify any biological or chemical changes that may be associated with wastewater discharge.

BACKGROUND

The City of San Diego began operation of the PLWTP and original ocean outfall off Point Loma in 1963, at which time treated effluent was discharged approximately 3.9 km offshore at a depth of about 60 m (200 ft). From 1963 to 1985, the plant operated as a primary treatment facility, removing approximately 60% of the total suspended solids (TSS) by gravity separation. Since then, considerable improvements have been made to the treatment process. For example, the City began upgrading the process to advanced primary treatment (APT) in mid-1985, with full APT status being achieved by July of 1986. This improvement involved the addition of chemical coagulation to the treatment process, and resulted in an increased TSS removal of about 75%. Since 1986, treatment has been further enhanced with the addition of several more sedimentation basins, expanded aerated grit removal, and refinements in chemical treatment. These enhancements have resulted in lower mass emissions from the plant, with TSS removals consistently greater than the 80% permit requirement. In addition, the PLOO was extended 3.3 km further offshore in the early 1990s in order to prevent intrusion of the wastewater plume into nearshore waters and thus comply with standards set forth in the COP for water contact sports areas. Construction of the outfall extension was completed in November 1993, at which time discharge was terminated at the original 60-m site. The outfall presently extends approximately 7.2 km offshore to a depth of 94 m (310 ft), where the pipeline splits into a Y-shaped multiport diffuser system. The two diffuser legs extend an additional 762 m to the north and south, each terminating at a depth of about 98 m (320 ft) near the edge of the continental shelf.

The average daily flow of effluent through the PLOO in 2005 was 183 mgd, ranging from 169 mgd in December to 217 mgd in February. This is higher than the average flow of 174 mgd during 2004. TSS removal averaged about 85% during 2005, with a total mass emissions of approximately 10,400 mt/yr (see City of San Diego 2006a).

RECEIVING WATERS MONITORING

Prior to 1994, the City conducted an extensive ocean monitoring program off Point Loma centered around the original 60-m discharge site. This program was subsequently modified and expanded with the construction and operation of the deeper outfall. Data from the last year of regular monitoring near the original inshore site are presented in City of San Diego (1995b), while the results of a 3-year recovery study for that area are summarized in City of San Diego (1998). From 1991 through 1993, the City also conducted a voluntary "predischarge" study in the vicinity of the new site in order to collect baseline data prior to the discharge of effluent in these deeper waters (City of San Diego 1995a, 1995b). Results of NPDES mandated monitoring for the extended PLOO from 1994 through 2003 are available in previous annual receiving waters monitoring reports (e.g., City of San Diego 2004). Additionally, the City has participated in a number of regional and other monitoring efforts off San Diego and throughout the Southern California Bight that have provided useful background information for the entire region (e.g., SCBPP 1998, Bight'98 Steering Committee 2003, City of San Diego 1999, 2006c).

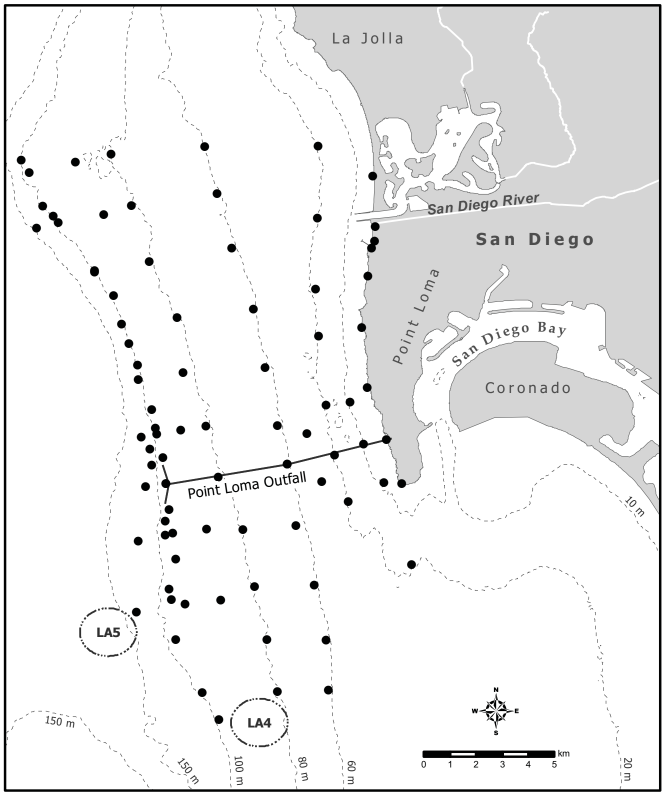

Figure 1.1
Receiving waters monitoring stations for the Point Loma Ocean Outfall Monitoring Program.

The current sampling area off Point Loma extends from La Jolla southward to Point Loma, and from the shoreline seaward to a depth of about 116 m (380 ft) (**Figure 1.1**). Fixed sites are generally arranged in a grid surrounding the outfall and are monitored in accordance with a prescribed sampling schedule. The monitoring program may be divided into the following major components, each comprising a separate chapter in this report: (1) Oceanographic Conditions; (2) Microbiology; (3) Sediment Characteristics; (4) Macrobenthic Communities; (5) Demersal Fishes and Megabenthic Invertebrates; (6) Bioaccumulation of Contaminants in Fish Tissues. Detailed information concerning station locations, sampling equipment, analytical techniques, and quality assurance procedures are included in the Environmental Monitoring and Technical Services Division Laboratory Quality Assurance Project Plan for the City's Ocean Monitoring Program (City of San Diego in prep). Results of the Laboratory's quality assurance procedures are included in the EMTS Division Laboratory Quality Assurance Report (City of San Diego 2006b). In addition, data files, detailed methodologies, completed reports, and other pertinent information submitted to the USEPA and the RWQCB throughout the year are available online at the City's Metropolitan Wastewater Department website (http://www.sandiego.gov/mwwd).

This report summarizes the results from the receiving waters monitoring conducted off Point Loma from January through December 2005. The data are compared to the results from previous years in order to examine long-term patterns of change in the region. In addition, results from the continuing coastal remote sensing study of the San Diego/Tijuana Region that is funded by the City and the International Boundary and Water Commission have been incorporated into the water quality sections of this report (Chapters 2 and 3). A glossary of technical terms is included.

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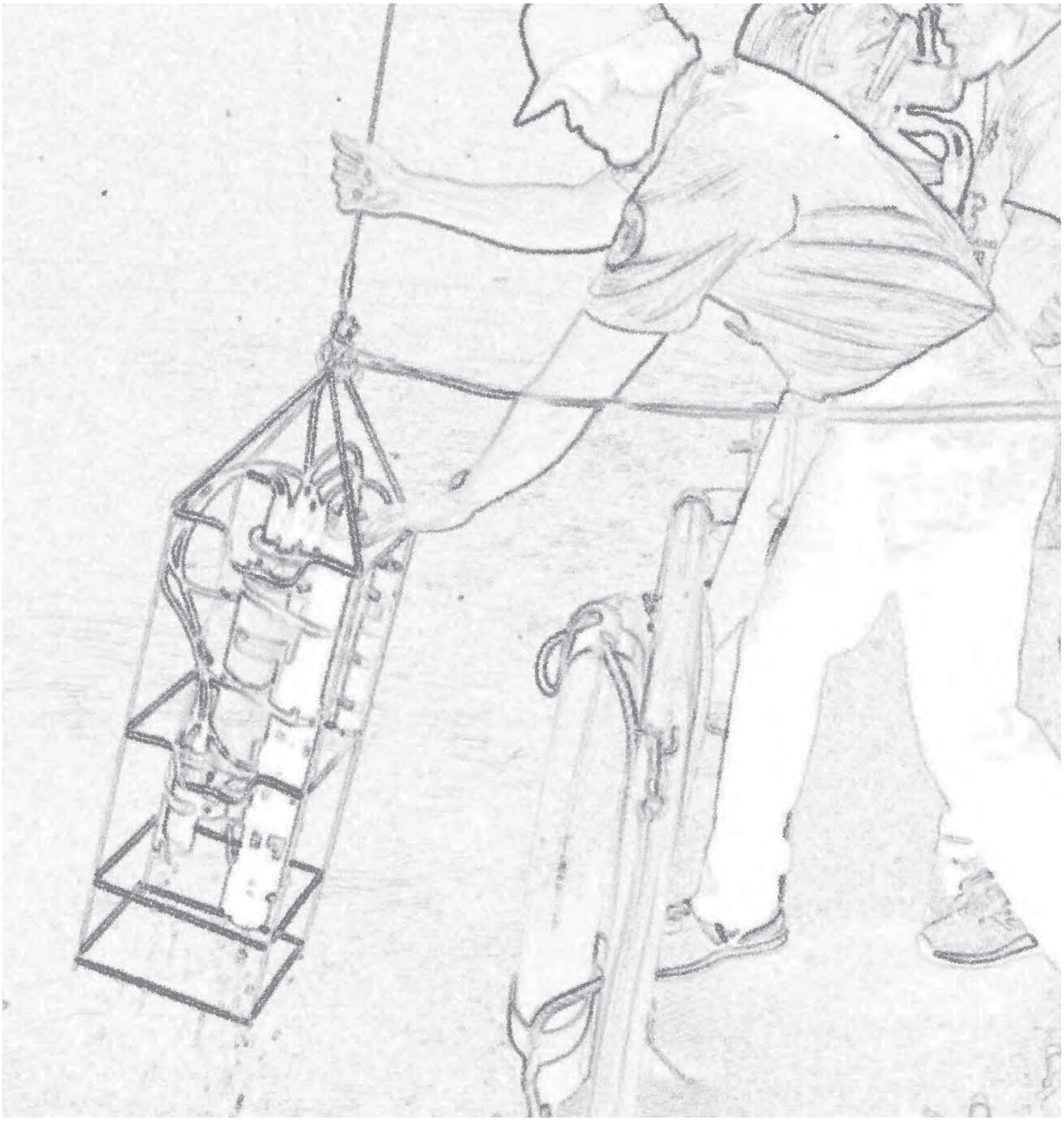
Chapter 2
Oceanographic Conditions



Chapter 2. Oceanographic Conditions

INTRODUCTION

The City of San Diego monitors oceanographic conditions in the region surrounding the Point Loma Ocean Outfall (PLOO) in order to assess possible impacts from outfall discharge on the environment. Changes in current patterns, temperature, salinity, and density can affect the fate of the wastewater plume. They can also affect the distribution of turbidity plumes produced by non-point sources such as tidal exchange and runoff from San Diego Bay, Mission Bay, and the San Diego and Tijuana Rivers. These factors can either individually or synergistically determine the water quality within the Point Loma region.

The fate of wastewater discharged into deep offshore waters is determined by oceanographic conditions and other events that suppress or facilitate horizontal and vertical mixing. Consequently, measurements of physical and chemical parameters such as water temperature, salinity, and density are important components of ocean monitoring programs because these properties determine water column mixing potential (Bowden 1975). Analysis of the spatial and temporal variability of these 3 parameters as well as transmissivity, dissolved oxygen, pH, and chlorophyll may also elucidate patterns of water mass movement. Taken together, analyses of such measurements for the receiving waters surrounding the PLOO can help: (1) describe deviations from expected patterns, (2) reveal the impact of the wastewater plume relative to other inputs, (3) determine the extent to which water mass movement or mixing affects the dispersion/dilution potential for discharged materials, and (4) demonstrate the influence of natural events such as storms or El Niño/La Niña oscillations.

In the absence of information on deepwater currents, bacterial distributions may provide the best indication of horizontal transport of discharged waters (Picard and Emery 1990; see Chapter 3). Thus, the City of San Diego combines measurements of physical oceanographic parameters with assessments of bacterial concentrations to provide further insight into the transport potential surrounding a discharge throughout the year. This chapter describes the oceanographic conditions that occurred off Point Loma during 2005, and is referred to in subsequent chapters to explain patterns of bacteriological occurrence (see Chapter 3) or other changes in the local marine environment (see Chapters 4–7).

MATERIALS AND METHODS

Oceanographic measurements were collected at fixed sampling sites located in a grid pattern surrounding the PLOO (**Figure 2.1**). Thirty-six offshore stations (designated F01–F36) were

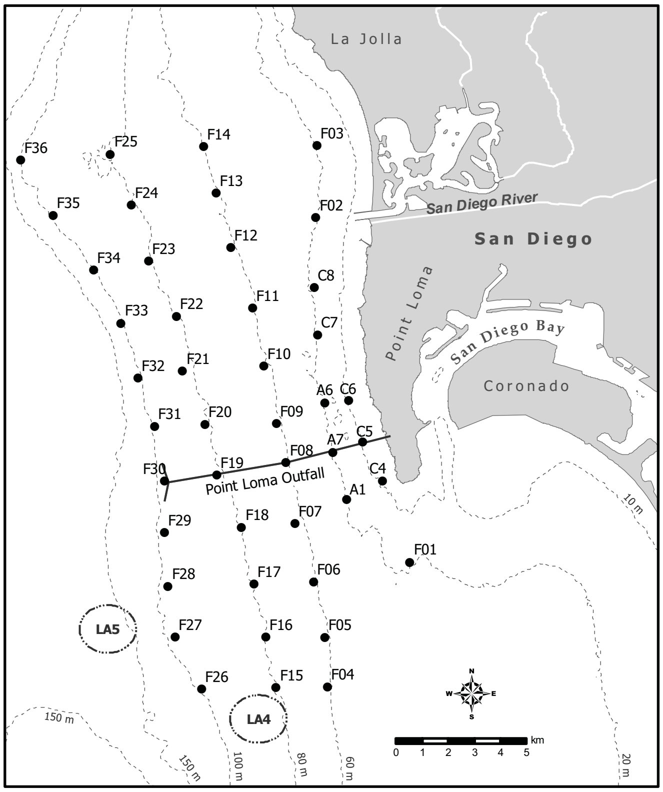


Figure 2.1
Locations of water quality monitoring stations where CTD casts are taken for the Point Loma Ocean Outfall Monitoring Program.

sampled quarterly in January, April, July, and October, usually over a 3-day period. Three of these stations (F01–F03) are located along the 18-m depth contour, while 11 sites are located along each of the following depth contours: 60-m contour (stations F04–F14); 80-m contour (stations F15–F25); 98-m contour (stations F26–F36). Eight additional stations located in the Point Loma kelp bed are subject to the 2001 California Ocean Plan (COP) water contact standards (SWRCB 2001). These stations include 3 sites (stations C4, C5, C6) located along the inshore edge of the kelp bed paralleling the 9-m depth contour, and 5 sites (stations A1, A6, A7, C7, C8) located along the 18-m depth contour near the offshore edge of the kelp bed. To meet the COP sampling frequency requirements for kelp bed areas, sampling at the 8 kelp bed stations was conducted 5 times per month.

Oceanographic measurements of temperature, salinity, density, pH, transmissivity (water clarity), chlorophyll *a*, and dissolved oxygen were collected by lowering a SeaBird conductivity, temperature, and depth (CTD) instrument through the water column. Profiles of each parameter were constructed for each station by batch process averaging of the data values recorded over 1-m depth intervals. This ensured that physical measurements used in subsequent data analyses corresponded with bacterial sampling depths. Further details regarding the CTD data processing are provided in the City's Quality Assurance Plan (City of San Diego in prep). Visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were also recorded prior to each CTD sampling event. Mean chlorophyll *a* data were calculated for depths between surface and 15 meters for water quality stations from the Point Loma and South Bay regions. Maps of average chlorophyll *a* distribution were generated with an inverse distance weighted interpolation algorithm in ArcView.

Monitoring of the PLOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging (OI) of Solana Beach, CA. All usable images captured during 2005 by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and several high clarity Landsat Thematic Mapper (TM) images were purchased monthly. Aerial images were collected with OI's DMSC-MKII digital multispectral sensor (DMSC). Its 4 channels were configured to a specific wavelength (color) combination which, according to OI's previous research, maximizes the detection of the PLOO plume's turbidity signature by differentiating between the wastewater plume and coastal turbidity. The depth penetration of the sensor varies between 8 and 15 meters, depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 meters. Several aerial overflights were performed each month for a total of 11 flights from January to April and November to December and 6 flights from May to October.

RESULTS AND DISCUSSION

Expected Seasonal Patterns of Physical and Chemical Parameters

Southern California weather can be classified into 2 basic seasons, wet (winter) and dry (spring through fall), and certain patterns in oceanographic conditions track these seasons. Each year, typical winter conditions are present in January and February as shown in a 5 year summary of annual changes in local ocean temperatures (**Figure 2.2**). A high degree of homogeneity within the water column is the normal winter signature for all physical parameters, although storm water runoff may intermittently influence density profiles by causing a freshwater lens within nearshore surface waters. The chance that the wastewater plume may surface is highest during these winter months when there is little, if any, stratification of the water column. These conditions often extend into March, when a decrease in the frequency of winter storms brings about the transition of seasons.

In late March or April, surface waters begin to warm and re-establish the seasonal thermocline and pycnocline to local coastal and offshore waters. Once water column stratification becomes established by

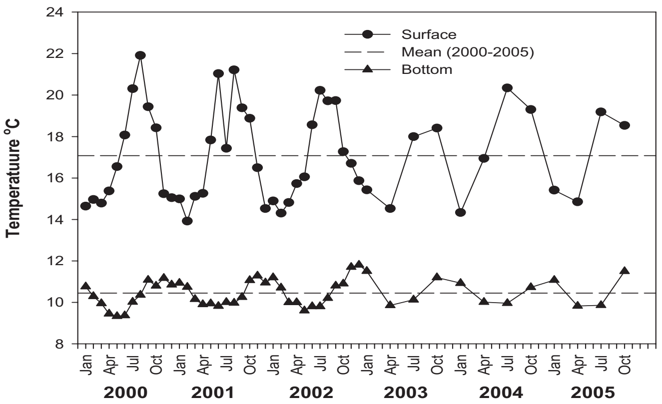


Figure 2.2

Average monthly surface and bottom temperatures (°C) for 2000–2005 compared to overall mean temperatures for 2000–2005.

late spring, minimal mixing conditions tend to remain throughout the summer and early fall months, with occasional interruptions by upwelling events. In October or November, cooler temperatures, reduced solar input, and increased stormy weather cause the return of the well-mixed, homogeneous waters that are characteristic of winter months. Despite a sampling schedule that is spread out over several days during each month, analyses of oceanographic data collected off Point Loma over the past 27 years support this pattern.

Observed Seasonal Patterns of Physical and Chemical Parameters

The record rainfall of October and December 2004 continued into early 2005, with above average rains occurring during January and February (**Figure 2.3A**, NOAA/NWS 2005). Normal conditions returned in March, continued through October, and were followed by drought conditions in November and December. Unseasonably warm air temperatures approaching the upper confidence limit for the historical averages occurred from January to March, and in May, and November (Figure 2.3B). Local weather conditions may have contributed to increased surface water temperatures during spring and summer, and decreased in salinity and transmissivity during the first part of the year, especially at the nearshore kelp bed stations (**Table 2.1**). Despite these circumstances, thermal stratification of the water column followed normal seasonal patterns at both nearshore and offshore sampling areas off Point Loma.

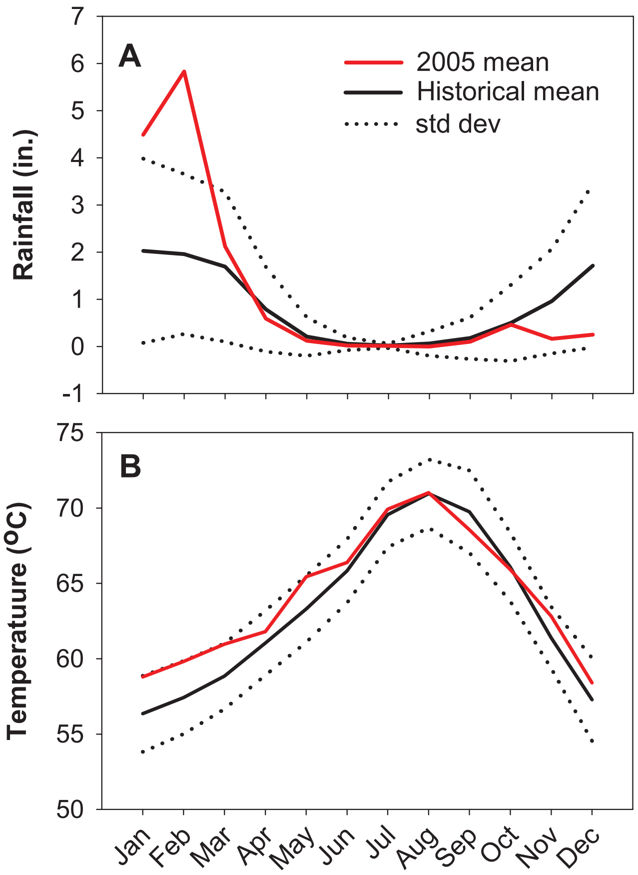


Figure 2.3

Total rainfall (A) and mean air temperatures (B) at Lindbergh Field (San Diego, CA) for each month in 2005 compared to monthly averages (+/-1 standard deviation) for the historical period 1914–2004.

Quarterly surface water temperatures at the offshore stations averaged from 14.8 to 19.2 °C, with the highest temperatures occurring in July and October (**Table 2.2**). Surface temperatures in January were approximately 1 °C warmer than the previous year while temperatures for April were about 2 °C cooler (**Table 2.3**). Temperatures for July and October were approximately 1 °C cooler than those of 2004. Bottom waters ranged from 9.8 to 11.5 °C and were similar to those of the previous year except during October when temperatures were nearly 1 °C warmer.

Monthly water temperatures at the kelp stations followed a similar pattern (Table 2.1). Mean surface temperatures in the kelp beds from

Table 2.1

Mean values of temperature (Temp, °C), salinity (ppt), density (δ/θ), dissolved oxygen (DO, mg/L), pH, transmissivity (XMS, %), and chlorophyll *a* (Chl *a,* µg/L) for top (≤2 m) and bottom (9 and 18 m) waters at all PLOO kelp station stations during 2005.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp	*Surface*	15.2	15.5	16.0	15.0	17.7	18.4	19.4	19.3	17.3	17.6	16.5	15.0
	Bottom	15.0	14.4	12.4	11.6	11.5	11.9	12.1	11.9	11.9	13.5	14.2	13.3
Salinity	*Surface*	32.77	32.89	32.74	33.38	33.43	33.54	33.52	33.42	33.41	33.37	33.37	33.41
	Bottom	33.16	33.19	33.42	33.65	33.65	33.64	33.55	33.49	33.50	33.43	33.38	33.42
Density	*Surface*	24.21	24.25	24.01	24.71	24.12	24.05	23.77	23.72	24.21	24.12	24.37	24.75
	Bottom	24.56	24.70	25.29	25.61	25.62	25.54	25.43	25.42	25.45	25.07	24.89	25.12
DO	*Surface*	7.9	8.2	8.4	9.4	8.5	8.7	9.4	10.2	8.9	7.8	7.3	7.8
	Bottom	7.0	6.9	5.1	4.6	4.7	3.9	5.3	5.0	4.6	5.5	5.8	6.2
pH	*Surface*	8.1	8.1	8.2	8.3	8.2	8.3	8.4	8.3	8.3	8.2	8.3	8.1
	Bottom	8.0	8.0	7.9	7.9	7.9	7.8	7.9	7.8	7.9	8.0	8.1	8.0
XMS	*Surface*	61	71	62	72	78	69	71	73	76	75	79	82
	Bottom	56	77	70	84	84	84	86	85	84	83	83	76
Chl *a*	*Surface*	2.17	2.19	3.61	6.46	2.80	9.90	10.91	9.41	3.48	3.14	2.58	2.75
	Bottom	1.93	1.67	1.92	3.72	2.85	1.49	2.31	2.02	2.77	1.95	1.94	1.95

January through March of 2005 ranged from 15.2 to 16.0 °C, which was slightly warmer than the previous year. Coincident with a subsequent decline in air temperature and possible upwelling (see below), April surface temperatures dropped slightly to 15.0 °C. The seasonal warming of the nearshore waters began in May, and mean surface waters ranged between 17.7 and 19.4 °C from May through August. Surface temperatures declined in September and October to about 17.0 °C, and then continued to decline through December (15.0 °C). Bottom waters at the kelp stations ranged from 11.5 to 15.0 °C during the year. Relative to 2004, bottom water temperatures in 2005 were over 1 °C warmer in January and February, but 0.9–3.2 °C cooler the rest of the year.

Thermal stratification in 2005 generally followed the typical annual pattern (**Figure 2.4**). Seasonal stratification of the upper water column at quarterly stations was absent in January with surface and mid-level waters differing by only 0.1 °C (**Table 2.4**). By April, mid-depth waters declined 3.6 °C, from 15.3 °C (January) to 11.7 °C (April), and a stratified upper water column had developed. Surface waters were highly stratified in July. Mean temperatures were above 19 °C at this time and differed from mid-level and bottom waters by 6.4 and 9.3 °C, respectively. Stratification continued into October, with a 4.1 °C difference between surface and mid-depth waters. The shallower kelp stations showed a similar pattern, with stratification beginning in March and breaking down in November (see Figure 2.5, Table 2.1). Bottom waters were generally much cooler than surface or mid-level waters over the 4 quarterly surveys, with temperatures at least 4.3 °C colder than surface waters, and 1.9 °C cooler than mid-level waters (Table 2.4). Since temperature is the main contributor to water column stratification in southern California (Dailey et. al. 1993), these differences were important to limiting the surfacing potential of the waste field to depths below 60 m (see Chapter 3). Although a region-wide phytoplankton bloom (see below) likely prevented Ocean Imaging's DMSC camera from penetrating much below 10 m depth, aerial imagery acquired

Table 2.2

Quarterly average values of temperature (Temp, °C), salinity (ppt), density (δ/θ), dissolved oxygen (DO, mg/L), pH, transmissivity (XMS, %), and chlorophyll *a* (Chl *a*, µg/L), for top (≤2 m), mid-depth (10–20 m), and bottom (≥88 m) waters at all quarterly PLOO stations during 2005 (stations F01–F36).

		Jan	Apr	Jul	Oct
Temp	*Surface*	15.4	14.8	19.2	18.5
	Mid	15.3	11.7	12.8	14.5
	Bottom	11.1	9.8	9.9	11.5
Salinity	*Surface*	32.62	33.31	33.48	33.40
	Mid	33.10	33.53	33.50	33.41
	Bottom	33.55	34.09	33.88	33.75
Density	*Surface*	24.1	24.7	23.8	23.9
	Mid	24.4	25.5	25.3	24.9
	Bottom	25.6	26.3	26.1	25.7
DO	*Surface*	8.6	9.9	8.7	8.8
	Mid	8.0	6.9	8.3	8.0
	Bottom	4.8	3.0	3.9	3.2
pH	*Surface*	8.1	8.3	8.3	8.3
	Mid	8.1	8.0	8.1	8.1
	Bottom	7.8	7.8	7.8	7.7
XMS	*Surface*	80	76	79	84
	Mid	84	82	83	84
	Bottom	90	91	90	90
Chl *a*	*Surface*	4.0	6.2	5.0	4.3
	Mid	3.2	7.6	7.2	6.1
	Bottom	0.6	0.5	0.4	0.6

for the Point Loma area confirmed that the plume remained below surface waters throughout the year (see Ocean Imaging 2005a, b, c, 2006).

Table 2.3

Differences between the surface (≤2 m) and bottom (≥88 m) waters for mean values of temperature (°C) at all PLOO stations during 2000–2005. The greatest differences (Δ) between surface and bottom values are in bold type.

		2000	2001	2002	2003	2004	2005
January	*Surface*	14.6	15.0	14.9	15.4	14.3	15.4
	Bottom	10.8	10.9	11.2	11.5	10.9	11.1
	Δ	3.8	4.1	3.7	3.9	3.4	**4.3**
April	*Surface*	15.4	15.3	15.7	14.5	16.9	14.8
	Bottom	9.5	9.9	10.0	9.8	10.0	9.8
	Δ	5.9	5.4	5.7	4.7	**6.9**	5.0
July	*Surface*	20.3	17.4	20.2	18.0	20.3	19.2
	Bottom	10.0	10.0	9.8	10.0	10.0	9.9
	Δ	10.3	7.4	**10.4**	8.0	10.3	9.3
October	*Surface*	18.4	18.9	17.3	18.4	19.3	18.5
	Bottom	10.8	11.1	10.9	11.2	10.7	11.5
	Δ	7.6	7.8	6.4	7.2	**8.6**	7.0

Surface water salinity was strongly influenced by above normal rainfall that occurred early in the year. Surface salinity at the offshore stations averaged from 32.62 to 33.48 ppt in 2005, with storm related runoff reducing mean surface salinity to <33.0 ppt in January (Table 2.2). The effects of storm runoff were stronger at the shallow kelp stations where mean surface salinity was <33.0 ppt from January through March (Table 2.1). Seawater density, a function of temperature, salinity, and pressure, reflected the changes brought about by the increased storm activity at the beginning of 2005. Water density was slightly lower during January at the quarterly stations and during January–March at the nearshore kelp stations where the influence of storm runoff was stronger. Generally, offshore water density throughout the water column from April through October was similar to densities in 2004.

Density increased in April as the result of a decline in surface and mid-level water temperatures (Table 2.2). This change was more apparent at the kelp stations where relatively dramatic changes in salinity and density were also apparent (Figure 2.5). These cooling events are similar to those of previous years and may be the result of localized upwelling or inshore movement of water originating from the California current.

Data for the various other measured parameters (i.e., pH, transmissivity, chlorophyll *a*, dissolved oxygen) mostly varied in response to sporadic natural events, such as storm activity and the increased primary productivity associated with a persistent local red tide event. Increased turbidity following rainfall

Table 2.4

Average temperature differences (°C) between surface waters (≤2 m), mid-depth waters (10–20 m) and bottom waters (≥88 m) surrounding the PLOO during 2005.

	Surface vs Mid	Surface vs Bot	Mid vs Bot
January	0.1	4.3	4.3
April	3.1	5.0	1.9
July	6.4	9.3	3.0
October	4.1	7.0	3.0

events was readily visible in satellite and aerial imagery (see Ocean Imaging 2005a, b, 2006), and data from transmissivity measurements generally supported these aerial observations. For example, aerial images from January through March revealed increased discharge of turbid waters from San Diego Bay, Mission Bay, the San Diego River, and more northern sources following storm activity (Ocean Imaging 2005a). During this period, the PLOO region was also affected periodically by northward-reaching runoff from the Tijuana River due to the combined effects of excessive runoff volume and relatively frequent northward current episodes (i.e., from April through December) (**Figure 2.5A**). When southerly currents prevailed, the PLOO region was subject to heavy sediment loads originating at the mouth of the San Diego River, and southward-advected effluent originating from North County lagoons (Figure 2.6B).

In April, a regional phytoplankton bloom developed that was apparent in aerial imagery and which strongly affected nearshore and offshore water clarity. This bloom developed into a red tide and persisted throughout the remainder of the year (**Figure 2.6**). The presence of the phytoplankton bloom was also apparent in CTD profile data. For example, mean chlorophyll *a* values at quarterly offshore stations in April reached 7.6 µg/L in mid-depth waters, with a maximum value of 91 µg/L occurring in July. Similarly, the nearshore kelp stations had mean chlorophyll *a* values >9 µg/L from June through August, with values as high as 70 µg/L in June and August (see City of San Diego 2005a, b, c, d). CTD profile data also included high dissolved oxygen levels (>10 mg/L) and decreased transmissivity values (<80% light transmission) that corresponded to increased chlorophyll *a* concentrations.

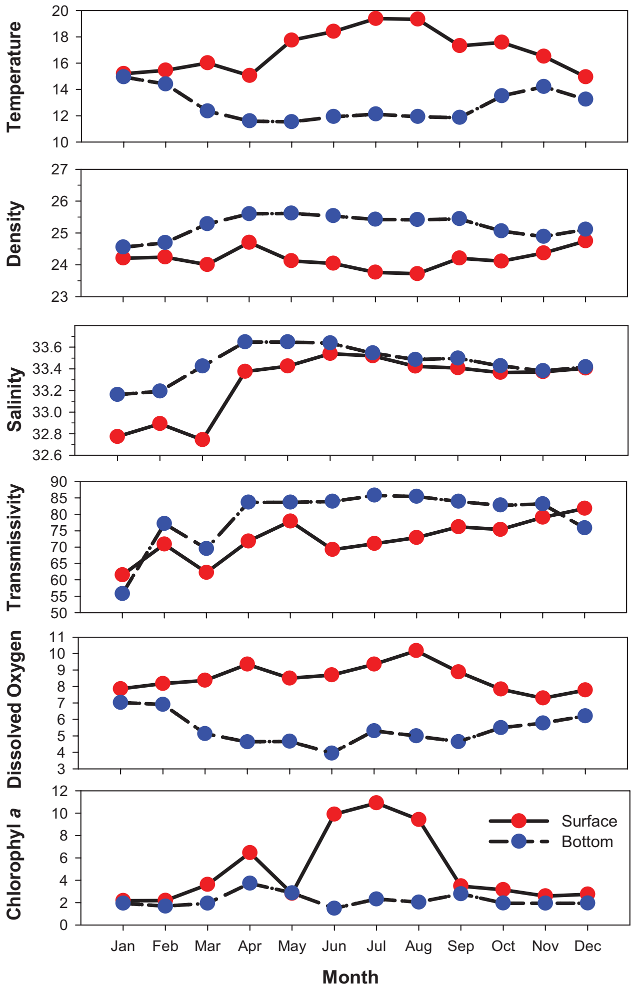


Figure 2.4

Average temperature (°C), density (δ/θ), salinity (ppt), transmissivity (%), dissolved oxygen (mg/L), and chlorophyll *a* (µg/L) for surface (<2 m) and bottom waters for the Point Loma nearshore kelp bed stations sampled during 2005.

A bloom of the dinoflagellate *Lingulodinium polyedra was the primary cause of the* red tides present in the region from April through October. This species has dominated the Southern California Bight since 1995. Gregorio and Pieper (2000) have found that this species persists at the Los Angeles River mouth from winter through summer and that river runoff during the rainy season provides significant amounts of nutrients that allow for rapid population increases. Runoff containing agricultural and effluent materials from the Tijuana River during the heavy rains of January through March most likely contributed to the widespread red tides observed in the South Bay (City of San

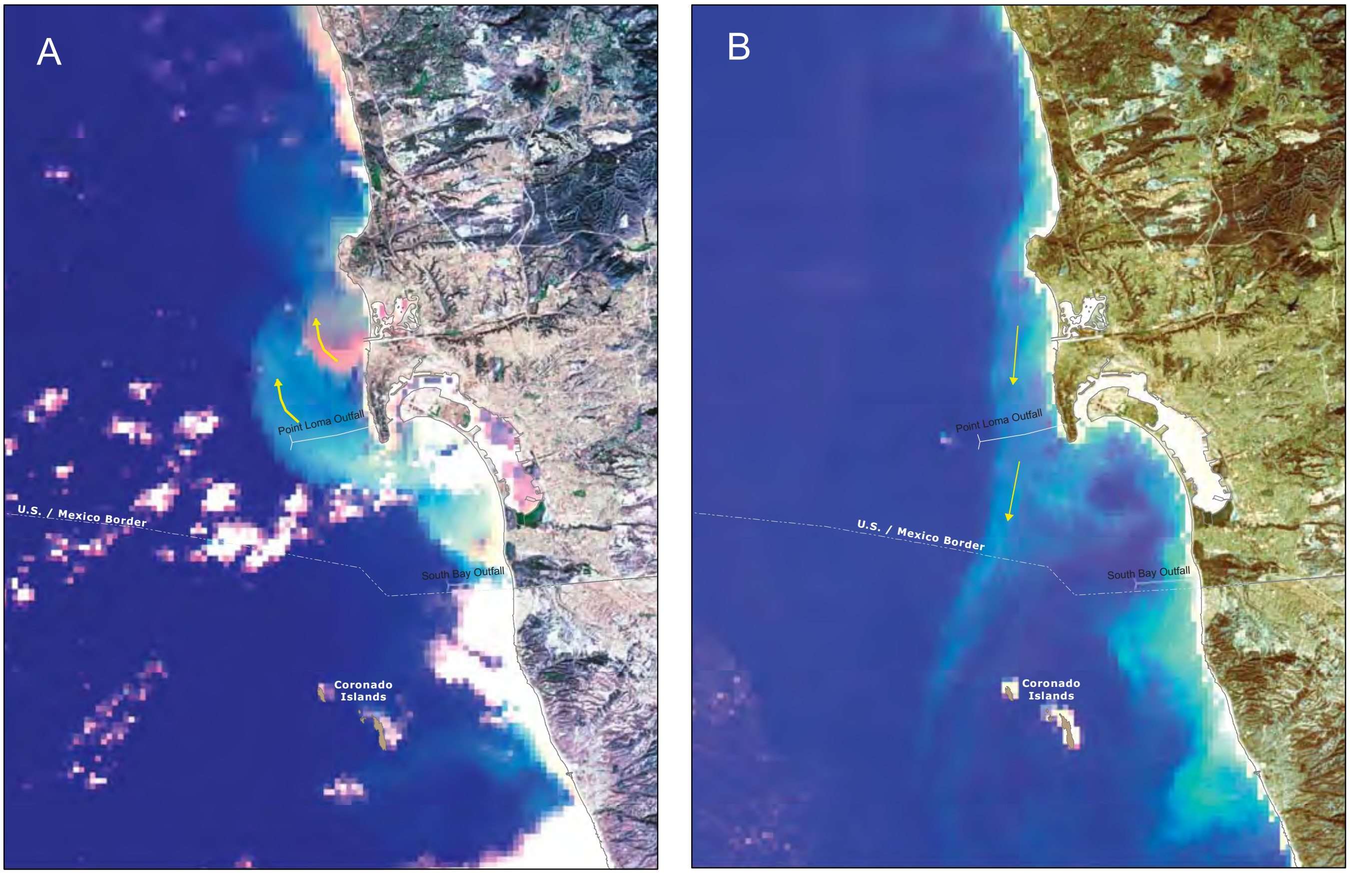


Figure 2.5
MODIS satellite images showing the San Diego water quality monitoring region with turbidity plumes indicating direction of surface current flow: (A) February 23, northward flow; (B) April 12, southward flow. White pixels in the MODIS image represent areas obscured by cloud cover offshore or "washout" or band saturation due to the histogram stretches used to enhance turbidity features in surface waters along the shoreline.

Diego 2006) (see **Figure 2.7**). High chlorophyll *a* values near the mouth of the San Diego River and Mission Bay during July suggest that these areas are also sources of nutrients that may have contributed to the development of the phytoplankton bloom.

SUMMARY AND CONCLUSIONS

The record rainfall of October and December 2004 that continued into early 2005 resulted in heavy runoff and turbid waters both inshore and offshore in the Point Loma region. In addition, air temperatures were unseasonably warm during January–March, May, and November. Despite these circumstances, oceanographic conditions during 2005 generally followed normal seasonal patterns. Surface water temperatures at the offshore stations were cool in January and April and warmest in July and October. In contrast, bottom temperatures were warmer in January and October and cooler during April and July. These conditions contributed to the typical cycle of water column thermal stratification, with seasonal stratification developing in spring. Although the greatest difference between surface and botom water temperatures occurred in July and declined thereafter, evidence of stratification remained apparent in nearshore waters through November.

Surface water salinity was lower during a period of above average rainfall during January–March, particularly in nearshore waters. Surface salinity early in the year was less than 33.0 ppt as a result of freshwater input from heavy rains and the resulting river and bay discharge. Salinity increased to more normal levels of >33.3 ppt from March to April. Seawater density values corresponded to lower

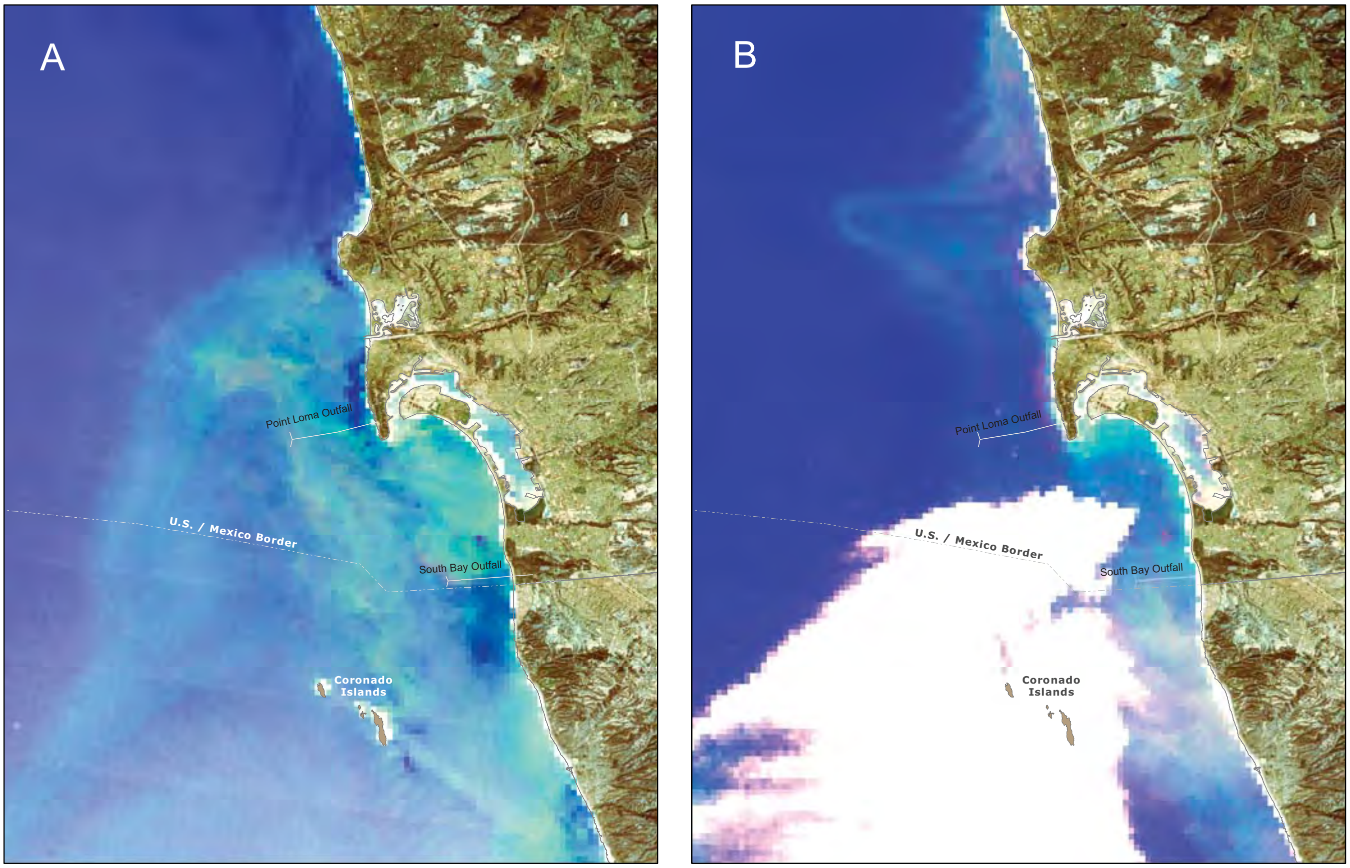


Figure 2.6
Satellite imagery of the Point Loma region acquired on (A) August 28, 2005 and (B) September 29, 2005. Both images show a red tide bloom extending over the outfall area.

salinity values during January through March, but returned to normal conditions from April through December.

