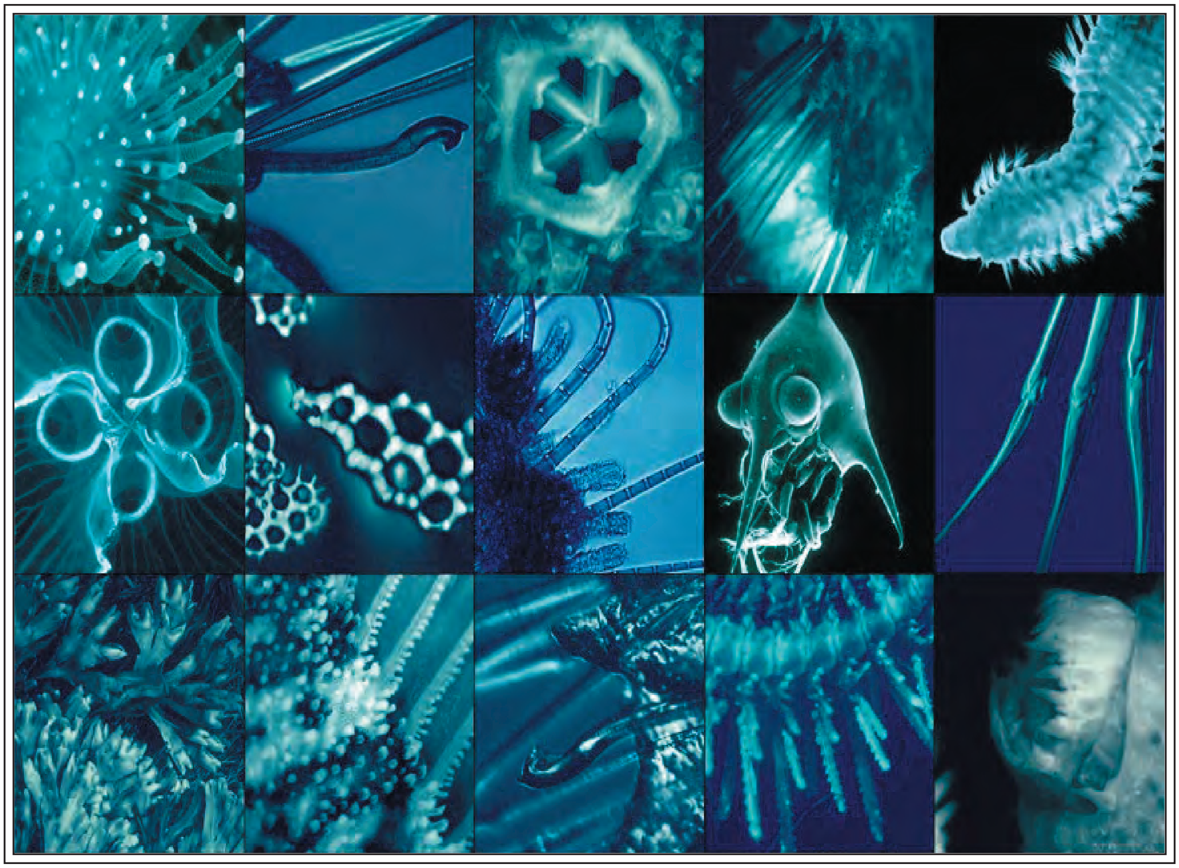
Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall
2006



City of San Diego
Ocean Monitoring Program

Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

THE CITY OF SAN DIEGO

July 1, 2007

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 2006 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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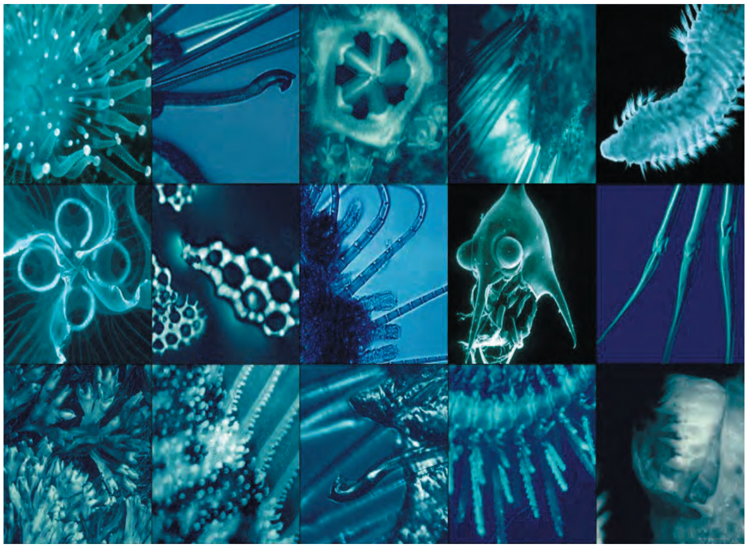
2006



Prepared by:

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

June 2007

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CITY OF SAN DIEGO
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Executive Summary

The monitoring and reporting requirements for the City of San Diego (City) Point Loma Wastewater Treatment Plant (PLWTP) are outlined in NPDES Permit No. CA0107409 and Monitoring and Reporting Program No. R9-2002-0025. The main objectives of the Point Loma ocean monitoring program is to assess the impact of wastewater discharged through the Point Loma Ocean Outfall (PLOO) on the marine environment off San Diego, provide data that satisfy NPDES permit requirements, demonstrate compliance with the 2001 California Ocean Plan (COP) as specified in the permit, monitor dispersion of the waste field, and identify any environmental changes that may have occurred. Specifically, the program was designed to assess the effects of wastewater discharge on ocean water quality, sediment conditions and marine organisms. 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 nearly 100 m. Monitoring at sites along the shore extends from Mission Beach southward to the tip of Point Loma, while offshore monitoring occurs in an adjacent area overlying the coastal continental shelf at sites ranging from 9 to 116 m in depth.

Prior to the initiation of wastewater discharge through the extended outfall in late 1993, the City conducted a 2½-year baseline study designed to characterize background environmental conditions in the Point Loma region in order to provide information against which post-discharge data could be compared. Additionally, each year the City also typically conducts a region-wide survey of benthic conditions at randomly selected sites from Del Mar to the Mexico border as part of NPDES requirements for the South Bay Water Reclamation Plant. Both of the above types of studies are useful for evaluating patterns and trends over a broader geographic area, thus providing additional information to help distinguish reference areas from sites impacted by anthropogenic influences. The results of the 2006 annual survey of randomly selected stations throughout San Diego are presented in City of San Diego (2007).

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 these activities, the City supports other projects relevant to assessing ocean quality in the region (see Chapter 1).

This report focuses on the results of ocean monitoring activities conducted off Point Loma during calendar year 2006. 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 has had only a limited effect on the local marine environment after 13 years of wastewater discharge at the present location. For example, water samples collected at sites within the Point Loma kelp bed were 100% compliant with 2001 COP bacterial water-contact standards in 2006. Compliance with COP standards was also very high along the shore, with all but one station being 100% compliance throughout the year. The one exception (95% compliance) occurred at a station located near the mouth of the San Diego

River, and exceedences at that site were related to stormwater runoff in March, the wettest month of the year. Elevated bacterial concentrations that could be attributable to wastewater discharge were mostly limited to depths of 60 m or below. The single sample from shallower waters that was indicative of contaminated water occurred south of Point Loma and was likely related to non-outfall sources. In addition, there was no evidence that the waste field from the outfall reached or affected any shoreline station in 2006, which is the same as that observed ever since the outfall was extended in 1993. An analysis of long-term data from 1991 through 2006 also shows a significant decline in bacteriological densities over time both along the shore and in the Point Loma kelp beds. There has also been no evidence of change in any physical or chemical water quality parameter (e.g., dissolved oxygen, pH) that can be attributed to wastewater discharge off Point Loma. Instead, changes in these parameters have historically been associated primarily with natural events such as storm activity and the presence of plankton blooms. Finally, drought conditions that began in late 2005 continued into 2006, which resulted in greatly reduced stormwater runoff or other inputs to coastal waters (e.g., river flows) during the year. Consequently, fewer sediment plumes were observed relative to the 2005 rain season with PLOO ocean waters generally appearing clearer throughout 2006.