Aerial and satellite imagery indicated that water clarity during 2005 was affected by sediment resuspension and embayment flushing following the heavy rainfall from January through March, and by a long lasting red tide that developed in April and persisted throughout the year. These events caused a decrease in surface water transmissivity, and increases in chlorophyll *a* and dissolved oxygen concentrations. Patterns in surface water turbidity resulting from these events indicated northward surface current patterns were relatively common during January through February, but southward surface flow with occasional northward reversals was dominant from April through December. When southerly currents prevailed, particularly in the latter part of the year, the PLOO region was affected by sediment-bearing surface plumes originating from the San Diego River and North County lagoons. Despite the limited visibility afforded by the reduced water clarity, aerial imagery collected throughout the year confirmed that the PLOO plume was not detected in surface waters during 2005, and was most likely restricted to lower depths by thermal stratification from March through November. Analysis of the physical water column properties in conjunction with aerial and satellite imagery acquired of the area surrounding Point Loma indicate that wastewater discharged via the PLOO did not reach either inshore sites or surface waters. Even during the winter months when water column stratification was weakest, there was no indication that the wastewater plume reached depths shallower than 60 m. These conditions are important to the analysis of spatial patterns of bacterial concentrations discussed in the following chapter.

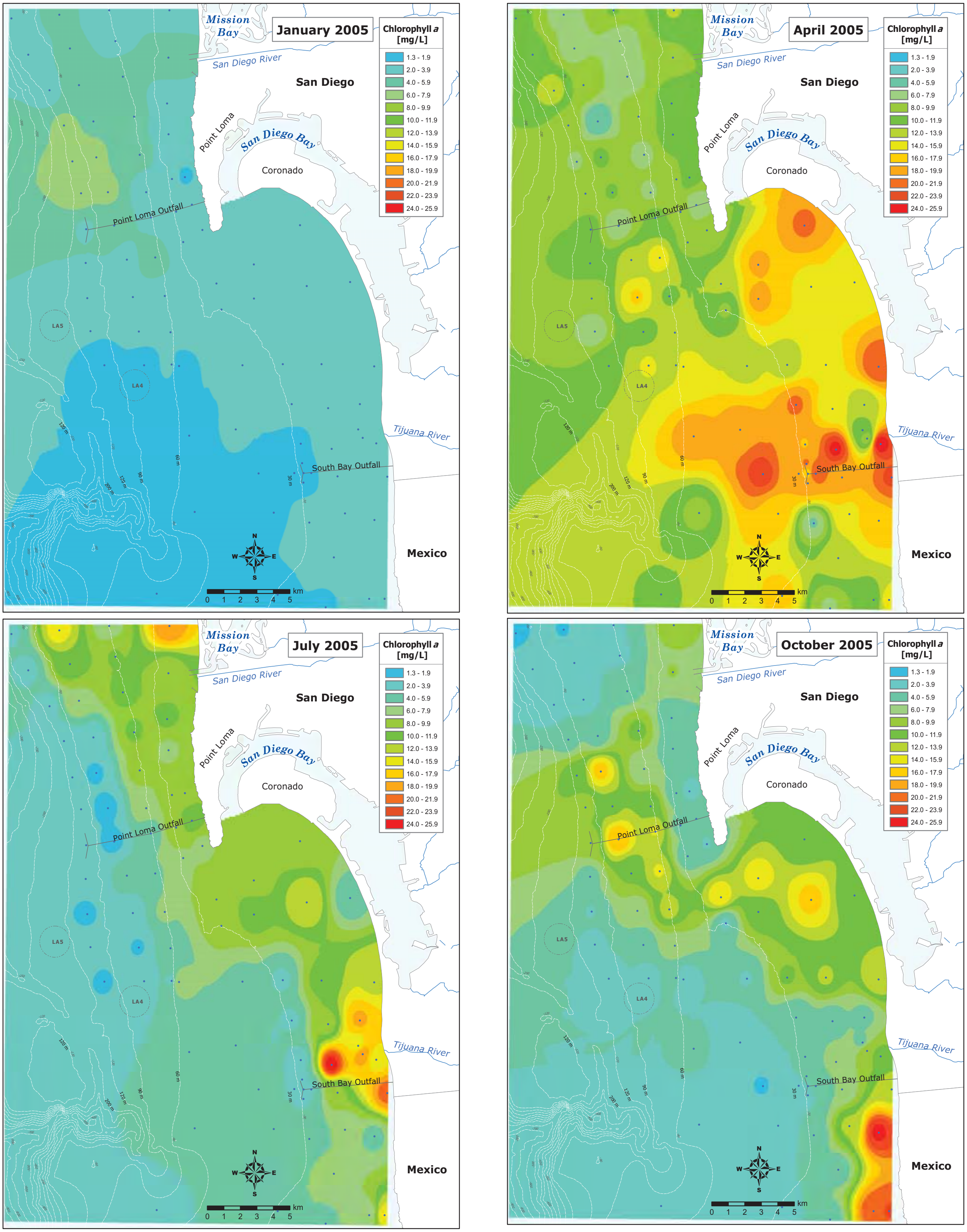


Figure 2.7
GIS plots of mean surface (0–15 m depth) chlorophyll *a* concentrations (µg/L) for the San Diego coast for January, April, July, and October of 2005.

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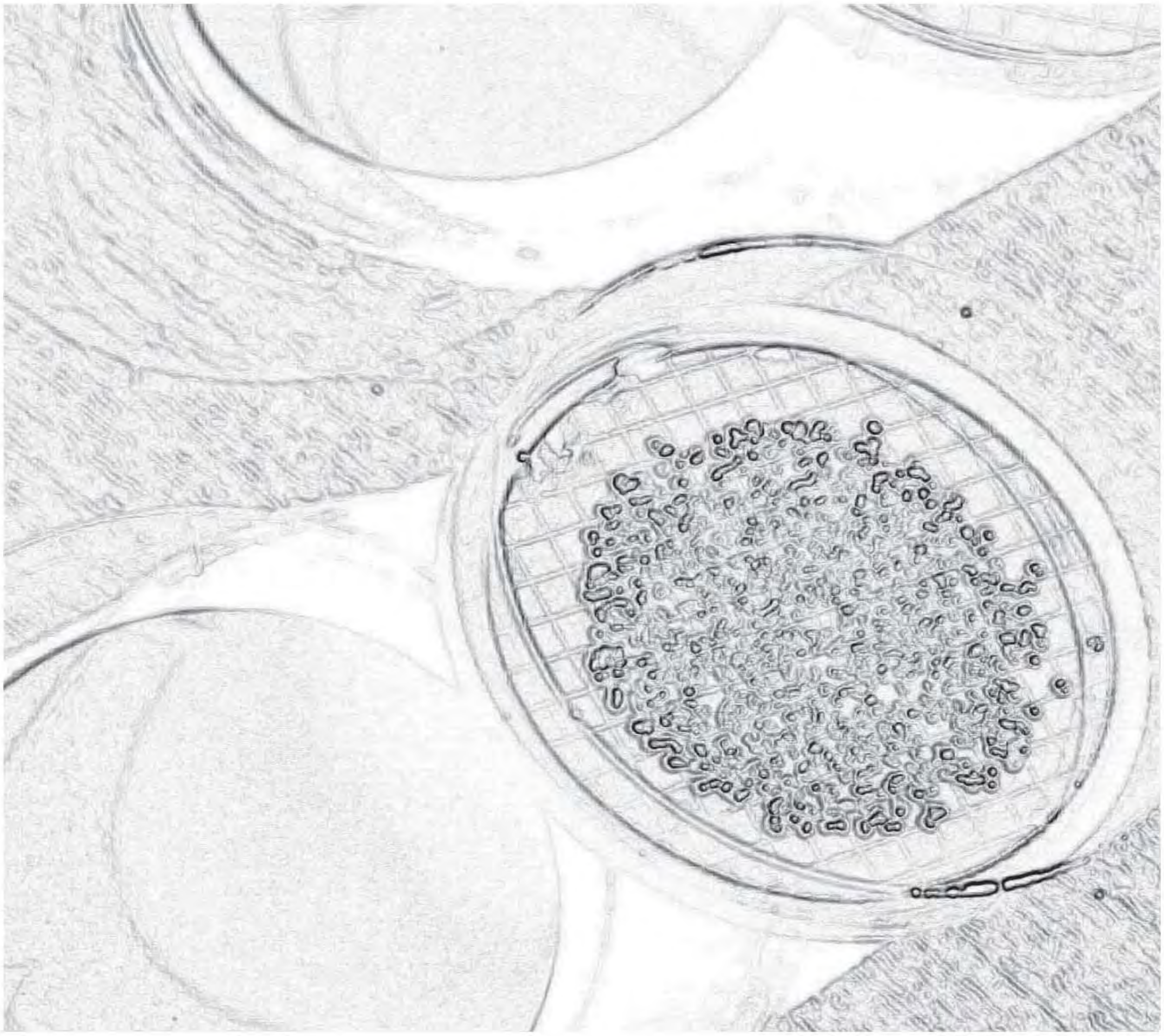
Chapter 3
Microbiology



Chapter 3. Microbiology

INTRODUCTION

The City of San Diego performs shoreline and water column bacterial monitoring in the region surrounding the Point Loma Ocean Outfall (PLOO). This program is designed to assess general water quality conditions, evaluate patterns in movement and dispersal of the wastewater plume, and monitor compliance with the 2001 California Ocean Plan (SWRCB 2001). The final results of bacteriological and individual station compliance data are submitted to the San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Overall bacteriological densities (total coliforms, fecal coliforms, enterococcus), together with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged through the outfall. Analyses of these data may also implicate point or non-point sources other than the outfall as contributing to bacterial contamination events in the region. This chapter summarizes and interprets patterns in bacterial concentration data collected for the Point Loma region during 2005.

MATERIALS AND METHODS

Field Sampling

Water samples for bacteriological analyses were collected at fixed shore and offshore sampling sites throughout the year (**Figure 3.1**). Weekly sampling was performed at 8 shore stations (D4, D5, D7–D12) to monitor bacterial levels along public beaches. Eight stations located in the Point Loma kelp bed were also monitored to assess water quality conditions in areas used for water contact sports (e.g., SCUBA and kayaking). These stations include 3 sites (stations C4, C5, C6) located near the inner edge of the kelp bed along the 9-m depth contour, and 5 sites (stations A1, A6, A7, C7, C8) located near the outer edge of the kelp bed along the 18-m depth contour. Samples were taken at 3 fixed depths for each kelp station (**Table 3.1**). The kelp stations were sampled weekly, such that each day of the week was represented over a 2-month period. Additional samples were collected at shore stations D5, D7, and D8 on October 7 in response to elevated enterococcus densities reported at station D5 on October 6. The data from this sampling event is included in the mean calculations.

Thirty-six offshore stations (F01–F36) were sampled quarterly (January, April, July, October) to estimate the spatial extent of the wastewater plume at these times. Sampling at these 36 sites usually takes place over a 3-day period. Three of these stations (F01–F03) are located along the 18-m depth contour, while 33 sites (11 per transect) are located along the

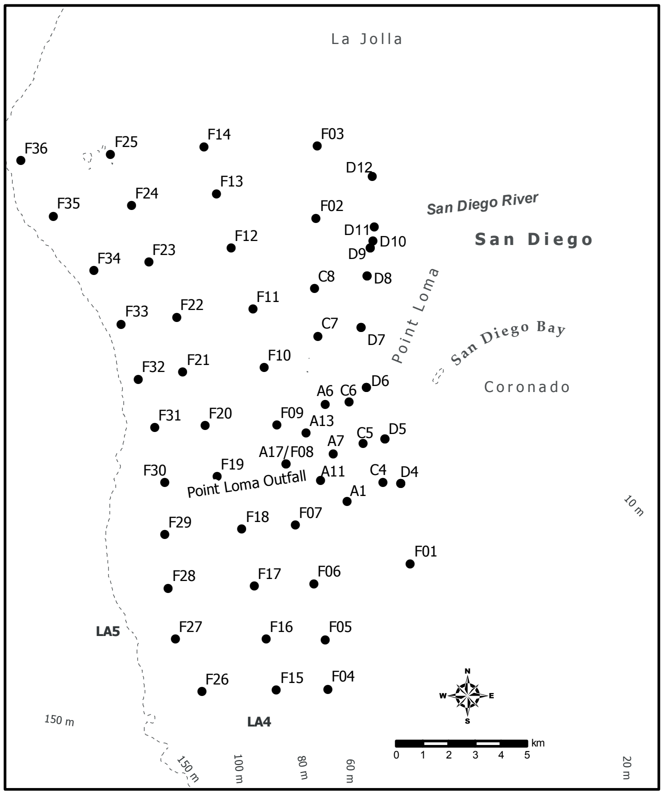


Figure 3.1
Water quality monitoring stations where bacteriological samples were collected, Point Loma Ocean Outfall Monitoring Program.

Table 3.1
Depths at which bacteriological samples are collected at the PLOO kelp and quarterly offshore stations.

	Sample depth (m)								
Station transect	1	3	9	12	18	25	60	80	98
9-m Kelp bed	x	x	x						
18-m Kelp bed	x			x	x				
18-m Quarterly	x			x	x				
60-m Quarterly	x					x	x		
80-m Quarterly	x					x	x	x	
98-m Quarterly	x					x	x	x	x

60-m (stations F04–F14), the 80-m (stations F15–F25), and the 98-m (stations F26–F36) contours. The number of samples collected at each station was depth-dependent and ranged from 3 to 5 fixed depths (Table 3.1).

Seawater samples were collected from the surf zone at each station and stored in sterile 250-mL bottles. Visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were recorded at the time of sample collection. The seawater samples were then transported on ice to the City's Marine Microbiology Laboratory and analyzed to determine concentrations of total coliform, fecal coliform, and enterococcus bacteria.

Seawater samples from the kelp bed and quarterly offshore stations were also analyzed for total coliforms, fecal coliforms, and enterococcus. These samples were collected using either a series of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Aliquots for each analysis were drawn into appropriate sample containers. The samples were refrigerated aboard ship and then transported to the City's Marine Microbiology Laboratory for bacteriological analysis. Visual observations of weather and water conditions were also recorded for each sampling event.

Monitoring of the San Diego area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging Corporation (OI). All usable images captured during 2005 by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and several quality Landsat Thematic Mapper (TM) images were purchased. Aerial images were collected with OI's DMSC-MKII digital multispectral sensor (DMSC). Its 4 channels were configured to a specific wavelength (color) combination which, according to OI's previous research, maximizes the detection of the PLOO plume's turbidity signature by differentiating between the wastewater plume and coastal turbidity. Such data helps distinguish between bacterial contamination events caused by the PLOO discharge and those attributable to other point and non-point sources (e.g., river and bay discharges). The depth penetration of the imaging varies between 8 and 15 meters, depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 meters. Several aerial overflights were performed each month for a total of 11 flights from January through April and November through December, and 6 flights from May through October.

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to the membrane filtration techniques outlined in the City's Quality Assurance Plan (City of San Diego in prep). The Marine Microbiology Laboratory follows guidelines issued by the EPA Water Quality Office, Water Hygiene Division and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program with respect to sampling and analytical procedures (Bordner et al. 1978, Greenberg et al. 1992).

Box 3.1

Bacteriological compliance standards for water contact areas, 2001 California Ocean Plan (SWRCB 2001). CFU = colony forming units.

(1) *30-day total coliform standard* — no more than 20% of the samples at a given station in any 30-day period may exceed a concentration of 1000 CFU per 100 mL.

(2) *10,000 total coliform standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU per 100 mL.

(3) *60-day fecal coliform standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU per 100 mL.

(4) *geometric mean* — the geometric mean of the fecal coliform concentration at any given station in any 30-day period may not exceed 200 CFU per 100 mL, based on no fewer than five samples.

Colony counting, calculation of results, data verification, and reporting all follow EPA guidelines (see Bordner et al. 1978). Plates with bacterial counts above or below the ideal counting range were given greater than (>), less than (<) or estimated (e) qualifiers. However, these qualifiers were dropped and the counts treated as discrete values during the calculation of compliance with 2001 California Ocean Plan (COP) water contact standards and means/values.

Shore and kelp bed station compliance with COP standards (see **Box 3.1**) were summarized according to the number of days that each station was out of compliance. Bacteriological data for offshore stations are not subject to COP standards, but were used to examine spatio-temporal patterns in the dispersion of the waste field. Such patterns were determined from mean densities of total coliform, fecal coliform, and enterococcus bacteria. These data were calculated for each station by month, station, and depth. Monthly rainfall data (Lindbergh Field, San Diego, CA), oceanographic conditions (see Chapter 2), as well as other events (e.g., storm water flows, nearshore and surface water circulation patterns) identified through remote sensing data were evaluated relative to the bacterial data. COP bacteriological benchmarks were used as reference points to distinguish elevated bacteriological values in receiving water samples discussed in this report. These benchmarks are a) ≥1000 CFU/100 mL for total coliform, b) ≥400 CFU/100 mL for fecal coliforms, and c) ≥104 CFU/100 mL for enterococcus. Furthermore, "contaminated" water samples were identified as samples that had total coliform concentrations ≥1000 CFU/ 100 mL and a fecal:total (F:T) ratio ≥0.1 (see CDHS 2000). Samples from offshore monthly water quality stations that met these criteria were used as indicators of the PLOO waste field.

Quality assurance tests were performed routinely on water samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split field samples were collected according to method requirements and processed by laboratory personnel to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in the Quality Assurance Report (City of San Diego 2006b).

Maps to show the distribution of the PLOO waste field as estimated from bacterial densities were created using total coliform counts from the offshore quarterly stations. Bacterial densities from samples shallower than 60 m were not used because contaminated water was only detected in 1 sample taken shallower than 60 m at station F01. The maps were generated using the Spatial Analyst extension for ArcGIS 9.0. The Inverse Distance

Weighting algorithm was used with the power set to 3, a neighborhood of 5, and default values for all other parameters. Interpolations of deep water total coliform concentrations are meant for simplified data visualization purposes only and were not statistically significant.

RESULTS AND DISCUSSION

Approximately 2485 bacteriological samples were collected in 2005, including 490 from the shoreline stations, 1431 at the kelp stations, and 564 at the quarterly offshore stations. Of all the samples collected, only 87 had total coliform concentrations ≥ the 1000 CFU/100 mL benchmark. Twelve of these samples were collected at the shore stations, 8 at the kelp stations, and 67 at the offshore stations. One kelp bed sample and 64 offshore samples had F:T ratios ≥0.1, which could be indicative of wastewater. These samples were used to evaluate possible patterns in plume movement.

Spatial and Temporal Trends – Shore Stations

Bacterial densities from the shore stations in 2005 were generally low despite the relatively large amounts of rain that fell from January through March (**Table 3.2**). For example, monthly total coliform densities during the year averaged from 3 to 1733 CFU/100 mL. Most of the high densities occurred during the wet months (e.g., January, February, and October). The highest mean total coliform and enterococcus densities occurred in January as a result of samples collected along the shore on January 3 and 9, when 3.2 inches of rain accumulated over a 7-day period (see NOAA/NWS 2006). However, only 6 out of 12 samples with total coliforms ≥1000 CFU/100 mL occurred in January and February during rain events (**Table 3.3**). Only 1 of these 6 samples contained bacterial levels that exceeded the benchmark values for fecal coliforms and enterococcus (400 and 104 CFU/100 mL, respectively) and was indicative of wastewater. This sample, collected from station D8 on January 3, had an F:T ratio ≥0.1 and densities of fecal coliforms and enterococcus above their benchmark values (400 and 104 CFU/100 mL, respectively). In contrast, samples from stations D8 and D11 on June 26, and station D11 on December 29 had total and fecal coliform densities well above their respective benchmark values but occurred when there was no recorded rainfall. Potential sources of contamination that may have contributed to these elevated bacterial densities include dogs, which were present at station D11 on June 26, and kelp, which was present at station D8 on June 26 and station D11 on December 29 (City of San Diego 2005b, 2006a). The beach around station D11 is unique in that it is a designated area for people to walk their dogs. In addition, contamination may have resulted from a population of transient people living upstream of station D11. High counts of indicator bacteria have also been present during dry periods at station D8 in previous years (City of San Diego 2005c).

Spatial and Temporal Trends – Kelp Bed and Offshore Stations

Most of the bacteriological samples collected from the kelp bed and offshore stations in 2005 were not indicative of contaminated waters. Only 3% (n=65) of the samples had total coliform densities ≥1000 CFU/100 mL and an F:T ratio ≥0.1 (**Appendix A.1**). Total coliform densities in shallow waters (1–25 m) ranged from 0 to 2600 CFU/100 mL throughout the year, while densities of fecal coliforms ranged from 0 to 500 CFU/100 mL. All but 2 of the samples indicative of contaminated water came from sample depths greater than 25 m. The highest mean indicator bacterial densities came from depths of 60 m and greater (**Figure 3.2A**), suggesting that the stratified water column restricted the plume to mid- and deep-water depths throughout the year (see Chapter 2).

There was little evidence that the wastewater plume reached nearshore waters in 2005. Mean bacterial densities were highest at stations along the 80 and 98-m transects (Figure 3.2B), with 60 of the 65 samples indicative of contaminated water collected from these sites. The other 5 samples came from stations A1 and F01 (18-m depth contour) and

Table 3.2

Shore station bacterial densities and rainfall data for the PLOO region during 2005. Mean total coliform, fecal coliform, and enterococcus bacterial densities are expressed as CFU/100 mL. Rainfall is expressed in inches as measured at Lindbergh Field, San Diego, CA. Sample size (n) for each station is given in parenthetically and includes resamples.

Month **(Rainfall)**		**D4** (60)	**D5** (62)	**D7** (62)	**D8** (62)	**D9** (61)	**D10** (61)	**D11** (61)	**D12** (61)	**All Stations**
Jan	Total	1733	405	369	968	45	184	348	80	517
(4.49)	Fecal	60	45	37	164	14	37	34	9	50
	Entero	113	27	24	332	24	28	42	15	75
Feb	Total	254	42	52	264	84	132	64	34	112
(5.83)	Fecal	18	2	22	17	12	10	11	8	12
	Entero	120	2	2	12	40	11	6	5	22
Mar	Total	12	12	85	86	66	115	140	30	67
(2.12)	Fecal	2	6	4	20	5	144	36	15	29
	Entero	2	2	8	28	10	103	38	20	26
Apr	Total	6	6	6	118	18	41	46	9	31
(0.59)	Fecal	6	6	2	6	6	10	22	3	8
	Entero	2	2	46	6	6	8	12	3	11
May	Total	6	8	36	68	14	32	228	6	50
(0.12)	Fecal	4	6	10	6	4	10	80	3	15
	Entero	2	2	3	9	3	8	27	5	7
Jun	Total	10	14	292	260	10	38	316	6	118
(0.02)	Fecal	2	5	2	186	5	14	242	4	57
	Entero	2	2	7	2	4	3	4	2	3
Jul	Total	44	15	50	66	10	10	35	22	31
(0.01)	Fecal	2	3	2	4	3	6	11	2	4
	Entero	2	2	6	4	2	3	4	4	4
Aug	Total	9	6	160	87	4	66	81	11	53
(0.00)	Fecal	2	3	23	70	3	24	49	3	22
	Entero	5	3	7	8	2	17	14	4	8
Sep	Total	13	12	96	116	14	50	24	21	43
(0.10)	Fecal	6	2	6	33	4	10	4	19	11
	Entero	3	2	2	8	9	3	3	2	4
Oct	Total	13	747	111	480	89	152	280	53	255
(0.46)	Fecal	2	71	60	99	4	18	189	9	58
	Entero	4	241	5	127	102	22	64	7	75
Nov	Total	6	6	13	209	9	12	8	7	34
(0.16)	Fecal	2	2	5	56	2	11	3	6	11
	Entero	2	2	2	26	2	2	4	6	6
Dec	Total	3	54	20	339	43	20	310	8	100
(0.25)	Fecal	4	28	18	43	21	9	161	3	36
	Entero	2	5	4	9	4	6	26	3	7
Annual Means										
	Total	172	119	108	256	33	70	155	24	
	Fecal	9	16	17	60	7	25	70	7	
	Entero	20	28	10	48	17	18	20	6	

Table 3.3

Elevated total coliform, fecal coliform, and enterococcus bacterial (Entero) densities (CFU/100 mL) at PLOO shore stations in 2005. Fecal to total coliform ratios (F:T) ≥0.1 are bolded. Rainfall (in inches) was measured at Lindbergh Field, San Diego, CA.

Date	72-Hour Rain	Station	Total	Fecal	Entero	F:T
January 3	1.08	D7	1600	160	52	**0.10**
		D8	3000	580	1300	**0.19**
January 9	1.53	D4	8400	280	480	0.03
		D5	1600	120	74	0.08
		D8	1400	110	280	0.08
February 14	0.25	D8	1000	16	16	0.02
June 26	0.00	D11	1300	1100	2	**0.85**
		D8	1200	900	2	**0.75**
October 6	0.00	D5	4200	20	1300	0.00
October 12	0.00	D8	1200	6	2	0.01
December 11	0.00	D8	1200	12	16	0.01
December 29	0.00	D11	1400	760	30	**0.54**

stations F08, F09, and F10 (60-m depth contour). Mean bacterial densities were generally highest at the 98 m stations in January and July, while the 60 and 80 m stations had high bacterial densities in April (**Table 3.4**). The kelp bed and 18 m offshore stations had similar bacterial densities for 3 of the 4 quarters (April, July, October). The higher mean value for the 18 m offshore stations in January was caused by 1 surface water sample collected at station F01 (see Appendix 1).

The spatial distribution of the waste field appeared to vary by quarter in 2005 (**Figure 3.3**). Interpolation of the bacteriological data from 60 m and below indicates: (a) a predominantly northward flow in January, (b) an isolated area in the northern part of the sampling grid that appears to be a result of northward flow in October, and (c) a south-east flow in April. The wastefield appeared to have moved eastward along the PLOO in April, but was not detected at special study stations A11 and A13 or at the kelp bed stations (City of San Diego 2005a). MODIS imagery indicated that surface waters were also flowing south in April (Ocean Imaging 2005). The July data suggests that there were no strong currents forcing the wastefield in either direction, and the wastefield was spread out equally north and south of the PLOO. Contaminated water was detected up to 12.5 km (7.8 mi) north of the PLOO (stations F36 and F25) in July and October and 7.3 km (4.5 mi) to the south (station F26) in April.

Compliance with California Ocean Plan Standards – Shore and Kelp Bed Stations

Despite heavy rainfall that periodically affected nearshore water quality (see Chapter 2), compliance with COP bacterial standards for the shore and kelp stations was generally high in 2005 (**Tables 3.5, 3.6**). For example, compliance with the 30-day total coliform standard at the shore stations ranged from 92 to 100% in 2005, with only 3 stations below 100% compliance. This is similar to 2004, another year of heavy rains, when compliance ranged

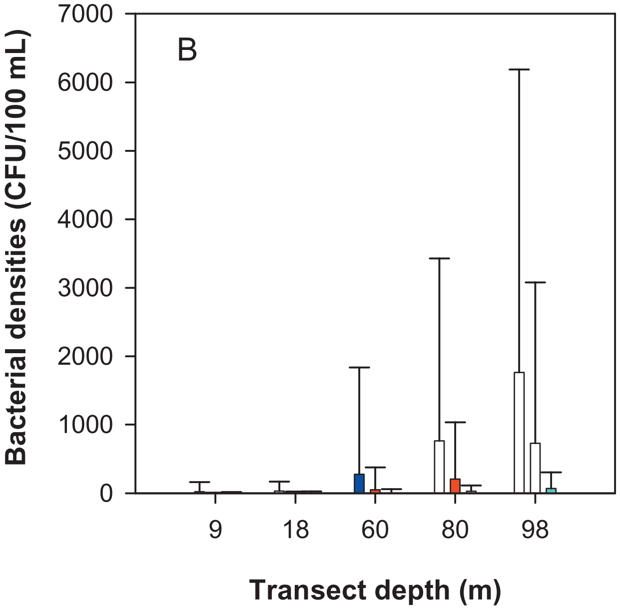


Figure 3.2

Kelp and quarterly offshore station bacterial densities for the PLOO region during 2005. Total coliform, fecal coliform, and enterococcus bacterial densities (mean±SD; CFU/100 mL) by (A) sample depth and (B) transect depth.

Table 3.4

Mean bacterial densities (CFU/100 mL) for January, April, July, and October 2005 sampling at PLOO offshore and kelp bed stations. Bacterial densities from all sample depths for each contour were used to calculate the means.

Month	Contour	n	Total	Fecal	Entero
Jan	9-m kelp bed	45	81	7	19
	18-m kelp bed	75	71	6	22
	18-m quarterly	9	195	61	27
	60-m quarterly	33	114	10	17
	80-m quarterly	44	265	57	36
	98-m quarterly	55	2004	814	135
Apr	9-m kelp bed	45	2	2	3
	18-m kelp bed	75	8	3	3
	18-m quarterly	9	8	4	4
	60-m quarterly	33	917	172	29
	80-m quarterly	44	1982	580	60
	98-m quarterly	55	1168	257	20
Jul	9-m kelp bed	45	27	2	2
	18-m kelp bed	72	21	3	3
	18-m quarterly	9	27	2	2
	60-m quarterly	33	37	7	3
	80-m quarterly	44	503	107	14
	98-m quarterly	55	2762	1241	94
Oct	9-m kelp bed	45	4	2	2
	18-m kelp bed	75	27	3	2
	18-m quarterly	9	5	2	2
	60-m quarterly	33	39	11	3
	80-m quarterly	44	305	80	10
	98-m quarterly	55	1130	603	29

from 89 to 100% and only 2 stations had <100% compliance. The few exceedances of the 30-day total coliform standard along the shoreline occurred at stations D4, D7, and D8 during the wettest months of January and February. Station D8 was the only shore station that exceeded the 60-day fecal coliform standard. Compliance with the 60-day fecal coliform standard at station D8 in 2005 (85%) was similar to compliance in 2004 (83%). All shore stations were 100% compliant with the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

Levels of compliance for the kelp stations were slightly lower in 2005 compared to 2004.

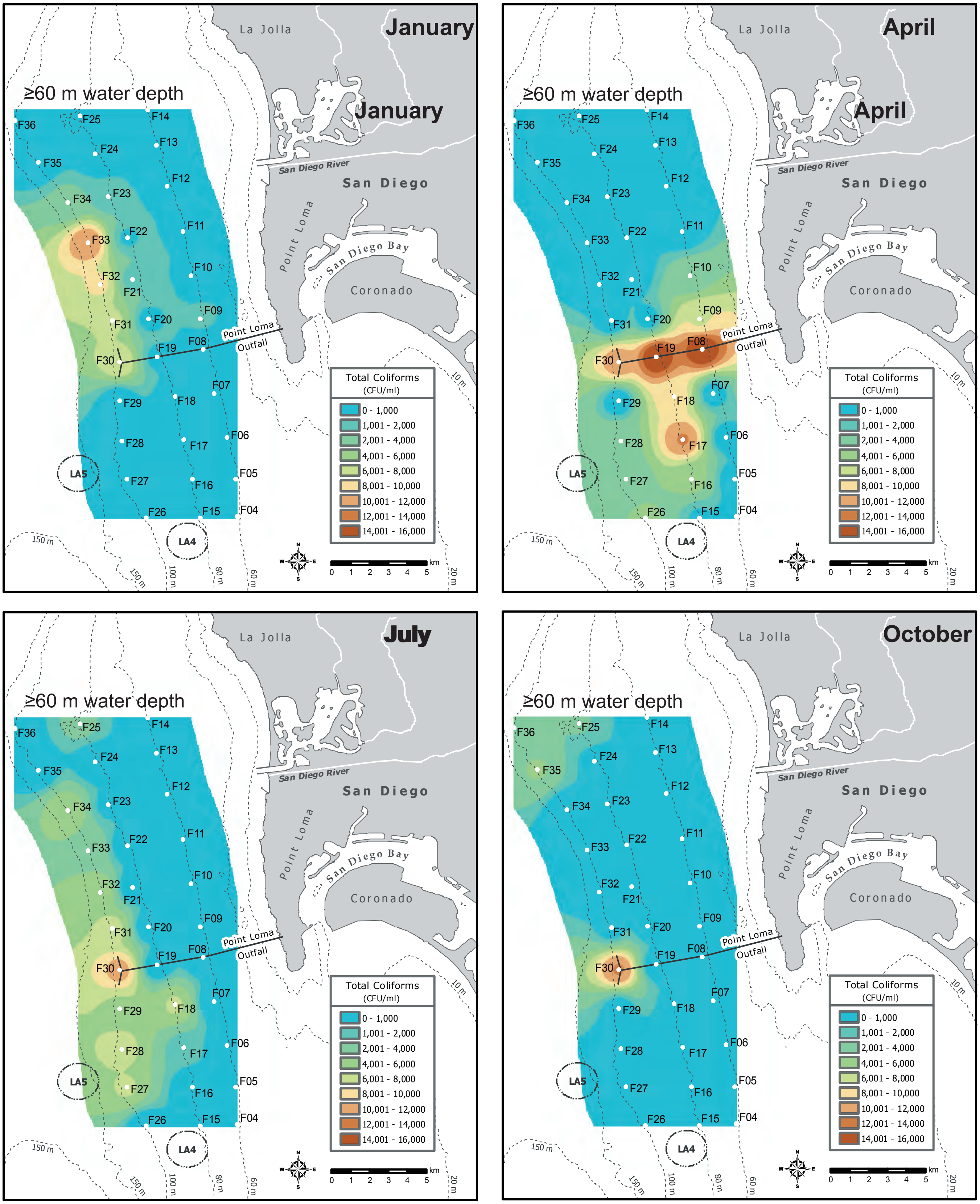


Figure 3.3

Distribution of mean total coliform counts from depths of 60 m and below collected during quarterly offshore sampling in 2005: (A) January, (B) April, (C) July, and (D) October. Contaminated water (see text) was generally not detected in samples shallower than 60 m depth.

Table 3.5

Summary of compliance with California Ocean Plan water contact standards for PLOO shore stations during 2005. The values reflect the number of days that each station exceeded the 30-day total and 60-day fecal coliform standards. Shore stations are listed left to right from south to north.

30-Day total coliform standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	24	29	0	0	0	0
February	28	6	0	0	1	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		98%	100%	93%	92%	100%	100%	100%	100%

60-Day fecal coliform standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	0	31	0	0	0	0
February	28	0	0	0	25	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		100%	100%	100%	85%	100%	100%	100%	100%

Compliance with the 30-day total coliform standard at these stations ranged from 92 to 100% in 2005 compared to 96 to 100% in 2004. The exceedances of the 30-day total coliform standard occurred only in January. Stations C4 and C5 were the only kelp stations out of compliance with the 60-day fecal coliform standard. Elevated total and fecal coliform levels from the end of December 2004 caused the initial exceedances in the beginning of 2005. All kelp stations were 100% compliant with the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

SUMMARY AND CONCLUSIONS

Record rainfall in 2005 had little affect on water quality conditions surrounding the Point Loma

Table 3.6

Summary of compliance with California Ocean Plan water contact standards for PLOO kelp bed stations during 2005. The values reflect the number of days that each station exceeded the 30-day total and 60-day fecal coliform standards. Kelp stations are listed left to right from south to north and by depth contour.

30-Day total coliform standard

		9-m stations			18-m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	28	28	18	18	1	0	0	11
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		92%	92%	95%	95%	100%	100%	100%	97%

60-Day Fecal Coliform Standard

		9-m stations			18-m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	31	15	0	0	0	0	0	0
February	28	27	17	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		84%	91%	100%	100%	100%	100%	100%	100%

Ocean Outfall (PLOO). Values from the shore and kelp bed stations that exceeded the COP bacterial standards were limited primarily to January and February and appear to have been caused by contamination from river discharge during and after storm events. Bacterial concentrations and information from satellite images indicate that water discharge from the San Diego River, San Diego Bay, and other non-point source runoff are all more likely than the PLOO to critically impact the water quality at shore and nearshore stations.

It is unlikely that the wastewater plume from the PLOO ever reached surface waters in 2005. Elevated bacterial densities within the kelp bed and along the shoreline were primarily limited to periods of heavy rainfall and river discharge that occurred in January and February. The exceptions occurred at shore stations D8 and D11 in June, and D11 in December. These stations are subject to heavy recreational use, which may have been the source of the elevated bacterial counts. Bacteriological evidence of contaminated water at the offshore stations was predominantly limited to samples collected from depths of 60 m and deeper. Additionally, the only sample indicative of contaminated water found inshore of the 60-m depth contour was taken at the surface (1 m) at offshore station F01 in January, and may have been due to storm-derived outflow from the San Diego Bay.

The depth of the discharge site (~98 m) may be the dominant factor that keeps the plume from reaching the surface. Wastewater is released into cold, dense sea water that does not appear to mix with the top 25 m of the water column. Physical parameters suggest that the water column is strongly stratified during the spring through fall months (see Chapter 2). The absence of evidence for bacteriological contamination in the surface waters during the winter months, when the water column is well mixed, suggests that stratification is not the only factor limiting the depth of the plume to 60 m and deeper.

The direction of the flow of the waste field from the PLOO varied spatially in 2005. High bacterial densities were detected at the northern limits of the quarterly sampling grid in July and October and at the southern limits in April. There was evidence that the plume moved inshore to the 60-m depth contour in April. It also appears that the plume may have dispersed further offshore than most of the sampling stations, such as in October, when contaminated water was only detected at the northwestern sampling sites. Overall, there did not appear to be one predominant pattern for the distribution of the wastefield.

Although rainfall was heavy in 2005, compliance rates with the COP standards were generally high. The levels of compliance for shore stations in 2005 was similar to that in 2004, another year with heavy rainfall, while the kelp station compliance levels were slightly lower in 2005. Shore station water quality samples were compliant with the 30-day total coliform standard over 90% of the time. Only 3 stations were compliant less than 100%. Similarly, station D8 was the only station not 100% compliant with the 60-day fecal coliform standard. All shoreline water quality samples were 100% compliant with both the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

Kelp station compliance rates with the COP standards were generally high as well. Kelp station water quality samples were compliant with the 30-day total coliform standard over 90% of the time. Station C4 was the only site that was less than 90% compliant with the 60-day fecal coliform standard. All kelp water quality samples were 100% compliant with both the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

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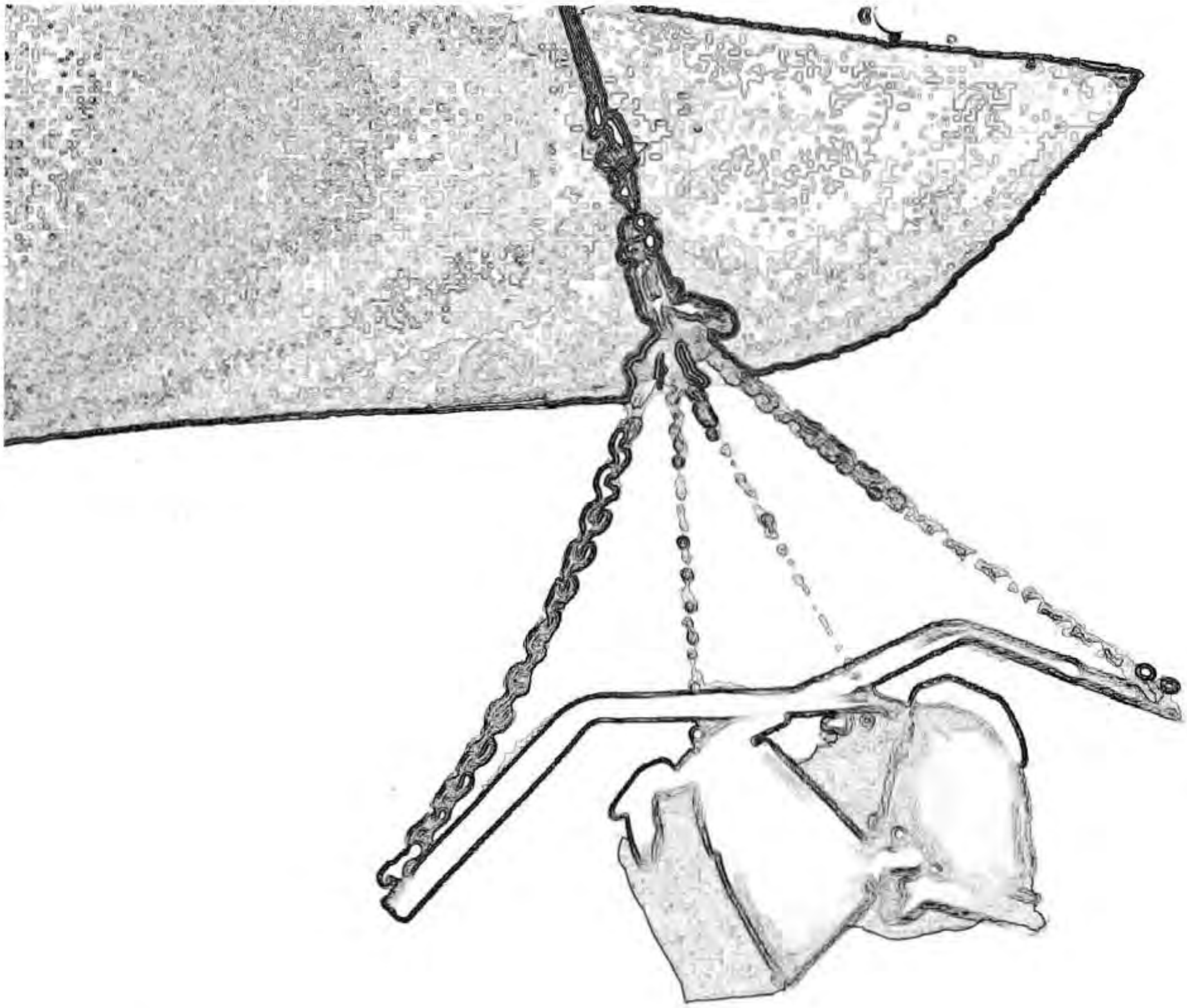
Chapter 4
Sediment Characteristics



Chapter 4. Sediment Characteristics

INTRODUCTION

Sediment conditions can influence the distribution of benthic invertebrates by affecting the ability of various species to burrow, build tubes or feed (Gray 1981, Snelgrove and Butman 1994). In addition, many demersal fishes are associated with specific sediment types that reflect the habitats of their preferred prey (Cross and Allen 1993). Both natural and anthropogenic processes affect the distribution, stability and composition of sediments.

Natural factors that may affect the distribution and stability of sediments on the continental shelf include bottom currents, wave exposure, the presence and abundance of calcareous organisms, and proximity to river mouths, sandy beaches, submarine basins, canyons and hills (Emery 1960). The analysis of various sediment parameters (e.g., particle size, sorting coefficient, percentages of sand, silt, and clay) can provide useful information relevant to the amount of wave action, current velocity, and sediment stability in an area.

The chemical composition of sediments can be affected by the geological history of an area. For example, erosion from cliffs and shores, and discharges from bays, rivers, and streams can contribute various metals and sedimentary detritus to a given area (Emery 1960). In addition, the organic content of sediments is greatly affected by primary productivity in nearshore waters, as well as terrestrial plant debris originating from bays, estuaries, and rivers (Mann 1982, Parsons et al. 1990). Finally, concentrations of various constituents within sediments are often affected by sediment particle size. For example, the levels of organic materials and trace metals within ocean sediments generally rise with increasing amounts of fine particles (Emery 1960, Eganhouse and Vanketesan 1993).

Ocean outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of sediments through the discharge of wastewater and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds in municipal wastewater discharges include various organic compounds (e.g., organic carbon, nitrogen, sulfides), trace metals, and pesticides (Anderson et al. 1993). Additionally, the physical structure of large outfall pipes can alter the hydrodynamic regime affecting sediment transport and subsequently substrate composition in the immediate area (see Shepard 1973).

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2005 in the region surrounding the Point Loma Ocean Outfall (PLOO). The major goals are to (1) assess impact of the wastewater discharge on sediment quality in the region by analyzing spatial and temporal patterns of various grain size and chemistry parameters, and (2) determine the presence or absence of sedimentary or chemical footprints near the discharge site.

MATERIALS AND METHODS

Field Sampling

Sediment samples were collected at 22 stations that span the terminus of the PLOO (**Figure 4.1**). These stations are located along the 88, 98, and 116-m depth contours, and include 17 “E” stations located within 8 km of the outfall, and 5 “B” stations located greater than 11 km from the outfall. In January, the sampling was limited to the 12 primary core stations located along the 98-m contour due to participation in special strategic process studies as determined by the City in coordination with the Executive Officer of the RWQCB and the United States Environmental Protection Agency (USEPA) (City of San Diego 2006a).

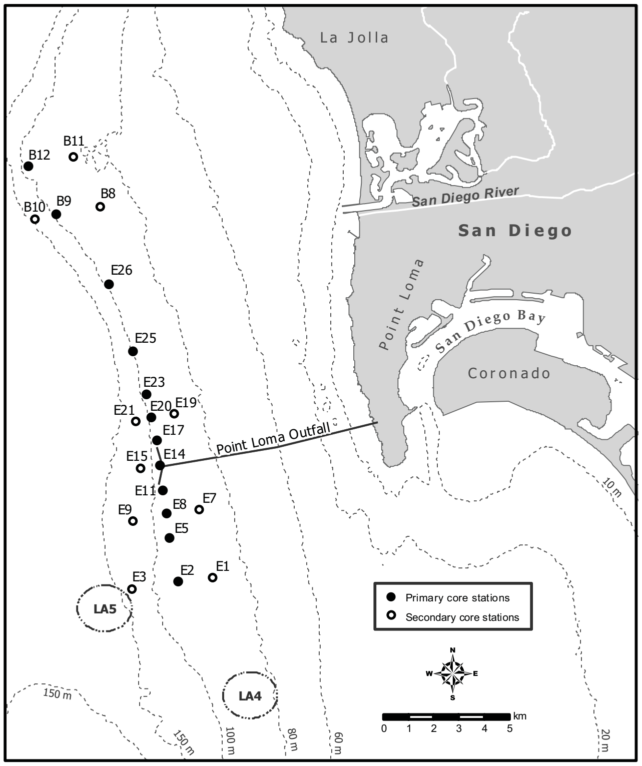


Figure 4.1
Benthic station locations sampled for the Point Loma Ocean Outfall Monitoring Program. The 12 primary core stations along the 98-m contour were sampled in January and July 2005. Secondary core stations along the 88 and 116-m contours were sampled in July 2005 only.

Benthic sediment samples were collected using a modified 0.1-m^2 chain-rigged, double van Veen grab (see City of San Diego in prep). Subsamples were taken from the top 2 cm of the sediment surface and handled according to USEPA guidelines (USEPA 1987).

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Laboratory (see City of San Diego 2006b). Particle size analysis was performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., -1 to 11 phi). Coarser sediments (e.g., very coarse sand, gravel, shell hash) were removed prior to analysis by screening the samples through a 2.0 mm mesh sieve. The retained material was weighed and expressed as the percent "Coarse" of the total sample sieved.

The data output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles ranging in size from <2 to 62.5 mm, silt as particles from <62.5 to 0.0039 mm, and clay as particles <0.0039 mm (see **Table 4.1**). These data were standardized and incorporated with a sieved coarse fraction containing particles >2.0 mm in diameter to obtain a distribution of coarse, sand, silt, and clay fractions totaling 100%. The coarse fraction was included with the phi -1 fraction in the calculation of various particle size parameters, using a normal probability scale (see Folk 1968). These parameters included mean and median phi size, standard deviation of phi size (sorting coefficient), skewness, kurtosis, and percent sediment type (coarse materials, sand, silt, clay).

Chemical parameters analyzed were total organic carbon (TOC), total nitrogen (TN), total sulfides, biological oxygen demand (BOD), total volatile solids (TVS), trace metals, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl compounds (PCBs) (**see Appendix B.1**). Prior to analysis, these data were generally limited to values above the method detection level (MDL). However, some parameters were occasionally determined to be present in a sample with high confidence (i.e., peaks are confirmed by mass-spectrometry) but at levels below the MDL. These data were included as estimated values. Null or "not detected" values represented instances where the substance was either not detected or detected below the MDL, but not confirmed by mass-spectrometry. These values were treated as a zero when calculating means.

Cumulative distribution functions (CDFs) were established previously for Southern California Bight using data from 1994 (Schiff and Gossett 1998). Sediment chemistry data for the San Diego region were compared against the median CDF levels for 12 trace metals, TN, TOC, pesticides (e.g., DDT), and total PCB in order to evaluate how these parameters compare to regional values of the entire SCB. Levels of sediment contamination were further evaluated by comparing the results of this study to the available Effects Range Low (ERL) sediment quality guidelines (see Long et al. 1995). The ERL represents chemical concentrations below which adverse biological effects were rarely observed.

Table 4.1

A subset of the Wentworth scale representative of the sediments encountered in the PLOO region. Particle size is presented in phi, microns, and millimeters along with the conversion algorithms. The sorting coefficients (standard deviation in phi units) are based on categories described by Folk (1968).

Wentworth Scale				Sorting Coefficient	
Phi Size	Microns	Millimeters	Description	Standard Deviation	Sorting
-2	4000	4	Pebble	Under 0.35 phi	very well sorted
-1	2000	2	Granule	0.35–0.50 phi	well sorted
0	1000	1	Very coarse sand	0.50–0.71 phi	moderately well sorted
1	500	0.5	Coarse sand	0.71–1.00 phi	moderately sorted
2	250	0.25	Medium sand	1.00–2.00 phi	poorly sorted
3	125	0.125	Fine sand	2.00–4.00 phi	very poorly sorted
4	62.5	0.0625	Very fine sand	Over 4.00 phi	extremely poorly sorted
5	31	0.0310	Coarse silt		
6	15.6	0.0156	Medium silt		
7	7.8	0.0078	Fine Silt		
8	3.9	0.0039	Very fine silt		
9	2	0.0020	Clay		
10	0.98	0.00098	Clay		
11	0.49	0.00049	Clay		

Conversions for diameter in phi to millimeters: $D(mm) = 2^{-phi}$

Conversions for diameter in millimeters to phi: $D(phi) = -3.3219\log10D(mm)$

RESULTS AND DISCUSSION

Particle Size Distribution

During 2005, ocean sediments off Point Loma were composed predominantly of very fine sand and coarse silt with a mean particle size of 0.066 mm or 3.9 phi (**Table 4.2**). Fine sediments (silt and clay fractions combined) averaged about 36% of the sediments overall, while sands accounted for 63%. Coarser materials such as shell hash and gravel comprised the remaining 1%. The sorting coefficients (standard deviation) were greater than 1.0 phi at every station, indicating that sediments within the survey area were poorly sorted (i.e., consisted of particles of varied sizes; see Table 4.1). These results are typical of the mid-shelf and reflect the multiple origins of sediments in the region (see Emery 1960, City of San Diego 2006c). This also suggests that these sites are subject to slow moving currents, reduced water motion, or some disturbance (e.g., storm surge, rapid suspension/deposition of materials). For example, 29 of the 34 samples in 2005 contained both fine particles and coarse materials (see **Appendix B.2**).

Particle size at most stations averaged between 0.04 and 0.09 mm in diameter. Generally, finer sediments occurred along the 88-m contour, with more coarse sediments along the 98 and 116-m contours (**Figure 4.2**). The smallest particles (mean <0.05 mm) occurred at the northern station B8 located along the 88-m depth contour, while the coarsest sediments (>0.09 mm) occurred at the deep reference station B12. Relatively coarse sediments (>0.07 mm) also occurred at the 2 stations along the 116-m contour, northern reference station B10 and the most southern deep station E3 located near the LA-5 dredge disposal site, and station E14 located along the 98-m contour. The coarser sediments at stations B12 and B10 may be partially related to their location along the outer shelf edge where strong currents and internal waves export fine sediments down the slope and leave shell hash and larger particles behind (see Shepard and Marshall 1978, Heathershaw et al. 1987, Boczar-Karakiewicz et al. 1991). The sediment at station E3 was composed of varying amounts of sandy materials likely related to its location near the LA-5 disposal site (see Gardner et al. 1998, City of San Diego 2005). Visual

Table 4.2

Summary of particle size parameters and organic loading indicators at PLOO stations during 2005. Data are expressed as annual means; n=2 for the 12 primary core stations (98-m contour); n=1 for 10 secondary core stations (88 and 116-m contours). CDF=cumulative distribution functions (see text); NA=not available. MDL=method detection limit. Area Mean=mean of all stations for 2005. Values that exceed the median CDF are indicated in bold type.

		Particle Size						Organic Indicators				
Station	**Depth (m)**	**Mean (mm)**	**Mean (phi)**	**SD (phi)**	**Coarse (%)**	**Sand (%)**	**Fines (%)**	**BOD (mg/L)**	**Sulfides (ppm)**	**TN (wt%)**	**TOC (wt%)**	**TVS (wt%)**
North reference stations												
B-11	88	0.063	4.0	2.3	4.7	51.9	**43.4**	533	0.8	**0.089**	**1.900**	4.54
B-8	88	0.044	4.5	1.6	0.0	44.6	**55.4**	351	3.3	**0.080**	**0.881**	3.07
B-12	98	0.091	3.4	2.1	1.9	67.6	30.5	424	1.2	**0.069**	**1.546**	3.60
B-9	98	0.056	4.1	1.6	0.0	60.5	**39.4**	335	0.5	0.046	**0.625**	3.81
B-10	116	0.072	3.8	1.6	0.0	71.4	28.6	361	0.5	**0.056**	**2.140**	3.18
Stations north of the outfall												
E-19	88	0.051	4.3	1.5	0.0	54.5	**45.5**	365	3.8	**0.078**	**0.800**	2.88
E-20	98	0.063	4.0	1.4	0.0	64.1	35.8	203	1.0	**0.051**	0.524	2.17
E-23	98	0.058	4.1	1.4	0.0	60.9	**39.0**	296	0.7	**0.059**	0.559	2.31
E-25	98	0.063	4.0	1.5	0.0	63.0	36.9	226	0.6	**0.051**	0.537	2.54
E-26	98	0.054	4.2	1.6	0.1	58.0	**41.8**	304	1.3	**0.058**	**0.638**	2.84
E-21	116	0.063	4.0	1.5	0.0	65.5	34.5	257	8.7	**0.052**	**0.624**	2.24
Outfall stations												
E-11	98	0.069	3.8	1.3	0.0	68.7	31.3	342	1.7	0.045	**0.609**	2.29
E-14	98	0.072	3.8	1.4	0.4	70.5	28.9	515	3.3	0.045	0.495	2.17
E-17	98	0.069	3.8	1.3	0.0	67.8	32.1	346	2.8	0.046	0.469	2.19
E-15	116	0.067	3.9	1.5	0.0	68.3	31.7	330	2.0	**0.058**	**0.796**	2.45
Stations south of the outfall												
E-1	88	0.063	4.0	1.9	2.3	58.4	**39.1**	235	1.4	**0.064**	**0.700**	2.39
E-7	88	0.058	4.1	1.5	0.0	59.0	**41.0**	306	0.8	**0.052**	**0.635**	2.64
E-2	98	0.067	3.9	2.0	3.3	58.1	38.4	329	3.3	**0.056**	**0.640**	2.70
E-5	98	0.067	3.9	1.5	0.0	65.7	34.2	425	0.7	0.049	0.592	2.63
E-8	98	0.069	3.8	1.4	0.1	68.4	31.4	247	1.2	0.042	0.478	2.37
E-3	116	0.088	3.5	2.1	0.3	68.1	31.6	253	0.8	0.035	0.448	2.22
E-9	116	0.063	4.0	2.0	1.8	61.0	37.2	282	1.1	**0.064**	**1.540**	3.04
Area Mean		0.066	3.9	1.6	0.6	63.2	36.1	330	1.7	0.055	0.762	2.70
MDL								2	0.14	0.005	0.010	0.11
50% CDF							38.5	NA	NA	0.050	0.597	NA

examination and observations of the field samples collected at several stations in the immediate area (e.g., E2, E5) have occasionally revealed the presence of coarse, black sand used as stabilizing material for the outfall pipe (see City of San Diego 2000, 2001, 2002, 2003a, 2004, 2005). During 2005, this type of black sand was present at stations near the outfall (i.e., E14, E15) and southward (E9) indicating the potential spread of this ballast material (see Appendix B.2). In addition, the presence of the PLOO has altered the sediment composition at station E14 over time. Prior to construction (1991–1994), percent fines at this station ranged from 30–41%, but have since become much more variable (2.4–35%) (City of San Diego 1995, 2004, 2005).

Organic Indicators

Generally, the distribution of organic indicators in PLOO sediments during 2005 was similar to that seen prior to discharge (see City of San Diego 1995). The northern reference stations had higher concentrations of organic indicators than stations farther south. For example, 4 of the

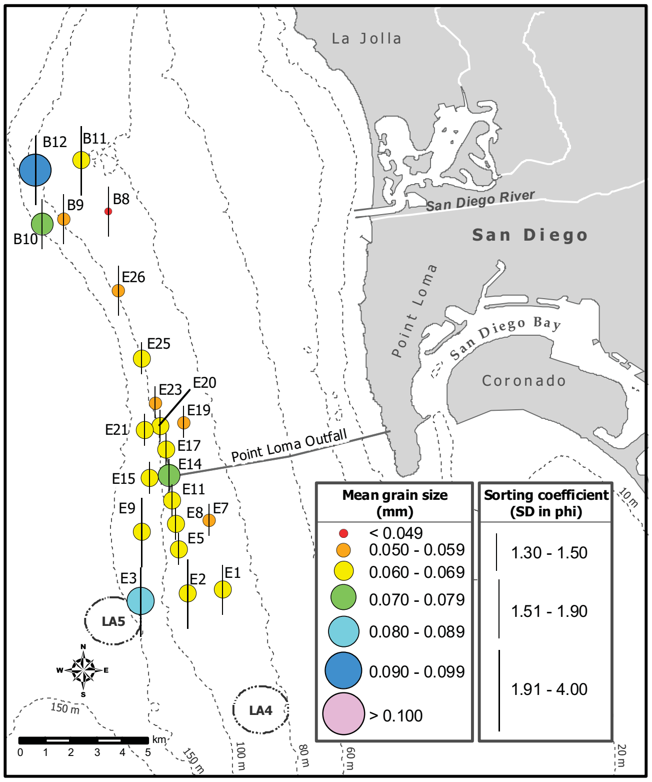


Figure 4.2

Particle size distribution for sediment chemistry stations sampled during 2005. n=2 for the primary core stations; n=1 for secondary core stations. Mean particle size is based on diameter in millimeters. Sorting coefficient (standard deviation) is in phi units.

5 reference sites contained TN and TOC values above median CDF values for the SCB, and included the 3 highest TOC and 2 highest TN values. Additionally, the greatest concentrations of TVS and most of the high BOD values were found at these northern stations. Outfall station E14 had the second highest concentration of BOD (515 mg/L); however, sulfide concentrations were low (3.3 ppm) compared to an historical average of 16 ppm (maximum=92 ppm). Concentrations of organic indicators were relatively low at other stations within the vicinity of the PLOO (i.e., E11, E15, E17). A review of historical data (1991–2005) generally supports these observations (**Figure 4.3**). However, while concentrations of the various organic indicators have been variable since inauguration of the outfall (see **Appendix B.3**), BOD has been highest during the post-discharge period (1994–2005) (**Figure 4.4**). Overall, with the exception of sulfides, there was no pattern of organic loading relative to proximity to the PLOO during 2005. The concentration of organics in sediments surrounding the PLOO are within the range of those found regionally (see City of San Diego 2006c).

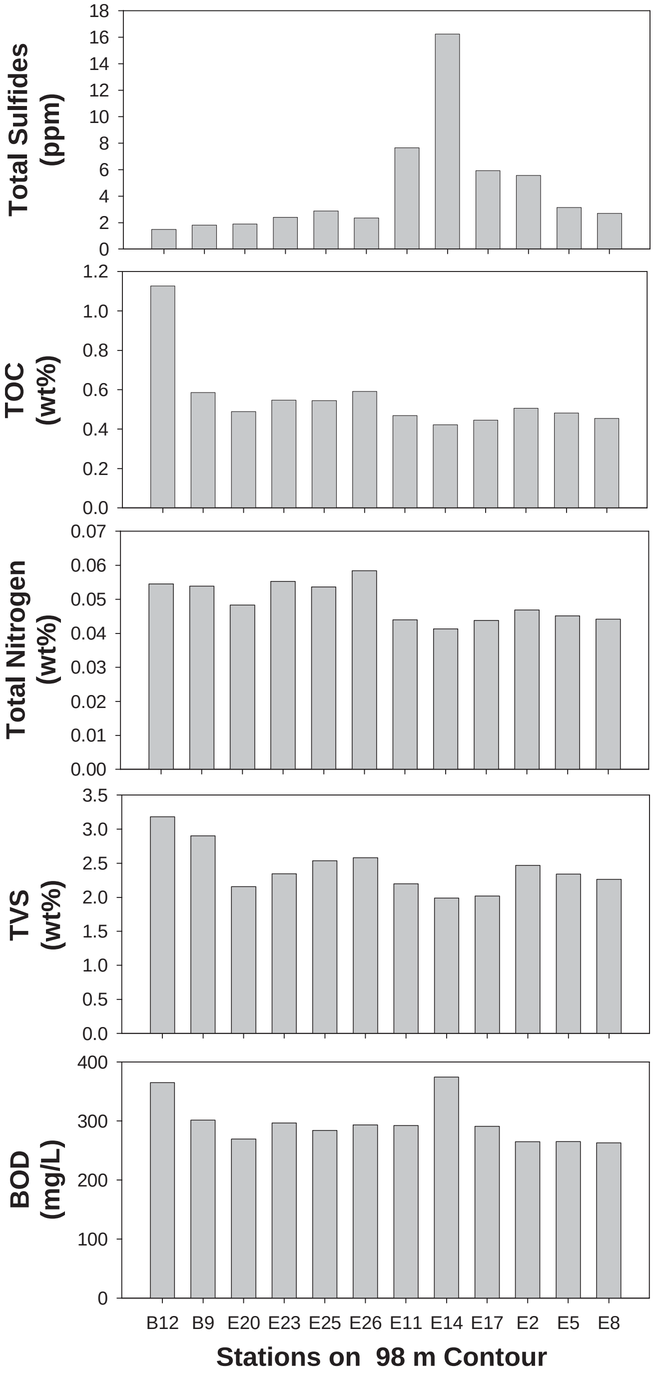


Figure 4.3

Means of organic indicators for 98 m contour stations for 1991–2005 from north to south (left to right). Organic indicators are total sulfides, total organic carbon (TOC), total nitrogen, total volatile solids (TVS) and biochemical oxygen demand (BOD).

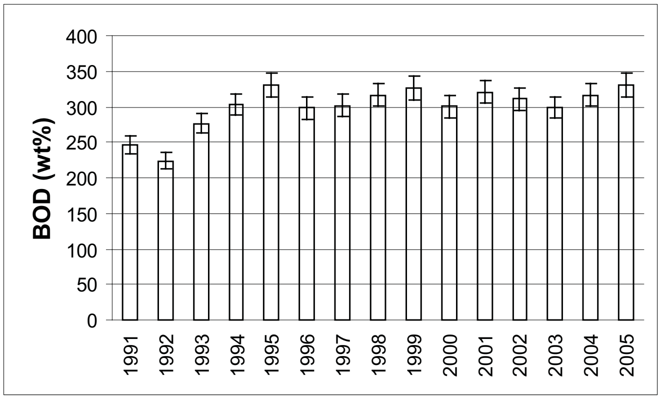


Figure 4.4
Annual mean concentrations of BOD (1991–2005) with 95% confidence limit.

Trace Metals

Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc were frequently detected at concentrations above their MDLs in the sediments off Point Loma (**Table 4.3**). Selenium, silver, and thallium were mostly undetected or occurred in concentrations that were near or below their MDLs.

Concentrations of trace metals in 2005 were highest in 2 general locations: (1) at the northern reference stations, particularly B8 and B11, and (2) at stations between the PLOO and the two dredge disposal sites (i.e., E2, E3, E9). The highest values for aluminum, arsenic, barium, beryllium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc were collected at one or more of these 5 sites. The high levels of copper, lead, mercury, and zinc at stations E2 or E9 may be related to the deposition of dredged sediments from the San Diego Bay, where these 4 metals occurred in high concentrations (see City of San Diego 2003b). Some of the lowest metals concentrations occurred at the 4 stations surrounding the PLOO (i.e., E11, E14, E15, E17), as well as several nearby stations (i.e., E7, E8, E20, E21). The 14 remaining stations contained 3 or more metals with mean concentrations greater than the median CDF. There was no discernable pattern of metal distribution related to proximity to the PLOO.

The concentrations of several metals have increased relative to previous surveys (**Appendix B.4**). Annual mean concentrations for aluminum, iron, and manganese in 2005 were much higher than all previous years. The mean concentration of lead (6.4 ppm) was also higher than previous surveys, but only slightly higher than 2004 (5.6 ppm). These higher values were observed throughout the region (City of San Diego 2006c) and may have been caused by increased sedimentation during the record rainfall and runoff of 2004 and 2005 when large turbidity plumes were frequently observed within the sampling area (see Chapter 3).

Pesticides, PCBs, and PAHs

Low levels of the pesticides heptachlor epoxide and DDT were detected at 5 stations in 2005 (**Table 4.4**). Heptachlor epoxide was found at station E2, and DDT was detected as its final metabolic degradation product (p,p-DDE) at stations E1, E2, E20, E21, and E23. Generally, pesticide contamination along the San Diego shelf appears to result from sources unrelated to the PLOO discharge. For example, total DDT concentrations throughout the study area peaked in 1993, just 2 years into a 7-yr period when 10 large dredging projects disposed contaminated sediments from San Diego Bay at the LA-5 disposal site (Steinberger et al. 2003) (see **Figure 4.5**). The decline in DDT values in 2005 relative to prior surveys continues a trend that began in 1996. The area mean for DDT decreased from 129 ppt in 2004 to 66 ppt during 2005.

PCBs were detected at only 2 stations in 2005. The congener PCB 110 occurred at station E3 with a value of 150 ppt, well below the MDL of 700 ppt. However, 11 PCB congeners totaling 5285 ppt were detected at station E9 in July, which is well above the CDF of 2600 ppt, but still below the ERL of 22,700 ppt. PCBs have historically occurred at these and other southern stations surrounding the LA-5 dredge disposal site.

Table 4.3

Concentrations of trace metals (ppm) detected at each station during 2005; n=2 for the 12 primary core stations (98-m contour); n=1 for 10 secondary core stations (88 and 116-m contours). CDF=cumulative distribution function (see text). MDL=method detection limit. ERL=Effects Range Low Threshold Value. NA=not available. Values that exceed the median CDF are indicated in bold type. The names of each trace metal represented by the periodic table symbol are presented in Appendix B.1.

Station	Depth	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
North reference stations																			
B-11	88	**20100**	nd	**6.10**	129.0	**0.56**	0.09	**34.5**	11.0	**29900**	7.4	265	**0.045**	12.1	0.24	nd	nd	2.5	**58.2**
B-8	88	**22100**	nd	4.33	65.3	**0.40**	0.19	29.4	11.4	**22500**	9.7	314	**0.043**	11.9	nd	nd	nd	2.6	49.6
B-12	98	**11350**	**1.2**	**5.56**	31.5	**0.50**	0.03	30.2	6.3	**26150**	3.5	184	0.020	7.4	nd	nd	nd	1.6	43.8
B-9	98	**15100**	**0.4**	3.67	64.9	**0.40**	0.14	28.4	7.6	**23750**	7.2	221	0.031	8.9	0.13	nd	nd	1.8	40.0
B-10	116	**12400**	nd	3.42	32.9	**0.43**	nd	24.4	5.8	**20200**	0.5	248	0.019	7.0	nd	nd	nd	1.5	40.5
Stations north of the outfall																			
E-19	88	**14700**	nd	3.99	54.8	**0.29**	0.10	22.0	11.1	15900	6.8	158	**0.045**	10.1	nd	nd	nd	2.0	38.1
E-20	98	**13600**	**0.5**	3.26	37.3	0.26	0.10	19.2	7.6	15300	6.0	225	0.028	7.9	nd	nd	nd	1.9	30.9
E-23	98	**15000**	**0.6**	3.23	41.4	**0.27**	0.14	20.7	7.8	16150	7.0	235	0.030	8.3	nd	nd	nd	2.2	32.7
E-25	98	**14500**	**0.5**	2.59	40.4	**0.28**	0.13	20.6	8.0	15800	6.8	229	0.031	8.2	nd	nd	nd	2.2	33.0
E-26	98	**16200**	**0.4**	3.28	43.8	**0.29**	0.15	22.0	8.2	**17500**	7.1	258	0.030	9.2	nd	nd	nd	2.3	36.9
E-21	116	**10800**	nd	2.67	31.8	0.24	0.05	16.4	7.6	11700	5.3	128	0.034	7.1	nd	nd	nd	1.5	27.7
Outfall stations																			
E-11	98	**10500**	**0.5**	3.61	29.7	0.22	0.09	16.1	6.9	12750	5.4	165	0.024	6.6	nd	nd	nd	1.7	25.9
E-14	98	**10700**	**0.4**	3.53	30.0	0.21	0.11	16.2	6.8	13050	5.2	178	0.023	6.5	nd	nd	nd	1.6	25.9
E-17	98	**11900**	**0.5**	2.96	34.4	0.23	0.11	17.3	7.2	13400	5.4	203	0.028	7.1	nd	0.1	nd	1.8	28.5
E-15	116	**11100**	nd	2.94	32.4	0.25	0.05	17.2	7.8	12800	5.3	154	0.030	7.2	nd	nd	nd	1.6	29.3
Stations south of the outfall																			
E-1	88	**14200**	**0.5**	3.06	47.0	**0.27**	0.05	19.1	10.5	16400	7.2	205	**0.055**	8.4	nd	nd	nd	2.0	37.3
E-7	88	**13200**	nd	3.97	45.5	0.26	0.10	19.2	9.2	14200	5.9	207	**0.042**	8.5	0.26	nd	nd	1.8	33.7
E-2	98	**17950**	**0.5**	3.07	61.0	**0.31**	0.09	21.8	**13.2**	**20300**	8.6	248	**0.067**	8.8	nd	nd	nd	2.3	39.7
E-5	98	**14000**	**0.4**	2.61	39.8	**0.27**	0.13	19.3	7.9	16700	6.3	254	0.032	7.5	nd	nd	nd	2.2	32.6
E-8	98	**13450**	**0.3**	2.41	35.0	0.26	0.11	18.8	6.9	16350	5.8	280	0.026	7.0	nd	nd	nd	2.2	31.1
E-3	116	**14600**	**0.6**	3.58	76.0	0.25	0.09	17.3	**16.6**	16500	10.7	181	**0.059**	6.9	nd	nd	nd	2.2	45.3
E-9	116	**12300**	nd	4.80	40.4	**0.33**	0.03	21.9	**31.6**	**16800**	11.7	144	**0.042**	8.4	nd	nd	0.7	1.8	**91.8**
Area Mean		**13941**	0.4	3.48	45.1	**0.30**	0.10	21.3	9.2	**17391**	6.4	216	0.034	8.1	0.02	0.0	0.0	2.0	36.9
MDL		1.15	0.13	0.33	0.002	0.001	0.01	0.016	0.028	0.75	0.142	0.004	0.003	0.036	0.24	0.013	0.022	0.059	0.052
50% CDF		9400	0.2	4.80	NA	0.26	0.29	34.0	12.0	16800	NA	NA	0.040	NA	0.29	0.17	NA	NA	56.0
ERL		NA	NA	8.2	NA	NA	1.2	81	34	NA	46.7	NA	0.2	20.9	NA	1.0	NA	NA	150

Table 4.4

Mean concentrations for pesticides (ppt), total PCBs (ppt), and total PAHs (ppb) in PLOO sediments during 2005. MDL=method detection limit. MDLs for PCBs and PAHs vary by each compound. CDF=cumulative distribution function (see text). Undetected values are indicated by "nd." NA=not available. ERL=Effects range low threshold value. n=2 for the 12 primary core stations (98-m contours); n=1 for 10 sedondary core stations (88 and 116-m contours).

Station	Depth (m)	Heptachlor epoxide	Total DDT	Total PCB	Total PAH
North reference stations					
B-11	88	nd	nd	nd	292
B-8	88	nd	nd	nd	387
B-12	98	nd	nd	nd	127
B-9	98	nd	nd	nd	198
B-10	116	nd	nd	nd	229
Stations north of the outfall					
E-19	88	nd	nd	nd	151
E-20	98	nd	195	nd	179
E-23	98	nd	500	nd	148
E-25	98	nd	nd	nd	187
E-26	98	nd	nd	nd	197
E-21	116	nd	300	nd	138
Outfall stations					
E-11	98	nd	nd	nd	179
E-14	98	nd	nd	nd	157
E-17	98	nd	nd	nd	188
E-15	116	nd	nd	nd	145
Stations south of the outfall					
E-1	88	nd	300	nd	450
E-7	88	nd	nd	nd	278
E-2	98	155	135	nd	349
E-5	98	nd	nd	nd	211
E-8	98	nd	nd	nd	171
E-3	116	nd	nd	150	352
E-9	116	nd	nd	**10,570**	**9941**
MDL		700	—	—	—
50% CDF		NA	10000	2600	NA
ERL			1580	22700	4022

PAH compounds were detected in low concentrations at most stations in 2005 (Table 4.4, **Appendix B.5**). Only sediments at station E9 contained total PAH concentrations above the ERL of 4022 ppb. Station E9 is one of 4 stations within the survey area where PAHs have been frequently detected. The other sites include E1, E2, and E3 (see City of San Diego 2000, 2001, 2002, 2003a–c). PAHs at these stations have largely been attributed to misplaced deposits intended for LA-5 (see Anderson et al. 1993). In contrast, PAH values at other Point Loma sites were near or below their respective MDL levels. The detection of low levels of PAHs at all stations appears to reflect a change in methodology where values below method detection limits can be reliably estimated with qualitative identification via a mass spectrophotometer (see Methods and Materials).

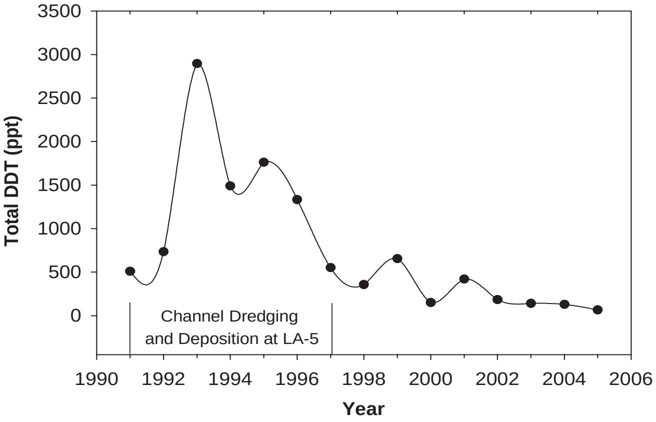


Figure 4.5

Changes in average total DDT within the PLOO sampling area for the period 1991–2005.

SUMMARY AND CONCLUSIONS

Ocean sediments at stations surrounding the PLOO in 2005 consisted primarily of very fine sands and coarse silt. Area sediments were poorly sorted and consisted of particles of varied sizes. This suggests that the region was subject to low wave and current activity and/or physical disturbance. Stations containing the finest particles were found along the 88-m contour, while those with the coarsest particles were found along the 98-m and 116-m contours. Stations with very coarse sediments included 2 northernmost reference sites (B12 and B10), and one southern site near the LA-5 disposal site (E3). Two stations located near the PLOO contained sand that was slightly more coarse than surrounding sites, and one site located between the outfall and LA-5 contained variable amounts of ballast sand, coarse particles, and shell hash. Generally, these results reflect multiple anthropogenic input (e.g., outfall construction, dredge disposal) and natural influences (e.g., Pleistocene and recent detrital deposits) on the region's sediment composition (Emery 1960).

The distribution of organic indicators in 2005 was generally similar to previous surveys. The one exception was TOC, which had a mean concentration in 2005 that was higher than 11 of the 13 previous years. This possibly reflects an increase in the input of organic materials associated with record rainfall and runoff, as well as a large enduring plankton bloom. The highest concentrations of BOD, total nitrogen, total carbon, and total volatile solids occurred at sites north of the PLOO. Stations located south of the outfall and near the LA-5 disposal site generally had relatively low values of organic indicators with the exception of station E9. Station E14, nearest the outfall, had the second highest BOD value, but very low sulfides compared to previous years.

Fifteen trace metals were detected frequently in sediments surrounding the PLOO during 2005, with the lowest concentrations occurring near the discharge site. Most metals were present at concentrations below median values for the SCB (median CDF) and other sediment quality guidelines. Only aluminum, antimony, and beryllium occurred in concentrations frequently above median CDF values, but mean concentrations for aluminum, iron, and manganese increased in 2005. These increases were seen throughout the San Diego coastal region (see City of San Diego 2006c), and were most likely related to the increased sedimentation resulting from record rainfall mentioned above and in Chapter 2. The resultant turbidity plumes likely included clay particles, which consist largely of aluminum and silicon oxides, as well as other associated metals such as iron and manganese (see Manahan 2000). All northern reference sites, one site north of the PLOO, and 2 stations near the LA-5 disposal site had concentrations of 3 or more trace metals that exceeded the median CDF. Several metals detected at stations near LA-5 were also present in high concentrations in sediments collected from San Diego Bay (see City of San Diego 2003b). Their presence at sites south of the PLOO and near LA-5 may be related to the disposal of materials dredged from the Bay.

Generally, concentrations of other contaminants (i.e., pesticides, PAHs and PCBs) were generally low in 2005. Low levels of pesticides were detected at only 5 stations. The pesticide DDT was more widely distributed within the PLOO area from 1991 to 1996, but there has been a steady reduction in detectable DDT concentrations since 1996. Low levels of PAHs were detected at all stations as a result of a change in methodology for confirming values below MDL levels. The highest concentration of PAHs and PCBs occurred at station E9 located between the PLOO and the LA-5 dredge materials disposal site. In general, concentrations of PAHs and PCBs have been higher at these southern stations than elsewhere off San Diego, and are most likely the result of misplaced deposits of dredged material that were originally destined for LA-5. Previous studies have attributed elevated levels of various contaminants such as PAHs, PCBs, trace metals, and DDT in this area to the deposits from LA-5 (see Anderson et al. 1993; City of San Diego 2003b; Steinberger et al. 2003). In contrast, PAHs have not been detected in effluents from large municipal wastewater treatment facilities in southern California (Steinberger and Schiff 2003), and low concentrations near the discharge site are not unexpected.

Generally, there was no evidence of an impact from the PLOO wastewater discharge. Instead data from the sediment composition and chemistry indicate that natural events (e.g., storms and plankton blooms) and anthropogenic sources (e.g., pollution from stormwater discharge and dredging activities) are the most likely reasons for many anomalous changes observed in 2005.

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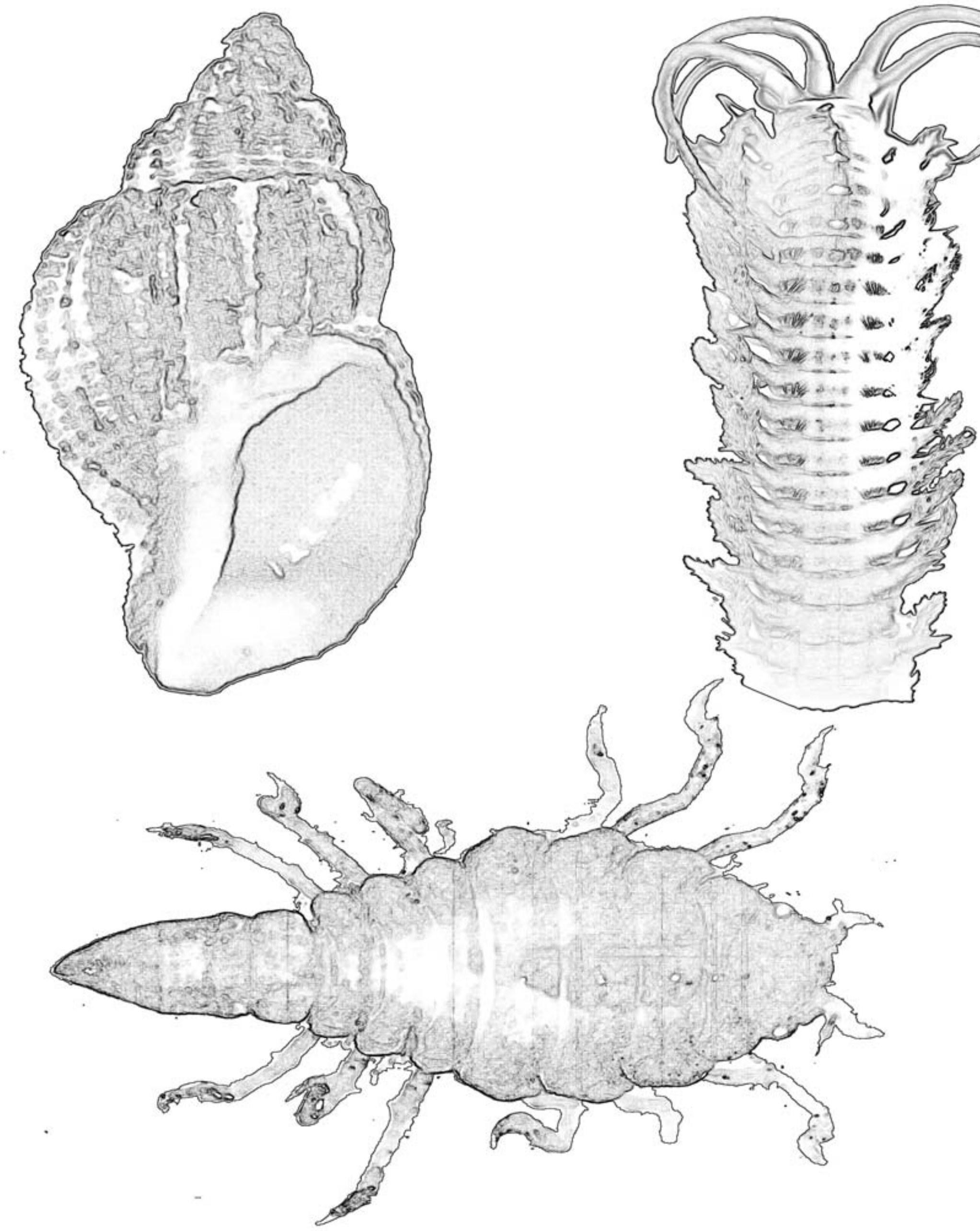
Chapter 5
Macrobenthic Communities



Chapter 5. Macrobenthic Communities

INTRODUCTION

The southern California coastal shelf contains a diverse community of macrofaunal invertebrates (Fauchald and Jones 1979, Thompson et al. 1992, Bergen et al. 2001). These animals are essential members of the marine ecosystem, serving vital functions in wide ranging capacities. For example, many species of benthic invertebrates are important for fish and other organisms, while others decompose organic material as a crucial step in nutrient cycling. The structure of marine macrofaunal communities is influenced by many factors including sediment conditions (e.g., particle size, sediment chemistry), water conditions (e.g., temperature, salinity, dissolved oxygen, current velocity), and biological factors (e.g., food availability, competition, predation). While human activities can affect these factors, natural processes largely control the structure of invertebrate communities in marine sediments. In order to determine whether changes in community structure are related to human impacts or natural processes, it is necessary to have documentation of background or reference conditions for an area. Such information is available for the region surrounding the Point Loma Ocean Outfall (PLOO) and the San Diego region in general (e.g., City of San Diego 1995, 1999, 2004).

Benthic macrofauna living in marine soft sediments can be sensitive indicators of environmental disturbance (Pearson and Rosenberg 1978). Because these animals have limited mobility, many are unable to avoid adverse conditions such as those brought about by natural stressors (e.g., El Niño/La Niña events) or human impacts (e.g., toxic contamination, organic enrichment). Consequently, assessment of benthic communities has been used to monitor the effects of municipal wastewater discharges on the ocean environment (see Zmarzly et al. 1994, Diener et al. 1995, Bergen et al. 2000). Analyses and interpretation of the macrofaunal data collected during 2005 at fixed stations surrounding the PLOO discharge site off San Diego, California are presented in this chapter. Descriptions and comparisons of the different assemblages that inhabit soft bottom sediments in the area and analysis of benthic community structure are included.

MATERIALS AND METHODS

Collection and Processing of Samples

Benthic samples were collected at 22 stations that span 8 km south and 11 km north of the outfall terminus and located along the 88, 98, and 116 m depth contours (**Figure 5.1**). A total of 68 benthic grabs were taken during 2 surveys in 2005. All 22 benthic stations were sampled in July while, sampling in January was limited to the 12 primary core stations located along the 98-m contour

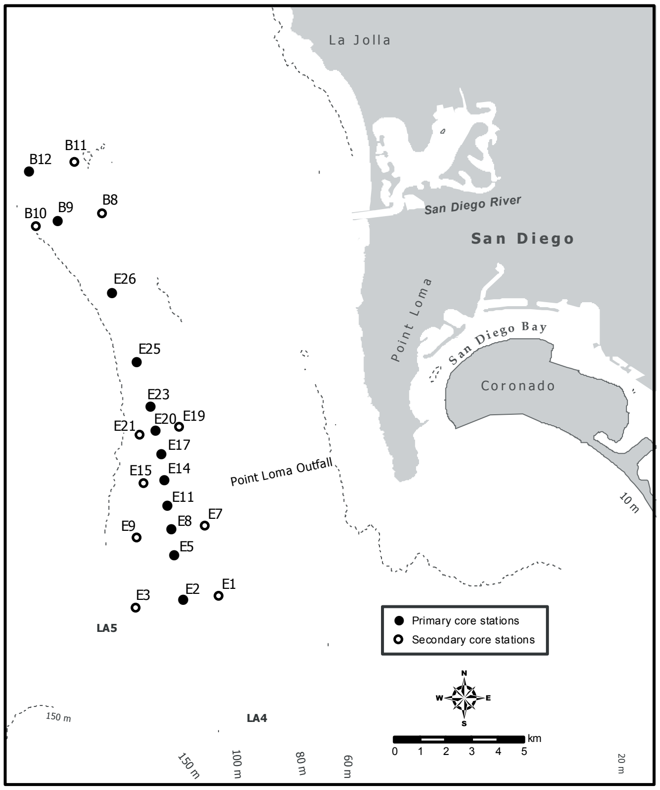


Figure 5.1

Benthic stations surrounding the City of San Diego's Point Loma Ocean Outfall. Primary core stations were sampled in January and July 2005. Secondary core stations were sampled July 2005.

due to participation in special strategic process studies as determined by the City in coordination with the Executive Officer of the RWQCB and the United States Environmental Protection Agency (USEPA) (see City of San Diego 2006). Detailed methods for locating the stations and conducting benthic sampling are described in the City of San Diego Quality Assurance Plan (City of San Diego in prep.).

Samples for benthic community analysis were collected from 2 replicate 0.1 m^2 van Veen grabs per station during each survey. The criteria established by the USEPA to ensure consistency of grab samples were followed with regard to sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0 mm mesh screen. Organisms retained on the screen were relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin (see City of San Diego in prep.). After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups by a subcontractor then identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

Statistical Analyses

Multivariate analyses were performed using PRIMER v5 (Plymouth Routines in Multivariate Ecological Research) software to examine spatio-temporal patterns in the overall similarity of benthic assemblages in the region (see Clarke 1993, Warwick 1993). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). Prior to analysis, macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for comparison in both classification and ordination. SIMPER (similarity percentage) analysis was used to identify individual species that typified each cluster group. Analyses were run on mean abundances of replicate grabs per station/survey to identify distinct cluster groups from 68 samples among 22 stations.