Benthic conditions off Point Loma continued to show some changes in 2006 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), an area where relatively coarse sediment particles have also tended to accumulate. However, other measures of environmental impact such as concentrations of sediment contaminants (e.g., trace metals, pesticides) showed no patterns related to wastewater discharge. For example, concentrations of trace metals in Point Loma sediments were lower in 2006 than during the previous year. Some descriptors of benthic community structure (e.g., abundance, species diversity) or indicators of environmental disturbance (e.g., brittle star populations) have shown temporal differences between reference areas and sites nearest the ZID. However, results from environmental disturbance indices such as the BRI that are used to evaluate the condition of benthic assemblages suggest that macrobenthic invertebrate communities in the Point Loma region remain characteristic of natural conditions. Analyses of bottom dwelling (demersal) fish and trawl-caught megabenthic invertebrate communities also reveal no spatial or temporal patterns that can be attributed to effects of wastewater discharge. Instead, a review of historical data (1991−2006) indicates that patterns of change in fish assemblages appear related to large-scale oceanographic events (e.g., El Niño conditions in 1998) or specific site locations (e.g., near dredge material disposal sites). The paucity of pathological evidence from local fishes and the results of bioaccumulation studies also suggest that local fish assemblages remain healthy and are not adversely affected by wastewater discharge or other anthropogenic inputs. Consequently, there is currently no evidence of significant long-term negative impacts on water quality, sediment quality, or biotic communities in the coastal waters off San Diego.

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Chapter 1. General Introduction

INTRODUCTION

Treated effluent from the City of San Diego 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, MRP 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 superseding 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, and data 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 provisions of the 2001 California Ocean Plan (COP) as specified within the NPDES permit, 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. 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. TSS removals are now 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 improve compliance 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 2 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 2006 was 170 mgd, ranging from 162 mgd in December to 180 mgd in March. This is 7% lower than the 2005 average flow of 183 mgd. TSS removal averaged about 88% during 2006, with a total mass emissions of approximately 8211 mt/yr relative to 10,400 mt/yr in 2005 (see City of San Diego 2007a).

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, b). 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, 2007c).

The current sampling area off Point Loma extends 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. Results of the Laboratory's quality assurance procedures are included in the EMTS Division Laboratory Quality Assurance Report (City of San Diego 2007b). 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).

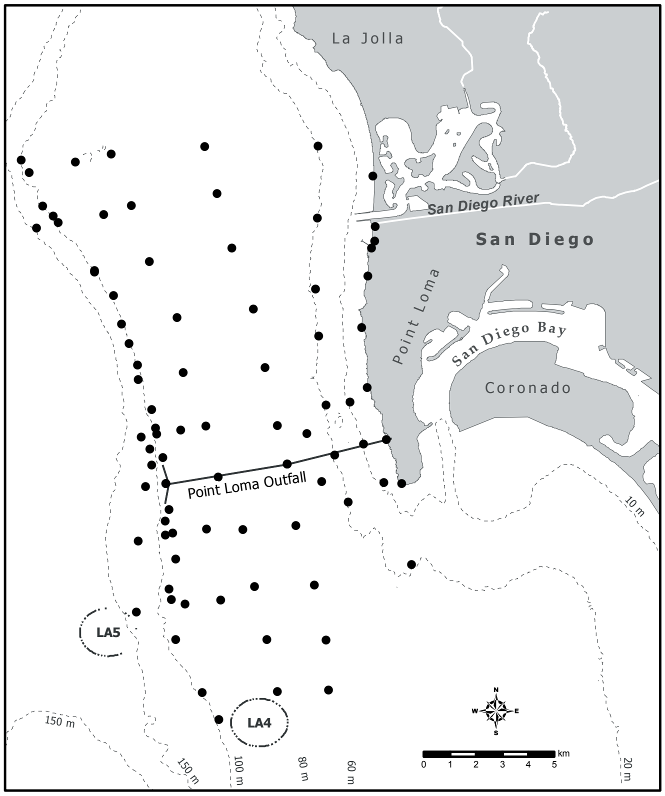

Figure 1.1
Receiving waters monitoring stations for the Point Loma Ocean Outfall Monitoring Program.

In addition to the above activities, the City participates in or 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). A long-term study of the Point Loma kelp forest funded by the City is also being conducted by scientists at the Scripps Institution of Oceanography (see City of San Diego 2003), while the City also participates with a number of other agencies to fund aerial surveys of all the major kelp beds from San Diego and Orange Counties (e.g., MBC 2006). Finally, the current MRP includes plans to perform adaptive or special strategic process studies as determined by the City in conjunction with the RWQCB and USEPA. Such studies have included a comprehensive scientific review of the Point Loma ocean monitoring program (see SIO 2004), a large-scale sediment mapping study of both the Point Loma and South Bay coastal regions (see Stebbins et al. 2004), and a pilot study of deep benthic habitats of the continental slope off San Diego (see Stebbins and Parnell 2005). Additionally, in 2004 the City began sampling again at the recovery stations mentioned above as part long-term annual assessment project of benthic conditions near the original outfall discharge site. In addition, a multi-phase project, the Moored Observation System Pilot Study (MOSPS), is underway to examine the dynamics and strength of the thermocline and local currents of the receiving waters off Point Loma (Storms et al. 2006). The project includes a system of moored temperature loggers (thermistor strings) and Acoustic Doppler Current Profilers (ADCPs) deployed in the vicinity of the PLOO to begin evaluating the major modes of circulation near the outfall.

This report summarizes the results of all regular receiving waters monitoring activities conducted off Point Loma during 2006. The data are also compared to results from previous years in order to examine long-term patterns of change in the region. In addition, results from the ongoing coastal remote sensing study of the San Diego/Tijuana Region that is funded by the City and IBWC 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. Ocean Conditions

INTRODUCTION

The City of San Diego monitors oceanographic conditions in the region surrounding the Point Loma Ocean Outfall (PLOO) 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 affect water quality within the Point Loma region.

The fate of PLOO wastewater discharged into deep offshore waters is determined by oceanographic conditions and other events that impact horizontal and vertical mixing. Consequently, physical and chemical parameters such as water temperature, salinity, and density determine water column mixing potential, and are thus important components of ocean monitoring programs (Bowden 1975). Analysis of the spatial and temporal variability of above 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.

Remote sensing observations from aerial and satellite imagery, and evaluation of bacterial distribution patterns may provide the best indication of the horizontal transport of discharged waters in the absence of information on deepwater currents (Pickard and Emery 1990; Ocean Imaging 2006, 2007a, b; also see Chapter 3). Thus, the City of San Diego combines measurements of physical oceanographic parameters with assessments of bacterial concentrations and remote sensing data to provide further insight into the transport potential in coastal waters surrounding the PLOO discharge site. This chapter describes the oceanographic conditions that occurred off Point Loma during 2006, 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

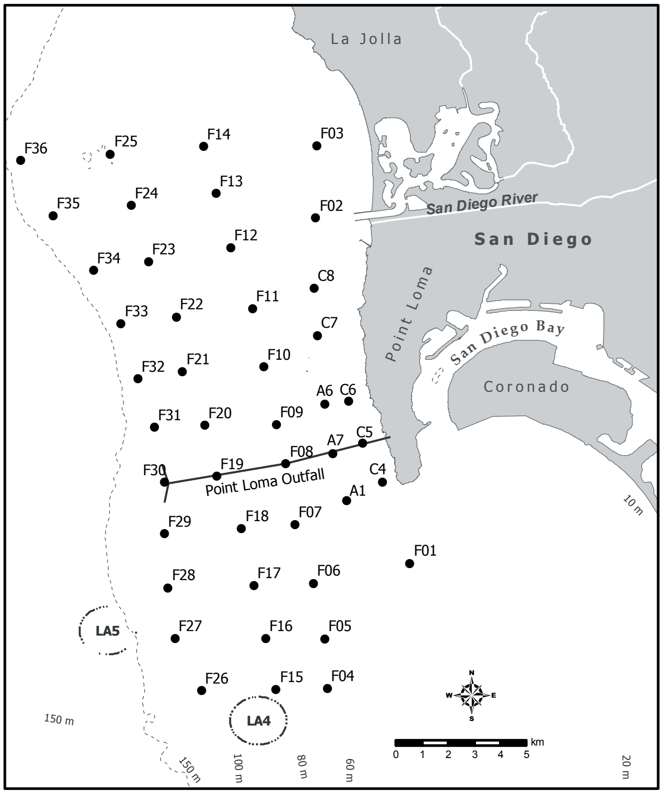

Figure 2.1
Water quality monitoring stations where CTD casts are taken, Point Loma Ocean Outfall Monitoring Program.

(designated F01–F36) were 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 2001 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, pH, transmissivity (water clarity), conductivity, chlorophyll *a*, and dissolved oxygen were collected by lowering a SeaBird (SBE 25) conductivity, temperature, and depth (CTD) instrument through the water column. Conductivity measurements were translated into salinity (ppt), and density was calculated from temperature, conductivity, and depth. 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. Visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were also recorded during each CTD sampling event.

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 2006 by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and several high clarity Landsat Thematic Mapper (TM) images were purchased. High resolution aerial images were collected with OI's DMSC-MKII digital multispectral sensor (DMSC). The sensor's 4 channels were configured to a specific wavelength (color) combination which 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. Sixteen overflights were done in 2006, which consisted of 2 overflights per month during the winter when the outfall plume had the greatest surfacing potential (see below) and one per month during spring and summer.

Three stations located closest to the outfall (F29, F30, F31) were selected for historical analysis of CTD parameters for the period 1995–2006 during which CTD measurements are comparable for all years. Mean data were determined for surface depths (≤2 m), sub-surface depths (10–20 m), bottom depths (≥88 m), and all depths combined for these stations. A time series of historical differences (anomalies) between monthly means for each year (1995–2006) and the monthly means for 2006 only were calculated for all depths for each CTD parameter. Means and standard deviations for surface, sub-surface, and bottom depths were calculated separately. Additionally, CTD profiles consisting of means ±1 SD at 5 m increments for 1995–2005 were compared with the 2006 mean profile data for temperature and salinity for these same 3 stations.

RESULTS AND DISCUSSION

Expected Seasonal Patterns of Physical and Chemical Parameters

Southern California weather can be classified into basically wet (winter) and dry (spring through fall) seasons (NOAA/NWS 2007), and changes in oceanographic conditions often track these seasons. Water properties in the Southern California Bight (SCB) show the most variability in the upper 100 m as the seasons change (Jackson 1986). A high degree

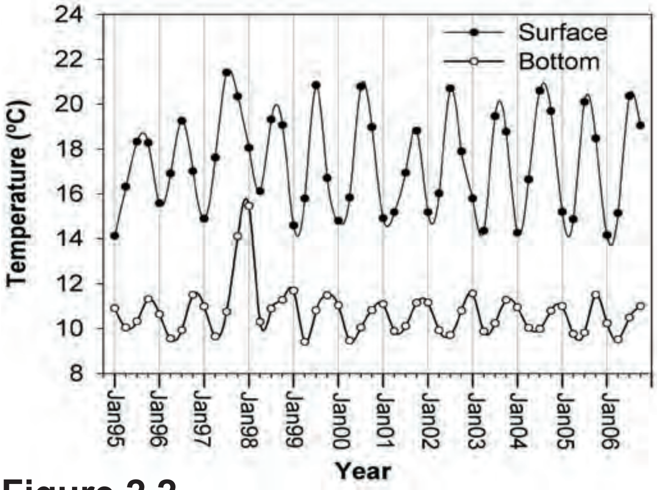

Figure 2.2
Mean quarterly surface and bottom temperatures (°C) for PLOO offshore stations from 1995–2006.

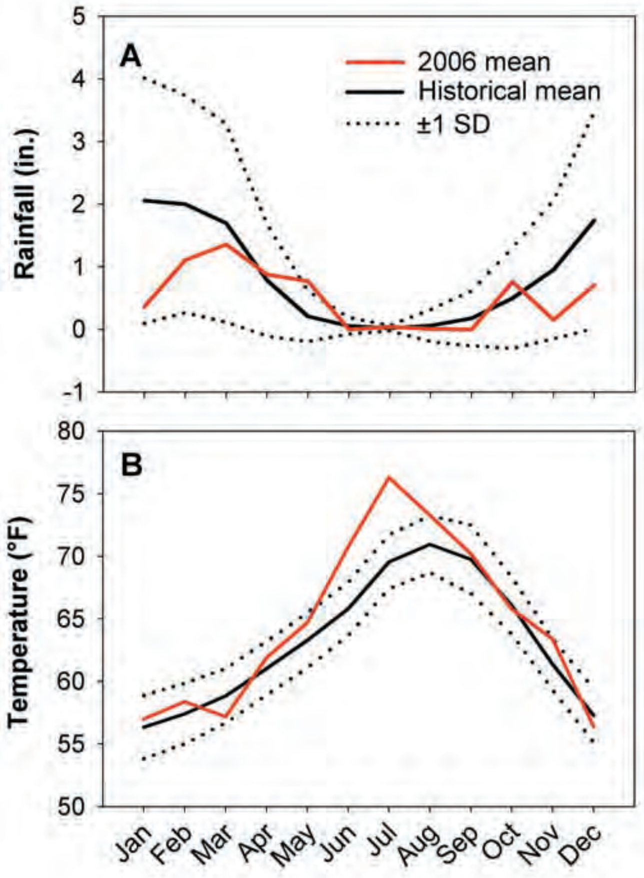

Figure 2.3
Total monthly rainfall (A) and monthly mean air temperature (B) at Lindbergh Field (San Diego, CA) for 2006 compared to monthly mean rainfall and air temperature (±1 SD) for the historical period of 1914 through 2005.

of homogeneity within the water column is the normal signature for all physical parameters from December through February (**Figure 2.2**). Storm water runoff however, may intermittently influence density profiles during these times by causing a low salinity lens within nearshore surface waters. The chance that the wastewater plume from the PLOO may surface is highest during these winter months when there is little, if any, stratification of the water column. These conditions will often extend into March, as the frequency of winter storms decreases and the seasons transition from wet to dry.

In late March or April, the increasing elevation of the sun and lengthening days begin to warm surface waters and re-establish the seasonal thermocline and pycnocline. Once water column stratification becomes established by late spring, minimal mixing conditions tend to remain throughout the summer and early fall months. In October or November, cooler temperatures, reduced solar input, and increased stormy weather begin to cause the return of the well-mixed, homogeneous water column characteristic of winter months.

Observed Seasonal Patterns of Physical and Chemical Parameters

The drought conditions present in late 2005 continued into January and February of 2006 when there was only 0.36 and 1.11 inches of rain, respectively (**Figure 2.3A**) (NOAA/NWS 2007). Rainfall for these months typically averages about 2.0 inches. Precipitation returned to normal levels in March and April, and was above average in May. Thereafter, only 1.62 inches of rain fell from September through December. The total rainfall for 2006 was 6.15 inches, 40% below the annual average of 10.26 inches (NOAA/NWS 2007). Average air temperature for March approached the lowest recorded value for 91 years of historical weather data, while near record warm air temperatures occurred in June–August (Figure 2.3B). Annual ocean surface temperatures peaked during these same months. Despite these variations in air and ocean temperatures, thermal stratification of the water column followed normal seasonal patterns.