Annual means for the following community parameters were calculated for each station and each cluster group: species richness (number of species); total number of species per site (i.e., cumulative of 2 replicate samples); abundance (number of individuals); biomass (grams, wet weight); Shannon diversity index (H′); Pielou's evenness index (J′); Swartz dominance index (minimum number of species accounting for 75% of the abundance; see Swartz 1978); Infaunal Trophic Index (ITI; see Word 1980) and Benthic Response Index (BRI; see Smith et al. 2001).

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis that there were no changes in various community parameters due to operation of the Point Loma outfall (see Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986, 1992, Osenberg et al. 1994). The BACIP model tests differences between control (reference) and impact sites at times before (i.e., July 1991–October 1993) and after (i.e., January 1994–July 2005) an Aimpact@ event (i.e., the onset of discharge). The analyses presented in this report are based on 2.5 years (10 quarterly surveys) of before impact data and 9 years (44 quarterly or semi-annual surveys) of after impact data. The E stations, located within 8 km of the outfall, are the most likely to be affected by the discharge. Station E14 was selected as the impact site for all analyses; this station is located nearest the Zone of Initial Dilution (ZID) and is probably the site most susceptible to impact. In contrast, the B stations are located farther from the outfall (>11 km) and are the obvious candidates for reference or control sites. However, benthic communities differed between the B and E stations prior to discharge (Smith and Riege 1994, City of San Diego 1995). Thus, 2 stations (E26 and B9) were selected to represent separate control sites in the BACIP tests. Station E26 is located 8 km from the outfall and is considered the E station least likely to be impacted. Previous analyses suggested that station B9 was one of the most appropriate B stations for comparison with the E stations (Smith and Riege 1994, City of San Diego 1995). Six dependent variables were analyzed, including 3 community parameters (number of species, infaunal abundance, ITI) and abundances of 3 taxa that are considered sensitive to organic enrichment. These indicator taxa included ophiuroids in the genus *Amphiodia* (mostly *A. urtica*), and amphipods in the genera *Ampelisca* and *Rhepoxynius*. All BACIP analyses were interpreted using a Type I error rate of $\alpha=0.05$.

RESULTS AND DISCUSSION

Community Parameters

Number of species

A total of 584 macrofaunal taxa were identified during the 2005 PLOO surveys. Mean values of species richness ranged from 93 to 160 species per 0.1 m^2 (**Table 5.1**). As in previous years, the number of species was highest at stations generally characterized by coarser sediments (e.g., E3, E9, B10), as well as the northern reference stations B11 and B12 which historically have been high in species richness (City of San Diego 2005). The lowest species richness was found at stations E5, E8, E21, E23, and B8, all of which had fewer than 100 species.

Polychaetes were the most diverse taxa in the region, accounting for 54% of all species collected during 2005. Crustaceans accounted for 26% of the species, molluscs 9%, echinoderms 6%, and all remaining taxa combined for 5% of the species.

Macrofaunal abundance

Mean macrofaunal abundance averaged 343 to 1074 animals per 0.1 m^2 in 2005 (Table 5.1). The largest number of animals occurred at stations B9 and B8, which averaged 1074 and 606 animals per 0.1 m^2, respectively. The fewest animals (<350 per 0.1 m^2) were collected at stations E14 and E21. The remaining sites had abundances ranging from 361 to 558 animals per 0.1 m^2.

Polychaetes were the most numerous animals, accounting for 62% of the total mean abundance. Crustaceans accounted for 21%, echinoderms 10%, molluscs 5%, and all other phyla combined 2%. There was an apparent change in community structure at E14 compared to 2004. Polychaete numbers decreased from 70% to 65% of the total abundance, while echinoderms (mostly ophiuroids) increased from 4% to 7% (see City of San Diego 2005). The 2 most abundant species collected in 2005 were the polychaete worm, *Prionospio* (*Prionospio) jubata* (n=1516), and the ophiuroid *Amphiodia urtica* (n=1492, not including unidentified juveniles).

Species diversity and dominance

Species diversity (H′) among sites ranged from 3.4 to 5.0 during the year (Table 5.1) which was similar to that observed prior to wastewater discharge (see City of San Diego 1995). The highest diversity occurred along the 98-m contour where every station had H′ >4.4. Diversity was lowest at station B11 (H′=3.4).

Species dominance was expressed as the Swartz 75% dominance index, the minimum number of species comprising 75% of a community by abundance. Therefore, lower index values (i.e., fewer species) indicate higher dominance. Benthic assemblages in 2005 were characterized by relatively high numbers of evenly distributed species (Table 5.1). Dominance averaged 37 species per station, higher than the 30 species per station typical in 2004 (see City of San Diego 2005). The highest Swartz dominance values (≥50) occurred at stations E3 and E9, while the lowest vlaues (≤31) were at stations B8, E8, and E23. Evenness (J′) varied little in 2005, with mean values ranging from 0.7 to 1.1.

Environmental disturbance indices

Mean benthic response index (BRI) values ranged from 3 to 13 at the various stations in 2005. These values suggest that benthic communities in the region are relatively undisturbed, as BRI values below 25 (on a scale of 100) are considered indicative of reference conditions (Smith et al. 2001). The highest value was measured at E14 (13), located nearest the PLOO discharge site. The only other stations with values ≥10 also occurred at 2 sites within 1.8 km of the PLOO (i.e., E11, E21).

Table 5.1

Benthic community parameters at PLOO stations sampled during 2005. Data are expressed as annual means for: species richness, no. species/0.1 m^2 (SR); total cumulative no. species for the year (Tot Spp); abundance/0.1 m^2 (Abun); diversity (H'); evenness (J'); Swartz dominance, no. species comprising 75% of a community by abundance (Dom); benthic response index (BRI); infaunal trophic index (ITI); n = number of replicate grabs.

Station*	n	SR	Tot Spp	Abun	H'	J'	Dom	BRI	ITI
88-m									
B11	2	160	223	471	3.4	0.7	34	4	75
B8	2	97	131	606	3.8	0.8	29	4	80
E19	2	115	154	377	4.1	0.9	39	8	82
E7	2	111	157	431	4.0	0.9	37	5	85
E1	2	119	163	460	4.1	0.9	41	4	87
98-m									
B12	4	133	184	361	5.0	1.0	45	8	77
B9	4	101	139	1074	4.8	1.1	34	3	82
E26	4	101	136	558	4.7	1.0	35	3	83
E25	4	103	132	399	4.7	1.0	34	7	82
E23	4	93	130	395	4.6	1.0	31	7	83
E20	4	102	136	509	4.6	1.0	32	8	82
E17	4	107	146	457	4.7	1.0	33	10	82
E14	4	103	142	343	4.5	1.0	29	13	77
E11	4	103	138	432	4.7	1.1	36	11	80
E8	4	97	133	426	4.5	1.0	31	6	85
E5	4	99	134	425	4.7	1.1	35	3	84
E2	4	108	154	400	4.8	1.1	38	4	86
116-m									
B10	2	143	201	456	4.2	0.8	43	8	75
E21	2	95	133	346	4.0	0.9	35	10	79
E15	2	115	164	379	4.3	0.9	42	7	83
E9	2	150	200	373	4.4	0.9	50	7	78
E3	2	152	207	435	4.5	0.9	57	5	81
All stations	Mean	114	156	460	4.4	1.0	37	7	81
	Min	93	130	343	3.4	0.7	29	3	75
	Max	160	223	1074	5.0	1.1	57	13	87

* 98-m sites = primary core stations sampled during January and July 2005; 88- and 116-m sites = secondary core stations sampled only in July 2005.

Mean ITI values ranged from 75 to 87 per station in 2005 (Table 5.1), and were similar to those reported in previous years (see City of San Diego 2005). These values were indicative of undisturbed sediments or "normal" environmental conditions (see Bascom et al. 1979).

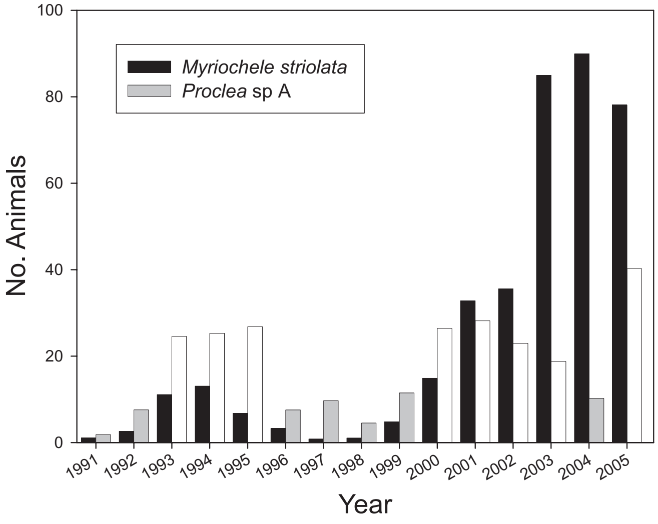
Dominant species

Most assemblages in the Point Loma region were dominated by polychaete worms (**Table 5.2**). For example, 10 polychaetes species, 3 crustaceans, 2 echinoderms, and 1 mollusc were among the dominant macroinvertebrates. The 3 most abundant species were the spionid *Prionospio* (*P.*) *jubata*, the terebellid polychaete *Proclea* sp A, and the ophiuroid *Amphiodia urtica*, each averaging >20 individuals per 0.1 m^2. However, since juvenile ophiuroids are usually identified to only the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae), mean abundances per sample underestimate actual populations of *A. urtica*. The only other species

Table 5.2

Dominant macroinvertebrates at the PLOO benthic stations sampled during 2005. Included are the 10 most abundant species overall, the 10 most abundant per occurrence, and the 10 most frequently collected (or widely distributed) species. Abundance values are expressed as mean number of individuals per 0.1 m^2 grab sample.

Species	Higher taxa	Abundance per sample	Abundance per occurence	Percent occurence
Most abundant				
Prionospio (*P.*) *jubata*	Polychaeta: Spionidae	22.3	22.3	100
Amphiodia urtica	Echinodermata: Ophiuroidea	21.9	23.3	94
Proclea sp A	Polychaeta: Terebellidae	20.1	20.1	100
Myriochele striolata	Polychaeta: Oweniidae	17.2	39.1	44
Euphilomedes carcharodonta	Crustacea: Ostracoda	14.7	15.2	97
Euphilomedes producta	Crustacea: Ostracoda	13.4	13.4	100
Spiophanes duplex	Polychaeta: Spionidae	12.8	12.8	100
Paraprionospio pinnata	Polychaeta: Spionidae	10.7	10.7	100
Amphiodia sp	Echinodermata: Ophiuroidea	10.1	10.1	100
Mediomastus sp	Polychaeta: Capitellidae	9.3	9.3	100
Most abundant per occurence				
Myriochele striolata	Polychaeta: Oweniidae	17.2	39.1	44
Amphiodia urtica	Echinodermata: Ophiuroidea	21.9	23.3	94
Prionospio (*P.*) *jubata*	Polychaeta: Spionidae	22.3	22.3	100
Proclea sp A	Polychaeta: Terebellidae	20.1	20.1	100
Euphilomedes carcharodonta	Crustacea: Ostracoda	14.7	15.2	97
Caecum crebricinctum	Mollusca: Gastropoda	1.3	15.2	9
Euphilomedes producta	Crustacea: Ostracoda	13.4	13.4	100
Spiophanes duplex	Polychaeta: Spionidae	12.8	12.8	100
Hamatoscalpellum californicum	Crustacea: Scalpellidae	0.3	11.5	3
Pholoides asperus	Polychaeta: Pholoidae	1.0	11.0	9
Most frequently collected				
Prionospio (*P.*) *jubata*	Polychaeta: Spionidae	22.3	22.3	100
Proclea sp A	Polychaeta: Terebellidae	20.1	20.1	100
Euphilomedes producta	Crustacea: Ostracoda	13.4	13.4	100
Spiophanes duplex	Polychaeta: Spionidae	12.8	12.8	100
Paraprionospio pinnata	Polychaeta: Spionidae	10.7	10.7	100
Amphiodia sp	Echinodermata: Ophiuroidea	10.1	10.1	100
Mediomastus sp	Polychaeta: Capitellidae	9.3	9.3	100
Spiophanes kimballi	Polychaeta: Spionidae	9.1	9.1	100
Paradiopatra parva	Polychaeta: Onuphidae	8.6	8.6	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.5	8.5	100



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of *Amphiodia* present off Point Loma in 2005 was *A. digitata*, which accounted for about 6% of ophiuroids in the genus *Amphiodia* that could be identified to species (i.e., *A. urtica* = 94%). If values for these taxa are adjusted accordingly, then the estimated population size for *A. urtica* becomes 29 animals per 0.1 m^2 off Point Loma.

Many of these abundant species were dominant prior to discharge and have remained dominant since the initiation of outfall operation in november 1993 (e.g., City of San Diego 1995, 1999, 2004). For example, *A. urtica* has been among the most abundant and most commonly occurring species along the outer shelf since sampling began. However, densities of some numerically dominant polychaetes have been more cyclical. For instance, while *Myriochele striolata* and *Proclea* sp A were among the most abundant polychaetes in 2005, their populations have varied considerably over time (**Figure 5.2**). Such variation can have significant effects on other descriptive statistics (e.g., dominance, diversity, and abundance) and environmental indices such as ITI and BRI that use the abundance of indicator species in their equations.

BACIP Analyses

Significant differences were found between the impact site (station E14) and the control sites (stations E26 and B9) in 7 out of 12 BACIP t-tests (**Table 5.3**). For example, there has been a net change in the mean difference between E14 and both control sites in species richness, ITI values and ophiuroid abundance (*Amphiodia* spp). The difference in species richness may be due to the increased variability and higher numbers of species at the impact site over time (**Figure 5.3A**). Some of the change in species richness between 1995 and 2005 also may be due to increased taxonomic resolution of certain taxa. For example, the polynoid polychaete recorded as *Malmgreniella* sp in 1995 was split into 4 recognizable species by 2005. Differences in *Amphiodia* populations mostly reflect a decrease in the number of these ophiuroids collected at E14 since discharge began (Figure 5.3e). However, 2005 saw an increase in *Amphiodia urtica* populations at E14 along with coincident decreases at the control sites. These changes in ophiuroid abundance in 2005 may be anomalous and future surveys will be needed to identify any lasting trend. Differences in ITI are generally due to lower index values at station E14

Table 5.3

Results of BACIP t-tests for number of species (SR), infaunal abundance, ITI, and the abundance of several representative taxa around the Point Loma Ocean Outfall (1991–2005). Impact site=near-ZID station E14; Control sites=far-field station E26 or reference station B9. Before impact period=July 1991 to October 1993 (n=10); After impact period=January 1994 to July 2005 (n=43). Critical t value=1.680 for α=0.05 (one-tailed t-tests, df=51). ns=not significant .

	Control vs Impact	t	p
	E26 v E14	-3.152	0.001
	B9 v E14	-3.671	<0.001
	E26 v E14	-1.415	ns
	B9 v E14	-2.712	0.005
	E26 v E14	-3.775	<0.001
	B9 v E14	-2.239	0.015
spp	E26 v E14	-7.381	<0.001
	B9 v E14	-5.004	<0.001
spp	E26 v E14	-1.598	ns
	B9 v E14	-0.041	ns
Rhepoxynius spp	E26 v E14	-0.830	ns
	B9 v E14	-0.922	ns

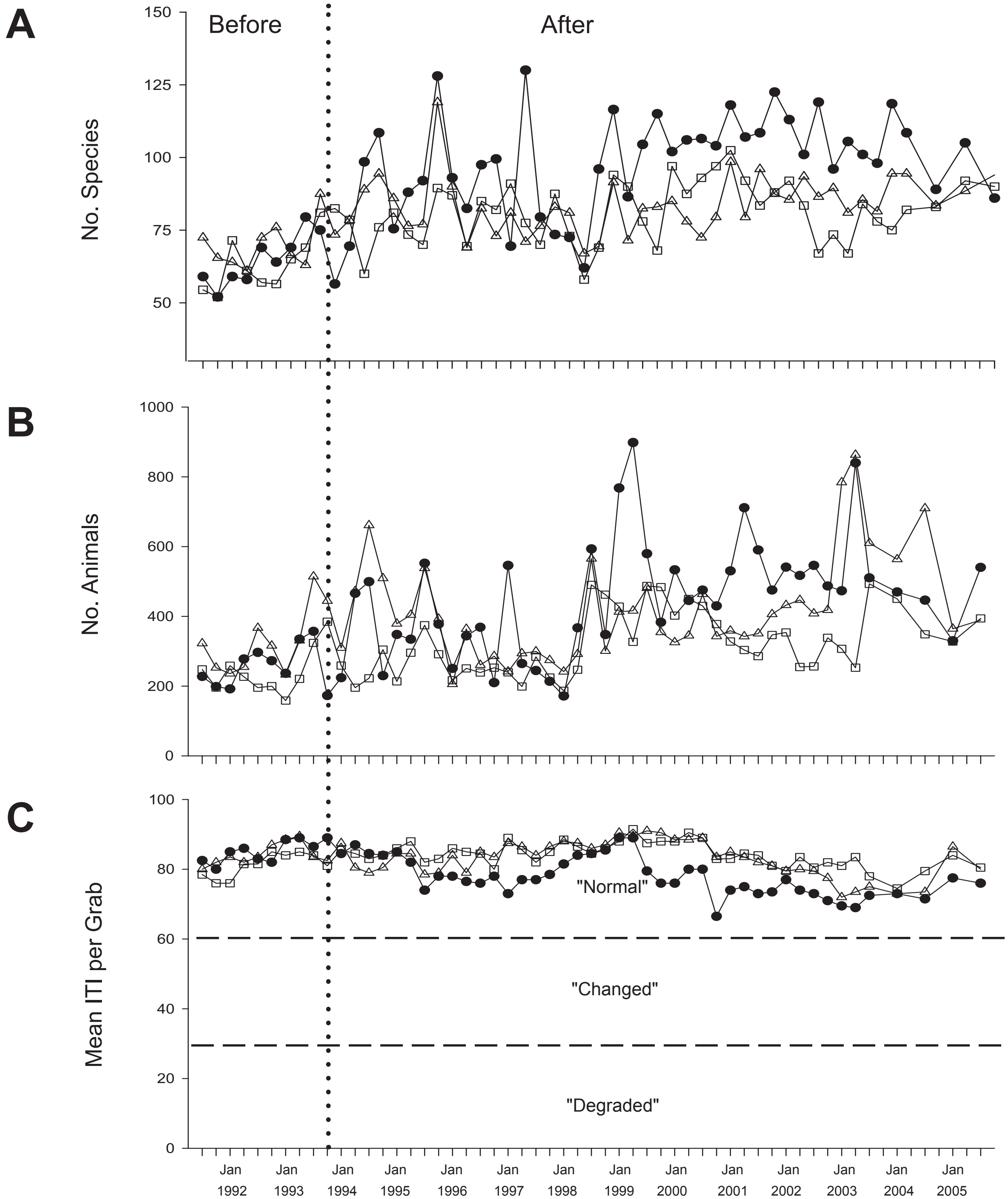


Figure 5.3

Comparison of several parameters at "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.3). Data for each station are expressed as means per 0.1 m^2 (n=2 per survey). (A) Number of infaunal species; (B) infaunal abundance; (C) infaunal trophic index (ITI); (D) abundance of *Ampelisca* spp (Amphipoda); (E) abundance of *Amphiodia* spp (Ophiuroidea).

over several prolonged periods (July 1995–July 1999 and October 1998–present, Figure 5.3C). These decreased ITI values may in part be explained by the historically lower numbers of *Amphiodia*. The results for total infaunal abundances were more ambiguous (Figure 5.3B, Table 5.3). Although a significant change is indicated between the impact site and station B9, no such pattern has been found regarding the second control site (E26). Finally, there was no net change in the mean difference between

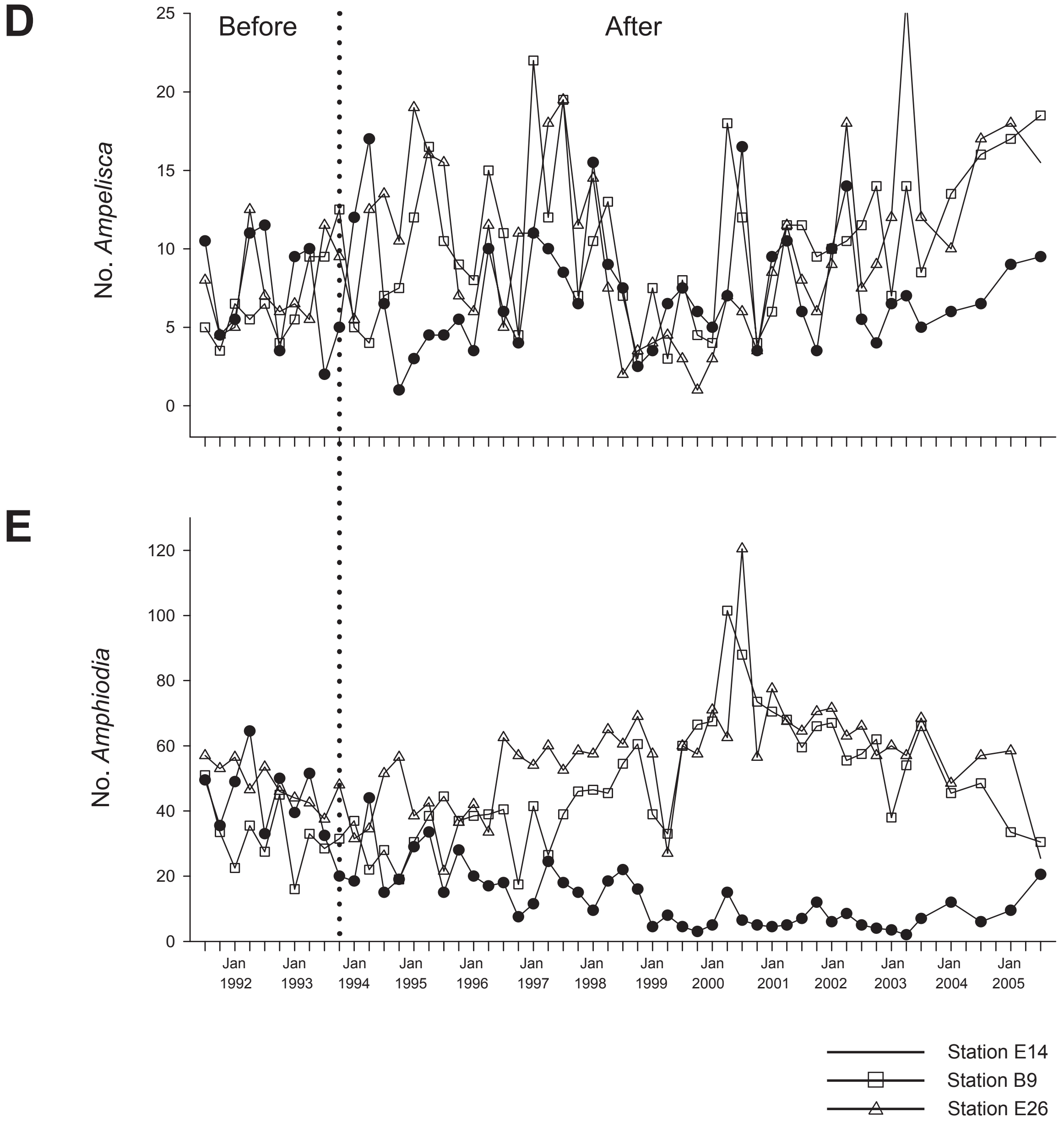


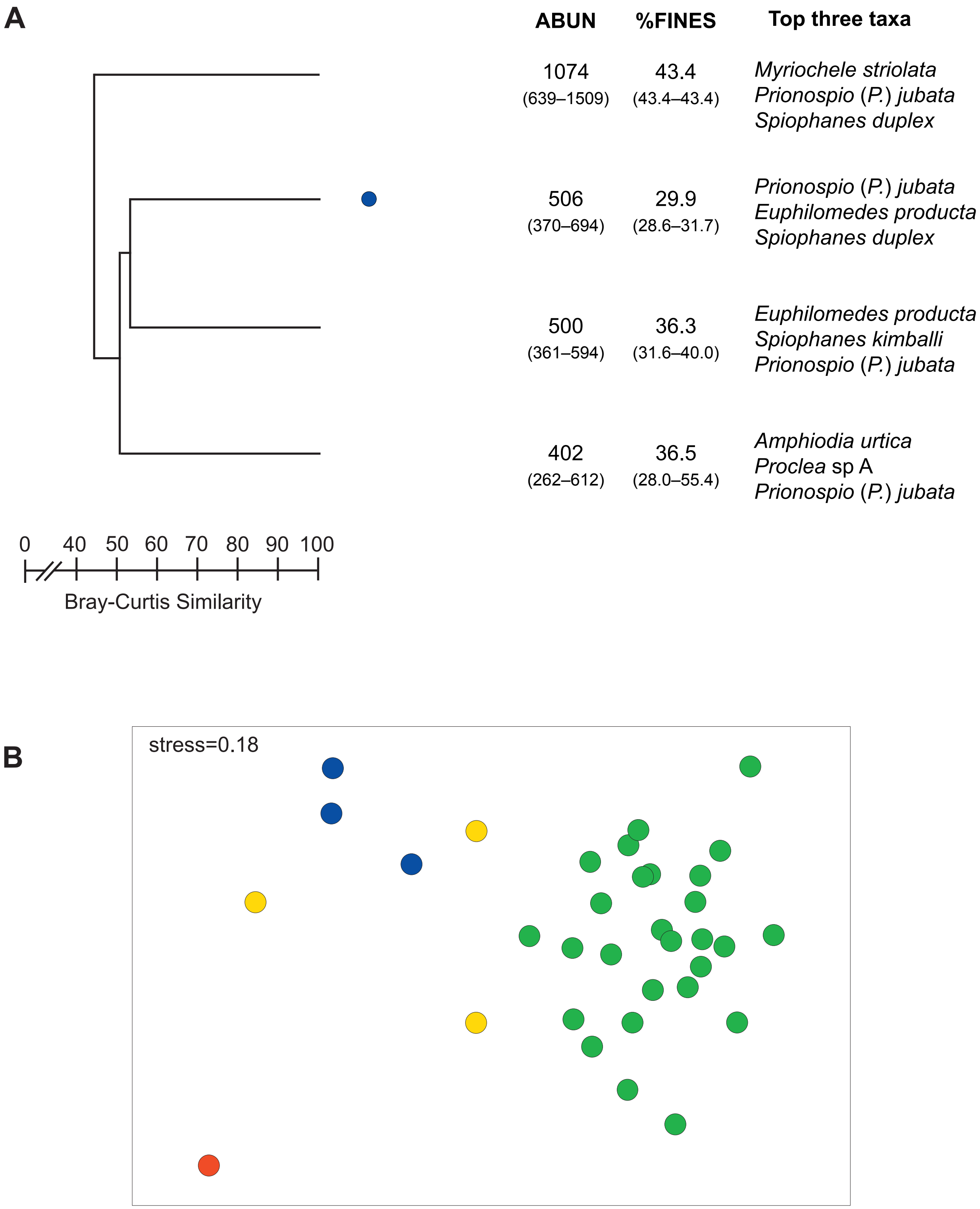
Figure 5.3 Continued

impact and control sites in numbers of ampeliscid or phoxocephalid amphipods.

Classification of Benthic Assemblages

Classification analyses discriminated differences between 4 main benthic assemblages (cluster groups A–D) during 2005 **(Figures 5.4, 5.5)**. These assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances. The dominant species for each assemblage are listed in **Table 5.4**. Additionally, a MDS ordination of the survey entities confirmed the validity of the major cluster groups (Figure 5.4).

Cluster group A comprised a single northern station located along the 88-m contour (B11). This station was sampled on during July in 2005. Sediments at this site were mixed with both a relatively high percentage of fine particles (~43%) and the most coarse particles among all cluster groups (~4.7%). This assemblage also had the highest average abundance (1074 per 0.1 m^2) and species richness



ABUN	%FINES	Top three taxa
1074 (639–1509)	43.4 (43.4–43.4)	*Myriochele striolata* *Prionospio* (*P.*) *jubata* *Spiophanes duplex*
506 (370–694)	29.9 (28.6–31.7)	*Prionospio* (*P.*) *jubata* *Euphilomedes producta* *Spiophanes duplex*
500 (361–594)	36.3 (31.6–40.0)	*Euphilomedes producta* *Spiophanes kimballi* *Prionospio* (*P.*) *jubata*
402 (262–612)	36.5 (28.0–55.4)	*Amphiodia urtica* *Proclea* sp A *Prionospio* (*P.*) *jubata*

Figure 5.4
(A) Cluster
are expressed
species; ABUN=number
of PLOO benthic
data for each
between major faunal assemblages.

(160 species per 0.1 m^2) compared to the other cluster groups. The oweniid polychaete *Myriochele striolata* was the overwhelmingly dominant species characterizing this assemblage, averaging more than 460 animals per 0.1 m^2. In contrast, the next two most abundant species, *Prionospio* (*P.*) *jubata* and *Spiophanes duplex* each averaged fewer than 50 worms per sample. The ophiuroid *Amphiodia urtica* (adults and juveniles) averaged 27 individuals per sample.

Cluster group B included 1 site each along the 98 and 116-m contours. Sediments associated with cluster group B had relatively high amounts of sand and the lowest percentage of fine particles (30%) compared to the other groups. As is typical of these sites, species richness was relatively high (136 species per 0.1 m^2). The spionid polychaete *Prionospio* (*Prionospio*) *jubata* was among the dominant animals in this assemblage. Other dominant species included the ostracod *Euphilomedes producta* and the spionid polychaete *Spiophanes duplex.*

Cluster group C represented samples from 3 southern stations, 2 along the 116-m contour (E3, E9), and the July sample from station E2 along the 98-m contour. Sediments at these stations were mixed, composed of silt and sand with some coarse materials and rock. This assemblage averaged 500 individuals and 142 species per 0.1 m^2. The dominant species in this group were the ophiuroid *Amphiodia urtica* (adults and juveniles), and the polychaetes *Spiophanes kimballi* and *Prionospio* (*P.*) *jubata*.

Cluster group D was the largest assemblage in 2005, representing 79% of the samples from 17 stations. The sediments of this cluster group were characterized by silty sand with ~37% fines. Infauna averaged 402 individuals and 102 species per 0.1 m^2, the lowest among all cluster groups. Dominant taxa included ophiuroids (i.e., *Amphiodia urtica*, *Amphiodia* sp, and Amphiuridae) as well as the terebellid polychaete *Proclea* sp A and *Prionospio* (*Prionospio*) *jubata*. Station E14 located nearest to the PLOO discharge site was included in this group. Historically, this station has not clustered with reference stations (City of San Diego 2004, 2005). However, an increase in the abundance of the ophiuroid *Amphiodia urtica* in 2005 altered the community structure at E14 making it statistically more similar to the other stations in this cluster group.

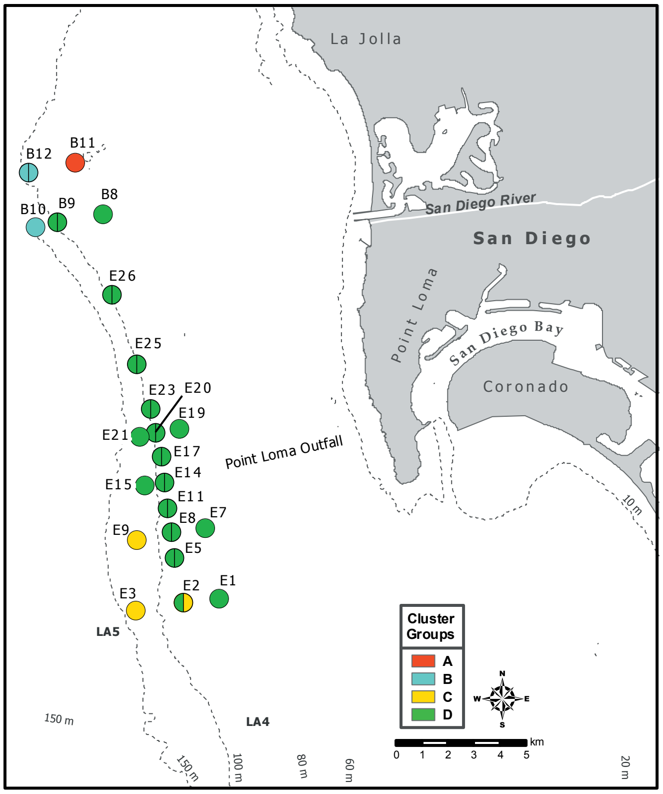


Figure 5.5

Results of ordination and classification analyses of macrofaunal abundance data during 2005. Cluster groups are color-coded on the map to reveal spatial patterns in the distribution of benthic assemblages.

SUMMARY AND CONCLUSIONS

Benthic communities around the PLOO continue to be dominated by ophiuroid-polychaete based assemblages, with few major changes having occurred since monitoring began (see City of San Diego 1995, 2004). Polychaetes continue to be the most abundant and diverse infauna in the region. Although many of the 2005 assemblages were dominated by similar species, the relative abundance of these species varied between sites. In contrast to 2004, the oweniid polychaete *Myriochele striolata* dominated just a single assemblage (cluster

Table 5.4

Summary of the most abundant taxa composing cluster groups A–D from the PLOO benthic stations surveyed in 2005. Data are expressed as mean abundance per sample (no./0.1m^2) and represent the 10 most abundant taxa in each group. Animals absent from a cluster group are indicated by a dash. The 3 most abundant taxa in each cluster group are bolded.

		Cluster group			
Species/Taxa	**Higher taxa**	**A** (n=1)	**B** (n=3)	**C** (n=3)	**D** (n=27)
Amphiodia sp	Echinodermata: Ophiuroide	6.0	2.2	8.8	11.3
Amphiodia urtica	Echinodermata: Ophiuroidea	17.5	1.5	14.3	**25.2**
Amphiuridae	Echinodermata: Ophiuroidea	3.5	2.7	5.5	9.3
Caecum crebricinctum	Mollusca: Gastropoda	—	14.3	0.8	—
Chaetozone hartmanae	Polychaeta: Cirratulidae	10.0	9.5	5.0	8.7
Euphilomedes carcharodonta	Crustacea: Ostracoda	7.0	8.0	6.0	16.7
Euphilomedes producta	Crustacea: Ostracoda	1.5	**27.2**	**21.7**	11.4
Exogone lourei	Polychaeta: Syllidae	3.0	0.8	9.5	0.2
Leptochelia dubia	Crustacea: Tanaidacea	14.0	7.8	3.0	2.5
Mediomastus sp	Polychaeta: Capitellidae	13.5	11.0	18.5	7.9
Myriochele striolata	Polychaeta: Oweniidae	**466.0**	0.7	—	4.4
Paradiopatra parva	Polychaeta: Onuphidae	3.5	19.3	10.5	7.4
Paraprionospio pinnata	Polychaeta: Spionidae	10.5	17.2	8.2	10.2
Pherusa negligens	Polychaeta: Flabelligeridae	11.5	0.3	—	0.0
Phisidia sanctaemariae	Polychaeta: Terebellidae	2.5	2.8	9.7	8.0
Pholoides asperus	Polychaeta: Pholoidae	24.5	—	2.8	—
Photis californica	Crustacea: Amphipoda	13.5	3.0	1.7	0.5
Prionospio (*Prionospio*) *jubata*	Polychaeta: Spionidae	**28.5**	**32.5**	**19.2**	**21.3**
Proclea sp A	Polychaeta: Terebellidae	3.0	1.7	15.8	**23.3**
Spiophanes berkeleyorum	Polychaeta: Spionidae	13.0	15.5	4.2	7.1
Spiophanes duplex	Polychaeta: Spionidae	**45.5**	**22.8**	15.3	10.2
Spiophanes kimballi	Polychaeta: Spionidae	8.5	12.0	**20.2**	7.6

group A). *Prionospio* (*P.*) *jubata* was the most widespread benthic invertebrate in the region, being dominant or co-dominant in all assemblages. Adult and presumed juvenile *Amphiodia urtica* combined were the most abundant taxon. Assemblages similar to those off Point Loma have been described for other areas in the Southern California Bight (SCB) by Barnard and Ziesenhenne (1961), Jones (1969), Fauchald and Jones (1979), Thompson et al. (1987, 1992, 1993), Zmarzly et al. (1994), Diener and Fuller (1995), and Bergen et al. (1998, 2000).

Although variable, benthic communities off Point Loma generally have remained similar between years in terms of the number of species, number of individuals, and dominance (City of San Diego 1995, 2005). In addition, values for these parameters in 2005 were similar to those described for other sites throughout the SCB (e.g., Thompson et al. 1992, Bergen et al. 1998, 2001). In spite of this overall stability, there has been an increase in the number of species and macrofaunal abundance since discharge began (see City of San Diego 1995, 2004). However, the increase in species has been most pronounced nearest the outfall, suggesting that significant environmental degradation is not occurring in the area. In addition, the observed increases in abundance at most stations have been accompanied by decreases in dominance, a pattern inconsistent with predicted pollution effects.

Whatever the cause of such changes, benthic communities around the PLOO are not numerically dominated by a few pollution tolerant species. For example, the opportunistic polychaete *Capitella capitata*, which is associated with degraded soft bottom habitats, continues to be found in low numbers off Point Loma. Only 29 individuals were found among all stations in 2005, with 15 (52%) recorded at E14. In heavily polluted environments, *Capitella capitata* can reach densities of >500 individuals per 0.1 m^2 and constitute as much as 85% of the total abundance (Swartz et al. 1986).

Changes near the outfall suggest some effects are coincident with anthropogenic activities. Benthic response index (BRI) values are higher at stations nearest the outfall (E14, E11, E17, and E21) than at other sites in the region In addition, a decrease in the infaunal trophic index (ITI) at station E14 after discharge began may be considered indicative of organic enrichment or some other type of disturbance (see City of San Diego 1995, 2004). However, both BRI and ITI values at this and all other sites remain characteristic of undisturbed areas. In addition, the increased variability in number of species and infaunal abundance at E14 since discharge began may be indicative of community destabilization (see Warwick and Clarke 1993, Zmarzly et al. 1994). The instability or patchiness of sediments near the PLOO and the corresponding shifts in assemblages suggest that changes in this area may be related to localized physical disturbance (e.g., shifting sediment types) associated with the structure of the outfall pipe as well as to organic enrichment associated with the discharge of effluent.

Populations of some indicator taxa revealed changes that correspond to organic enrichment near the outfall, while populations of others revealed no evidence of impact. For example, since 1997, there has been a significant change in the difference between ophiuroid (*Amphiodia* spp) populations that occur near the outfall (i.e., station E14) and those present at reference sites, though 2005 was an exception. This difference is due mostly to a historic decrease in numbers of ophiuroids near the outfall as compared to those at the control sites during the post-discharge period. Although long term changes in *Amphiodia* populations at E14 are likely to be related to organic enrichment, predation pressure from fish, altered sediment composition or some other factor, abundances of *Amphiodia* off Point Loma are still within the range of those occurring naturally in the SCB. In addition, natural population fluctuations of these and other resident organisms (e.g. *Myriochele striolata* and *Proclea* sp A) are common off San Diego (Zmarzly et al. 1994, Deiner et al. 1995). Further complicating the picture, stable patterns in populations of pollution sensitive amphipods (i.e., *Rhepoxynius, Ampelisca*) and a limited presence of pollution tolerant species (e.g., *Capitella capitata*) do not offer strong evidence of outfall-related effects. In 2005, station E14 saw an increase in the abundance of the pollution sensitive ophiuroid, *Amphiodia urtica*, as well as a decrease in abundances of *Capitella capitata*. Continued sampling in future years will help to determine if this is a trend in the shift of community structure or a temporal anomaly.

While it is difficult to detect specific effects of the PLOO on the offshore benthos, it is possible to see some changes occurring nearest the discharge site (e.g., E14). Because of the minimal extent of these changes, it has not been possible to conclusively determine whether the observed effects are due solely to the physical structure of the outfall pipe or to organic enrichment in the area. Such impacts have spatial and temporal dimensions that vary depending on a range of biological and physical factors. In addition, abundances of soft bottom invertebrates exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, 1992b, Otway 1995). The effects associated with the discharge of advanced primary treated and secondary treated sewage may be negligible or difficult to detect in areas subjected to strong currents that facilitate the dispersion of the wastewater plume (see Diener and Fuller 1995). Although some changes in benthic assemblages have appeared near the outfall, assemblages in the region are still similar to those observed prior to discharge and to natural indigenous communities characteristic of the southern California continental shelf.

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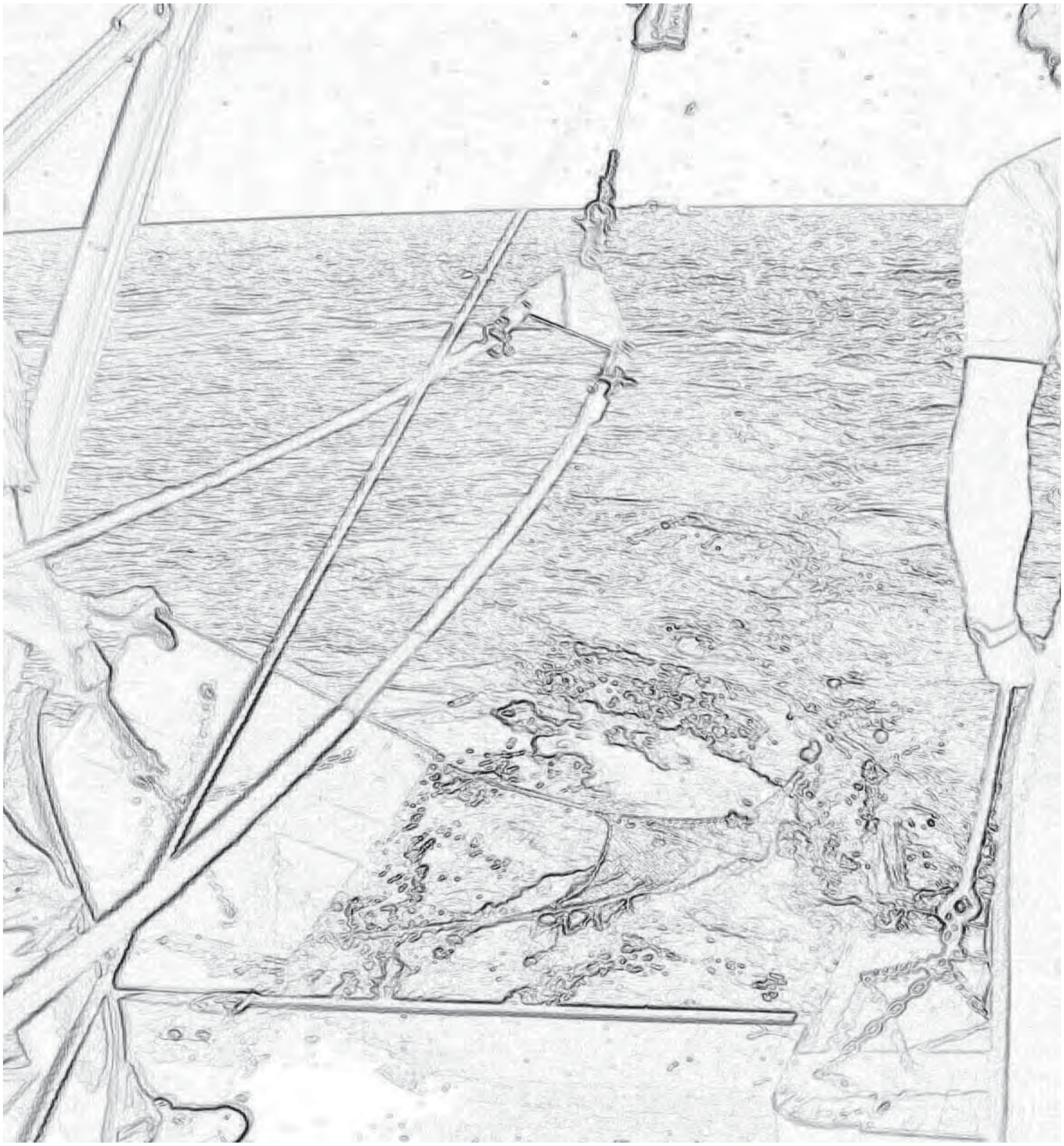
Chapter 6
Demersal Fishes
and Megabenthic Invertebrates



Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Demersal fishes and megabenthics are conspicuous members of continental shelf and slope habitats, and assessment of their communities has become an important focus of ocean monitoring programs throughout the world. Such assemblages have been sampled for more than 30 years on the mainland shelf of the Southern California Bight (SCB), primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of demersal fish inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998). For the region surrounding the Point Loma Ocean Outfall (PLOO), the most common trawl-caught fishes include Pacific sanddab, longfin sanddab, Dover sole, hornyhead turbot, California tonguefish, plainfin midshipman, and yellowchin sculpin. Common trawl-caught invertebrates include relatively large taxa such as sea urchins and sea stars.