Mean surface temperatures at the offshore water quality stations ranged from a low of 14.1 °C in April to a high of 20.8 °C in July (**Table 2.1**). In contrast, sub-surface and bottom waters were less variable, and ranged from 11.5–15.0 °C, and 9.5–11.0 °C, respectively. January surface and sub-surface temperatures were 1.3 °C and 2.0 °C lower than comparative values for 2005 (City of San Diego 2006a).

Overall average surface temperatures for the 3 historical stations nearest the PLOO (F29, F30, F31) during January and April of 2006 were 0.9 °C and 1.2 °C below the historical average, respectively. April temperatures were outside the standard deviation of the historical mean (**Table 2.2**). In contrast, surface temperatures for July and October were more similar to the historical average, and well within the standard deviation. Bottom waters ranged from 9.5 to 11.0 °C, and were close to average temperatures during April, July, and October, but below average during January (**Figure 2.4**). However, during January and April temperatures at most depths were colder than the historical means, and salinity was well above average at lower depths. These deviations from the norm indicate the intrusion of cold upwelled water into the region (see below).

Monthly water temperatures at the nearshore kelp stations followed a similar pattern (**Table 2.3, Figure 2.5**). Mean surface temperatures in the kelp beds from January through April of 2006 ranged from 13.1 to 14.7 °C, which were cooler than previous year means of 15.0 to 16.0 °C over the same period (City of San Diego 2006a). A decline in surface and bottom temperatures in March coupled with an increase in salinity from March–June is supportive of the intrusion of cold upwelled water mentioned above. The seasonal warming of the nearshore waters began in May, and mean surface waters ranged between 17.3 and 21.1 °C from May through August. Mean surface temperatures declined between September and December from 18.1 °C to 15.9 °C. Bottom waters at the kelp stations ranged from 11.3 to 16.4 °C during the year. Relative to 2005, bottom water temperatures in 2006 were over 1 °C cooler from January through March, but 1.4–3.1 °C warmer the rest of the year (City of San Diego 2006a).

Table 2.1

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), sub-surface (10– 20 m), and bottom (≥88 m) waters at all quarterly PLOO stations during 2006.

		Jan	**Apr**	**Jul**	**Oct**
Temp	*Surface*	14.1	15.2	20.8	18.7
	Sub-surface	13.3	11.5	14.2	15.0
	Bottom	10.4	9.5	10.4	11.0
Salinity	*Surface*	33.34	33.45	33.55	33.43
	Sub-surface	33.37	33.70	33.57	33.38
	Bottom	33.87	34.16	33.73	33.64
Density	*Surface*	24.9	24.7	23.4	23.9
	Sub-surface	25.1	25.7	25.0	24.7
	Bottom	26.0	26.4	25.9	25.7
DO	*Surface*	8.4	9.9	8.1	7.7
	Sub-surface	7.4	6.6	8.0	8.3
	Bottom	3.5	2.6	3.6	4.5
pH	*Surface*	8.1	8.3	8.2	8.2
	Sub-surface	8.1	8.0	8.1	8.2
	Bottom	7.8	7.7	7.8	7.9
XMS	*Surface*	84	83	84	88
	Sub-surface	87	87	82	89
	Bottom	90	91	90	90
Chl *a*	*Surface*	3.2	2.9	2.4	0.9
	Sub-surface	4.6	6.7	8.4	2.4
	Bottom	0.3	0.3	0.7	0.6

Thermal stratification in 2006 generally followed the typical annual pattern (Figures 2.2, 2.4, 2.5). A weak, shallow thermocline occurred between 10–20 m in January (City of San Diego 2006b). In contrast, the thermocline present during January 2005 was deeper (average depth of 35 m) as a result of colder bottom water (City of San Diego 2005a). Thermoclines of a 1 ºC change within 1 m depth were well developed at offshore stations in April, July and October. Differences between surface and bottom waters ranged from over 5.7 ºC to 10.4 ºC for these months (Table 2.2). April and

Table 2.2

Mean data for surface (≤2 m), sub-surface (≥10 and ≤27), and bottom depths (≥27 m) for 2006 compared to mean data (±1 SD) for 1995–2005 at stations F29, F30, and F31. Delta (∆) is the difference between 2006 and 1995–2005 mean data. Data includes temperature (Temp °C), salinity (ppt), density (δ/θ), dissolved oxygen (DO, mg/L), pH, transmissivity (XMS %), and chlorophyll *a* (µg/L).

	Surface depths				**Sub-surface depths**				**Bottom depths**				**All depths**			
	Jan	**Apr**	**Jul**	**Oct**	**Jan**	**Apr**	**Jul**	**Oct**	**Jan**	**Apr**	**Jul**	**Oct**	**Jan**	**Apr**	**Jul**	**Oct**
Temperature																
2006	14.2	15.1	20.4	19.1	13.4	12.1	14.5	15.3	10.2	9.5	10.5	11.0	11.6	10.5	12.2	13.0
1995–2005	15.1	16.3	19.7	18.7	15.0	13.1	14.2	16.1	11.4	9.8	10.2	11.6	13.2	11.2	12.0	13.7
SD	1.0	1.0	1.4	1.2	1.2	1.5	2.0	1.9	1.3	0.3	0.4	1.1	1.9	1.9	2.6	2.6
∆	-0.9	-1.2	0.7	0.4	-1.6	-1.0	0.3	-0.8	-1.2	-0.3	0.3	-0.6	-1.6	-0.7	0.2	-0.7
Salinity																
2006	33.33	33.48	33.54	33.45	33.36	33.66	33.57	33.39	33.89	34.18	33.72	33.60	33.56	33.94	33.61	33.47
1995–2005	33.39	33.42	33.60	33.50	33.48	33.68	33.55	33.44	33.70	33.99	33.86	33.61	33.55	33.78	33.66	33.49
SD	0.39	0.23	0.11	0.11	0.25	0.54	0.15	0.13	0.16	0.13	0.15	0.18	0.23	0.28	0.19	0.15
∆	-0.06	0.06	-0.06	-0.05	-0.12	-0.02	0.02	-0.05	0.19	0.19	-0.14	-0.01	0.01	0.16	-0.05	-0.02
Density																
2006	24.88	24.73	23.44	23.90	25.05	25.53	24.96	24.67	26.05	26.39	25.87	25.69	25.54	26.03	25.44	25.19
1995–2005	24.65	24.49	23.69	23.93	24.76	25.36	24.96	24.47	25.65	26.19	26.03	25.56	25.18	25.78	25.50	25.03
SD	0.31	0.28	0.32	0.31	0.20	0.54	0.48	0.42	0.26	0.13	0.18	0.33	0.41	0.50	0.64	0.60
∆	0.23	0.24	-0.25	-0.03	0.29	0.17	0.00	0.20	0.40	0.20	-0.16	0.13	0.36	0.25	-0.06	0.16
Dissolved Oxygen																
2006	8.5	9.6	8.1	7.6	7.6	7.6	8.0	8.4	3.5	2.6	3.6	4.6	5.4	4.4	5.3	6.4
1995–2005	8.0	8.4	8.1	7.6	7.9	8.1	8.7	8.3	4.7	3.4	4.2	5.0	6.5	5.2	6.2	6.8
SD	0.6	1.3	0.9	0.9	0.6	1.2	0.7	0.8	0.7	0.6	0.7	1.4	1.4	2.0	1.9	1.6
∆	0.5	1.2	0.0	-0.0	-0.3	-0.5	-0.7	0.1	-1.2	-0.8	-0.6	-0.4	-1.1	-0.8	-0.9	-0.4
pH																
2006	8.2	8.3	8.2	8.2	8.1	8.1	8.1	8.2	7.8	7.7	7.8	7.9	7.9	7.9	7.9	8.0
1995–2005	8.1	8.2	8.1	8.2	8.1	8.0	8.0	8.1	7.8	7.7	7.6	7.8	8.0	7.8	7.8	8.0
SD	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
∆	0.1	0.1	0.0	0.0	-0.0	0.1	0.1	0.1	-0.0	0.0	0.2	0.1	-0.0	0.1	0.1	0.0
Transmissivity																
2006	84	84	85	89	88	85	84	89	91	91	89	88	90	90	88	90
1995–2005	84	81	85	88	86	84	88	88	86	88	87	88	87	88	88	89
SD	10	4	5	3	7	5	3	3	7	5	4	3	7	4	3	3
∆	0	3	-0	1	2	1	-4	1	5	3	2	0	3	2	0	1
Chlorophyll a																
2006	5.0	2.2	2.0	0.9	5.2	8.3	6.0	2.1	0.3	0.3	0.8	0.6	1.9	2.1	3.0	2.2
1995–2005	3.3	3.0	3.5	2.8	4.2	7.8	3.7	4.4	1.9	1.3	1.7	1.5	3.1	3.1	3.3	2.9
SD	1.9	1.5	4.8	2.0	1.9	6.7	1.9	2.6	1.3	1.0	1.1	1.8	1.9	3.8	2.4	2.6
∆	1.7	-0.8	-1.5	-2.0	1.0	0.5	2.3	-2.3	-1.6	-1.0	-0.9	-0.9	-1.2	-1.0	-0.3	-0.7