The structure of these communities is inherently variable and may be influenced by both anthropogenic and natural factors. Anthropogenic factors, such as inputs from ocean outfalls and storm drain runoff, can impact demersal fishes and megabenthic invertebrates because they live in close proximity to sediments potentially altered by these inputs. Natural factors include prey availability (Cross et al. 1985), bottom relief and sediment structure (Helvey and Smith 1985), and changes in water temperature associated with large scale oceanographic events such as El Niños (Karinen et al. 1985). These natural factors can impact the migration of adult fish or the recruitment of juveniles into an area (Murawski 1993). Population fluctuations that affect diversity and abundance may also be due to the mobile nature of many species (e.g., schools of fish or aggregations of urchins).

The City of San Diego Ocean Monitoring Program was designed to monitor the effects of the Point Loma Ocean Outfall (PLOO) on the local marine environment. This chapter presents analyses and interpretation of demersal fish and megabenthic invertebrate data collected under this program during 2005. A long-term analysis of changes in these communities from 1991 through 2005 is also presented.

MATERIALS AND METHODS

Field Sampling

A total of 12 trawls were performed during 2 surveys off Point Loma in 2005. The trawling area extends from about 8 km north to 9 km south of the PLOO. Six stations (SD7, SD8, SD10, SD12, SD13, SD14) are located along the 100-m contour and were sampled during January and July (**Figure 6.1**). A single trawl was performed at each station using a 7.6-m Marinovich otter trawl fitted with a 1.3-cm cod-end mesh net. The net was towed for 10 minutes

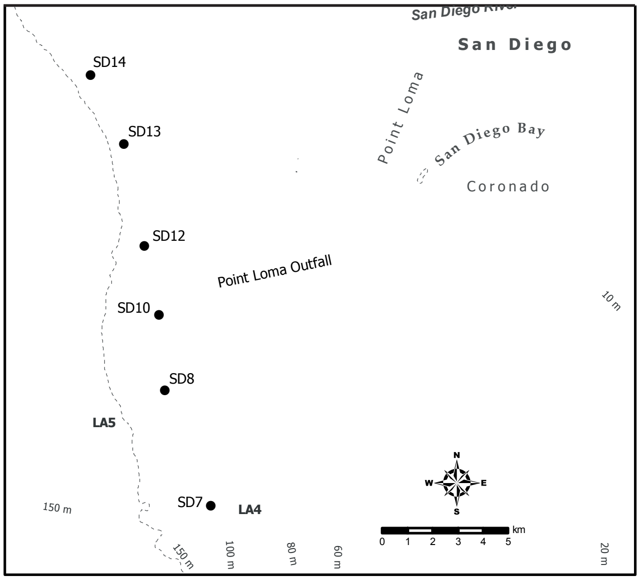


Figure 6.1
Otter trawl station locations, Point Loma Ocean Outfall Monitoring Program.

bottom time at a speed of about 2.5 knots along a predetermined heading. Detailed methods for locating the stations and conducting trawls are described in the City of San Diego Quality Assurance Plan (City of San Diego in prep).

Trawl catches were brought on board ship for sorting and inspection. All organisms were identified to species or to the lowest taxon possible. If an animal could not be identified in the field, it was returned to the laboratory for further identification. For fish, the total number of individuals and total biomass (wet weight, kg) were recorded for each species. Additionally, each individual fish was inspected for the presence of external parasites or physical anomalies (e.g., tumors, fin erosion, discoloration) and measured to the nearest centimeter according to standard protocols (see City of San Diego in prep). When extremely large hauls of fish were obtained, a 10 kg subsample was size classed. Total abundance was then estimated by multiplying the number of individuals per 1.0 kg by the total fish biomass, and the number of fish per size class was estimated based on the proportion of each size class in the measured fish. For invertebrates, the total number of individuals was recorded per species. When the white sea urchin, *Lytechinus pictus,* was collected in large numbers, its abundance was estimated by multiplying the total number of individuals per 1.0 kg subsample by the total urchin biomass.

Data Analyses

Populations of each fish and invertebrate species were summarized in terms of percent abundance, frequency of occurrence and mean abundance per occurrence. In addition, species richness (number of species), total abundance, and Shannon diversity index (H') were calculated for both fish and invertebrate assemblages at each station. Total biomass was also calculated for each fish species by station.

Multivariate analyses were performed on the 6 stations using PRIMER software to examine spatio-temporal patterns in the overall similarity of fish assemblages in the region (see Clarke 1993, Warwick 1993). These analyses consisted of classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking. The fish abundance data were square-root transformed and the Bray-Curtis measure of dissimilarity was used as the basis for classification. The SIMPER ("similarity percentages") analysis was used to identify individual species that determined inter- and intra- group differences.

RESULTS

Fish Community

Thirty-five species of fish were collected in the area surrounding the PLOO during 2005 (**Table 6.1**). The total catch for the year was 7596 fishes representing an average of 633 individuals/haul. Halfbanded rockfish was the overall most abundant taxon collected in 2005, although most of the individuals occurred in just 2 hauls. The 2 trawls collected at stations SD10 and SD12 in January included 2537 hafbanded rockfish, representing 1/3 of the total catch. Only 292 other halfbanded rockfish were collected from the remaining 10 trawls. Overall this species accounted for 37% of the total catch. Pacific sanddab, typically the most abundant fish in this area, was the second most abundant species (2532 individuals) and comprised 33% of the total catch. These 2 species, as well as Dover sole, yellowchin sculpin, plainfin midshipman, and shortspine combfish occurred in every haul. Other common fishes present in at least half of the hauls were longspine combfish, slender sole, English sole, pink seaperch, stripetail rockfish, greenstriped rockfish, California tonguefish, roughback sculpin, greenspotted rockfish, and hornyhead turbot. These 10 species tended to be relatively small with average lengths <20 cm (**Appendix C.1**).

Fish abundance and biomass were highly variable during 2005. Mean abundance ranged from 288 to 1368 fish per haul (**Table 6.2**). The largest hauls were collected at both of the nearfield stations, SD10 and SD12, due to the large halfbanded rockfish catches described above. Among the farfield station pairs, abundances at northern stations SD13 and SD14 was nearly twice that of southern stations SD7 and SD8.

Table 6.1

Demersal fish species collected in 12 trawls in the PLOO region during 2005. Data for each species are expressed as: percent abundance (PA); frequency of occurrence (FO); mean abundance per occurrence (MAO).

Species	PA	FO	MAO
Halfbanded rockfish	37	100	236
Pacific sanddab	33	100	211
Longspine combfish	8	92	52
Dover sole	7	100	47
Yellowchin sculpin	5	100	31
Plainfin midshipman	2	100	10
Shortspine combfish	1	100	7
Slender sole	1	50	12
English sole	1	83	6
Pink seaperch	1	92	5
Stripetail rockfish	1	50	9
Greenstriped rockfish	1	92	4
Spotfin sculpin	<1	25	9
California tonguefish	<1	58	4
Squarespot rockfish	<1	17	13
Roughback sculpin	<1	58	3
Blacktip poacher	<1	33	5
Greenspotted rockfish	<1	50	4
Greenblotched rockfish	<1	42	3
Hornyhead turbot	<1	67	2
Bigfin eelpout	<1	17	6
Blackbelly eelpout	<1	25	3
Juvenile rockfish	<1	17	2
Pygmy poacher	<1	33	2
California skate	<1	33	2
Spotted cuskeel	<1	33	2
Chilipepper rockfish	<1	8	4
Bigmouth sole	<1	25	1
Bluespotted poacher	<1	17	1
Juvenile sanddab	<1	8	2
Pacific argentine	<1	17	1
Bay goby	<1	8	1
Bluebanded ronquil	<1	8	1
Flag rockfish	<1	8	1
Longfin sanddab	<1	8	1
Pink rockfish	<1	8	1
Shiner perch	<1	8	1

As in past years, this difference was primarily due to substantial numbers of Pacific sanddab present at SD13 and SD14 (**Appendix C.2**). The wide range in total fish biomass per haul (mean=4.4–24.6 kg) was generally due to large hauls of halfbanded rockfish and Pacific sanddabs, which resulted in relatively high biomass where they occurred in high numbers.

Table 6.2

Summary of demersal fish community parameters for PLOO stations sampled during 2005. Data are presented for cumulative (total) and mean number of species, abundance, diversity (H'), and biomass (BM) (kg, wet weight); n=2 for each station.

	No. of Species				
Station	Total	Mean	Abund	H'	BM
SD7	19	15	288	1.40	4.4
SD8	22	17	315	1.48	5.7
SD10	24	18	1368	1.03	24.6
SD12	22	17	762	1.56	11.3
SD13	26	19	562	1.66	10.3
SD14	23	18	506	1.55	14.3

For example, the highest biomass of any haul (38.1 kg) occurred at station SD10 in January and was due to large numbers (1929) of halfbanded rockfish weighing approximately 33 kg.

In contrast to abundance and biomass, values for species richness and diversity (H') varied little and were relatively low in 2005 (Table 6.2). The mean number of species ranged from 15 to 19 per haul, while the (cumulative) total number of species was less than 30 at all stations over the year. Diversity values were less than 2 at all stations. These relatively low diversity values are due to the predominance of Pacific sanddabs or, in the case of SD10 and SD12, halfbanded rockfish.

Fluctuating populations of dominant species have been the primary factor contributing to variation in the structure of the fish community off Point Loma since 1992 (**Figure 6.2, Figure 6.3**). For example, mean species richness has remained fairly consistent over the years, ranging from 10 to 20 species per station, while mean abundances have fluctuated substantially (e.g., 93–1368 individuals) (Figure 6.2). These fluctuations in abundance have been greatest at stations SD10, SD12, SD13, SD14 and generally reflect differences in populations of several dominant species, especially the Pacific sanddab (Figure 6.3). Overall, none of the observed changes appear to be associated with wastewater discharge from the Point Loma outfall.

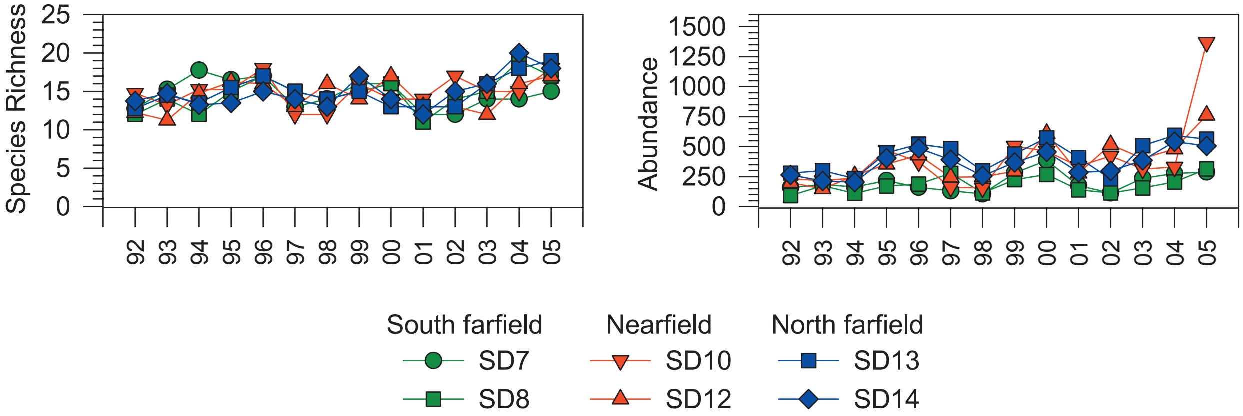


Figure 6.2
Annual mean species richness (number of species) and abundance (number of individuals) per PLOO station of demersal fish collected from 1992 through 2005; n=4 1992-2002, n=3 in 2003, and n=2 during 2004-2005.

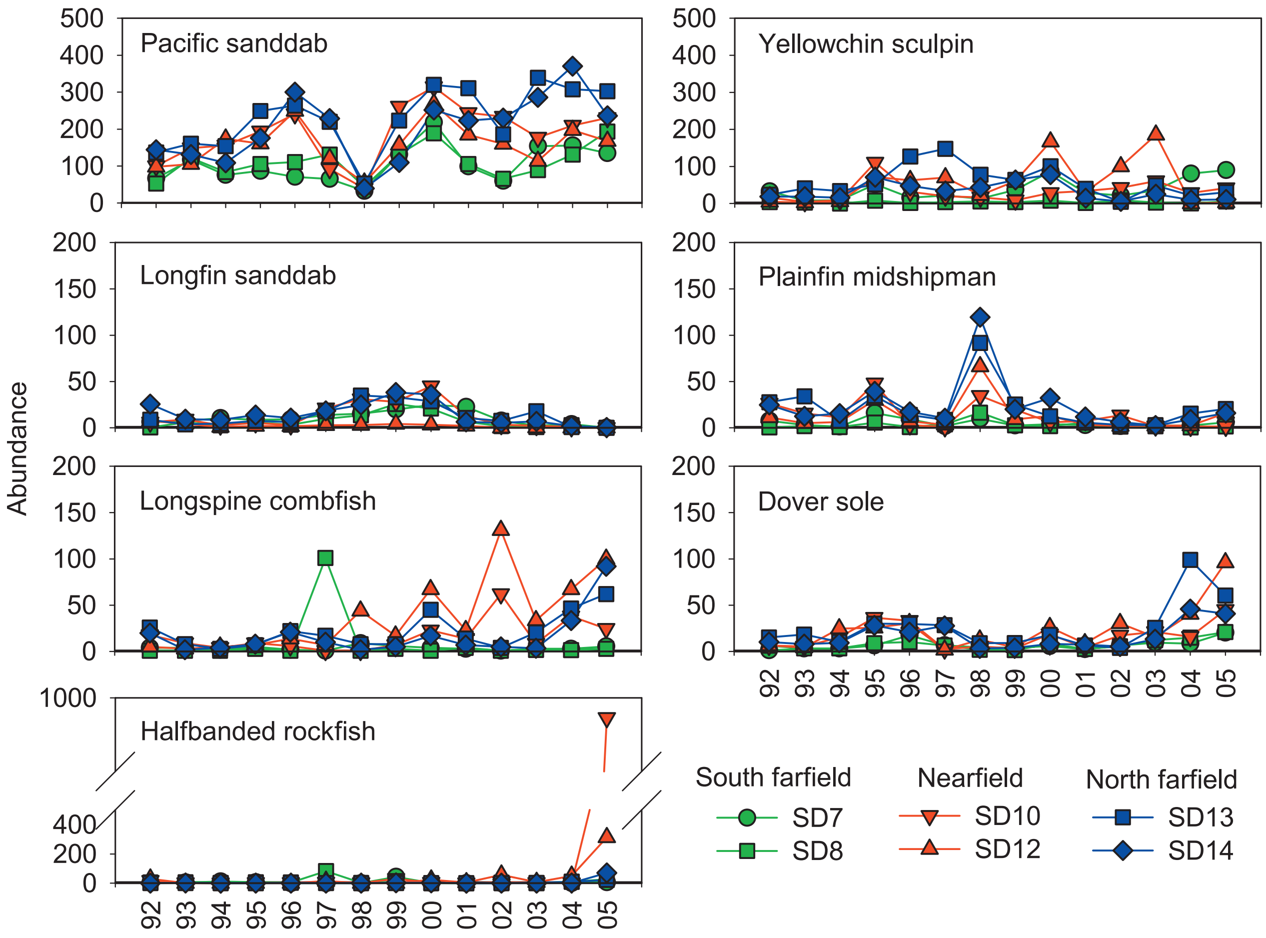


Figure 6.3
Annual mean abundance (number of individuals) per PLOO station for the seven most abundant fish species collected from 1992 through 2005; n=4 1992-2002, n=3 in 2003, and n=2 during 2004-2005.

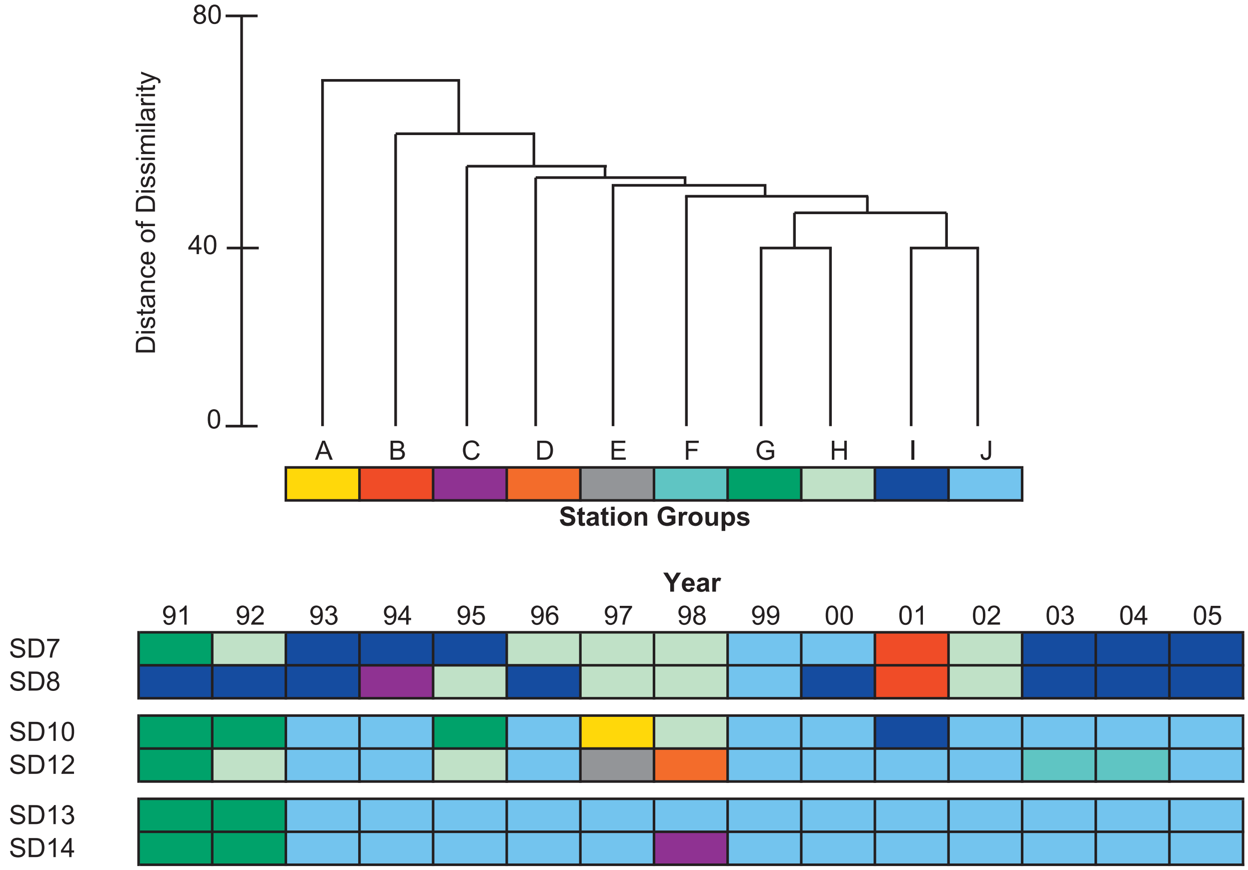


Figure 6.4

Results of ordination and classification analysis of demersal fish collected at PLOO stations SD7–SD14 between 1991 and 2005 (July surveys only). Data are also presented as a matrix showing distribution over time.

Classification analyses of fish data from July surveys between 1991 and 2005 resulted in 10 major cluster groups (station groups A–J) (see **Figure 6.4**). All of the assemblages were dominated by Pacific sanddabs and were differentiated by relative abundances of this and other common species, or by the presence of rare species. None of these differences appear to be associated with the PLOO discharge during 2005 or in years past. Instead, differences in fish assemblages seem to be related to oceanographic events (e.g., El Niño conditions in 1991/1992 and 1998) or location. For example, stations SD7, SD8, and SD12 frequently grouped apart from the remaining stations. Characteristic species for each station group are described below (**Table 6.3**).

Station groups A–F comprised 6 unique assemblages formed by 1 or 2 station/survey entities. Each of these groups was unique in terms of size (i.e., lower species richness and abundances) and/or composition (e.g., fewer of the more common flatfish such as Pacific sanddabs). Groups A, B, and C were all fairly small, averaging 7–11 species and less than 75 individuals per haul. Pacific sanddabs dominated the assemblages represented by groups A–C, but average abundance was low relative to the other assemblages. Other important species in these groups included halfbanded rockfish (group A), bigmouth sole and yellowchin sculpin (group B), and Dover sole (group C). Groups D, E, and F were composed solely of station SD12 in 1998, 1997, and 2003–2004, respectively. These 3 station groups were similar in size to the remaining 4 groups (G, H, I, J) but differed in composition. For example, group E was unique due to the presence of squarespot rockfish and vermilion rockfish (Table 6.3).

Table 6.3

Summary of the most abundant species comprising station groups A–J defined in Figure 6.4. Data include number of hauls, overall similarity within each group, mean species richness, and mean abundance for each station group, as well as the mean abundance of species that together account for 90% of the similarity (or 90% of total abundance for groups with n < 2). Values in bold type indicate the species that are most representative of a station group (i.e., 3 highest similarity/SD values > 2 for groups with n > 2, or highest abundance for groups with n </= 2).

	Group A	**Group B**	**Group C**	**Group D**	**Group E**	**Group F**	**Group G**	**Group H**	**Group I**	**Group J**
Number of hauls	1	2	2	1	1	2	9	12	15	45
Overall similarity	na	57	62	na	na	70	65	60	61	63
Mean species richness	7	11	11	16	19	15	12	12	16	15
Mean abundance	44	68	74	261	231	274	217	100	209	376
Species	**Mean Abundance**									
Bigmouth sole		**3**								
Blackbelly eelpout						6				
California tonguefish								4	3	
Dover sole			**6**	**36**		**32**	**14**	**9**	**14**	**30**
Juv sanddab							2			
Greenblotched rockfish			2		8					
Greenspotted rockfish	**1**									
Greenstriped rockfish			1							
Gulf sanddab	**1**									
Halfbanded rockfish	**16**				**60**	27			3	7
Longfin sanddab	**1**	3					4	**6**	3	8
Longspine combfish			**2**	7		**34**			2	15
Pacific sanddab	**23**	**46**	**48**	**75**	**110**	**105**	**118**	**61**	**143**	**247**
Pink seaperch	**1**								2	5
Plainfin midshipman			2	**116**			**41**	5	2	9
Roughback sculpin		2								
Shortspine combfish						12		2	**6**	
Slender sole						27				6
Spotfin sculpin	**1**								6	
Spotted cuskeel						2				
Squarespot rockfish					**23**					
Stripetail rockfish							22			15
Vermilion rockfish					6					
Yellowchin sculpin		**5**						4	9	**16**

Station group G comprised most stations sampled during the 1991/1992 El Niño, as well as station SD10 sampled in 1995. This assemblage averaged 12 species and 217 individuals per haul and was dominated by Pacific sanddabs, Dover sole, and plainfin midshipman. It differed from the other assemblages in the relative contributions of gulf sanddab, greenblotched rockfish, greenstriped rockfish, and shortspine combfish.

Station groups H and I included some hauls from stations SD10 and SD12, but consisted primarily of fish assemblages from the southern farfield stations SD7 and SD8 during two different temperature regimes. Group H contained one or both of these stations from 1992, 1995–1998, and 2002 while group I contained one or both of these stations from 1991–1996 and 2003–2005. Group H averaged 12 species and an abundance of just 100 individuals per haul. The assemblage represented by this group was dominated by Pacific sanddab, Dover sole, and longfin sanddab. They differed from the other assemblages in the relative contributions of shortspine combfish, halfbanded rockfish, and Dover sole. Although Pacific sanddab comprised a large proportion of the hauls in this station group, their numbers were substantially lower than at the other station groups. As with groups A–C, the low numbers of Pacific sanddabs caused the lower average abundance at group H (see Table 6.3). This pattern is likely due to warmer water associated with 1998 El Niño conditions when populations of Pacifics, a species that tends to prefer colder water, significantly declined. The assemblage represented by group I was also dominated by Pacific sanddabs and Dover sole, but with higher numbers of sanddabs, reflecting the cooler water temperatures during these years. The relative contribution of Dover sole and halfbanded rockfish abundances also differentiated this group from the others.

Station group J was the largest station group, comprising 45 station/survey entities from 1993 through 2005. This group comprised sites primarily located around or north of the outfall, and included most samples collected from the 2 northernmost stations, SD13 and SD14. This group had the highest mean abundance and was dominated by Pacific sanddabs, Dover sole, and yellowchin sculpin. The relatively high numbers of these three species distinguish stations in this group from the others.

Physical Abnormalities and Parasitism

Fin rot was absent, and the occurrences of other physical abnormalities were generally low in fish populations off Point Loma during 2005. For example, only 2 Dover soles (less than 1% of the Dover population) were found to have tumors. According to Dr. M. J. Allen of the Southern California Coastal Water Research Project (personal communication), these tumors are likely from a Dover specific infection and have not been associated with degraded environments. A tumor was also found on a single yellowchin sculpin. The copepod eye parasite *Phrixocephalus cincinnatus* occurred on 2% of the Pacific sanddabs collected and was present at all stations during all surveys.

Invertebrate Community

A total of 24,069 megabenthic invertebrates, representing 42 species, were collected during 2005 (**Table 6.4**, **Appendix C.4**). The white sea urchin *Lytechinus pictus* was the most abundant and most frequently captured species. It was present in all trawls and accounted for 92% of the total invertebrate catch. Other common species that occurred in at least 1/2 of the hauls included the sea pen *Acanthoptilum* sp, the sea stars *Astropecten verrilli* and *Luidia foliolata*, the brittle star *Ophiura luetkenii,* the sea cucumber *Parastichopus californicus*, the sea hare *Pleurobranchaea california*, and the sea spider *Nymphon pixellae*.

As with the fishes, invertebrate abundances varied among stations and between surveys during the year, while species richness and diversity were relatively uniform (**Table 6.5, Appendix C.5**). For example, the mean number of species per station ranged from 9 to 16, while abundance per station averaged from 473 to 4740 individuals. The largest hauls (in terms of abundance) occurred at stations SD8, SD10, and SD12, primarily due to large numbers of the urchin *L. pictus*. Diversity values were also extremely low (<1) for the entire area due to the numerical dominance of this urchin. Dominance of *L. pictus* is typical of similar habitats throughout the SCB.

Invertebrate species richness and abundance have varied over time (**Figure 6.5**). Annual species richness has averaged from 5 to 20 species since 1992, although the patterns of change have been similar among stations. In contrast, changes in abundance have differed greatly among stations. The average annual invertebrate catches were consistently low at stations SD13 and SD14, while the remaining stations demonstrated large peaks

Table 6.4

Megabenthic invertebrate species collected in 12 trawls in the PLOO region during 2005. Data for each species are expressed as: percent abundance (PA); frequency of occurrence (FO); mean abundance per occurrence (MAO).

Species	PA	FO	MAO
Lytechinus pictus	92	100	1842
Acanthoptilum sp	5	75	125
Allocentrotus fragilis	2	25	184
Astropecten verrilli	<1	83	6
Parastichopus californicus	<1	83	4
Luidia foliolata	<1	75	3
Pleurobranchaea californica	<1	92	3
Sicyonia ingentis	<1	42	3
Ophiura luetkenii	<1	58	2
Metridium farcimen	<1	42	2
Octopus rubescens	<1	42	2
Florometra serratissima	<1	25	3
Luidia asthenosoma	<1	25	3
Nymphon pixellae	<1	50	1
Platymera gaudichaudii	<1	33	1
Luidia armata	<1	25	1
Ophiopholis bakeri	<1	17	2
Thesea sp B	<1	25	1
Astropecten ornatissimus	<1	8	3
Megasurcula carpenteriana	<1	17	2
Adelogorgia phyllosclera	<1	17	1
Cancellaria crawfordiana	<1	8	2
Loligo opalescens	<1	8	2
Loxorhynchus crispatus	<1	8	2
Ophiuroidea	<1	8	2
PORIFERA	<1	17	1
Tritonia diomedea	<1	8	2
Acanthodoris brunnea	<1	8	1
Amphichondrius granulatus	<1	8	1
Amphipholis squamata	<1	8	1
Asterina miniata	<1	8	1
Crangon alaskensis	<1	8	1
Henricia sp	<1	8	1
Mediaster aequalis	<1	8	1
Neosimnia barbarensis	<1	8	1
Ophionereis eurybrachiplax	<1	8	1
Ophiothrix spiculata	<1	8	1
Paguristes bakeri	<1	8	1
Paguroidea	<1	8	1
Philine auriformis	<1	8	1
Pteropurpura macroptera	<1	8	1
Pyromaia tuberculata	<1	8	1
Rathbunaster californicus	<1	8	1
Rossia pacifica	<1	8	1
Spatangus californicus	<1	8	1

Table 6.5

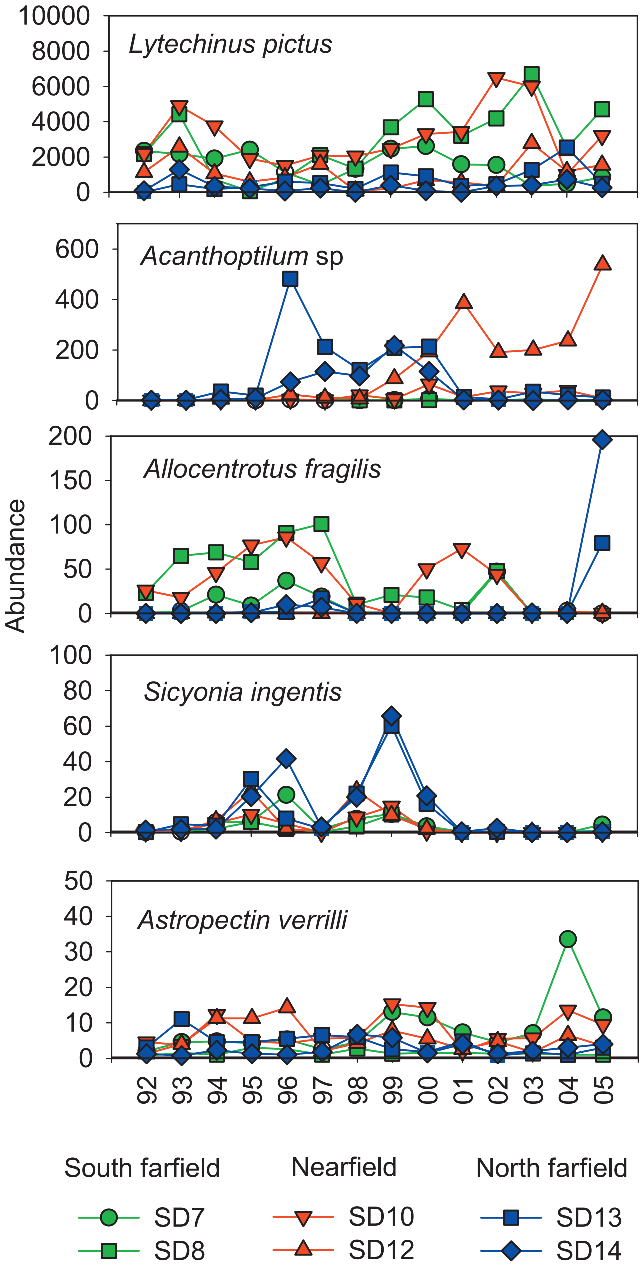
Summary of megabenthic invertebrate community parameters for PLOO stations sampled during 2005. Data are presented for cumulative (total) and mean number of species, abundance, diversity (H'), and biomass (BM) (kg, wet weight); n=2 for each station.

	No. of Species			
Station	Total	Mean	Abund	H’
SD7	19	14	888	0.49
SD8	22	16	4740	0.07
SD10	17	11	3242	0.09
SD12	14	9	2099	0.55
SD13	15	12	593	0.61
SD14	12	9	473	0.44

in abundance at various times. These fluctuations typically reflect changes in *L. pictus*, as well as the urchin *Allocentrotus fragilis*, and the sea pen *Acanthoptilum* sp to a lesser degree (**Figure 6.6**). The abundances of these 3 taxa is much lower at the 2 northern sites, and likely reflects differences in the sediment composition (e.g., fine sands vs. mixed coarse/fine sediments). None of the observed variability in the invertebrate community could be attributed to the discharge of wastewater from the PLOO.

SUMMARY AND CONCLUSIONS

As in previous years, Pacific sanddabs continued to dominate fish assemblages surrounding the Point Loma Ocean Outfall during 2005. They were present in relatively high numbers at all stations. However, 2005 was unique in that 2 very large hauls of halfbanded rockfish were collected near the outfall in January, which made this species the most abundant overall. Other characteristic, but less abundant species, included Dover sole, longspine combfish, slender sole, English sole, pink seaperch, stripetail rockfish, greenstriped rockfish, California tonguefish, roughback sculpin, greenspotted rockfish, and hornyhead turbot. Although the composition and structure of the fish assemblages varied among stations, most differences were due to fluctuations in Pacific sanddab populations.



are located in slightly shallower (~95–100 m) sediments that are poorly sorted (i.e., of varied sizes), and are subject to influences from dredge spoils disposal. Station SD7 is located near LA-4, a the defunct dredge spoils disposal site, and SD8 is located near LA-5, an active disposal site. Both locations have coarse sediments and are subject to disturbance (see Chapter 4, City of San Diego

2006). Additionally, species collected at station SD12 tended to differ (at least on occasion) from the other nearfield station (SD10) and the northern farfield stations. This may be because of its location just north of the outfall, where extra relief from ballast rock in the area, or the outfall pipe may be providing refuge for resident fishes against the prevailing northward currents.

Overall, results of the trawl surveys conducted in 2005 provide no evidence that the discharge of wastewater from the Point Loma Ocean Outfall affected fish or megabenthic invertebrate communities in the region during the year. Although highly variable, patterns in the abundance and distrubtion of species were similar at stations located near the outfall and further away. Changes in these communities that have occurred over time appear to be more likely due to natural factors such as changes in water temperature associated with large scale oceanographic events (El Niño), sediment conditions, and the mobile nature of many of the species collected. Finally, the general absence of disease or physical abnormalities on local fishes suggests that populations in the area continue to be healthy.

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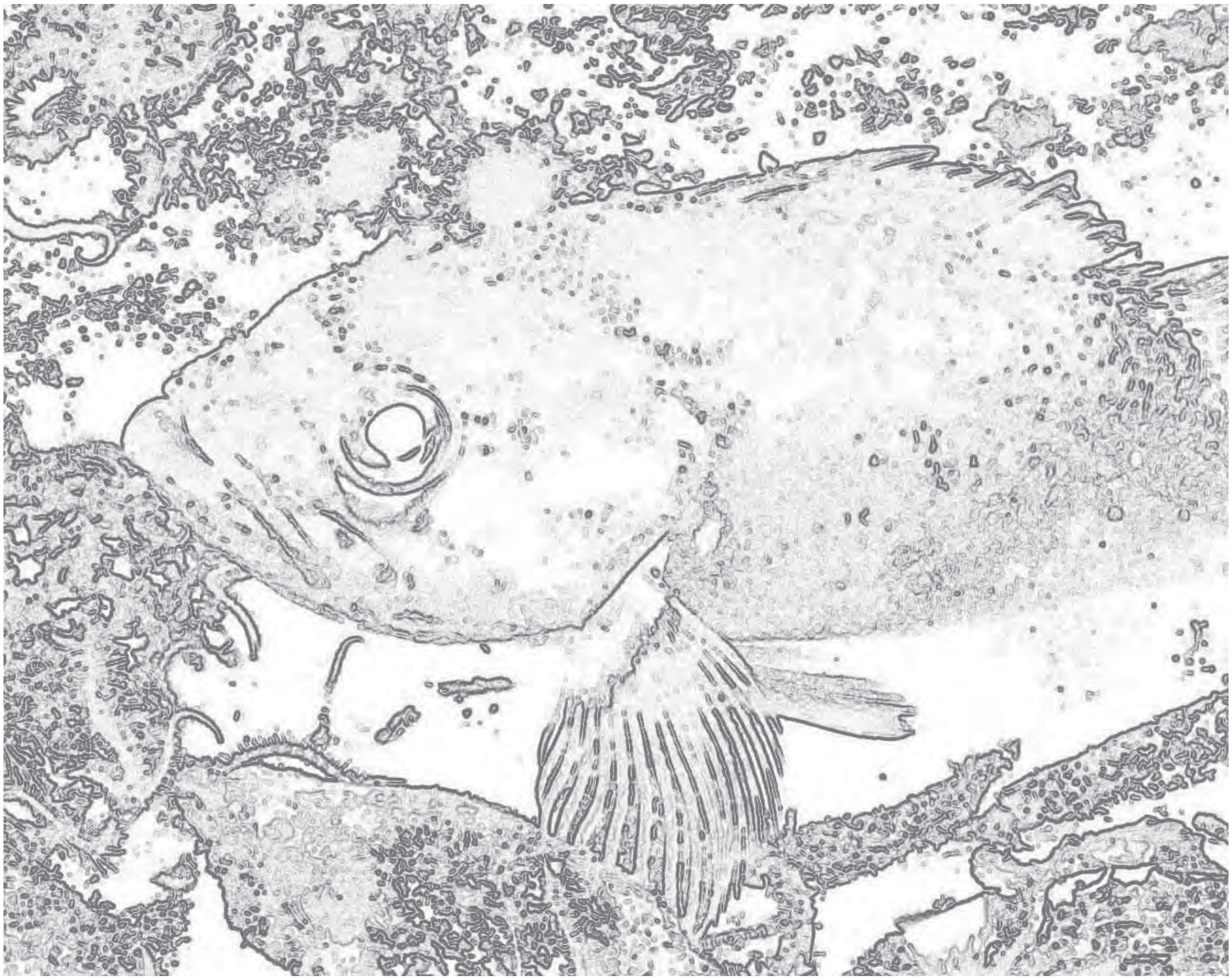
Chapter 7
Bioaccumulation of Contaminants in Fish Tissues



Chapter 7: Bioaccumulation of Contaminants in Fish Tissues

INTRODUCTION

Bottom dwelling (i.e., demersal) fishes are collected as part of the Point Loma Ocean Outfall (PLOO) monitoring program to assess the accumulation of contaminants in their tissues. Bioaccumulation in fish occurs through biological uptake and retention of chemical contaminants derived from various exposure pathways (Tetra Tech 1985). Exposure routes for demersal fishes include the adsorption or absorption of dissolved chemical constituents from the water and the ingestion and assimilation of pollutants from food sources. Fish may also accumulate pollutants by ingesting pollutant-containing suspended particulate matter or sediment particles. Demersal fishes are useful in biomonitoring programs because of their proximity to bottom sediments. For this reason, levels of contaminants in tissues of these fishes are often related to those found in the environment (Schiff and Allen 1997).

The bioaccumulation portion of the PLOO monitoring program consists of 2 components: (1) liver tissues analyzed from trawl-caught fishes; (2) muscle tissues analyzed from fishes collected by rig fishing. Fishes collected from trawls are considered representative of the demersal fish community, and certain species are targeted based on their ecological significance (i.e., prevalence in the community). Chemical analyses are performed using livers because this is the organ where contaminants typically concentrate. In contrast, fishes targeted for collection by rig fishing represent species from a typical sport fisher's catch, and are therefore of recreational and commercial importance. Muscle tissue is analyzed from these fish because it is the tissue most often consumed by humans, and therefore the results have human health implications.

All muscle and liver samples were analyzed for contaminants as specified in the NPDES discharge permit governing the PLOO monitoring program. Most of these contaminants are also sampled for the NOAA National Status and Trends Program. NOAA initiated this program to detect changes in the quality of the nation's estuarine and coastal waters by tracking contaminants thought to be of concern for the environment (Lauenstein and Cantillo 1993). This chapter presents the results of all tissue analyses that were performed during 2005.

MATERIALS AND METHODS

Collection

Pacific sanddabs (*Citharichthys sordidus*) were collected by trawl in 4 zones and various rockfish (*Sebastes* spp) were collected at 2 rig fishing stations (RF1 and RF2) during October 2005 (**Figure 7.1, Table 7.1**). Zone 1 includes the two nearfield trawl stations, SD10 and SD12, located just south and just north of the PLOO, respectively; Zone 2 includes the two northern farfield trawl

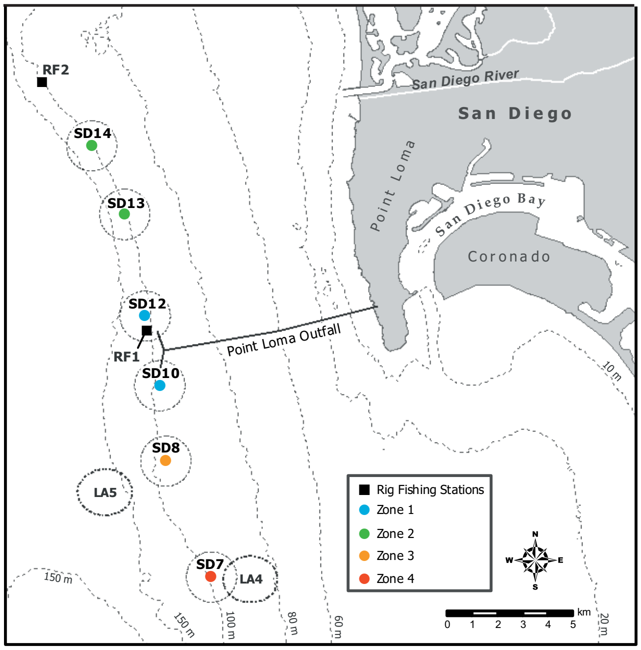


Figure 7.1
Otter trawl and rig fishing stations/zones surrounding the City of San Diego's Point Loma Ocean Outfall.

Table 7.1

Species of fish collected for tissue analysis from each trawl zone or rig fishing station (RF1–RF2) as part of the PLOO monitoring program during October 2005.

Station	Rep 1	Rep 2	Rep 3
Zone 1	Pacific sanddab	Pacific sanddab	Pacific sanddab
Zone 2	Pacific sanddab	Pacific sanddab	Pacific sanddab
Zone 3	Pacific sanddab	Pacific sanddab	Pacific sanddab
Zone 4	Pacific sanddab	Pacific sanddab	Pacific sanddab
RF1	Rosethorn rockfish	Mixed rockfish	Mixed rockfish
RF2	Squarespot rockfish	Squarespot rockfish	Speckled rockfish

stations, SD13 and SD14; Zone 3 is trawl station SD8, located near the LA-5 dredged materials dumpsite; Zone 4 is trawl station SD7, located several kilometers to the south of the outfall. Sanddabs were collected, measured and weighed following guidelines described in Chapter 6 of this report. Rockfish were collected at rig fishing sites using primarily rod and reel fishing tackle following standard procedures (City of San Diego in prep). Only fishes >13 cm standard length were retained for tissue analyses. These fishes were sorted into composite samples, each containing a minimum of 3 individuals. The fishes were then wrapped in aluminum foil, labeled, put in ziplock bags, and placed on dry ice for transport to the freezer in the Marine Biology Laboratory.