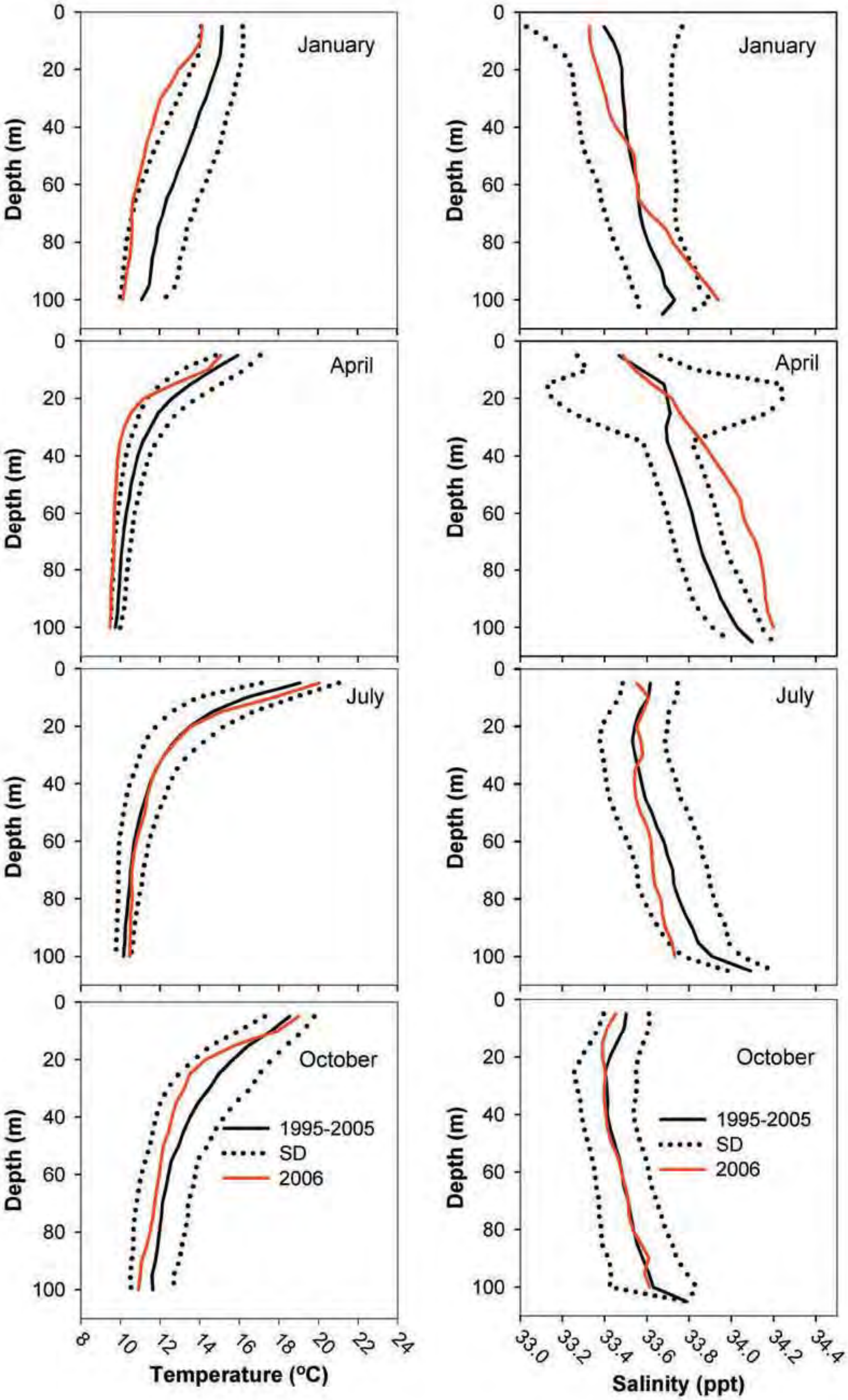

Figure 2.4
Mean temperature and salinity data for 2006 compared to mean temperature and salinity (±1 SD) for the historical period 1995 through 2005 at stations F29, F30, and F31 combined.

Table 2.3

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 (10–20 m) waters at all nearshore PLOO kelp stations during 2006.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp	*Surface*	13.9	14.3	13.1	14.7	17.3	19.0	21.1	19.0	18.1	18.1	17.6	15.9
	Bottom	13.2	12.9	11.3	11.3	12.9	13.7	15.2	14.2	14.7	16.4	16.2	15.5
Salinity	*Surface*	33.38	33.41	33.49	33.53	33.56	33.56	33.53	33.47	33.45	33.42	33.45	33.51
	Bottom	33.43	33.47	33.68	33.73	33.68	33.67	33.47	33.45	33.46	33.41	33.43	33.50
Density	*Surface*	24.95	24.90	25.19	24.90	24.34	23.90	23.33	23.83	24.05	24.04	24.18	24.62
	Bottom	25.13	25.22	25.69	25.72	25.37	25.21	24.73	24.92	24.84	24.43	24.50	24.71
DO	*Surface*	7.9	8.5	8.6	8.7	8.9	7.5	7.9	8.5	8.5	7.8	7.7	7.7
	Bottom	6.9	6.9	6.1	4.4	5.3	5.6	7.4	7.5	7.4	7.6	7.5	7.3
pH	*Surface*	8.2	8.2	8.2	8.2	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.2
	Bottom	8.1	8.1	8.0	7.9	8.0	8.0	8.1	8.1	8.1	8.1	8.1	8.1
XMS	*Surface*	79.17	82.80	76.24	75.75	75.33	76.84	80.65	82.93	81.94	85.06	80.94	77.50
	Bottom	78.86	84.90	83.44	83.26	83.01	82.27	85.72	83.10	83.62	86.58	84.07	77.74
Chl *a*	*Surface*	2.8	3.4	5.0	8.0	6.9	3.2	3.1	2.4	2.5	1.4	2.0	1.8
	Bottom	4.6	4.5	7.7	6.1	7.9	6.3	2.9	7.4	3.5	2.2	2.7	2.4

July thermoclines occurred at an average depth of ~9 m and increased to a depth of ~11 m in October (City of San Diego 2006c, d, e). Thermoclines with a difference of 1 ºC within 1 m depth at the kelp stations were few and near the bottom (17–18 m) in January and February (City of San Diego 2006b, c). From March to September the thermoclines became shallow (6–9 m) as surface temperatures increased (City of San Diego 2006d–j). Thermoclines persisted at sub-surface depths (13–14 m) in October and November, and were gone by December (City of San Diego 2006k–m). Since temperature is the main contributor to water column stratification in southern California (Dailey et. al. 1993), these differences between surface and bottom waters along with seasonal thermoclines were important to limiting the surfacing potential of the waste field throughout the year (see Chapter 3). Moreover, the wastewater plume was not detectable in aerial imagery during 2006, and the plume's signature was never detected in the remote sensing data, even in the satellite thermal bands, which have detected it occasionally in the past (see Ocean Imaging 2006, 2007a, b).

Surface and sub-surface water salinities were similar to previous years with a range of 33.34–33.70 at the quarterly offshore stations (Table 2.1), and 33.38–33.73 ppt for surface and bottom depths at kelp stations (Table 2.3). Salinity increased with depth at the quarterly offshore stations with the highest values occurring at bottom depths in April due to the intrusion of upwelled water (Table 2.2, Figure 2.4). There was little difference between surface and bottom salinity at the kelp stations from January to February and from July to December (Figure 2.5). The greatest differences occurred between March and June as a result of the intrusion of upwelled water.

Seawater density (a function of temperature, salinity, and pressure) inversely reflected the changes in thermal stratification. Consequently, the cooler, more saline water present in quarterly bottom and sub-surface waters in January and April had higher density values in 2006 relative to historical values (see Table 2.2) In contrast, average surface density was lowest in July at quarterly offshore and kelp stations when surface temperatures peaked (see Figure 2.5).

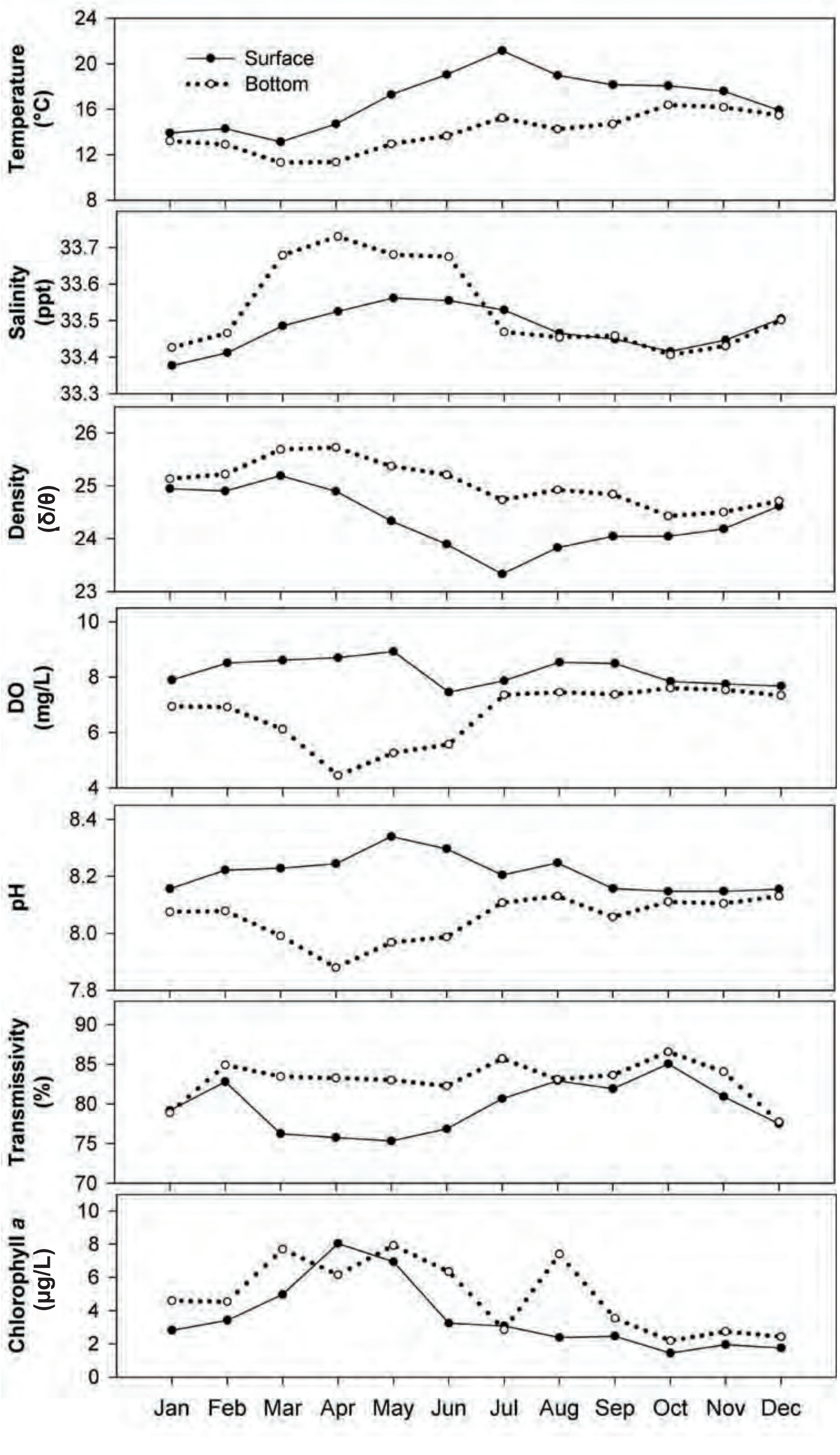

Figure 2.5
Monthly mean temperature (°C), salinity (ppt), density (δ/θ), dissolved oxygen (DO, mg/L), pH, transmissivity (%), and chlorophyll *a* (µg/L) values for surface (≤2m) and bottom (10–20 m) waters at the kelp water quality stations during 2006.

With the limited rainfall during 2006, variability in pH, transmissivity, chlorophyll *a*, and dissolved oxygen appeared mostly due to responses to plankton blooms. Plankton was observed primarily at inshore kelp stations from January through July as increased concentrations of chlorophyll *a* and dissolved oxygen, and decreased percent transmissivity (City of San Diego 2006b–h). Chlorophyll *a* spiked upwards at bottom depths in August, and was accompanied by a slight drop in water clarity, but returned to normal levels for the remainder of the year (Figure 2.5). Chlorophyll *a* concentrations at quarterly offshore stations during 2006 were low, indicating lower levels of phytoplankton in the offshore waters. The highest mean value (8.3 µg/L) occurred in July 2006 (City of San Diego 2006h), and contrasted greatly with that of July 2005 when the occurrence of a persistent red tide produced mean values above 75 µg/L (City of San Diego 2005c). DMSC and high resolution satellite imagery supported the presence of nearshore plankton blooms on several occasions during the summer, and indicated that offshore water surrounding the PLOO was relatively clear throughout the year (Ocean Imaging 2006, 2007a, b).

Remote sensing data provided several interesting observations regarding patterns of water movement in 2006. Satellite and aerial imagery indicated that surface waters generally flowed south for much of 2006, although northward flows did occasionally occur, they were often of short duration (Ocean Imaging 2006, 2007a, b). However, one such event caused a sedimentary plume from the Tijuana River following an April storm to spread northward towards Point Loma. The plume did not reach the shore or the kelp beds, although it may have affected water quality conditions at some southern stations (see Chapter 3). Thermal radiance imagery from TM and AVHRR satellites revealed a sharp thermal boundary that separated inner waters containing the kelp bed and nearshore open water from waters farther offshore (**Figure 2.6**; see Ocean Imaging 2007a). This boundary also corresponds to an ocean current shear zone, with the offshore currents being much stronger and generally southward directed relative to the inshore currents. A satellite image from November 9 also indicated an area of slightly cooler water over the outfall wye that has been observed previously, and is probably due to a doming or upwelling effect of slightly cooler subsurface water caused by displacement of underlying outfall discharge (Ocean Imaging 2006). However, the impact of these events on the physical and chemical properties of the water column in the area have not been fully characterized.