Tissue Processing and Chemical Analyses

All dissections were performed according to standard techniques for tissue analysis (see City of San Diego in prep). Each fish was partially defrosted and then cleaned with a paper towel to remove loose scales and excess mucus prior to dissection. The standard length (cm) and weight (g) of each fish were recorded (**Appendix D.1**). Dissections were carried out on Teflon pads that were cleaned between samples. Tissue samples were then placed in glass jars, sealed, labeled, and stored in a freezer at -20°C prior to chemical analyses. All samples were subsequently delivered to the City of San Diego Wastewater Chemistry Laboratory within 10 days of dissection.

Tissue samples were analyzed for the chemical constituents specified by the permit under which this sampling was performed. These chemical constituents include trace metals, chlorinated pesticides, PCBs, and PAHs as listed in **Appendix D.2**. Values for all parameters detected in each sample are summarized in **Appendix D.3**. Estimated values are included for some parameters determined to be present in a sample with high confidence (i.e., peaks are confirmed by mass-spectrometry), but at levels below the MDL. A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Laboratory (City of San Diego 2006).

RESULTS

Contaminants in Trawled Fish

Metals

Twelve metals, including aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, selenium, thallium, and zinc occurred in over 80% of the liver samples analyzed from Pacific sanddabs collected by trawl in 2005 (**Table 7.2**). Antimony, mercury, nickel, and tin were also detected, but less frequently. Although silver and tin were detected in almost all of the Pacific sanddab samples collected in 2004, tin was detected in less than 10% of the samples this year and silver was not detected at all. Concentrations of most metals were < 7 ppm. Exceptions occurred for iron and zinc, which had concentrations above 20 ppm in at least one sample.

Table 7.2

Concentrations of metals, total PCB, and pesticides detected in liver tissues from trawl-caught Pacific sanddabs during October 2005. n=number of detected values out of 12 samples.

Parameter	n	Min	Max	Mean
Metals (ppm)				
Aluminum	11	1.12	11.70	6.98
Antimony	6	0.57	1.25	0.91
Arsenic	12	4.27	6.07	5.39
Barium	12	0.01	0.25	0.10
Cadmium	12	1.37	8.75	4.41
Chromium	10	0.21	3.10	0.70
Copper	12	2.33	7.37	4.16
Iron	12	33.30	124.00	63.44
Lead	12	0.47	1.42	0.86
Manganese	12	0.56	1.18	0.84
Mercury	8	0.03	0.09	0.05
Nickel	8	0.10	1.25	0.32
Selenium	12	0.44	0.88	0.62
Thallium	12	4.60	6.35	5.76
Tin	1	0.25	0.25	0.25
Zinc	12	15.70	22.10	19.16
Pesticides (ppb)				
Total DDT	12	147.30	534.50	322.73
Lindane				
BHC (beta isomer)	1	5.70	5.70	5.70
BHC (delta isomer)	1	3.40	3.40	3.40
HCB, Hexachlorobenzene	12	2.40	4.70	3.32
Chlordane				
alpha (*cis*) Chlordane	12	4.10	8.70	5.63
gamma (*trans*) Chlordane	1	1.90	1.90	1.90
cis-Nonachlor	10	2.50	4.80	3.21
trans-Nonachlor	12	4.50	11.00	6.45
Total PCB (ppb)	12	76.70	321.20	189.76
Lipids (%wt)	12	43.5	60.90	48.55

Comparisons of the frequently detected metals from samples collected closest to the discharge (Zone 1) to those located farther away (Zones 2–4) suggest that there was no clear relationship between contaminant loads and proximity to the outfall (**Figure 7.2**). Instead, other patterns were suggested by the data. For example, the highest mean values of chromium, lead, manganese, mercury, nickel, and zinc occurred in Zone 3, the zone closest to the LA-5 dredge material site. However, the data were too variable to determine if these trends were significant.

Pesticides and PCBs

Several chlorinated pesticides were detected in liver tissues during 2005 (**Table 7.2**). Total DDT (tDDT; see Appendix D.2 for individual components) was found in all samples at concentrations ranging from about 147 to 535 ppb.

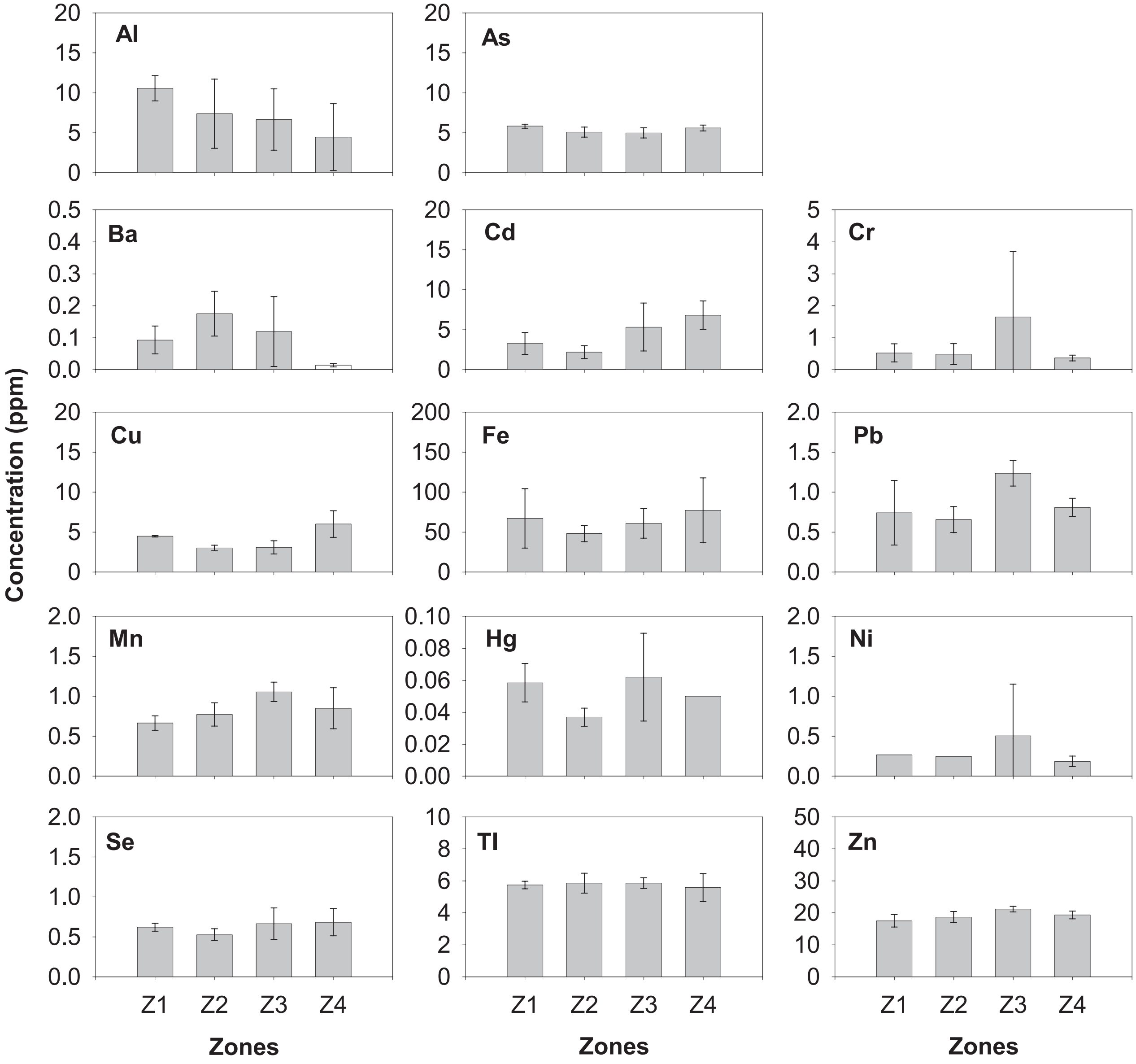


Figure 7.2

Concentrations of metals detected frequently in liver tissues of trawl-caught Pacific sanddabs collected during October 2005 at Zones 1–4 (Z1–Z4) off Point Loma. Data are means ± 1 STD; n is between 1 and 3, depending on the number of samples with detected values. Zone 1 represents the zone located closest to the discharge site.

Other pesticides that were detected frequently included hexachlorobenzene (HCB), alpha (*cis*) Chlordane, *cis*-Nonachlor, and *trans*-Nonachlor. In contrast, BHC (Lindane) and gamma (*trans*) Chlordane were rarely detected. The maximum concentration for any one of these pesticides was 11 ppb (*trans*-Nonachlor), which was very low relative to total DDT.

PCBs occurred in all samples. Concentrations for the individual PCB congeners are listed separately in Appendix D.3. Total PCB concentrations (i.e., the sum of all congeners detected in a sample, tPCB) were variable, ranging from about 77 to 321 ppb, with a mean of approximately 190 ppb.

As with metals, there was no clear relationship between concentrations of the frequently occurring pesticides or PCBs and proximity to the outfall (**Figure 7.3**). Generally, higher values of tPCB, tDDT, alpha (*cis*) Chlordane, *cis*- and *trans*- Nonachlor occurred in Zones 1, 3 or 4, but these values were not substantially different from those that occurred in Zone 2.

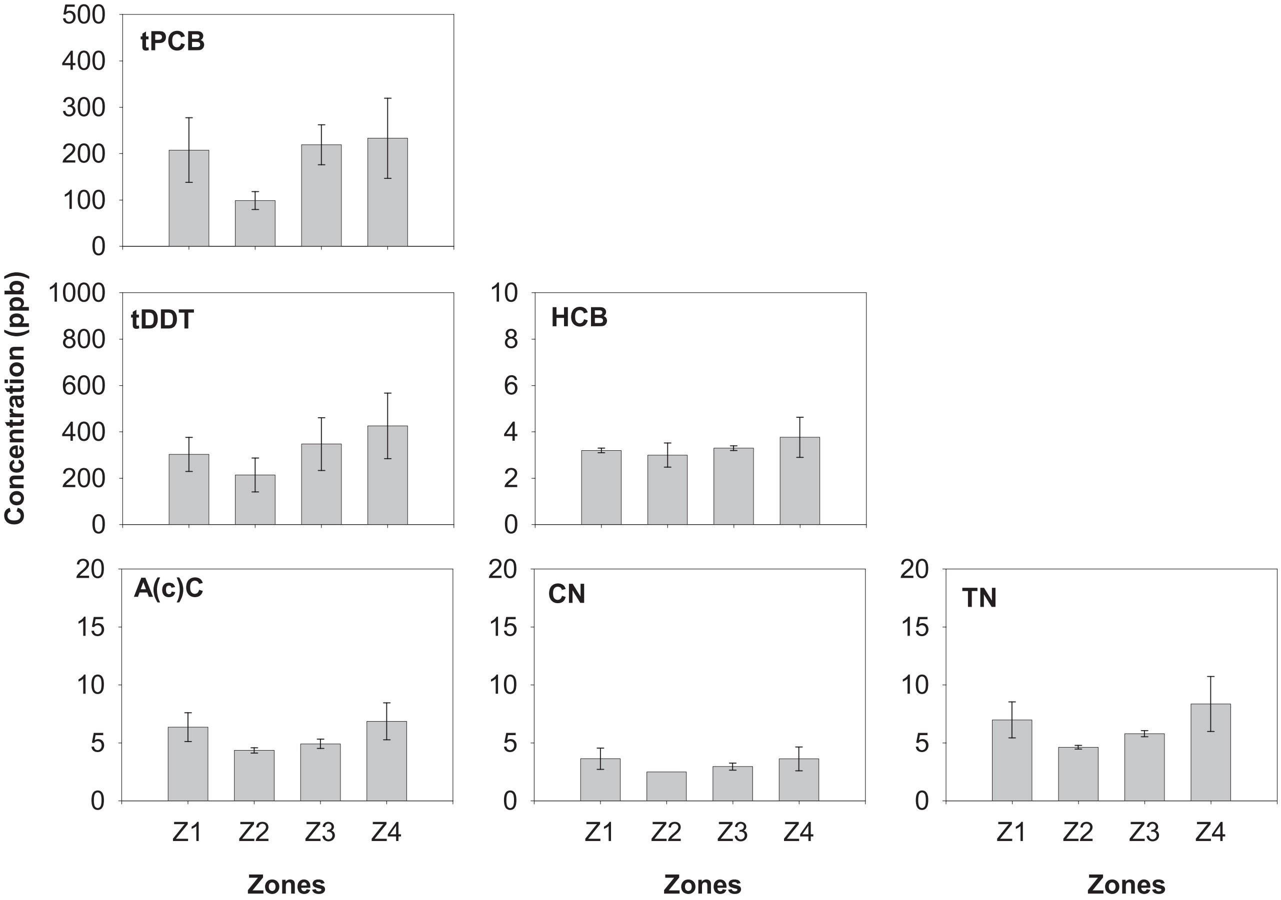


Figure 7.3
Concentrations of frequently detected chlorinated pesticides (tDDT=total DDT; HCB=hexachlorobenzene; A(c)C=alpha (*cis*) Chlordane; CN=*cis*-Nonachlor; TN=*trans*-Nonachlor) and total PCB detected in liver tissues of trawl-caught Pacific sanddabs during October 2004 at Zones 1–4 (Z1–Z4) off Point Loma. Data are means ± 1 STD; n is between 1 and 3, depending on the number of samples with detected values. Zone 1 represents the zone located closest to the discharge site.

Contaminants in Fishes Collected by Rig Fishing

Aluminum, arsenic, barium, copper, iron, manganese, mercury, selenium, thallium, and zinc occurred in at least two-thirds of the muscle tissue samples from various rockfish collected at rig fishing stations in 2005 (**Table 7.3**). Chromium, lead, and silver were also detected, but only in one-half or fewer of the samples. The metals with the highest mean concentrations included aluminum, arsenic, iron, thallium, and zinc. Each exceeded 2 ppm for at least one species of fish sampled; however there was little difference between species relative to the mean concentration for these metals. Other contaminants, such as DDT and PCB, were detected in 100% of the muscle samples, while the pesticides BHC (Lindane), HCB, and Chlordane were found much less frequently (**Table 7.4**).

To address human health concerns, concentrations of constituents found in muscle tissue samples were compared to both national and international limits and standards (Tables 7.3, Table 7.4). The United States Food and Drug Administration (FDA) has set limits on the amount of mercury, total DDT, and Chlordane in seafood that is to be sold for human consumption and there are also international standards for acceptable concentrations of various metals (see Mearns et al. 1991). While many compounds were detected in the muscle tissues of fish collected as part of the PLOO monitoring program, only arsenic and

Table 7.3
Metals detected in muscle tissues from fishes collected at PLOO rig fishing stations during October 2005. Data are compared to U.S. FDA action limits and median international standards when possible. Bold values exceed these standards; n=number of detected values; nd=not detected.

	Al	As	Ba	Cr	Cu	Fe	Pb	Mn	Hg	Se	Ag	Th	Zn
Mixed rockfish													
N (out of 2)	1	2	2	1	2	2	nd	2	2	2	nd	2	2
Min	3.28	**2.60**	0.011	0.048	0.73	1.7	—	0.05	0.05	**0.347**	—	2.6	3.1
Max	3.28	**2.87**	0.064	0.048	1.01	2.9	—	0.07	0.11	**0.478**	—	2.9	3.1
Mean	3.28	**2.74**	0.037	0.048	0.87	2.3	—	0.06	0.08	**0.412**	—	2.8	3.1
Rosethorn rockfish													
N (out of 1)	1	1	1	nd	1	1	nd	1	1	1	nd	1	1
Value	1.09	**2.49**	0.013	—	0.76	2.0	—	0.08	0.11	**0.367**	—	2.6	2.9
Speckled rockfish													
N (out of 1)	1	1	nd	nd	1	1	1	1	1	1	1	1	1
Value	1.87	**1.71**	—	—	0.27	2.2	0.34	0.05	0.07	**0.352**	0.5	2.62	3.0
Squarespot rockfish													
N (out of 2)	1	2	1	1	2	2	2	2	2	2	nd	2	2
Min	2.47	**2.16**	0.008	0.087	0.25	3.7	0.32	0.03	0.21	0.275	—	2.8	3.2
Max	2.47	**2.54**	0.008	0.087	0.46	5.0	0.42	0.06	0.26	**0.364**	—	2.9	3.4
Mean	2.47	**2.35**	0.008	0.087	0.36	4.3	0.37	0.04	0.24	**0.320**	—	2.9	3.3
ALL SPECIES													
% Detected	67	100	67	33	100	100	50	100	100	100	17	100	100
US FDA Action Limit*									1				
Median International Standard*		1.40		1.0	20		2		0.5	0.3			70

*From Mearns et al. 1991. US FDA mercury action limits and all international standards are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

selenium had concentrations that were higher than international standards.

In addition to addressing health concerns, spatial patterns were assessed for total DDT and total PCB, as well as all metals that occurred frequently in muscle tissue samples (**Figure 7.4**). A single sample of mixed rockfish at RF1 had concentrations of tPCB, tDDT, and barium that were well above other samples. These parameters were detected in a sample that included tissue from a rockfish that was 7 cm larger than all other fishes collected (39 cm SL vs < 32 cm SL), indicating that this fish was likely much older than the other fishes and therefore had a longer exposure to the sediments. Overall, concentrations of metals, HCB, DDT, and PCB were somewhat variable in the muscle tissues from fishes at both rig fishing stations, and there was no evident relationship with proximity to the outfall.

Comparison of contaminant loads between RF1 and RF2 should be considered with caution

Table 7.4

Concentrations of chlorinated pesticides, PCBs, and lipids detected in muscle tissues from rockfish collected at rig fishing stations during October 2005. Data are compared to U.S. FDA action limits and median international standards when possible. BHC(B)=BHC, beta isomer; BHC(D)=BHC, delta isomer; HCB=hexachlorobenzene; A(c)C=alpha (*cis*) Chlordane; G(t)C= gamma (*trans*) Chlordane; CN=*cis*-Nonachlor; TN=*trans*-Nonachlor. Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt). n=number of detected values, nd=not detected.

	Total	Lindane			Chlordane				Total	
	DDT	**BHC(B)**	**BHC(D)**	**HCB**	**A(c)C**	**G(t)C**	**CN**	**TN**	**PCB**	**Lipids**
Mixed rockfish										
N (out of 2)	2	nd	nd	2	2	1	1	2	2	2
Min	11	—	—	0.1	0.3	0.3	0.5	0.4	6	2.31
Max	63.6	—	—	0.3	0.7	0.3	0.5	1.2	34.4	3.13
Mean	37.3	—	—	0.2	0.5	0.3	0.5	0.8	20.2	2.72
Rosethorn rockfish										
N (out of 1)	1	nd	nd	nd	nd	nd	nd	nd	1	1
Value	2.3	—	—	—	—	—	—	—	0.8	0.3
Speckled rockfish										
N (out of 1)	1	nd	nd	1	nd	nd	nd	nd	1	1
Value	5.7	—	—	0.1	—	—	—	—	1.3	1.4
Squarespot rockfish										
N (out of 2)	2	1	1	2	1	1	nd	1	2	2
Min	12.4	5.8	7.6	0.1	0.9	1.0	—	0.4	3.2	2.09
Max	15.1	5.8	7.6	0.2	0.9	1.0	—	0.4	3.8	2.76
Mean	13.75	5.8	7.6	0.15	0.9	1.0	—	0.4	3.5	2.425
ALL SPECIES										
% Detected	100	17	17	83	50	33	17	50	100	
US FDA Action Limit*	5000									
Median International Standard*	5000									

*From Table 2.3 in Mearns et al. 1991. USFDA action limit for total DDT is for fish muscle tissue, US FDA mercury action limits and all international standards are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

however, because different species of fish were collected at the two sites. All specimens belong to the same family, Scorpaenidae, and have similar life histories (e.g., bottom dwelling tertiary carnivores), so they have similar mechanisms of exposure (e.g., exposure from direct contact with the sediments and through possibly similar food sources). These species are therefore comparable to a certain degree. However, since they are not the same species, differences in physiology and food choices may exist that could affect the accumulation of contaminants.

SUMMARY AND CONCLUSIONS

Twelve trace metals, 3 pesticides, and a combination of PCBs were each detected in over 80% of the liver samples from Pacific sanddabs collected around the Point Loma Ocean Outfall (PLOO) in 2005. Contaminant loads were within the range of those reported previously for other Southern California Bight (SCB) fish assemblages (see Mearns et al. 1991, Allen et al. 1998, 2002). In addition, concentrations of these contaminants

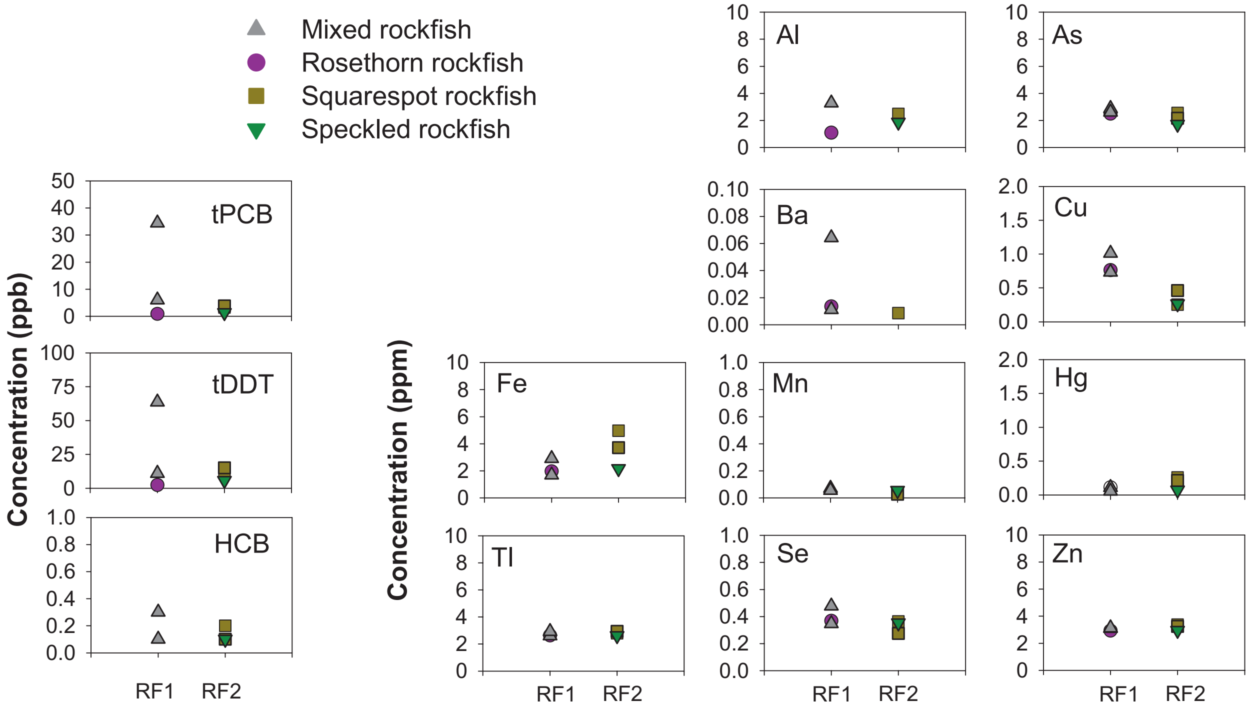


Figure 7.4

Concentrations of frequently detected metals, hexachlorobenzene (HCB), total DDT and total PCB in muscle tissues of fishes collected from each PLOO rig fishing station during 2005. Missing data represent concentrations below detection limits. RF1 represents the area located closest to the discharge site.

were generally similar to those reported previously by the City of San Diego (City of San Diego 1996–2004). Concentrations of most parameters were similar across zones/stations, and no clear relationship with proximity to the outfall was evident.

The occurrence of metals and chlorinated hydrocarbons in PLOO fish tissues may be due to many factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB. In fact, many metals (e.g., aluminum and iron) occur naturally in the environment, although little information is available on their background levels in fish tissues. Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. For example, exposure to contaminants can vary greatly between species and also among individuals of the same species depending on migration habits (Otway 1991). Fish may be exposed to contaminants in one highly contaminated area and then move into an area that is less contaminated. This may explain why many of the pesticides and PCBs detected in fish collected off Point Loma in 2005 were found in low concentrations or were not detected at all in sediments surrounding the outfall (see Chapter 4). In addition, differences in feeding habits, age, reproductive status, and gender can affect the amount of contaminants a fish will retain in its tissues (e.g., Connell 1987, Evans et al. 1993). These factors make comparisons of contaminants among species and between stations difficult.

Overall, there was no evidence that fishes collected in 2005 were contaminated by the discharge of waste water from the PLOO. Concentrations of mercury and DDT in muscle tissues from sport fish collected in the area were below FDA human consumption limits. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot or other physical anomalies (see Chapter 6).

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Glossary

GLOSSARY

Absorption The movement of a dissolved substance (e.g., pollution) into cells by osmosis or diffusion.

Adsorption The accumulation of a dissolved substance on the sediment or on the surface of an organism (e.g., a flatfish).

Ambicoloration A term specific to flatfish that describes the presence of pigmentation on both the eyed and the blind sides. Only the eyed side is normally pigmented in flatfish.

Anthropogenic Made and introduced into the environment by humans, especially pertaining to pollutants.

Assemblage An association of interacting populations in a given habitat (e.g., an assemblage of benthic invertebrates on the ocean floor).

BACIP (Before-After-Control-Impact-Paired) An analytical tool used to assess environmental changes caused by the effects of pollution. A statistical test is applied to data from matching pairs of control and impacted sites before and after an event (i.e., initiation of wastewater discharge) to test for significant change. Significant differences are generally interpreted as being the result of the environmental change attributed to the event. Variation that is not significant reflects natural variation.

Benthic Pertaining to the environment inhabited by organisms living on or in the ocean bottom.

Benthos Living organisms (e.g., algae and animals) associated with the sea bottom.

Bioaccumulation The process by which a chemical in animal tissue becomes accumulated over time through direct intake of contaminated water, the consumption of contaminated prey, or absorption through the skin.

BOD (Biochemical Oxygen Demand) The amount of oxygen consumed (through biological or chemical processes) during the decomposition of organic material contained in a water or sediment sample. It is a measure for certain types of organic pollution, such that high BOD levels suggest elevated levels of organic pollution.

Biota The living organisms within a habitat or region.

BRI (Benthic Response Index) An index that measures levels of environmental disturbance by assessing the condition of a benthic assemblage. The index was based on organisms found in the soft sediments of the Southern California Bight.

California Ocean Plan (COP) California's ocean water quality control plan. It limits wastewater discharge and implements ocean monitoring. Federal law requires the plan to be reviewed every three years.

CFU (colony-forming unit) A unit (measurement) of density used to estimate bacteria concentrations in ocean water. The number of bacterial cells that grow to form entire colonies, which can then be quantified visually.

Congeners The EPA defines a PCB congener as, "one of the 209 different PCB compounds. A congener may have between 1 and 10 chlorine atoms, which may be located at various positions on the PCB molecule."

Control site A geographic location that is far enough from a known pollution source (e.g., ocean outfall) to be considered representative of an undisturbed environment. Information collected within control sites is used as a reference and compared to impacted sites.

Crustacea A group (subphylum) of marine invertebrates characterized by jointed legs and an exoskeleton. Crabs, shrimps, and lobsters are examples.

CTD (conductivity, temperature, and depth) A device consisting of a group of sensors that continually measure various physical and chemical properties such as conductivity (a proxy for salinity), temperature, and pressure (a proxy for depth) as it is lowered through the water. These parameters are used to assess the physical ocean environment.

Demersal Organisms living on or near the bottom of the ocean and capable of active swimming (e.g., flatfish).

Dendrogram A tree-like diagram used to represent hierarchal relationships from a multivariate analysis where results from several monitoring parameters are compared among sites.

Detritus Particles of organic material from decomposing organisms. Used as an important source of nutrients in a food web.

Diversity (Shannon diversity index, H') A measurement of community structure that describes the abundances of different species within a community, taking into account their relative rarity or commonness.

Dominance (Swartz) A measurement of community structure that describes the minimum number of species accounting for 75% of the abundance in each grab.

Echinodermata A group (phylum) of marine invertebrates characterized by the presence of spines, a radially symmetrical body, and tube feet. For example, sea stars, sea urchins, and sea cucumbers

Ectoparasite A parasite that lives on the outside of its host, and not within the host's body. Isopods and leeches attached to flatfish are examples.

Effluent Wastewater that flows out of a sewer, treatment plant outfall, or other point source and is discharged into a water body (e.g. ocean, river).

Epibenthic Referring to organisms that live on or near, not within, the sediments. See demersal.

Epifauna Animals living on the surface of sea bottom sediments.

Halocline A vertical zone of water in which the salinity changes rapidly with depth.

Impact site A geographic location that has been altered by the effects of a pollution source, such as a wastewater outfall.

Indicator Species Marine invertebrates whose presence in the community reflects the health of the environment. The loss of pollution-sensitive species or the introduction of pollution-tolerant species can indicate anthropogenic impact.

Infauna Animals living in the soft bottom sediments usually burrowing or building tubes within.

Invertebrate An animal without a backbone. For example, a seastar, crab, or worm.

ITI (Infaunal Trophic Index) An environmental disturbance index based on the feeding structure of marine soft-bottom benthic communities and the rationale that a change in sediment quality will restructure the invertebrate community to one best suited to feed in the altered sediment type. Generally, ITI values less than 60 indicate a pollution impacted benthic community.

Kurtosis A measure that describes the shape (i.e., peakedness or flatness) of distribution relative to a normal distribution (bell shape) curve. Kurtosis can indicate the range of a data set, and is used herein to describe the distribution of particle sizes within sediment samples.

Macrobenthic invertebrate (Macrofauna) Epifaunal or infaunal benthic invertebrates that are visible with the naked eye. This group typically includes those animals larger than meiofauna and smaller than megafauna. These animals are collected in grab samples from soft-bottom marine habitats and retained on a 1 mm mesh screen.

MDL (method detection limit) The EPA defines MDL as "the minimum concentration that can be determined with 99% confidence that the true concentration is greater than zero."

Megabenthic invertebrate (Megafauna) A larger, usually epibenthic and motile, bottom-dwelling animal such as a sea urchin, crab, or snail. These animals are ypically collected by otter trawls with a minimum mesh size of 1 cm.

Mollusca A taxonomic group (phylum) of invertebrates characterized as having a muscular foot, visceral mass, and a shell. Examples include snails, clams, and octupuses.

Motile Self-propelled or actively moving.

NPDES (National Pollutant Discharge Elimination System) A federal permit program that controls water pollution by regulating point sources that discharge pollutants into waters of the United States.

Niskin Bottle A long plastic tube allowing water to pass through until the caps at both ends are triggered to close from the surface. They often are arrayed with several others in a rosette sampler to collect water at various depths.

Non-point source Pollution sources from numerous points, not a specific outlet, generally carried into the ocean by storm water runoff.

Ophiuroidea A taxonomic group (class) of echinoderms that comprises the brittle stars. Brittle stars usually have five long, flexible arms and a central disk-shaped body.

PAHs (Polynuclear Aromatic Hydrocarbons) The USGS defines PAHs as, "hydrocarbon compounds with multiple benzene rings. PAHs are typical components of asphalts, fuels, oils, and greases. They are also called Polycyclic Aromatic Hydrocarbons."

PCBs (Polychlorinated Biphenyls) The EPA defines PCBs as, "a category, or family, of chemical compounds formed by the addition of Chlorine (C_{l2}) to Biphenyl ($C_{12}H_{10}$), which is a dual-ring structure comprising two 6-carbon Benzene rings linked by a single carbon-carbon bond."

Phi (size) The conventional unit of sediment size based on the log of sediment grain diameter. The larger the Phi number, the smaller the grain size.

Plankton Animal and plant-like organisms, usually microscopic, that are passively carried by the ocean currents.

PLOO (Point Loma Ocean Outfall) The PLOO is the underwater pipe originating at the Point Loma Wastewater Treatment Plant and used to discharge treated wastewater. It extends 7.2 km (4.5 miles) offshore and discharges into 96 m (320 ft) of water.

Point source Pollution discharged from a single source (e.g., municipal wastewater treatment plant, storm drain) to a specific location through a pipe or outfall.

Polychaeta A taxonomic group (class) of invertebrates characterized as having worm-like features, segments, and bristles or tiny hairs. Examples include bristle worms and tube worms.

Pycnocline A depth zone in the ocean where density increases (associated with a decline in temperature and increase in salinity) rapidly with depth.

Recruitment The retention of young individuals into the adult population in an open ocean environment.

Relict sand Coarse reddish-brown sand that is a remnant of a pre-existing formation after other parts have disappeared. Typically originating from land and transported to the ocean bottom through erosional processes.

Rosette sampler
A device consisting of a round metal frame housing a CTD in the center and multiple bottles (see

Niskin bottle) arrayed about the perimeter. As the instrument is lowered through the water column, continuous measurements of various physical and chemical parameters are recorded by the CTD. Discrete water samples are captured at desired depths by the bottles.

Shell hash Sediment composed of shell fragments with the size and consistency of very coarse sand.

Skewness A measure of the lack of symmetry in a distribution or data set. Skewness can indicate where most of the data lies within a distribution. It can be used to describe the distribution of particle sizes within sediment grain size samples.

Sorting The range of grain sizes that comprise marine sediments. Also refers to the process by which sediments of similar size are naturally segregated during transport and deposition according to the velocity and transporting medium. Well sorted sediments are of similar size (such as desert sand), while poorly sorted sediments have a wide range of grain sizes (as in a glacial till).

SBOO (South Bay Ocean Outfall) The SBOO is the underwater pipe originating at the International Wastewater Treatment Plant and used to discharge treated wastewater. It extends 5.6 km (4.5 miles) offshore and discharges into about 27 m (90 ft) of water.

South Bay Water Reclamation Plant Provides local wastewater treatment services and reclaimed water to the South Bay. The plant began operation in 2002 and has a wastewater treatment capacity of 15 million gallons a day

SCB (Southern California Bight) The geographic region that stretches from Point Conception, U.S.A. to Cabo Colnett, Mexico and encompasses nearly 80,000 km^2 of coastal land and sea

Species Richness The number of species per unit area. A metric used to evaluate the health of macrobenthic communities.

Standard length The measurement of a fish from the most forward tip of the body to the base of the tail (excluding the tail fin rays). Fin rays can sometimes be eroded by pollution or preservation so a measurement that includes them (i.e., total length) is considered less reliable.

Terrigenous Suspended oceanic sediments that are derived from land-based material.

Thermocline The zone in a thermally stratified body of water that separates warmer surface water from colder deep water. At a thermocline, temperature decreases rapidly over a short depth.

Tissue burden The total amount of measured chemicals that are present in the tissue (e.g. fish muscle) at a given point in time.

Transmissivity A measure of water clarity based upon the ability of water to transmit light along a straight path. Light that is scattered or absorbed by particulates (e.g., plankton, suspended solid materials) decreases the transmissivity (or clarity) of the water.

Upwelling The movement of nutrient-rich and typically cold water from the depths of the ocean to the surface waters.

USGS (United States Geological Survey) The USGS provides geologic, topographic, and hydrologic information on water, biological, energy, and mineral resources.

Van Dorn bottle A water sampling device made of a plastic tube open at both ends that allows water to flow through. Rubber caps at the tube ends can be triggered to close underwater to collect water at a specified depth.

Van Veen Grab A mechanical device designed to collect bottom sediment samples. The device consists of a pair of hinged jaws and a release mechanism that allows the opened jaws to close and entrap a 0.1 m^2 sediment sample once they touch bottom.

Wastewater A mixture of water and waste materials originating from homes, businesses, industries, and sewage treatment plants.

ZID (zone of initial dilution) The region of initial mixing of the surrounding receiving waters with wastewater from the diffuser ports of an outfall. This area includes the underlying seabed. In the ZID, the environment is chronically exposed to pollutants and often is the most impacted.

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Appendices

Appendix A

Supporting Data

2005 PLOO Stations

Microbiology

Appendix A.1

Samples where total coliform densities were ≥ 1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥ 0.1 (see text) for the PLOO quarterly and kelp water quality stations sampled in 2005. N=north of the 2 km radius surrounding the PLOO wye; O=stations within 2 km of the PLOO wye or along the PLOO; S=south of the 2 km radius surrounding the PLOO wye. Sample depth is in meters.

Date	Station	Transect position	Sample depth	Total	Fecal	Entero	F:T
January	F01	18-m – S	1	1200	500	110	0.42
	F20	80-m – N	80	1300	400	80	0.31
	F21	80-m – N	80	1800	340	220	0.19
	F21	80-m – N	60	1200	260	70	0.22
	F22	80-m – N	80	1400	480	220	0.34
	F23	80-m – N	80	1600	360	180	0.23
	F19	80-m – O	80	1400	360	280	0.26
	F31	98-m – N	98	3000	560	110	0.19
	F31	98-m – N	80	16000	4000	700	0.25
	F32	98-m – N	98	8400	1800	400	0.21
	F32	98-m – N	80	16000	12000	1400	0.75
	F33	98-m – N	98	15000	3800	740	0.25
	F33	98-m – N	60	4400	1200	540	0.27
	F33	98-m – N	80	16000	6200	2200	0.39
	F34	98-m – N	80	6800	1200	260	0.18
	F30	98-m – O	98	7200	1800	160	0.25
	F30	98-m – O	80	16000	12000	720	0.75
March	A1	18-m – S	18	1000	130	34	0.13
April	F09	60-m – N	60	7800	1000	120	0.13
	F10	60-m – N	60	2800	500	100	0.18
	F08	60-m – O	60	16000	3600	480	0.23
	F19	80-m – O	80	16000	5800	500	0.36
	F19	80-m – O	60	16000	6000	400	0.38
	F30	98-m – O	98	8000	1600	100	0.20
	F30	98-m – O	80	10000	2200	180	0.22
	F30	98-m – O	60	16000	6400	380	0.40
	F15	80-m – S	60	1100	180	56	0.16
	F16	80-m – S	60	8600	1800	130	0.21
	F17	80-m – S	80	8200	1200	240	0.15
	F17	80-m – S	60	16000	4000	560	0.25
	F18	80-m – S	60	16000	5400	440	0.34
	F18	80-m – S	80	1800	680	110	0.38
	F26	98-m – S	80	4200	600	90	0.14
	F26	98-m – S	60	8200	1200	78	0.15
	F27	98-m – S	60	5000	600	36	0.12
	F28	98-m – S	60	8800	1100	62	0.13
July	F23	80-m – N	60	1300	320	6	0.25
	F25	80-m – N	60	4200	980	10	0.23
	F34	98-m – N	80	16000	6000	460	0.38
	F31	98-m – N	98	4000	420	50	0.11

Appendix A.1 continued

Date	Station	Transect position	Sample depth	Total	Fecal	Entero	F:T
July	F31	98-m – N	80	16000	6200	180	0.39
	F32	98-m – N	80	16000	4200	240	0.26
	F33	98-m – N	80	11000	3000	260	0.27
	F30	98-m – O	60	16000	12000	580	0.75
	F30	98-m – O	80	16000	12000	1400	0.75
	F17	80-m – S	80	2800	960	98	0.34
	F18	80-m – S	60	2400	400	38	0.17
	F18	80-m – S	80	10000	1800	240	0.18
	F27	98-m – S	98	2400	660	80	0.28
	F27	98-m – S	80	16000	7200	600	0.45
	F28	98-m – S	98	3400	460	82	0.14
	F28	98-m – S	80	16000	12000	720	0.75
	F29	98-m – S	80	16000	3600	340	0.23
October	F21	80-m – N	80	1800	420	56	0.23
	F23	80-m – N	80	1200	180	42	0.15
	F24	80-m – N	80	1500	480	72	0.32
	F25	80-m – N	80	4000	800	72	0.20
	F35	98-m – N	80	11000	4000	300	0.36
	F35	98-m – N	98	1300	540	72	0.42
	F36	98-m – N	80	6800	1600	140	0.24
	F36	98-m – N	98	1000	620	62	0.62
	F31	98-m – N	98	1500	460	56	0.31
	F30	98-m – O	98	4400	1100	34	0.25
	F30	98-m – O	60	16000	12000	380	0.75
	F30	98-m – O	80	16000	12000	340	0.75

Appendix B

Supporting Data

2005 PLOO Stations

Sediment Characteristics

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Appendix B.1

Sediment chemistry constituents analyzed for Point Loma Ocean Outfall sampling during 2005.

Cholorinated Pesticides

Aldrin
Alpha (cis) Chlordane
Alpha Endosulfan
Beta Enddosulfan
BHC, Alpha isomer
BHC, Beta isomer
BHC, Delta isomer
BHC, Gamma isomer
cis-Nonachlor
Dieldrin
Endosulfan sulfate
Endrin
Endrin aldehyde
Gamma (trans) Chlordane
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Methoxychlor
Mirex
o,p-DDD
o,p-DDE
o,p-DDT
Oxychlordane
p,p-DDD
p,p-DDE
p,p-DDT
trans-Nonachlor

Polycylic Aromatic Hydrocarbons

1-methylnaphthalene
1-methylphenanthrene
2,3,5-trimethylnaphthalene
2,6-dimethylnaphthalene
2-methylnaphthalene
3,4-benzo(B)fluoranthene
Acenaphthene
Acenaphthylene
Anthracene
Benzo[A]anthracene
Benzo[A]pyrene
Benzo[e]pyrene
Benzo[G,H,I]perylene
Benzo[K]fluoranthene
Biphenyl
Chrysene
Dibenzo(A,H)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-CD)pyrene
Naphthalene
Perylene
Phenanthrene
Pyrene

Metals

Aluminum (Al)
Antimony (Sb)
Arsenic (As)
Barium (Ba)
Beryllium (Be)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Lead (Pb)
Manganese (Mn)
Mercury (Hg)
Nickel (Ni)
Selenium (Se)
Silver (Ag)
Thallium (Tl)
Tin (Sn)
Zinc (Zn)

PCB Congeners

PCB 18
PCB 28
PCB 37
PCB 44
PCB 49
PCB 52
PCB 66
PCB 70
PCB 74
PCB 77
PCB 81
PCB 87
PCB 99
PCB 101
PCB 105
PCB 110
PCB 114
PCB 118
PCB 119
PCB 123
PCB 126
PCB 128
PCB 138
PCB 149
PCB 151
PCB 153/168
PCB 156
PCB 157
PCB 158
PCB 167
PCB 169
PCB 170
PCB 177
PCB 180
PCB 183
PCB 187
PCB 189
PCB 194
PCB 201
PCB 206

Appendix B.2

Particle size statistics for sediments of the Point Loma Ocean Outfall Monitoring Program for the January 2005 survey. Only 10 primary core stations were sampled.