Historical Analyses of CTD Data

A review of historical oceanographic data for 3 stations surrounding the PLOO (1996–2006) did not reveal any measurable impact from wastewater discharge which began in November 1993 (**Figure 2.7**). Instead, these data were consistent with observed climate changes within the California Current System. Three significant climate events have affected the California Current System during the last decade: (1) the 1997–1998 El Niño; (2) a dramatic shift to cold ocean conditions that lasted from 1999 through 2002; (3) a more subtle but persistent return to warm ocean conditions initiated in October 2002 (Peterson et al. 2006). The long-term temperature and salinity data for Point Loma are consistent with the first 2 events, although recent data show a trend of cooler water beginning in 2005. This trend is more consistent with coastal data from northern Baja, Mexico where temperatures were below the decadal mean during 2005 and 2006 (Peterson et al. 2006). Salinity values were also mostly below the decadal mean from late 2002–2006, but increased in 2006 in the southern California and northern Baja California regions.

Water clarity (transmissivity) has generally increased in the Point Loma region since initiation of discharge through the extended outfall. However, several changes in water clarity unrelated to the outfall were also apparent in the historical data. Lower transmissivity values observed in 1995 and 1996 were likely related to a large San Diego Bay dredging project in which dredged sediments were disposed of at the LA-5 dredge disposal site, which left large, visible plumes of sediment throughout

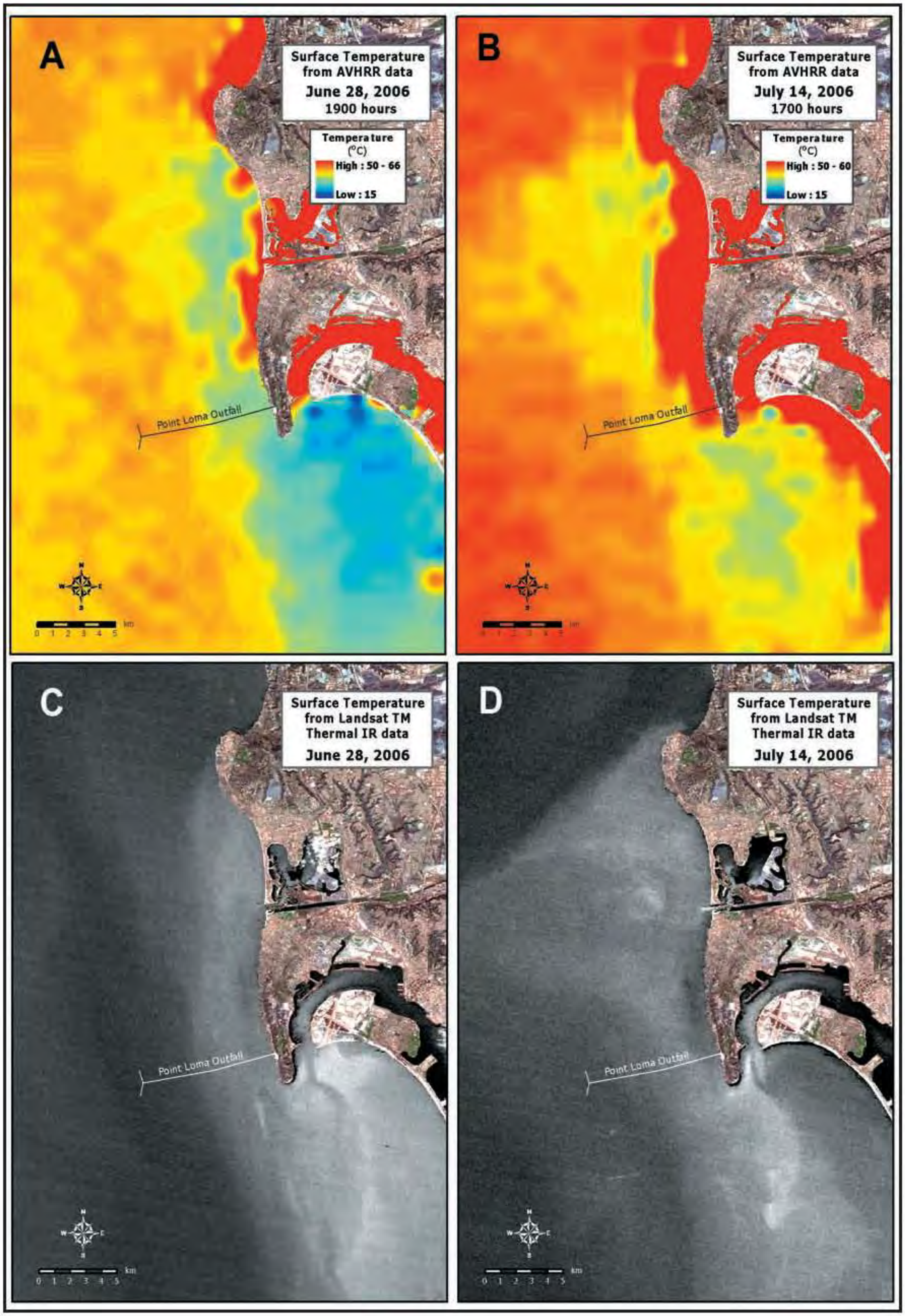

Figure 2.6
Satellite imagery showing the South Bay water quality monitoring region on June 28 and July 14, 2006 using AVHRR sensor data (A and B), and Landsat TM Infrared data (C and D). Cooler water resulting from upwelling events appears as shades of blue in AVHRR images and as lighter shades of gray in infrared images.