Stations	Depth (m)	Mean mm	Mean Phi	SD Phi	Median Phi	Skewness Phi	Kurtosis Phi	Coarse %	Sand %	Silt %	Clay %	Sediment Observations
North Reference Stations												
B-12	98	0.095	3.4	2.1	2.8	0.3	1.1	0.8	69.9	27.1	2.2	Coarse sand, sand, silt, shell hash
B-9	98	0.054	4.2	1.6	3.7	0.5	1.0	0.0	59.3	37.8	2.9	Sand, silt, mud, pea gravel
Station North of the Outfall												
E-20	98	0.063	4.0	1.4	3.7	0.4	1.2	0.0	63.6	33.6	2.7	Silt, shell hash
E-23	98	0.058	4.1	1.4	3.7	0.5	1.2	0.0	61.2	36.1	2.7	Silt, shell hash
E-25	98	0.063	4.0	1.5	3.6	0.5	1.2	0.0	62.6	34.5	2.9	Silt, shell hash
E-26	98	0.054	4.2	1.5	3.7	0.5	1.1	0.0	59.1	37.9	3.0	Silt, shell hash
Outfall Stations												
E-11	98	0.072	3.8	1.3	3.4	0.4	1.4	0.0	68.9	29.1	2.0	Silt, coarse sand, shell hash
E-14	98	0.072	3.8	1.4	3.4	0.4	1.4	0.0	71.9	25.9	2.1	Silt, coarse black sand, shell hash
E-17	98	0.072	3.8	1.3	3.5	0.5	1.4	0.0	68.1	29.8	2.1	Silt, shell hash
Stations South of the Outfall												
E-2	98	0.072	3.8	2.1	3.4	0.2	1.0	2.5	60.4	34.3	2.7	Coarse sand, sand, silt, shell hash
E-5	98	0.067	3.9	1.5	3.5	0.5	1.2	0.0	65.1	32.3	2.6	shell hash
E-8	98	0.072	3.8	1.4	3.4	0.4	1.4	0.0	69.0	28.9	2.1	Coarse sand, silt, shell hash

Appendix B.2 (continued)

Particle size statistics for sediments of the Point Loma Ocean Outfall Monitoring Program for the July 2005 survey.

Stations	Depth (m)	Mean mm	Mean Phi	SD Phi	Median Phi	Skewness Phi	Kurtosis Phi	Coarse %	Sand %	Silt %	Clay %	Sediment Observations
North Reference Stations												
B-11	88	0.063	4.0	2.3	3.6	0.1	1.1	4.7	51.9	39.9	3.5	Coarse and fine sand, mud, gravel, pea gravel, shell hash
B-8	88	0.044	4.5	1.6	4.2	0.3	1.0	0.0	44.6	52.0	3.4	Fine sand, clay
B-12	98	0.088	3.5	2.1	3.0	0.3	1.0	3.0	65.3	29.3	2.4	Fine sand, mud, pea gravel, shell hash
B-9	98	0.058	4.1	1.7	3.5	0.5	1.1	0.0	61.8	35.4	2.8	Fine sand, clay, mud, pea gravel, shell hash
B-10	116	0.072	3.8	1.6	3.1	0.6	1.3	0.0	71.4	26.1	2.5	Fine sand, clay, shell hash
Station North of the Outfall												
E-19	88	0.051	4.3	1.5	3.9	0.4	1.1	0.0	54.5	42.8	2.7	Silt, clay
E-20	98	0.063	4.0	1.4	3.6	0.5	1.3	0.0	64.6	33.2	2.2	Silt, clay
E-23	98	0.058	4.1	1.5	3.7	0.4	1.2	0.0	60.7	36.5	2.7	Fine sand, clay, shell hash
E-25	98	0.063	4.0	1.5	3.6	0.4	1.2	0.0	63.4	33.9	2.6	Fine sand, silt, clay, shell hash
E-26	98	0.054	4.2	1.7	3.7	0.4	1.1	0.3	57.0	39.5	3.2	Fine sand, silt
E-21	116	0.063	4.0	1.5	3.5	0.6	1.2	0.0	65.5	32.0	2.5	Silt
Outfall Stations												
E-11	98	0.067	3.9	1.4	3.4	0.6	1.4	0.0	68.5	29.0	2.5	Fine sand, silt, shell hash
E-14	98	0.072	3.8	1.5	3.5	0.4	1.3	0.8	69.1	27.7	2.2	Fine sand, silt,shell hash
E-17	98	0.067	3.9	1.4	3.6	0.4	1.3	0.0	67.5	30.0	2.4	Silt, clay, shell hash
E-15	116	0.067	3.9	1.5	3.4	0.5	1.4	0.0	68.3	29.2	2.5	Coarse black sand, fine sand, silt, shell hash
Stations South of the Outfall												
E-1	88	0.063	4.0	1.9	3.6	0.3	1.0	2.3	58.4	36.4	2.7	Coarse sand, sand, silt, shell hash
E-7	88	0.058	4.1	1.5	3.7	0.4	1.1	0.0	59.0	38.3	2.7	Fine sand, silt, shell hash
E-2	98	0.063	4.0	2.0	3.5	0.2	1.0	4.2	55.9	37.0	3.0	Coarse sand, rock, silt, clay, shell hash
E-5	98	0.067	3.9	1.5	3.4	0.5	1.3	0.0	66.4	30.9	2.7	Silt, shell hash
E-8	98	0.067	3.9	1.4	3.4	0.5	1.6	0.3	67.8	29.5	2.4	Coarse sand, silt, shell hash
E-3	116	0.088	3.5	2.1	2.8	0.4	1.0	0.3	68.1	29.0	2.6	Coasrs sand, sand, rock, silt, shell hash
E-9	116	0.063	4.0	2.0	3.4	0.3	1.4	1.8	61.0	34.2	3.0	Coarse black sand, silt

Appendix B.3

Annual area mean concentrations of Point Loma Ocean Outfall Monitoring Program organic indicators, 1991–2005. CDF=cumulative distribution functions (see text); NA=not analyzed. Values that exceed the median CDF are indicated in bold type.

YEAR	BOD (mg/L)	Sulfides (ppm)	TN (wt%)	TOC (wt%)	TVS (wt%)
1991	246	0.4			2.36
1992	224	0.9	0.044	0.530	2.25
1993	276	2.4	0.032	0.533	2.35
1994	303	3.2	**0.050**	**0.813**	2.40
1995	331	3.2	0.034	**0.652**	2.65
1996	298	3.8	**0.059**	**0.805**	2.67
1997	302	6.0	**0.056**	**0.741**	2.62
1998	316	5.7	**0.056**	0.531	2.58
1999	327	8.7	**0.055**	0.514	2.78
2000	300	3.0	**0.058**	0.528	2.74
2001	321	2.4	**0.052**	0.524	2.63
2002	311	3.9	**0.054**	**0.606**	2.75
2003	298	3.5	**0.063**	**0.617**	2.48
2004	316	5.6	**0.055**	0.546	2.44
2005	330	1.7	**0.055**	**0.762**	2.70
MDL	2	0.14	0.005	0.010	0.11
50% CDF	NA	NA	0.050	0.597	NA

Appendix B.4

Annual mean concentrations of trace metals for the Point Loma Ocean Outfall Monitoring Program, 1991–2005. CDF=cumulative distribution function (see text). MDL=method detection limit. ERL=Effects Range Low Threshold Value. NA=not available. nd=not detected. ns=not sampled. Values that exceed the median CDF are indicated in bold type. The names of each trace metal represented by the periodic table symbol are presented in Appendix B.1.

YEAR	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
1991	ns	nd	2.0	ns	**0.77**	0.15	21.6	8.7	ns	3.1	ns	0.017	8.2	0.111	0.000	nd	nd	33.9
1992	ns	nd	2.6	ns	**0.28**	**0.38**	16.1	7.9	ns	2.9	ns	0.019	5.5	0.084	**0.377**	1.4	ns	29.0
1993	ns	**0.31**	3.0	ns	0.01	**2.54**	18.3	7.9	13023	0.7	ns	0.003	6.9	0.281	0.000	13.1	nd	27.5
1994	**9700**	nd	3.7	ns	0.03	**1.71**	20.3	10.2	13880	4.1	ns	0.010	8.5	0.228	0.000	nd	nd	31.5
1995	**10426**	**1.02**	3.9	ns	0.17	0.01	19.9	9.7	14946	2.0	ns	0.007	7.3	0.243	0.083	0.3	ns	31.7
1996	**9744**	**1.98**	3.8	ns	0.18	nd	20.2	9.3	13871	2.2	92.0	0.030	8.3	0.229	0.060	nd	2.07	29.0
1997	**10603**	**2.40**	3.8	ns	**0.33**	0.04	19.1	10.8	13677	1.1	95.1	0.030	7.9	0.283	0.000	nd	4.34	36.0
1998	**11847**	**3.83**	3.9	ns	**0.74**	0.01	15.4	8.9	14391	2.8	105.0	0.018	7.9	0.234	0.000	0.5	nd	33.4
1999	**11545**	**0.42**	3.9	ns	**0.73**	**0.78**	16.4	8.6	14832	0.6	102.9	0.005	7.7	0.224	0.000	0.1	nd	33.2
2000	**9714**	**1.04**	3.4	ns	nd	0.01	14.8	9.4	13938	1.7	108.0	0.007	7.2	0.253	0.000	nd	0.46	30.6
2001	**10185**	**1.89**	3.4	ns	0.09	0.06	17.8	10.2	14023	1.4	98.1	0.009	6.9	0.195	0.000	0.2	nd	29.8
2002	**10206**	**1.63**	3.8	ns	0.03	0.02	16.3	10.4	13902	1.0	95.0	0.017	5.7	0.130	0.088	0.4	nd	29.6
2003	**10164**	**0.61**	3.7	35.7	0.06	0.12	18.7	9.5	13907	2.0	98.3	0.037	4.8	0.044	0.153	nd	0.15	30.8
2004	**10389**	**0.61**	3.0	43.0	0.21	0.14	19.3	7.4	14131	5.6	143.0	0.033	7.3	0.007	0.043	nd	1.77	32.8
2005	**13941**	**0.40**	3.5	45.1	**0.30**	0.10	21.3	9.2	**17391**	6.4	216.4	0.034	8.1	0.020	0.000	nd	2.00	36.9
MDL	1.15	**0.13**	0.33	0.002	0.001	0.01	0.016	0.028	0.75	0.142	0.004	0.003	0.036	0.24	0.013	0.022	0.059	0.052
50% CDF	9400	0.2	4.80	NA	0.26	0.29	34.0	12.0	16800	NA	NA	0.040	NA	0.29	0.17	NA	NA	56.0
ERL	NA	NA	8.2	NA	NA	1.2	81	34	NA	46.7	NA	0.2	20.9	NA	1.0	NA	NA	150

Appendix B.5

Summary of annual mean concentrations of PAHs (ppb) for Point Loma Ocean Outfall Monitoring Program sediment monitoring stations during 2005. MDL=method detection limit. Undetected values are indicated by "nd." Primary core stations are indicated in bold type.

Station	1-Methylnaphthalene	1-Methylphenanthrene	2,3,5-Trimethylnaphthalene
B-8	30.3	nd	nd
B-9	15.2	nd	5.4
B-10	16.9	nd	nd
B-11	24.9	nd	nd
B-12	13.3	nd	nd
E-1	16.3	nd	nd
E-2	15.5	nd	4.0
E-3	14.9	nd	nd
E-5	14.4	nd	nd
E-7	21.2	nd	nd
E-8	14.4	nd	6.1
E-9	19.7	32.8	nd
E-11	13.8	nd	4.9
E-14	15.1	nd	nd
E-15	14.8	nd	nd
E-17	14.8	nd	6.7
E-19	17.9	nd	nd
E-20	14.8	nd	5.6
E-21	12.9	nd	nd
E-23	13.7	nd	nd
E-25	15.0	nd	3.9
E-26	16.3	nd	5.3
MDL	12	41	21

Appendix B.5 *continued*

Station	2,6-Dimethylnaphthalene	2-Methylnaphthalene	3,4-Benzo(B)fluoranthene
B-8	48.1	109.0	nd
B-9	28.0	48.2	nd
B-10	28.6	67.0	nd
B-11	41.8	89.0	nd
B-12	24.8	39.1	nd
E-1	30.7	47.6	59.5
E-2	28.3	42.2	16.6
E-3	30.4	43.9	nd
E-5	27.0	42.5	nd
E-7	42.2	67.3	nd
E-8	28.5	41.0	nd
E-9	41.2	72.7	944.0
E-11	28.8	40.1	nd
E-14	31.7	39.7	nd
E-15	26.8	42.1	nd
E-17	30.6	42.0	nd
E-19	32.9	49.7	nd
E-20	33.1	43.0	nd
E-21	25.8	38.1	nd
E-23	27.2	40.1	nd
E-25	29.4	41.5	nd
E-26	33.0	44.4	nd
MDL	32	12	63

Appendix B.5 *continued*

Station	Acenaphthene	Acenaphthylene	Anthracene	Benzo[A]Anthracene	Benzo[A]Pyrene
B-8	nd	nd	nd	28.9	nd
B-9	nd	nd	nd	18.7	nd
B-10	nd	nd	nd	19.8	nd
B-11	nd	nd	nd	nd	nd
B-12	nd	nd	nd	nd	nd
E-1	nd	4.0	11.9	46.3	nd
E-2	nd	nd	4.6	34.5	17.5
E-3	nd	nd	nd	47.4	nd
E-5	nd	nd	1.9	26.8	nd
E-7	nd	nd	nd	29.6	nd
E-8	nd	nd	nd	11.0	nd
E-9	nd	nd	1290.0	957.0	727.0
E-11	nd	nd	1.5	11.4	nd
E-14	nd	nd	nd	10.7	nd
E-15	nd	nd	nd	21.2	nd
E-17	nd	nd	nd	13.9	nd
E-19	nd	nd	nd	nd	nd
E-20	nd	nd	1.9	17.0	nd
E-21	nd	nd	nd	23.9	nd
E-23	nd	nd	2.0	12.3	nd
E-25	nd	nd	nd	17.5	nd
E-26	nd	nd	nd	12.4	nd
MDL	28	15	18	32	55

Appendix B.5 *continued*

Station	Benzo[e]pyrene	Benzo[G,H,I]perylene	Benzo[K]fluoranthene	Biphenyl	Chrysene
B-8	nd	nd	nd	23.3	nd
B-9	nd	nd	nd	18.0	4.1
B-10	nd	nd	nd	18.5	nd
B-11	nd	nd	nd	20.3	nd
B-12	nd	nd	nd	18.9	nd
E-1	nd	nd	nd	20.9	28.7
E-2	nd	12.0	15.8	17.0	34.4
E-3	nd	nd	nd	21.6	28.1
E-5	nd	nd	nd	17.6	8.8
E-7	nd	nd	nd	20.9	7.6
E-8	nd	nd	nd	17.9	1.5
E-9	396.0	209.0	402.0	23.4	1490.0
E-11	nd	nd	nd	16.6	3.0
E-14	nd	nd	nd	17.0	1.7
E-15	nd	nd	nd	17.0	nd
E-17	nd	nd	nd	17.1	3.3
E-19	nd	nd	nd	18.5	nd
E-20	nd	nd	nd	17.1	3.1
E-21	nd	nd	nd	16.6	nd
E-23	nd	nd	nd	17.5	1.0
E-25	nd	nd	nd	18.1	6.9
E-26	nd	nd	nd	18.3	nd
MDL	57.00	56.00	82.00	10.00	36.00

Appendix B.5 *continued*

Station	Dibenzo(A,H)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-CD)pyrene
B-8	nd	11.9	7.0	nd
B-9	nd	3.3	2.1	nd
B-10	nd	4.7	3.8	nd
B-11	nd	9.4	6.2	nd
B-12	nd	nd	nd	nd
E-1	nd	41.7	9.7	nd
E-2	nd	16.8	nd	10.6
E-3	nd	39.2	nd	nd
E-5	nd	10.5	2.1	nd
E-7	nd	13.9	5.3	nd
E-8	nd	2.9	nd	nd
E-9	124.0	1000.0	57.5	290.0
E-11	nd	2.6	4.0	nd
E-14	nd	nd	2.6	nd
E-15	nd	nd	3.2	nd
E-17	nd	3.8	4.5	nd
E-19	nd	1.4	4.3	nd
E-20	nd	3.5	1.6	nd
E-21	nd	nd	3.0	nd
E-23	nd	2.0	1.1	nd
E-25	nd	4.2	2.0	nd
E-26	nd	8.2	4.8	nd
MDL	52	24	13	76

Appendix B.5 *continued*

Station	Naphthalene	Perylene	Phenanthrene	Pyrene	Total PAH
B-8	72.6	nd	32.9	23.4	387
B-9	34.3	nd	15.5	5.8	198
B-10	42.8	nd	18.3	8.8	229
B-11	48.6	nd	33.0	19.2	292
B-12	26.6	nd	nd	3.8	127
E-1	28.7	nd	40.6	63.2	450
E-2	24.4	3.9	6.8	31.0	349
E-3	25.1	nd	29.3	72.4	352
E-5	32.7	nd	6.4	20.8	211
E-7	39.8	nd	nd	30.2	278
E-8	23.7	18.5	nd	5.9	171
E-9	35.8	263.0	166.0	1400.0	9941
E-11	22.4	13.4	11.6	5.7	179
E-14	20.4	12.3	nd	6.6	157
E-15	20.0	nd	nd	nd	145
E-17	24.4	nd	9.0	17.9	188
E-19	26.1	nd	nd	nd	151
E-20	23.6	nd	nd	14.6	179
E-21	18.0	nd	nd	nd	138
E-23	22.3	nd	nd	8.7	148
E-25	23.5	nd	15.7	9.2	187
E-26	26.8	13.3	nd	14.6	197
MDL	21	23	21	35	

Appendix C

Supporting Data

2005 PLOO Stations

Demersal Fishes and Megabenthic Invertebrates

Appendix C.1

Summary of demersal fish species captured during 2005 at PLOO stations. Data are number of fish collected (n), biomass (BM; wet weight, kg), minimum (Min), maximum (Max), and mean length (cm). Taxonomic arrangement and scientific names are sesnu Eschmeyer and Herald (1998) and Allen (2005).*

				LENGTH		
Taxon/Species	**Common Name**	**n**	**BM**	**Min**	**Max**	**Mean**
RAJIFORMES						
Rajidae						
Raja inornata	California skate	7	3.9	14	60	31
OSMERIFORMES						
Argentinidae						
Argentina sialis	Pacific argentine	2	0.2	5	8	7
OPHIDIIFORMES						
Ophidiidae						
Chilara taylori	spotted cuskeel	7	0.4	14	18	16
BATRACHOIDIFORMES						
Batrachoididae						
Porichthys notatus	plainfin midshipman	123	2.3	6	16	11
SCORPAENIFORMES						
Scorpaenidae	(juv. rockfish unid.)	3	0.2	4	7	6
Sebastes chlorostictus	greenspotted rockfish	22	0.7	4	16	9
Sebastes elongatus	greenstriped rockfish	41	1.4	5	13	8
Sebastes eos	pink rockfish	1	0.1	7	7	7
Sebastes goodei	chilipepper rockfish	4	0.3	15	16	15
Sebastes hopkinsi	squarespot rockfish	25	1	7	15	12
Sebastes rosenblatti	greenblotched rockfish	14	0.8	7	20	10
Sebastes rubrivinctus	flag rockfish	1	0.1	9	9	9
Sebastes saxicola	stripetail rockfish	53	0.8	6	11	8
Sebastes semicinctus	halfbanded rockfish	2829	44.6	5	15	9
Hexagrammidae						
Zaniolepis frenata	shortspine combfish	78	2.5	6	17	13
Zaniolepis latipinnis	longspine combfish	571	9.3	7	16	12
Cottidae						
Chitonotus pugetensis	roughback sculpin	24	0.7	3	10	7
Icelinus quadriseriatus	yellowchin sculpin	366	2.2	3	8	6
Icelinus tenuis	spotfin sculpin	28	0.3	7	9	8
Agonidae						
Odontopyxis trispinosa	pygmy poacher	9	0.4	7	14	9
Xeneretmus latifrons	blacktip poacher	20	0.4	11	14	13
Xeneretmus triacanthus	bluespotted poacher	2	0.2	9	15	12
PERCIFORMES						
Embiotocidae						
Cymatogaster aggregata	shiner perch	1	0.1	12	12	12
Zalembius rosaceus	pink seaperch	59	1.3	5	14	9
Bathymasteridae						
Rathbunella hypoplecta	bluebanded ronquil	1	0.1	13	13	13
Zoarcidae						
Lycodes cortezian	bigfin eelpout	11	0.4	14	25	20
Lycodopsis pacifica	blackbelly eelpout	10	0.5	17	25	21
Gobiidae						
Lepidogobius lepidus	bay goby	1	0.1	7	7	7

Appendix C.1 continued

Taxon/Species	Common Name	n	BM	LENGTH Min	LENGTH Max	LENGTH Mean
PLEURONECTIFORMES						
Paralichthyidae						
Chitharichthy sp		2	0.1	3	3	3
Citharichthys sordidus	Pacific sanddab	2531	45	4	24	10
Citharichthys xanthostigma	longfin sanddab	1	0.1	14	14	14
Hippoglossina stomata	bigmouth sole	3	0.6	18	25	21
Pleuronectidae						
Eopsetta exilis	slender sole	74	1.4	9	16	12
Microstomus pacificus	Dover sole	568	12.1	6	20	11
Parophrys vetulus	English sole	63	4.1	9	23	15
Pleuronichthys verticalis	hornyhead turbot	14	1.4	8	19	13
Cynoglossidae						
Symphurus atricauda	California tonguefish	27	0.9	11	16	14

* Eschmeyer, W. N. and E.S. Herald. 1998. A Field Guide to Pacific Coast Fishes of North America. Houghton and Mifflin Company, New York. 336 p.

Allen, M.J. 2005. The check list of trawl-caught fishes for Southern California from depths of 2–265 m. Southern California Research Project, Westminister, CA.

Appendix C.2

Summary of total abundance by species and station for demersal fish at the PLOO trawl stations during 2005. Species abundance by survey is cumulative for 6 stations.

January 2005

Name	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species Abundance by Survey**
Halfbanded rockfish	14	44	1929	608	23	79	2697
Pacific sanddab	98	188	198	99	281	213	1077
Longspine combfish	6	3	41	138	54	178	420
Yellowchin sculpin	136	11	60	5	60	19	291
Dover sole	18	31	19	103	65	45	281
Plainfin midshipman	11	1	2	5	35	26	80
Shortspine combfish	5	24	4	10	5	2	50
English sole		13	8	2	6	14	43
Stripetail rockfish	13				20	7	40
Pink seaperch	1	3	9	3	8	9	33
Greenstriped rockfish	2	9	2	11	2	1	27
Squarespot rockfish			24				24
Spotfin sculpin		20	3				23
Greenspotted rockfish		6	5	6	2	2	21
Roughback sculpin	4	1	8	2	6		21
California tonguefish	6	6		4		3	19
Blackbelly eelpout				5	1	4	10
Hornyhead turbot			2	1	2	1	6
Chilipepper rockfish			4				4
Pygmy poacher		4					4
Bluespotted poacher				1		1	2
Juvenile sanddab					2		2
Juvenile rockfish			2				2
Bay goby		1					1
Bigmouth sole			1				1
Blacktip poacher		1					1
California skate						1	1
Flag rockfish			1				1
Longfin sanddab						1	1
Pacific argentine					1		1
Shiner perch					1		1
Spotted cuskeel					1		1
QUARTER	314	366	2322	1003	575	606	5186

July 2005

Name	SD7	SD8	SD10	SD12	SD13	SD14	Species Abundance by Survey
Pacific sanddab	172	199	263	236	325	259	1454
Dover sole	23	11	71	89	56	37	287
Longspine combfish	5		8	62	70	6	151
Halfbanded rockfish	1	9	17	18	23	64	132
Yellowchin sculpin	45	1	23	1	2	3	75
Slender sole	3	5	7	38	14	7	74
Plainfin midshipman	1	2	1	27	6	6	43
Shortspine combfish	1	7	5	11	2	2	28
Pink seaperch		1	5	4	15	1	26
English sole	1	3	4	8	4		20
Blacktip poacher				12	4	3	19
Greenblotched rockfish	1		1	2	5	5	14
Greenstriped rockfish	1	5	2	5		1	14
Stripetail rockfish			3		6	4	13
Bigfin eelpout					8	3	11
California tonguefish	1	6	1				8
Hornyhead turbot		1		3	2	2	8
California skate	1		1		4		6
Spotted cuskeel	1	3		2			6
Pygmy poacher		3		1	1		5
Spotfin sculpin		5					5
Roughback sculpin	2					1	3
Bigmouth sole				1	1		2
Bluebanded ronquil		1					1
Greenspotted rockfish						1	1
Pacific argentine	1						1
Rockfish unid.			1				1
Rosy rockfish	1						1
Squarespot rockfish		1					1
QUARTER	261	263	413	520	548	405	2410
GRAND TOTAL	**575**	**629**	**2735**	**1523**	**1123**	**1011**	**7596**

Appendix C.3

Summary of total biomass by species and station for demersal fish at the PLOO trawl stations during 2005. Species biomass by survey is cumulative for 6 stations. Biomass is slightly overestimated due to the rounding up of weights less than 0.1 kg.

	January 2005						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Biomass By Survey**
Halfbanded rockfish	0.1	0.7	32.7	7	0.3	1	41.8
Pacific sanddab	0.9	1.5	1	0.7	4	4.3	12.4
Longspine combfish	0.1	0.1	0.7	1.8	0.8	2.7	6.2
Dover sole	0.5	0.6	0.1	1.3	0.5	0.7	3.7
English sole		1	0.5	0.2	0.3	0.7	2.7
Shortspine combfish	0.2	1	0.1	0.2	0.2	0.1	1.8
Yellowchin sculpin	0.5	0.1	0.4	0.1	0.3	0.1	1.5
Plainfin midshipman	0.1	0.1	0.1	0.1	0.5	0.3	1.2
Squarespot rockfish			0.9				0.9
Greenstriped rockfish	0.1	0.3	0.1	0.1	0.1	0.1	0.8
Hornyhead turbot			0.4	0.1	0.1	0.1	0.7
Pink seaperch	0.1	0.1	0.1	0.1	0.1	0.2	0.7
Stripetail rockfish	0.1				0.3	0.1	0.5
Blackbelly eelpout				0.2	0.1	0.2	0.5
California tonguefish	0.2	0.1		0.1		0.1	0.5
Juvenile rockfish		0.1	0.1	0.1	0.1	0.1	0.5
Roughback sculpin	0.1	0.1	0.1	0.1	0.1		0.5
Chilipepper rockfish			0.3				0.3
Greenspotted rockfish		0.1	0.2				0.3
Bluespotted poacher				0.1		0.1	0.2
Spotfin sculpin		0.1	0.1				0.2
Bay goby		0.1					0.1
Bigmouth sole			0.1				0.1
Blacktip poacher		0.1					0.1
California skate						0.1	0.1
Juvenile sanddab					0.1		0.1
Flag rockfish			0.1				0.1
Longfin sanddab						0.1	0.1
Pacific argentine					0.1		0.1
Pygmy poacher		0.1					0.1
Shiner perch					0.1		0.1
Spotted cuskeel					0.1		0.1
QUARTER	3	6.3	38.1	12.3	8.2	11.1	79

Appendix C.3 continued

	July 2005						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Biomass By Survey**
Pacific sanddab	3.6	3	6.7	4.5	8.4	6.4	32.6
Dover sole	0.5	0.3	1.1	2.7	1.8	2	8.4
California skate	0.1		0.8		2.9		3.8
Longspine combfish	0.1		0.1	1	1.8	0.1	3.1
Halfbanded rockfish	0.1	0.2	0.4	0.4	0.4	1.3	2.8
English sole	0.1	0.1	0.2	0.7	0.3		1.4
Slender sole	0.1	0.1	0.1	0.8	0.2	0.1	1.4
Plainfin midshipman	0.1	0.1	0.1	0.6	0.1	0.1	1.1
Greenblotched rockfish	0.1		0.1	0.1	0.4	0.1	0.8
Hornyhead turbot		0.1		0.4	0.1	0.1	0.7
Shortspine combfish	0.1	0.2	0.1	0.1	0.1	0.1	0.7
Yellowchin sculpin	0.2	0.1	0.1	0.1	0.1	0.1	0.7
Greenstriped rockfish	0.1	0.2	0.1	0.1		0.1	0.6
Pink seaperch		0.1	0.1	0.1	0.2	0.1	0.6
Bigmouth sole				0.4	0.1		0.5
Bigfin eelpout					0.3	0.1	0.4
California tonguefish	0.1	0.2	0.1				0.4
Blacktip poacher				0.1	0.1	0.1	0.3
Pygmy poacher		0.1		0.1	0.1		0.3
Spotted cuskeel	0.1	0.1		0.1			0.3
Stripetail rockfish			0.1		0.1	0.1	0.3
Roughback sculpin	0.1					0.1	0.2
Bluebanded ronquil		0.1					0.1
Greenspotted rockfish						0.1	0.1
Pacific argentine	0.1						0.1
Juvenile rockfish			0.1				0.1
Rosy rockfish	0.1						0.1
Spotfin sculpin		0.1					0.1
Squarespot rockfish		0.1					0.1
QUARTER	5.7	5.2	10.3	12.3	17.5	11.1	62.1
GRAND TOTAL	**8.7**	**11.5**	**48.4**	**24.6**	**25.7**	**22.2**	**141.1**

Appendix C.4

List of megabenthic invertebrate taxa collected at PLOO stations during 2005 surveys. n=total number of individuals collected. Taxonomic arrangement from SCAMIT 2001.*

Taxon/Species	**n**
PORIFERA	2
CNIDARIA	
ANTHOZOA	
Alcyonacea	
Gorgoniidae	
Adelogorgia phyllosclera	2
Muriceidae	
Thesea sp B	4
Pennatulacea	
Virgulariidae	
Acanthoptilum sp	1125
Actiniaria	
Metridiidae	
Metridium farcimen	11
MOLLUSCA	
GASTROPODA	
Neotaeniglossa	
Ovulidae	
Neosimnia barbarensis	1
Neogastropoda	
Muricidae	
Pteropurpura macroptera	1
Cancellariidae	
Cancellaria crawfordiana	2
Turridae	
Megasurcula carpenteriana	3
Cephalaspidea	
Philinidae	
Philine auriformis	1
Notaspidea	
Pleurobranchidae	
Pleurobranchaea californica	30
Nudibranchia	
Onchidorididae	
Acanthodoris brunnea	1
Tritoniidae	
Tritonia diomedea	2
CEPHALOPODA	
Sepiolida	
Sepiolidae	
Rossia pacifica	1
Teuthida	
Loliginidae	
Loligo opalescens	2
Octopoda	
Octopodidae	
Octopus rubescens	10

Appendix C.4 continued

Taxon/Species	n
ARTHROPODA	
PYCNOGONIDA	
Pegmata	
Nymphonidae	
Nymphon pixellae	8
MALACOSTRACA	
Decapoda	
Sicyoniidae	
Sicyonia ingentis	14
Crangonidae	
Crangon alaskensis	1
Paguroidae	1
Diogenidae	
Paguristes Bakeri	1
Calappidae	
Platymera gaudichaudii	5
Majidae	
Loxorhynchus crispatus	2
Pyromaia tuberculata	1
ECHINODERMATA	
CRINOIDEA	
Comatulida	
Antedonidae	
Florometra serratissima	9
ASTEROIDEA	
Paxillosida	
Luidiidae	
Luidia armata	4
Luidia asthenosoma	9
Luidia foliolata	31
Astropectinidae	
Astropecten ornatissimus	3
Astropecten verrilli	61
Forcipulatida	
Asteriidae	
Rathbunaster californicus	1
Valvatida	
Goniasteridae	
Mediaster aequalis	1
Asterinidae	
Asterina miniata	1
Spinulosida	
Echinasteridae	
Henricia sp	1

Appendix C.4 continued

Taxon/Species	n
OPHIUROIDEA	2
Ophiurida	
Ophiactidae	
Ophiopholis bakeri	4
Amphiuridae	
Amphichondrius granulatus	1
Amphipholis squamata	1
Ophiotricidae	
Ophiothrix spiculata	1
Ophionereidae	
Ohpioneris eurybrachiplax	1
Ophiuridae	
Ophiura luetkenii	13
ECHINOIDEA	
Temnopleuroida	
Toxopneustidae	
Lytechinus pictus	22098
Echinoida	
Strongylocentrotidae	
Allocentrotus fragilis	552
Spatangoida	
Spatangidae	
Spatangus californicus	1
HOLOTHURIODEA	
Aspidochirotida	
Stichopodidae	
Parastichopus californicus	43

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*[SCAMIT] The Southern California Association of Marine Invertebrate Taxonomists. 2001. A taxonomic listing of soft bottom marco- and megabenthic invertebrates from infaunal and epibenthic monitoring programs in the Southern California Bight; Edition 4. SCAMIT. San Pedro, CA.

Appendix C.5

Summary of total abundance by species and station for megabenthic invertebrates at the PLOO trawl stations during 2005. Species abundance by survey is cumulative for 6 stations.

	January 2005						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species Abundance By Survey**
Lytechinus pictus	210	6106	4182	2548	595	441	14082
Acanthoptilum sp			14	1000	21	2	1037
Astropecten verrilli	13	2	7	3	5	4	34
Parastichopus californicus	8	7		4	3	1	23
Pleurobranchaea californica	1	7	1	2	2	1	14
Sicyonia ingentis	8	3			1	1	13
Luidia foliolata	2	2	1		2	4	11
Luidia asthenosoma	4				2	3	9
Metridium farcimen		2	3		4		9
Nymphon pixellae	2	1			1	2	6
Octopus rubescens	2	1		1			4
Ophiopholis bakeri	1		3				4
Florometra serratissima		3					3
Luidia armata	1	2					3
Ophiura luetkenii	1				1	1	3
Loligo opalescens	2						2
Loxorhynchus crispatus			2				2
Megasurcula carpenteriana			2				2
Ophiuroidea		2					2
Thesea sp B		1		1			2
Tritonia diomedea					2		2
Adelogorgia phyllosclera		1					1
Allocentrotus fragilis				1			1
Amphichondrius granulatus				1			1
Crangon alaskensis				1			1
Neosimnia barbarensis				1			1
Ophiothrix spiculata	1						1
Platymera gaudichaudii						1	1
Rathbunaster californicus				1			1
Tritonia diomedea			1				1
QUARTER	256	6140	4216	3564	639	461	15276

Appendix C.5 continued

	July 2005						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species Abundance By Survey**
Lytechinus pictus	1491	3302	2232	547	366	78	8016
Allocentrotus fragilis					159	392	551
Acanthoptilum sp		1	4	76	4	3	88
Astropecten verrilli	10		12	4	1		27
Luidia foliolata	3	4			5	8	20
Parastichopus californicus	3	11	4		1	1	20
Pleurobranchaea californica	1		4	5	4	2	16
Ophiura luetkenii	5		3		1	1	10
Florometra serratissima	1	5					6
Octopus rubescens		2			4		6
Platymera gaudichaudii		2		1	1		4
Astropecten ornatissimus			3				3
Cancellaria crawfordiana			2				2
Metridium farcimen		1			1		2
Nymphon pixellae	1	1					2
Porifera		1	1				2
Thesea sp B		2					2
Acanthodoris brunnea	1						1
Adelogorgia phyllosclera		1					1
Amphipholis squamata	1						1
Asterina miniata				1			1
Henricia sp		1					1
Luidia armata		1					1
Mediaster aequalis		1					1
Megasurcula carpenteriana			1				1
Ophionereis eurybrachiplax		1					1
Paguristes bakeri			1				1
Paguroidea		1					1
Philine auriformis			1				1
Pteropurpura macroptera		1					1
Pyromaia tuberculata	1						1
Sicyonia ingentis	1						1
Spatangus californicus	1						1
QUARTER	1520	3339	2268	634	547	485	8793
GRAND TOTAL	**1776**	**9479**	**6484**	**4198**	**1186**	**946**	**24069**

Appendix D

Supporting Data

2005 PLOO Stations

Bioaccumulation of Contaminants in Fish Tissues

Appendix D.1

Lengths and weights of fishes used in PLOO fish tissue samples for October 2005.

				Length			Weight		
Station	Rep	Species	n	min	max	mean	min	max	mean
RF1	1	Rosethorn rockfish	3	16	18	17	97	133	109
RF1	2	Mixed rockfish	3	16	39	25	112	1200	499
RF1	3	Mixed rockfish	3	19	32	24	144	1000	447
RF2	1	Squarespot rockfish	3	20	24	23	174	257	203
RF2	2	Squarespot rockfish	3	21	25	22	183	272	228
RF2	3	Speckled rockfish	3	24	27	26	365	600	458
Zone 1	1	Pacific sanddab	3	19	21	20	90	163	130
Zone 1	2	Pacific sanddab	5	15	19	17	67	101	86
Zone 1	3	Pacific sanddab	3	18	23	20	98	187	142
Zone 2	1	Pacific sanddab	3	18	19	18	103	119	109
Zone 2	2	Pacific sanddab	3	18	20	19	100	141	123
Zone 2	3	Pacific sanddab	3	19	20	20	124	126	125
Zone 3	1	Pacific sanddab	3	18	20	19	94	130	114
Zone 3	2	Pacific sanddab	3	16	22	19	64	170	114
Zone 3	3	Pacific sanddab	4	18	19	19	92	130	109
Zone 4	1	Pacific sanddab	4	16	20	18	60	132	96
Zone 4	2	Pacific sanddab	5	17	18	17	68	89	79
Zone 4	3	Pacific sanddab	4	18	20	19	85	114	102

Appendix D.2

Analyzed constituents for fish tissue samples analyzed for the PLOO monitoring program during October 2005.

Chlorinated Pesticides

Aldrin
Alpha (cis) Chlordane
Gamma (trans) Chlordane
Alpha Endosulfan
BHC, Alpha isomer
BHC, Beta isomer
BHC, Delta isomer
BHC, Gamma isomer
Cis Nonachlor
Dieldrin
Endrin
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Mirex
o,p-DDD
o,p-DDE
o,p-DDT
p,p-DDD
p,p-DDE
p,p-DDMU
p,p-DDT
Oxychlordane
Trans Nonachlor
Toxaphene

Metals

Aluminum (Al)
Antimony (Sb)
Arsenic (As)
Barium (Ba)
Beryllium (Be)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Lead (Pb)
Manganese (Mn)
Mercury (Hg)
Nickel (Ni)
Selenium (Se)
Silver (Ag)
Thallium (Tl)
Tin (Sn)
Zinc (Zn)

PCB Congeners

PCB 18
PCB 28
PCB 37
PCB 44
PCB 49
PCB 52
PCB 66
PCB 70
PCB 74
PCB 77
PCB 81
PCB 87
PCB 99
PCB 101
PCB 105
PCB 110
PCB 114
PCB 118
PCB 119
PCB 123
PCB 126
PCB 128
PCB 138
PCB 149
PCB 151
PCB 153/168
PCB 156
PCB 157
PCB 158
PCB 167
PCB 169
PCB 170
PCB 177
PCB 180
PCB 183
PCB 187
PCB 189
PCB 194
PCB 201
PCB 206

Appendix D.3

Summary of all parameters detected in each sample collected as part of the PLOO monitoring program during October 2005.

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
RF1	1	Rosethorn rockfish	Muscle	Aluminum	1.09		mg/kg	0.583
RF1	1	Rosethorn rockfish	Muscle	Arsenic	2.49		mg/kg	0.375
RF1	1	Rosethorn rockfish	Muscle	Barium	0.0134		mg/kg	0.007
RF1	1	Rosethorn rockfish	Muscle	Copper	0.762		mg/kg	0.068
RF1	1	Rosethorn rockfish	Muscle	Iron	1.95		mg/kg	0.096
RF1	1	Rosethorn rockfish	Muscle	Lipids	0.3		%wt	0.005
RF1	1	Rosethorn rockfish	Muscle	Manganese	0.0837		mg/kg	0.007
RF1	1	Rosethorn rockfish	Muscle	Mercury	0.108		mg/kg	0.03
RF1	1	Rosethorn rockfish	Muscle	p,p-DDD	0.1	E	ug/kg	
RF1	1	Rosethorn rockfish	Muscle	p,p-DDE	2.2		ug/kg	1.33
RF1	1	Rosethorn rockfish	Muscle	PCB 118	0.2	E	ug/kg	
RF1	1	Rosethorn rockfish	Muscle	PCB 138	0.2	E	ug/kg	
RF1	1	Rosethorn rockfish	Muscle	PCB 153/168	0.3	E	ug/kg	
RF1	1	Rosethorn rockfish	Muscle	PCB 180	0.1	E	ug/kg	
RF1	1	Rosethorn rockfish	Muscle	Selenium	0.367		mg/kg	0.06
RF1	1	Rosethorn rockfish	Muscle	Thallium	2.61		mg/kg	0.845
RF1	1	Rosethorn rockfish	Muscle	Total DDT	2.3		ug/kg	
RF1	1	Rosethorn rockfish	Muscle	Total PCB	0.8		ug/kg	
RF1	1	Rosethorn rockfish	Muscle	Total Solids	21.4		%wt	0.4
RF1	1	Rosethorn rockfish	Muscle	Zinc	2.91		mg/kg	0.049
RF1	2	Mixed rockfish	Muscle	Alpha (cis) Chlordane	0.7	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	Arsenic	2.87		mg/kg	0.375
RF1	2	Mixed rockfish	Muscle	Barium	0.0112		mg/kg	0.007
RF1	2	Mixed rockfish	Muscle	Chromium	0.0485		mg/kg	0.08
RF1	2	Mixed rockfish	Muscle	Cis Nonachlor	0.5	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	Copper	1.01		mg/kg	0.068
RF1	2	Mixed rockfish	Muscle	Gamma (trans) Chlordane	0.3	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	Hexachlorobenzene	0.3	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	Iron	2.9		mg/kg	0.096
RF1	2	Mixed rockfish	Muscle	Lipids	3.13		%wt	0.005
RF1	2	Mixed rockfish	Muscle	Manganese	0.0701		mg/kg	0.007
RF1	2	Mixed rockfish	Muscle	Mercury	0.11		mg/kg	0.03
RF1	2	Mixed rockfish	Muscle	o,p-DDE	0.9	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	o,p-DDT	0.2	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	p,p-DDD	1	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	p,p-DDE	60		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	p,-p-DDMU	0.6	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	p,p-DDT	0.9	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 101	1.8		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 105	1	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 110	1.4		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 118	2.5		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 123	0.3	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 128	0.8	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 138	3.7		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 149	1.7		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 151	0.6	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
RF1	2	Mixed rockfish	Muscle	PCB 153/168	6.1		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 156	0.4	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 157	0.1	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 158	0.3	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 167	0.2	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 170	1.1	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 177	0.6	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 180	2.8		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 183	0.8	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 187	2.3		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	PCB 194	0.7	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 201	0.9	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 206	0.4	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 28	0.1	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 49	0.4	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 52	0.4	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 66	0.5	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 70	0.3	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 74	0.3	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 87	0.4	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	PCB 99	1.5		ug/kg	1.33
RF1	2	Mixed rockfish	Muscle	Selenium	0.347		mg/kg	0.06
RF1	2	Mixed rockfish	Muscle	Thallium	2.6		mg/kg	0.845
RF1	2	Mixed rockfish	Muscle	Total DDT	63.6		ug/kg	
RF1	2	Mixed rockfish	Muscle	Total PCB	34.4		ug/kg	
RF1	2	Mixed rockfish	Muscle	Total Solids	22.3		%wt	0.4
RF1	2	Mixed rockfish	Muscle	Trans Nonachlor	1.2	E	ug/kg	
RF1	2	Mixed rockfish	Muscle	Zinc	3.08		mg/kg	0.049
RF1	3	Mixed rockfish	Muscle	Alpha (cis) Chlordane	0.3	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	Aluminum	3.28		mg/kg	0.583
RF1	3	Mixed rockfish	Muscle	Arsenic	2.6		mg/kg	0.375
RF1	3	Mixed rockfish	Muscle	Barium	0.0642		mg/kg	0.007
RF1	3	Mixed rockfish	Muscle	Copper	0.733		mg/kg	0.068
RF1	3	Mixed rockfish	Muscle	Hexachlorobenzene	0.1	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	Iron	1.68		mg/kg	0.096
RF1	3	Mixed rockfish	Muscle	Lipids	2.31		%wt	0.005
RF1	3	Mixed rockfish	Muscle	Manganese	0.0547		mg/kg	0.007
RF1	3	Mixed rockfish	Muscle	Mercury	0.054		mg/kg	0.03
RF1	3	Mixed rockfish	Muscle	o,p-DDE	0.2	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	p,p-DDD	0.4	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	p,p-DDE	9.6		ug/kg	1.33
RF1	3	Mixed rockfish	Muscle	p,-p-DDMU	0.5	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	p,p-DDT	0.3	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 101	0.4	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 105	0.2	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 110	0.3	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 118	0.5	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 128	0.2	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 138	0.7	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 149	0.4	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 151	0.1	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 153/168	1.1	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
RF1	3	Mixed rockfish	Muscle	PCB 158	0.1	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 170	0.2	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 180	0.4	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 183	0.2	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 187	0.4	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 194	0.1	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 49	0.1	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 52	0.1	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 66	0.1	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	PCB 99	0.4	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	Selenium	0.478		mg/kg	0.06
RF1	3	Mixed rockfish	Muscle	Thallium	2.92		mg/kg	0.845
RF1	3	Mixed rockfish	Muscle	Total DDT	11		ug/kg	
RF1	3	Mixed rockfish	Muscle	Total PCB	6		ug/kg	
RF1	3	Mixed rockfish	Muscle	Total Solids	21.9		%wt	0.4
RF1	3	Mixed rockfish	Muscle	Trans Nonachlor	0.4	E	ug/kg	
RF1	3	Mixed rockfish	Muscle	Zinc	3.13		mg/kg	0.049
RF2	1	Squarespot rockfish	Muscle	Aluminum	2.47		mg/kg	0.583
RF2	1	Squarespot rockfish	Muscle	Arsenic	2.54		mg/kg	0.375
RF2	1	Squarespot rockfish	Muscle	Barium	0.0086		mg/kg	0.007
RF2	1	Squarespot rockfish	Muscle	Chromium	0.087		mg/kg	0.08
RF2	1	Squarespot rockfish	Muscle	Copper	0.253		mg/kg	0.068
RF2	1	Squarespot rockfish	Muscle	Hexachlorobenzene	0.2	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	Iron	4.96		mg/kg	0.096
RF2	1	Squarespot rockfish	Muscle	Lead	0.32		mg/kg	0.3
RF2	1	Squarespot rockfish	Muscle	Lipids	2.09		%wt	0.005
RF2	1	Squarespot rockfish	Muscle	Manganese	0.0565		mg/kg	0.007
RF2	1	Squarespot rockfish	Muscle	Mercury	0.26		mg/kg	0.03
RF2	1	Squarespot rockfish	Muscle	o,p-DDE	0.2	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	p,p-DDD	0.3	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	p,p-DDE	11		ug/kg	1.33
RF2	1	Squarespot rockfish	Muscle	p,-p-DDMU	0.5	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	p,p-DDT	0.4	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 101	0.3	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 105	0.1	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 110	0.2	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 118	0.3	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 138	0.4	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 149	0.3	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 153/168	0.6	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 170	0.1	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 180	0.3	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 187	0.2	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 49	0.1	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 52	0.1	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	PCB 99	0.2	E	ug/kg	
RF2	1	Squarespot rockfish	Muscle	Selenium	0.364		mg/kg	0.06
RF2	1	Squarespot rockfish	Muscle	Thallium	2.79		mg/kg	0.845
RF2	1	Squarespot rockfish	Muscle	Total DDT	12.4		ug/kg	
RF2	1	Squarespot rockfish	Muscle	Total PCB	3.2		ug/kg	
RF2	1	Squarespot rockfish	Muscle	Total Solids	23.2		%wt	0.4
RF2	1	Squarespot rockfish	Muscle	Zinc	3.37		mg/kg	0.049

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
RF2	2	Squarespot rockfish	Muscle	Alpha (cis) Chlordane	0.9	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	Arsenic	2.16		mg/kg	0.375
RF2	2	Squarespot rockfish	Muscle	BHC, Beta isomer	5.8		ug/kg	2
RF2	2	Squarespot rockfish	Muscle	BHC, Delta isomer	7.6		ug/kg	2
RF2	2	Squarespot rockfish	Muscle	Copper	0.461		mg/kg	0.068
RF2	2	Squarespot rockfish	Muscle	Gamma (trans) Chlordane	1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	Hexachlorobenzene	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	Iron	3.71		mg/kg	0.096
RF2	2	Squarespot rockfish	Muscle	Lead	0.42		mg/kg	0.3
RF2	2	Squarespot rockfish	Muscle	Lipids	2.76		%wt	0.005
RF2	2	Squarespot rockfish	Muscle	Manganese	0.0256		mg/kg	0.007
RF2	2	Squarespot rockfish	Muscle	Mercury	0.213		mg/kg	0.03
RF2	2	Squarespot rockfish	Muscle	o,p-DDE	0.3	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	o,p-DDT	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	p,p-DDD	0.6	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	p,p-DDE	13		ug/kg	1.33
RF2	2	Squarespot rockfish	Muscle	p,-p-DDMU	0.7	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	p,p-DDT	0.4	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 101	0.3	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 105	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 110	0.2	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 118	0.3	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 128	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 138	0.4	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 149	0.3	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 151	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 153/168	0.6	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 170	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 177	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 180	0.3	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 183	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 187	0.2	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 201	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 49	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 52	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 66	0.1	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	PCB 99	0.2	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	Selenium	0.275		mg/kg	0.06
RF2	2	Squarespot rockfish	Muscle	Thallium	2.93		mg/kg	0.845
RF2	2	Squarespot rockfish	Muscle	Total DDT	15.1		ug/kg	
RF2	2	Squarespot rockfish	Muscle	Total PCB	3.8		ug/kg	
RF2	2	Squarespot rockfish	Muscle	Total Solids	22.8		%wt	0.4
RF2	2	Squarespot rockfish	Muscle	Trans Nonachlor	0.4	E	ug/kg	
RF2	2	Squarespot rockfish	Muscle	Zinc	3.24		mg/kg	0.049
RF2	3	Speckled rockfish	Muscle	Aluminum	1.87		mg/kg	0.583
RF2	3	Speckled rockfish	Muscle	Arsenic	1.71		mg/kg	0.375
RF2	3	Speckled rockfish	Muscle	Copper	0.265		mg/kg	0.068
RF2	3	Speckled rockfish	Muscle	Hexachlorobenzene	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	Iron	2.16		mg/kg	0.096
RF2	3	Speckled rockfish	Muscle	Lead	0.34		mg/kg	0.3
RF2	3	Speckled rockfish	Muscle	Lipids	1.4		%wt	0.005
RF2	3	Speckled rockfish	Muscle	Manganese	0.0545		mg/kg	0.007

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
RF2	3	Speckled rockfish	Muscle	Mercury	0.071		mg/kg	0.03
RF2	3	Speckled rockfish	Muscle	p,p-DDD	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	p,p-DDE	5.4		ug/kg	1.33
RF2	3	Speckled rockfish	Muscle	p,p-DDT	0.2	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 101	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 105	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 110	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 118	0.2	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 138	0.2	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 149	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 153/168	0.3	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 180	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	PCB 99	0.1	E	ug/kg	
RF2	3	Speckled rockfish	Muscle	Selenium	0.352		mg/kg	0.06
RF2	3	Speckled rockfish	Muscle	Silver	0.5		mg/kg	0.057
RF2	3	Speckled rockfish	Muscle	Thallium	2.62		mg/kg	0.845
RF2	3	Speckled rockfish	Muscle	Total DDT	5.7		ug/kg	
RF2	3	Speckled rockfish	Muscle	Total PCB	1.3		ug/kg	
RF2	3	Speckled rockfish	Muscle	Total Solids	22.4		%wt	0.4
RF2	3	Speckled rockfish	Muscle	Zinc	2.95		mg/kg	0.049
ZONE1	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.7	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	Arsenic	6.07		mg/kg	0.375
ZONE1	1	Pacific sanddab	Liver	Barium	0.132		mg/kg	0.007
ZONE1	1	Pacific sanddab	Liver	Cadmium	4.87		mg/kg	0.029
ZONE1	1	Pacific sanddab	Liver	Chromium	0.776		mg/kg	0.08
ZONE1	1	Pacific sanddab	Liver	Copper	4.4		mg/kg	0.068
ZONE1	1	Pacific sanddab	Liver	Hexachlorobenzene	3.3	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	Iron	107		mg/kg	0.096
ZONE1	1	Pacific sanddab	Liver	Lead	0.52		mg/kg	0.3
ZONE1	1	Pacific sanddab	Liver	Lipids	49.7		%wt	0.005
ZONE1	1	Pacific sanddab	Liver	Manganese	0.756		mg/kg	0.007
ZONE1	1	Pacific sanddab	Liver	Mercury	0.067		mg/kg	0.03
ZONE1	1	Pacific sanddab	Liver	Nickel	0.267		mg/kg	0.094
ZONE1	1	Pacific sanddab	Liver	o,p-DDE	2.7	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	o,p-DDT	1.5	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	p,p-DDD	5.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	p,p-DDE	200		ug/kg	13.3
ZONE1	1	Pacific sanddab	Liver	p,-p-DDMU	9.9	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	p,p-DDT	5.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 101	6.2	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 105	3.2	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 110	5.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 118	9.5	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 123	1.3	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 128	3.4	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 138	14		ug/kg	13.3
ZONE1	1	Pacific sanddab	Liver	PCB 149	5.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 151	3.2	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 153/168	24		ug/kg	13.3
ZONE1	1	Pacific sanddab	Liver	PCB 156	1.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 158	1.1	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 167	1.1	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE1	1	Pacific sanddab	Liver	PCB 170	4	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 177	2.3	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 180	9.6	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 183	3	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 187	8.9	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 194	2.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 201	2.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 206	1.7	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 28	0.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 49	2.2	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 52	2.9	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 66	1.8	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 70	1.6	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 74	0.9	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 87	1.7	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	PCB 99	6.9	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	Selenium	0.675		mg/kg	0.06
ZONE1	1	Pacific sanddab	Liver	Thallium	5.54		mg/kg	0.845
ZONE1	1	Pacific sanddab	Liver	Total DDT	225.7		ug/kg	
ZONE1	1	Pacific sanddab	Liver	Total PCB	134.3		ug/kg	
ZONE1	1	Pacific sanddab	Liver	Total Solids	62.1		%wt	0.4
ZONE1	1	Pacific sanddab	Liver	Trans Nonachlor	5.2	E	ug/kg	
ZONE1	1	Pacific sanddab	Liver	Zinc	19.6		mg/kg	0.049
ZONE1	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.6	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	Aluminum	9.46		mg/kg	0.583
ZONE1	2	Pacific sanddab	Liver	Arsenic	5.58		mg/kg	0.375
ZONE1	2	Pacific sanddab	Liver	Barium	0.101		mg/kg	0.007
ZONE1	2	Pacific sanddab	Liver	Cadmium	2.64		mg/kg	0.029
ZONE1	2	Pacific sanddab	Liver	Chromium	0.582		mg/kg	0.08
ZONE1	2	Pacific sanddab	Liver	Cis Nonachlor	3	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	Copper	4.6		mg/kg	0.068
ZONE1	2	Pacific sanddab	Liver	Hexachlorobenzene	3.2	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	Iron	61.6		mg/kg	0.096
ZONE1	2	Pacific sanddab	Liver	Lead	1.21		mg/kg	0.3
ZONE1	2	Pacific sanddab	Liver	Lipids	43.6		%wt	0.005
ZONE1	2	Pacific sanddab	Liver	Manganese	0.577		mg/kg	0.007
ZONE1	2	Pacific sanddab	Liver	o,p-DDD	1.1	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	o,p-DDE	2.2	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	o,p-DDT	2.4	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	p,p-DDD	6.3	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	p,p-DDE	280		ug/kg	13.3
ZONE1	2	Pacific sanddab	Liver	p,-p-DDMU	11	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	p,p-DDT	8.5	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 101	11	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 105	5.1	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 110	8.1	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 118	14		ug/kg	13.3
ZONE1	2	Pacific sanddab	Liver	PCB 119	0.7	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 123	2.1	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 128	5.2	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 138	24		ug/kg	13.3
ZONE1	2	Pacific sanddab	Liver	PCB 149	8.4	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE1	2	Pacific sanddab	Liver	PCB 151	5	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 153/168	43		ug/kg	13.3
ZONE1	2	Pacific sanddab	Liver	PCB 156	2.7	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 157	0.7	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 158	2	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 167	1.6	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 170	6.3	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 177	3.6	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 180	16		ug/kg	13.3
ZONE1	2	Pacific sanddab	Liver	PCB 183	4.5	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 187	15		ug/kg	13.3
ZONE1	2	Pacific sanddab	Liver	PCB 194	3.9	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 201	4.6	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 206	2.6	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 28	0.8	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 49	2.3	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 52	3.5	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 66	2.5	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 70	1.9	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 74	1.1	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 87	2.6	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	PCB 99	11	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	Selenium	0.602		mg/kg	0.06
ZONE1	2	Pacific sanddab	Liver	Thallium	6		mg/kg	0.845
ZONE1	2	Pacific sanddab	Liver	Total DDT	311.5		ug/kg	
ZONE1	2	Pacific sanddab	Liver	Total PCB	215.8		ug/kg	
ZONE1	2	Pacific sanddab	Liver	Total Solids	56.7		%wt	0.4
ZONE1	2	Pacific sanddab	Liver	Trans Nonachlor	7.9	E	ug/kg	
ZONE1	2	Pacific sanddab	Liver	Zinc	15.7		mg/kg	0.049
ZONE1	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	7.8	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	Aluminum	11.7		mg/kg	0.583
ZONE1	3	Pacific sanddab	Liver	Arsenic	5.89		mg/kg	0.375
ZONE1	3	Pacific sanddab	Liver	Barium	0.0462		mg/kg	0.007
ZONE1	3	Pacific sanddab	Liver	BHC, Beta isomer	5.7	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	BHC, Delta isomer	3.4	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	Cadmium	2.35		mg/kg	0.029
ZONE1	3	Pacific sanddab	Liver	Chromium	0.219		mg/kg	0.08
ZONE1	3	Pacific sanddab	Liver	Cis Nonachlor	4.3	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	Copper	4.45		mg/kg	0.068
ZONE1	3	Pacific sanddab	Liver	Hexachlorobenzene	3.1	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	Iron	33.3		mg/kg	0.096
ZONE1	3	Pacific sanddab	Liver	Lead	0.5		mg/kg	0.3
ZONE1	3	Pacific sanddab	Liver	Lipids	48.8		%wt	0.005
ZONE1	3	Pacific sanddab	Liver	Manganese	0.662		mg/kg	0.007
ZONE1	3	Pacific sanddab	Liver	Mercury	0.05		mg/kg	0.03
ZONE1	3	Pacific sanddab	Liver	o,p-DDE	4.5	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	o,p-DDT	2.5	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	p,p-DDD	12	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	p,p-DDE	330		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	p,-p-DDMU	15		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	p,p-DDT	8	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 101	17		ug/kg	13.3

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE1	3	Pacific sanddab	Liver	PCB 105	6.8	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 110	13	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 118	19		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	PCB 119	1	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 123	2.4	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 128	5.9	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 138	27		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	PCB 149	11	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 151	5.6	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 153/168	46		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	PCB 157	0.7	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 158	1.9	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 167	1.7	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 170	6.5	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 177	4.5	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 18	1.1	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 180	19		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	PCB 183	4.8	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 187	18		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	PCB 194	4.7	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 201	5.5	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 206	2.6	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 28	1.7	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 44	2.5	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 49	5.8	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 52	7.7	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 66	4.5	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 70	3	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 74	2	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 87	4	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	PCB 99	16		ug/kg	13.3
ZONE1	3	Pacific sanddab	Liver	Selenium	0.582		mg/kg	0.06
ZONE1	3	Pacific sanddab	Liver	Thallium	5.68		mg/kg	0.845
ZONE1	3	Pacific sanddab	Liver	Total DDT	372		ug/kg	
ZONE1	3	Pacific sanddab	Liver	Total PCB	272.9		ug/kg	
ZONE1	3	Pacific sanddab	Liver	Total Solids	56.8		%wt	0.4
ZONE1	3	Pacific sanddab	Liver	Trans Nonachlor	7.9	E	ug/kg	
ZONE1	3	Pacific sanddab	Liver	Zinc	17.2		mg/kg	0.049
ZONE2	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	4.5	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	Aluminum	11.5		mg/kg	0.583
ZONE2	1	Pacific sanddab	Liver	Arsenic	5.26		mg/kg	0.375
ZONE2	1	Pacific sanddab	Liver	Barium	0.172		mg/kg	0.007
ZONE2	1	Pacific sanddab	Liver	Cadmium	2.99		mg/kg	0.029
ZONE2	1	Pacific sanddab	Liver	Copper	2.76		mg/kg	0.068
ZONE2	1	Pacific sanddab	Liver	Hexachlorobenzene	2.4	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	Iron	39		mg/kg	0.096
ZONE2	1	Pacific sanddab	Liver	Lead	0.77		mg/kg	0.3
ZONE2	1	Pacific sanddab	Liver	Lipids	44		%wt	0.005
ZONE2	1	Pacific sanddab	Liver	Manganese	0.608		mg/kg	0.007
ZONE2	1	Pacific sanddab	Liver	o,p-DDE	1.6	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	o,p-DDT	1.3	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	p,p-DDD	4.7	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE2	1	Pacific sanddab	Liver	p,p-DDE	130		ug/kg	13.3
ZONE2	1	Pacific sanddab	Liver	p,-p-DDMU	6.4	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	p,p-DDT	3.3	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 101	3.7	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 105	1.9	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 110	3.2	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 118	4.9	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 123	0.7	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 128	1.8	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 138	7.3	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 149	3.4	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 151	1.6	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 153/168	13	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 156	1.1	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 158	0.7	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 167	0.5	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 170	2.4	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 177	1.4	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 180	5.4	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 183	1.4	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 187	5	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 194	1.8	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 201	1.9	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 206	1.2	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 28	0.7	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 44	0.7	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 49	1.2	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 52	1.8	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 66	1.3	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 70	1	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 74	0.6	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 87	1.5	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	PCB 99	3.6	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	Selenium	0.581		mg/kg	0.06
ZONE2	1	Pacific sanddab	Liver	Thallium	6.35		mg/kg	0.845
ZONE2	1	Pacific sanddab	Liver	Total DDT	147.3		ug/kg	
ZONE2	1	Pacific sanddab	Liver	Total PCB	76.7		ug/kg	
ZONE2	1	Pacific sanddab	Liver	Total Solids	59.2		%wt	0.4
ZONE2	1	Pacific sanddab	Liver	Trans Nonachlor	4.8	E	ug/kg	
ZONE2	1	Pacific sanddab	Liver	Zinc	16.7		mg/kg	0.049
ZONE2	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	4.5		ug/kg	
ZONE2	2	Pacific sanddab	Liver	Aluminum	2.88		mg/kg	0.583
ZONE2	2	Pacific sanddab	Liver	Arsenic	4.42		mg/kg	0.375
ZONE2	2	Pacific sanddab	Liver	Barium	0.247		mg/kg	0.007
ZONE2	2	Pacific sanddab	Liver	Cadmium	2.24		mg/kg	0.029
ZONE2	2	Pacific sanddab	Liver	Chromium	0.255		mg/kg	0.08
ZONE2	2	Pacific sanddab	Liver	Cis Nonachlor	2.5		ug/kg	
ZONE2	2	Pacific sanddab	Liver	Copper	2.88		mg/kg	0.068
ZONE2	2	Pacific sanddab	Liver	Hexachlorobenzene	3.3		ug/kg	
ZONE2	2	Pacific sanddab	Liver	Iron	59.2		mg/kg	0.096
ZONE2	2	Pacific sanddab	Liver	Lead	0.73		mg/kg	0.3
ZONE2	2	Pacific sanddab	Liver	Lipids	49.3		%wt	0.005

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE2	2	Pacific sanddab	Liver	Manganese	0.883		mg/kg	0.007
ZONE2	2	Pacific sanddab	Liver	Mercury	0.033		mg/kg	0.03
ZONE2	2	Pacific sanddab	Liver	o,p-DDE	2.2		ug/kg	
ZONE2	2	Pacific sanddab	Liver	o,p-DDT	1.55		ug/kg	
ZONE2	2	Pacific sanddab	Liver	p,p-DDD	6.4		ug/kg	
ZONE2	2	Pacific sanddab	Liver	p,p-DDE	180		ug/kg	13.3
ZONE2	2	Pacific sanddab	Liver	p,-p-DDMU	9.1		ug/kg	
ZONE2	2	Pacific sanddab	Liver	p,p-DDT	3.95		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 101	5	E	ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 105	2.7	E	ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 110	4.4		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 118	7.45		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 123	1.15		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 128	2.75		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 138	11	E	ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 149	4.6		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 151	2.3		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 153/168	18.5		ug/kg	13.3
ZONE2	2	Pacific sanddab	Liver	PCB 156	1.55		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 158	1		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 167	0.75		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 170	3.85		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 177	2.35		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 180	8.75		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 183	2.55		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 187	7.8		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 194	2.45		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 201	3.1		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 206	1.5	E	ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 28	0.7		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 44	0.4		ug/kg	13.3
ZONE2	2	Pacific sanddab	Liver	PCB 49	1.5	E	ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 52	2.15		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 66	1.55		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 70	1.3		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 74	0.8		ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 87	1.4	E	ug/kg	
ZONE2	2	Pacific sanddab	Liver	PCB 99	5.05		ug/kg	
ZONE2	2	Pacific sanddab	Liver	Selenium	0.556		mg/kg	0.06
ZONE2	2	Pacific sanddab	Liver	Thallium	5.15		mg/kg	0.845
ZONE2	2	Pacific sanddab	Liver	Total DDT	203.2		ug/kg	
ZONE2	2	Pacific sanddab	Liver	Total PCB	110.35		ug/kg	
ZONE2	2	Pacific sanddab	Liver	Total Solids	52.7		%wt	0.4
ZONE2	2	Pacific sanddab	Liver	Trans Nonachlor	4.5		ug/kg	
ZONE2	2	Pacific sanddab	Liver	Zinc	19.5		mg/kg	0.049
ZONE2	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	4.1	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	Aluminum	7.84		mg/kg	0.583
ZONE2	3	Pacific sanddab	Liver	Arsenic	5.64		mg/kg	0.375
ZONE2	3	Pacific sanddab	Liver	Barium	0.107		mg/kg	0.007
ZONE2	3	Pacific sanddab	Liver	Cadmium	1.37		mg/kg	0.029
ZONE2	3	Pacific sanddab	Liver	Chromium	0.72		mg/kg	0.08
ZONE2	3	Pacific sanddab	Liver	Cis Nonachlor	2.5	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE2	3	Pacific sanddab	Liver	Copper	3.43		mg/kg	0.068
ZONE2	3	Pacific sanddab	Liver	Hexachlorobenzene	3.3	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	Iron	46.4		mg/kg	0.096
ZONE2	3	Pacific sanddab	Liver	Lead	0.47		mg/kg	0.3
ZONE2	3	Pacific sanddab	Liver	Lipids	46.7		%wt	0.005
ZONE2	3	Pacific sanddab	Liver	Manganese	0.828		mg/kg	0.007
ZONE2	3	Pacific sanddab	Liver	Mercury	0.041		mg/kg	0.03
ZONE2	3	Pacific sanddab	Liver	Nickel	0.249		mg/kg	0.094
ZONE2	3	Pacific sanddab	Liver	o,p-DDE	2.4	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	o,p-DDT	1.3	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	p,p-DDD	5.3	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	p,p-DDE	270		ug/kg	13.3
ZONE2	3	Pacific sanddab	Liver	p,-p-DDMU	9.3	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	p,p-DDT	3.9	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 101	4.5	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 105	2.6	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 110	4.6	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 118	6.8	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 123	1.1	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 128	2.7	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 138	11	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 149	4.1	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 151	2.4	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 153/168	19		ug/kg	13.3
ZONE2	3	Pacific sanddab	Liver	PCB 156	1.7	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 158	0.9	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 167	0.6	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 170	3.5	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 177	2	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 180	9.5	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 183	2.5	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 187	7.8	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 194	2.6	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 201	3.1	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 206	1.7	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 28	0.5	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 44	0.8	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 49	1.3	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 52	2.2	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 66	1.5	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 70	1.3	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 74	0.7	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 87	1.7	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	PCB 99	4.9	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	Selenium	0.44		mg/kg	0.06
ZONE2	3	Pacific sanddab	Liver	Thallium	6.07		mg/kg	0.845
ZONE2	3	Pacific sanddab	Liver	Tin	0.25		mg/kg	0.24
ZONE2	3	Pacific sanddab	Liver	Total DDT	292.2		ug/kg	
ZONE2	3	Pacific sanddab	Liver	Total PCB	109.6		ug/kg	
ZONE2	3	Pacific sanddab	Liver	Total Solids	59.5		%wt	0.4
ZONE2	3	Pacific sanddab	Liver	Trans Nonachlor	4.6	E	ug/kg	
ZONE2	3	Pacific sanddab	Liver	Zinc	19.8		mg/kg	0.049

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE3	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.3	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	Aluminum	11.1		mg/kg	0.583
ZONE3	1	Pacific sanddab	Liver	Antimony	1.08		mg/kg	0.478
ZONE3	1	Pacific sanddab	Liver	Arsenic	4.27		mg/kg	0.375
ZONE3	1	Pacific sanddab	Liver	Barium	0.234		mg/kg	0.007
ZONE3	1	Pacific sanddab	Liver	Cadmium	4.18		mg/kg	0.029
ZONE3	1	Pacific sanddab	Liver	Chromium	3.1		mg/kg	0.08
ZONE3	1	Pacific sanddab	Liver	Cis Nonachlor	3.3	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	Copper	2.98		mg/kg	0.068
ZONE3	1	Pacific sanddab	Liver	Hexachlorobenzene	3.4	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	Iron	70.1		mg/kg	0.096
ZONE3	1	Pacific sanddab	Liver	Lead	1.42		mg/kg	0.3
ZONE3	1	Pacific sanddab	Liver	Lipids	52.7		%wt	0.005
ZONE3	1	Pacific sanddab	Liver	Manganese	1.05		mg/kg	0.007
ZONE3	1	Pacific sanddab	Liver	Mercury	0.034		mg/kg	0.03
ZONE3	1	Pacific sanddab	Liver	Nickel	1.25		mg/kg	0.094
ZONE3	1	Pacific sanddab	Liver	o,p-DDE	2.8	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	o,p-DDT	1.8	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	p,p-DDD	7.7	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	p,p-DDE	240		ug/kg	13.3
ZONE3	1	Pacific sanddab	Liver	p,-p-DDMU	11	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	p,p-DDT	5	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 101	9.1	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 105	4.1	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 110	8.6	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 118	13	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 119	0.5	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 123	1.7	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 128	4.4	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 138	18		ug/kg	13.3
ZONE3	1	Pacific sanddab	Liver	PCB 149	9.1	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 151	3.9	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 153/168	31		ug/kg	13.3
ZONE3	1	Pacific sanddab	Liver	PCB 156	2.2	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 158	1.7	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 167	1.1	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 170	4.7	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 177	2.9	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 180	13	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 183	3.9	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 187	13	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 194	3	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 201	3.5	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 206	1.8	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 28	1	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 44	1.7	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 49	2.8	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 52	4	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 66	2.6	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 70	2	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 74	1.1	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	PCB 87	2.7	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE3	1	Pacific sanddab	Liver	PCB 99	9.1	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	Selenium	0.495		mg/kg	0.06
ZONE3	1	Pacific sanddab	Liver	Thallium	6.18		mg/kg	0.845
ZONE3	1	Pacific sanddab	Liver	Total DDT	268.3		ug/kg	
ZONE3	1	Pacific sanddab	Liver	Total PCB	181.2		ug/kg	
ZONE3	1	Pacific sanddab	Liver	Total Solids	57.4		%wt	0.4
ZONE3	1	Pacific sanddab	Liver	Trans Nonachlor	5.6	E	ug/kg	
ZONE3	1	Pacific sanddab	Liver	Zinc	20.8		mg/kg	0.049
ZONE3	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	5	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	Aluminum	4.55		mg/kg	0.583
ZONE3	2	Pacific sanddab	Liver	Antimony	0.57		mg/kg	0.478
ZONE3	2	Pacific sanddab	Liver	Arsenic	5.47		mg/kg	0.375
ZONE3	2	Pacific sanddab	Liver	Barium	0.108		mg/kg	0.007
ZONE3	2	Pacific sanddab	Liver	Cadmium	3.08		mg/kg	0.029
ZONE3	2	Pacific sanddab	Liver	Chromium	0.205		mg/kg	0.08
ZONE3	2	Pacific sanddab	Liver	Cis Nonachlor	2.7	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	Copper	2.33		mg/kg	0.068
ZONE3	2	Pacific sanddab	Liver	Hexachlorobenzene	3.3	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	Iron	39.8		mg/kg	0.096
ZONE3	2	Pacific sanddab	Liver	Lead	1.17		mg/kg	0.3
ZONE3	2	Pacific sanddab	Liver	Lipids	46.7		%wt	0.005
ZONE3	2	Pacific sanddab	Liver	Manganese	1.18		mg/kg	0.007
ZONE3	2	Pacific sanddab	Liver	Mercury	0.089		mg/kg	0.03
ZONE3	2	Pacific sanddab	Liver	Nickel	0.168		mg/kg	0.094
ZONE3	2	Pacific sanddab	Liver	o,p-DDE	2.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	o,p-DDT	1.9	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	p,p-DDD	6.3	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	p,p-DDE	450		ug/kg	13.3
ZONE3	2	Pacific sanddab	Liver	p,-p-DDMU	12	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	p,p-DDT	5.9	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 101	7.9	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 105	6.6	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 110	10	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 118	22		ug/kg	13.3
ZONE3	2	Pacific sanddab	Liver	PCB 119	0.4	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 123	2.5	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 128	7.1	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 138	32		ug/kg	13.3
ZONE3	2	Pacific sanddab	Liver	PCB 149	7.4	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 151	5.6	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 153/168	50		ug/kg	13.3
ZONE3	2	Pacific sanddab	Liver	PCB 156	4.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 157	1.1	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 158	3.1	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 167	2.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 170	8.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 177	3.8	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 180	23		ug/kg	13.3
ZONE3	2	Pacific sanddab	Liver	PCB 183	6.3	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 187	19		ug/kg	13.3
ZONE3	2	Pacific sanddab	Liver	PCB 194	5.7	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 201	6.3	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE3	2	Pacific sanddab	Liver	PCB 206	3.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 28	0.8	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 44	1.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 49	2.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 52	3.2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 66	2.3	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 70	2	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 74	1.3	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 87	2.4	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	PCB 99	13	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	Selenium	0.616		mg/kg	0.06
ZONE3	2	Pacific sanddab	Liver	Thallium	5.89		mg/kg	0.845
ZONE3	2	Pacific sanddab	Liver	Total DDT	478.3		ug/kg	
ZONE3	2	Pacific sanddab	Liver	Total PCB	266		ug/kg	
ZONE3	2	Pacific sanddab	Liver	Total Solids	54.5		%wt	0.4
ZONE3	2	Pacific sanddab	Liver	Trans Nonachlor	5.7	E	ug/kg	
ZONE3	2	Pacific sanddab	Liver	Zinc	20.5		mg/kg	0.049
ZONE3	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	4.5	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	Aluminum	4.37		mg/kg	0.583
ZONE3	3	Pacific sanddab	Liver	Antimony	0.94		mg/kg	0.478
ZONE3	3	Pacific sanddab	Liver	Arsenic	5.24		mg/kg	0.375
ZONE3	3	Pacific sanddab	Liver	Barium	0.0162		mg/kg	0.007
ZONE3	3	Pacific sanddab	Liver	Cadmium	8.75		mg/kg	0.029
ZONE3	3	Pacific sanddab	Liver	Cis Nonachlor	2.9	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	Copper	3.99		mg/kg	0.068
ZONE3	3	Pacific sanddab	Liver	Hexachlorobenzene	3.2	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	Iron	73.1		mg/kg	0.096
ZONE3	3	Pacific sanddab	Liver	Lead	1.12		mg/kg	0.3
ZONE3	3	Pacific sanddab	Liver	Lipids	44.7		%wt	0.005
ZONE3	3	Pacific sanddab	Liver	Manganese	0.936		mg/kg	0.007
ZONE3	3	Pacific sanddab	Liver	Mercury	0.063		mg/kg	0.03
ZONE3	3	Pacific sanddab	Liver	Nickel	0.098		mg/kg	0.094
ZONE3	3	Pacific sanddab	Liver	o,p-DDE	2.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	o,p-DDT	1.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	p,p-DDD	6.9	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	p,p-DDE	270		ug/kg	13.3
ZONE3	3	Pacific sanddab	Liver	p,-p-DDMU	10	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	p,p-DDT	5.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 101	9	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 105	5.2	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 110	9	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 118	15		ug/kg	13.3
ZONE3	3	Pacific sanddab	Liver	PCB 119	0.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 123	1.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 128	5.2	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 138	23		ug/kg	13.3
ZONE3	3	Pacific sanddab	Liver	PCB 149	7.1	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 151	4.6	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 153/168	39		ug/kg	13.3
ZONE3	3	Pacific sanddab	Liver	PCB 156	2.8	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 158	2.4	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 167	1.5	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE3	3	Pacific sanddab	Liver	PCB 170	6.2	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 177	3.3	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 18	0.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 180	16		ug/kg	13.3
ZONE3	3	Pacific sanddab	Liver	PCB 183	5.3	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 187	15		ug/kg	13.3
ZONE3	3	Pacific sanddab	Liver	PCB 194	3.9	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 201	4.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 206	2.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 28	0.9	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 44	1	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 49	2.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 52	3.7	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 66	2.4	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 70	2.1	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 74	1.2	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 87	2.5	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	PCB 99	10	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	Selenium	0.88		mg/kg	0.06
ZONE3	3	Pacific sanddab	Liver	Thallium	5.51		mg/kg	0.845
ZONE3	3	Pacific sanddab	Liver	Total DDT	297		ug/kg	
ZONE3	3	Pacific sanddab	Liver	Total PCB	210.5		ug/kg	
ZONE3	3	Pacific sanddab	Liver	Total Solids	51.4		%wt	0.4
ZONE3	3	Pacific sanddab	Liver	Trans Nonachlor	6.1	E	ug/kg	
ZONE3	3	Pacific sanddab	Liver	Zinc	22.1		mg/kg	0.049
ZONE4	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.8	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	Aluminum	3.12		mg/kg	0.583
ZONE4	1	Pacific sanddab	Liver	Antimony	1.25		mg/kg	0.478
ZONE4	1	Pacific sanddab	Liver	Arsenic	5.26		mg/kg	0.375
ZONE4	1	Pacific sanddab	Liver	Barium	0.0129		mg/kg	0.007
ZONE4	1	Pacific sanddab	Liver	Cadmium	4.93		mg/kg	0.029
ZONE4	1	Pacific sanddab	Liver	Chromium	0.448		mg/kg	0.08
ZONE4	1	Pacific sanddab	Liver	Cis Nonachlor	3.2	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	Copper	4.17		mg/kg	0.068
ZONE4	1	Pacific sanddab	Liver	Hexachlorobenzene	3.6	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	Iron	50.4		mg/kg	0.096
ZONE4	1	Pacific sanddab	Liver	Lead	0.75		mg/kg	0.3
ZONE4	1	Pacific sanddab	Liver	Lipids	43.5		%wt	0.005
ZONE4	1	Pacific sanddab	Liver	Manganese	0.95		mg/kg	0.007
ZONE4	1	Pacific sanddab	Liver	Nickel	0.143		mg/kg	0.094
ZONE4	1	Pacific sanddab	Liver	o,p-DDE	2.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	o,p-DDT	2.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	p,p-DDD	7.6	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	p,p-DDE	500		ug/kg	13.3
ZONE4	1	Pacific sanddab	Liver	p,-p-DDMU	14		ug/kg	13.3
ZONE4	1	Pacific sanddab	Liver	p,p-DDT	8.1	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 101	11	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 105	5.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 110	7.9	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 118	15		ug/kg	13.3
ZONE4	1	Pacific sanddab	Liver	PCB 123	2.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 128	5.4	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE4	1	Pacific sanddab	Liver	PCB 138	26		ug/kg	13.3
ZONE4	1	Pacific sanddab	Liver	PCB 149	7.8	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 151	4.3	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 153/168	46		ug/kg	13.3
ZONE4	1	Pacific sanddab	Liver	PCB 156	2.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 157	0.8	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 158	2	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 167	1.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 170	7	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 177	4.1	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 180	19		ug/kg	13.3
ZONE4	1	Pacific sanddab	Liver	PCB 183	5.5	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 187	17		ug/kg	13.3
ZONE4	1	Pacific sanddab	Liver	PCB 194	4.1	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 201	5.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 206	2.1	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 28	0.8	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 44	1.2	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 49	2.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 52	3.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 66	2.4	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 70	2.1	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 74	1.3	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 87	2.9	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	PCB 99	12	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	Selenium	0.618		mg/kg	0.06
ZONE4	1	Pacific sanddab	Liver	Thallium	6.26		mg/kg	0.845
ZONE4	1	Pacific sanddab	Liver	Total DDT	534.5		ug/kg	
ZONE4	1	Pacific sanddab	Liver	Total PCB	230.5		ug/kg	
ZONE4	1	Pacific sanddab	Liver	Total Solids	58.4		%wt	0.4
ZONE4	1	Pacific sanddab	Liver	Trans Nonachlor	7.7	E	ug/kg	
ZONE4	1	Pacific sanddab	Liver	Zinc	19.4		mg/kg	0.049
ZONE4	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	8.7	E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	Aluminum	9.16		mg/kg	0.583
ZONE4	2	Pacific sanddab	Liver	Antimony	0.96		mg/kg	0.478
ZONE4	2	Pacific sanddab	Liver	Arsenic	5.61		mg/kg	0.375
ZONE4	2	Pacific sanddab	Liver	Barium	0.0201		mg/kg	0.007
ZONE4	2	Pacific sanddab	Liver	Cadmium	8.47		mg/kg	0.029
ZONE4	2	Pacific sanddab	Liver	Chromium	0.383		mg/kg	0.08
ZONE4	2	Pacific sanddab	Liver	Cis Nonachlor	4.8	E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	Copper	6.53		mg/kg	0.068
ZONE4	2	Pacific sanddab	Liver	Gamma (trans) Chlordane	1.9	E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	Hexachlorobenzene	4.7	E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	Iron	124		mg/kg	0.096
ZONE4	2	Pacific sanddab	Liver	Lead	0.94		mg/kg	0.3
ZONE4	2	Pacific sanddab	Liver	Lipids	60.9		%wt	0.005
ZONE4	2	Pacific sanddab	Liver	Manganese	0.558		mg/kg	0.007
ZONE4	2	Pacific sanddab	Liver	Mercury	0.05		mg/kg	0.03
ZONE4	2	Pacific sanddab	Liver	Nickel	0.262		mg/kg	0.094
ZONE4	2	Pacific sanddab	Liver	o,p-DDE	4.8	E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	o,p-DDT	3.7	E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	p,p-DDD	9.4	E	ug/kg	

Station/Zone	Rep	Species	Tissue	Parameter	Value	Units	MDL
ZONE4	2	Pacific sanddab	Liver	p,p-DDE	430	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	p,-p-DDMU	19	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	p,p-DDT	10 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 101	13 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 105	7.5 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 110	10 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 118	22	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	PCB 119	0.8 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 123	3.2 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 128	9 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 138	40	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	PCB 149	9 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 151	5.4 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 153/168	65	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	PCB 156	4.2 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 158	3.4 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 167	2.3 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 170	11 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 177	4.6 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 180	27	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	PCB 183	7.7 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 187	22	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	PCB 194	6.1 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 201	6.1 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 206	3.7 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 28	0.9 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 44	1.3 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 49	3.2 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 52	4.6 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 66	3.3 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 70	2.7 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 74	1.7 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 87	3.5 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	PCB 99	17	ug/kg	13.3
ZONE4	2	Pacific sanddab	Liver	Selenium	0.878	mg/kg	0.06
ZONE4	2	Pacific sanddab	Liver	Thallium	5.87	mg/kg	0.845
ZONE4	2	Pacific sanddab	Liver	Total DDT	476.9	ug/kg	
ZONE4	2	Pacific sanddab	Liver	Total PCB	321.2	ug/kg	
ZONE4	2	Pacific sanddab	Liver	Total Solids	65.4	%wt	0.4
ZONE4	2	Pacific sanddab	Liver	Trans Nonachlor	11 E	ug/kg	
ZONE4	2	Pacific sanddab	Liver	Zinc	18.1	mg/kg	0.049
ZONE4	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	6.1 E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	Aluminum	1.12	mg/kg	0.583
ZONE4	3	Pacific sanddab	Liver	Antimony	0.63	mg/kg	0.478
ZONE4	3	Pacific sanddab	Liver	Arsenic	5.98	mg/kg	0.375
ZONE4	3	Pacific sanddab	Liver	Barium	0.0099	mg/kg	0.007
ZONE4	3	Pacific sanddab	Liver	Cadmium	7.09	mg/kg	0.029
ZONE4	3	Pacific sanddab	Liver	Chromium	0.269	mg/kg	0.08
ZONE4	3	Pacific sanddab	Liver	Cis Nonachlor	2.9 E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	Copper	7.37	mg/kg	0.068
ZONE4	3	Pacific sanddab	Liver	Hexachlorobenzene	3 E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	Iron	57.4	mg/kg	0.096

Station/Zone	Rep	Species	Tissue	Parameter	Value		Units	MDL
ZONE4	3	Pacific sanddab	Liver	Lead	0.74		mg/kg	0.3
ZONE4	3	Pacific sanddab	Liver	Lipids	52		%wt	0.005
ZONE4	3	Pacific sanddab	Liver	Manganese	1.04		mg/kg	0.007
ZONE4	3	Pacific sanddab	Liver	Nickel	0.156		mg/kg	0.094
ZONE4	3	Pacific sanddab	Liver	o,p-DDE	3	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	o,p-DDT	2	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	p,p-DDD	5.6	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	p,p-DDE	240		ug/kg	13.3
ZONE4	3	Pacific sanddab	Liver	p,-p-DDMU	9.9	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	p,p-DDT	5.3	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 101	5.9	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 105	3.7	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 110	5.7	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 118	10	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 119	0.5	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 123	1.6	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 128	3.4	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 138	16		ug/kg	13.3
ZONE4	3	Pacific sanddab	Liver	PCB 149	5.2	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 151	3.1	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 153/168	28		ug/kg	13.3
ZONE4	3	Pacific sanddab	Liver	PCB 156	1.9	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 157	0.6	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 158	1.5	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 167	1.1	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 170	4.3	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 177	2.5	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 180	11	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 183	3.7	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 187	11	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 194	2.9	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 201	3.6	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 206	2.1	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 28	0.6	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 44	0.9	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 49	1.7	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 52	2.4	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 66	1.8	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 70	1.8	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 74	1	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 87	1.8	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	PCB 99	6.8	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	Selenium	0.553		mg/kg	0.06
ZONE4	3	Pacific sanddab	Liver	Thallium	4.6		mg/kg	0.845
ZONE4	3	Pacific sanddab	Liver	Total DDT	265.8		ug/kg	
ZONE4	3	Pacific sanddab	Liver	Total PCB	148.1		ug/kg	
ZONE4	3	Pacific sanddab	Liver	Total Solids	53.7		%wt	0.4
ZONE4	3	Pacific sanddab	Liver	Trans Nonachlor	6.4	E	ug/kg	
ZONE4	3	Pacific sanddab	Liver	Zinc	20.5		mg/kg	0.049