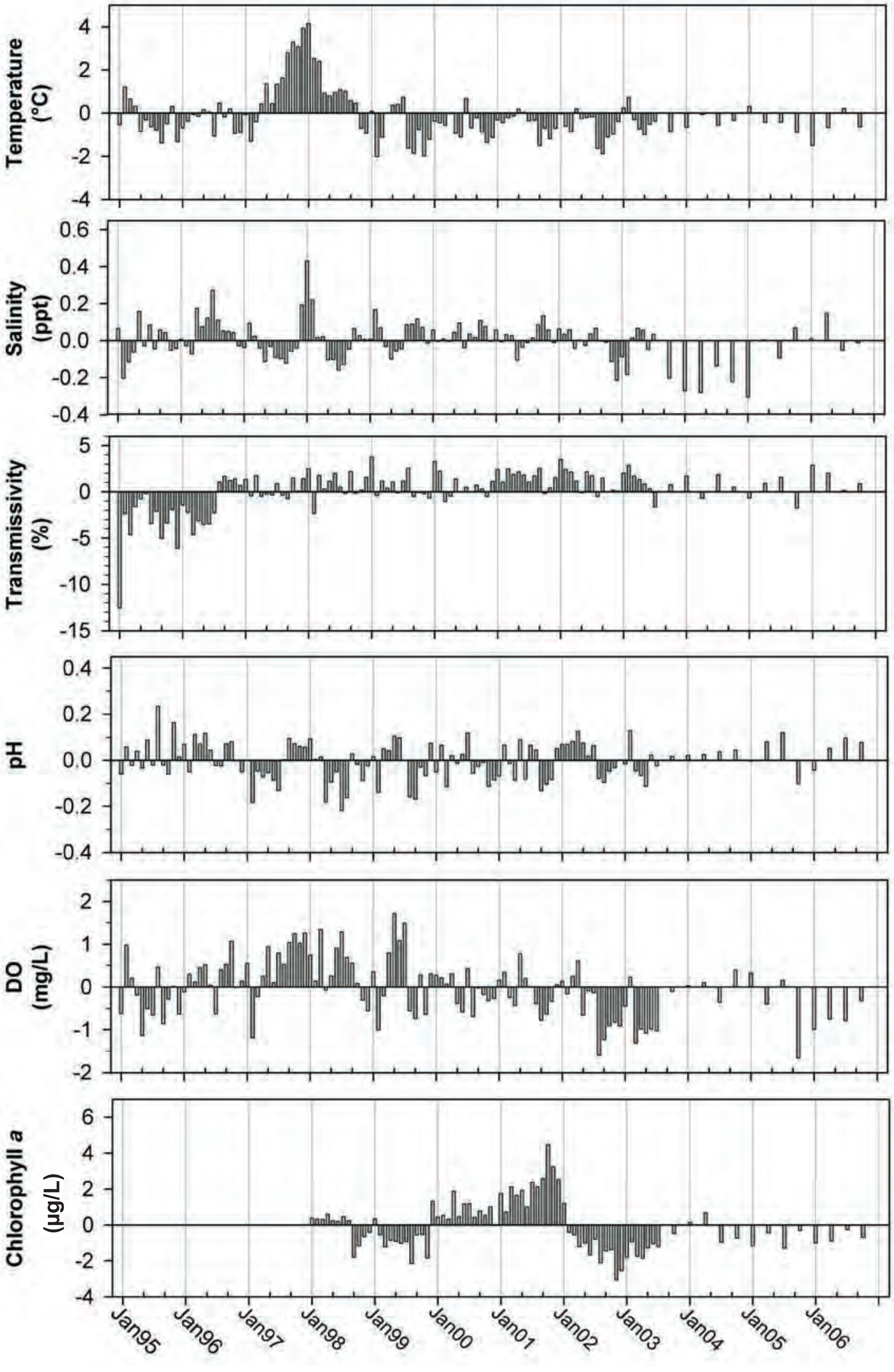

Figure 2.7
Time series of differences between means for each month and historical means for 1995–2006 for temperature (°C), salinity (ppt), transmissivity (%), pH, dissolved oxygen (DO, mg/L), and chlorophyll *a* (µg/L).

the region (see City of San Diego 2006a). Other smaller decreases in transmissivity values such as those seen at the beginning of 1998 and 2000 were likely a result of the increased amounts of suspended sediments caused by strong storm activity, whereas other such events appear to be related to plankton blooms.

Although chlorophyll *a* levels in most of southern California have increased during recent years as a result of general intensification within the California Current (Peterson et al. 2006), the Point Loma data are more consistent with the lower levels observed off northern Baja California, Mexico. For example, Figure 2.7 shows that chlorophyll *a* has decreased since 2001. However, red tides caused by blooms of the dinoflagellate *Lingulodinium polyedra* (formally *Gonyaulax polyedra*) have occurred on several occasions in the region, such as in 2001 and 2005. This species persists in river mouths and responds with rapid population increases to optimal environmental conditions, such as significant amounts of nutrients from river runoff during rainy seasons (Gregorio and Pieper 2000). The large plankton bloom of 2005 is not apparent in data from the 3 stations included in the historical analysis (see City of San Diego 2005c), and therefore is also not reflected in Figure 2.7.

Trends in relation to wastewater discharge from the PLOO were not apparent from pH and dissolved oxygen data. These 2 parameters are complex, dependent on temperature and depth, and sensitive to physicochemical and biological processes (Skirrow 1975). Moreover, dissolved oxygen and pH are subject to diurnal and seasonal variations with temporal changes often being difficult to decipher. For example, during daylight hours photosynthesis decreases dissolved CO_2 concentrations to a late afternoon minimum, which causes pH and dissolved oxygen to rise and peak in the afternoon. Thus, changes in pH and dissolved oxygen are more closely related to changes in phytoplankton populations as reflected by chlorophyll *a* concentrations as well as changes in temperature and the carbonate cycle.

SUMMARY AND CONCLUSIONS

Drought conditions in November and December 2005 continued into 2006, resulting in greatly reduced runoff and few sediment plumes relative to the 2005 rain season. As a result, ocean waters around the PLOO were relatively clear throughout 2006 compared to 2005 ocean conditions. Meanwhile, air temperatures were near a record low in March and approached high records during June–August when surface water temperatures also peaked. Despite these circumstances, oceanographic conditions during 2006 generally followed normal seasonal patterns with some exceptions. Water temperatures for all depths at the kelp and offshore stations were much cooler during January–April than in previous years, and surface temperatures were warmest during June–August. This varies from past years when surface water temperatures around the PLOO were warmest between July and September, and bottom temperatures were coldest during April through July. Additionally, salinity values were much higher at sub-surface to bottom depths, especially at bottom depths in January and below 30 m in April during 2006. These cooler temperatures and high salinity values suggest an intrusion of upwelled water during these months.

Water column stratification generally followed the typical annual pattern, despite the slight variations in temperature and salinity. Thermal stratification first developed in spring, after which stratification peaked in July and then declined thereafter. At the kelp stations, thermoclines persisted at sub-surface depths in October and November, and were gone by December.

During 2006, there was no apparent relationship between the outfall and values of pH, transmissivity, chlorophyll *a*, and dissolved oxygen. Changes in these parameters have historically been associated primarily with storm activity and plankton blooms. However, with the relatively low rainfall in 2006, variability of these parameters was mostly associated with nearshore plankton blooms measured as chlorophyll *a* concentrations. DMSC and high resolution satellite imagery supported the presence of nearshore plankton blooms on several occasions during the summer, and indicated that offshore waters surrounding the PLOO were mostly clear throughout the year.

Satellite and aerial imagery indicated that surface waters generally flowed south during 2006. Infrared and thermal satellite data also revealed the presence of a sharp thermal boundary separating the inner waters containing the kelp bed from offshore waters surrounding the PLOO outfall with offshore ocean currents being stronger.

Historical CTD data for 1995–2006 did not reveal changes in water parameters as a result of the wastewater discharge from the outfall. However, historical temperature and salinity data for Point Loma recorded 2 of 3 significant climate events that affected the California Current System: the 1997–1998 El Niño, and a dramatic shift to cold ocean conditions that lasted from 1999 through 2002. The third event, a subtle but persistent return to warm ocean conditions initiated in October 2002, was not observed. Instead, ocean conditions during that time were more consistent with data from coastal waters off northern Baja, Mexico where a condition of colder than normal temperatures occurred during 2005 and 2006.

Water clarity measured as transmissivity has increased in the Point Loma region since initiation of wastewater discharge through the extended PLOO outfall. Reduced transmissivity values observed during 1995 and 1996 were most likely related to the disposal of dredged material from San Diego Bay at LA-5. Plankton blooms in the region are complex, stimulated by localized upwelling, and occasionally influenced by large red tides created when the rivers are flowing and nutrients are more readily available. However, chlorophyll *a* levels around the PLOO have generally decreased through time and were more consistent with those of northern Baja California, whereas levels within most of southern California mostly increased. Changes in pH and dissolved oxygen did not exhibit any apparent trends related to wastewater discharge.

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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 the movement and dispersal of the wastewater plume, and monitor compliance with the 2001 California Ocean Plan (SWRCB 2001). Bacteriological densities (total coliforms, fecal coliforms, enterococcus), together with oceanographic data (see Chapter 2), provide information about the direction the wastewater plume is traveling in relation to ocean currents and large scale events (see Pickard and Emery 1990). 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. The data from the bacteriological sampling and individual station compliance are regularly submitted to the San Diego Regional Water Quality Control Board in monthly receiving waters monitoring reports. This chapter summarizes and interprets patterns in bacterial concentrations collected for the Point Loma region during 2006, as well as historical data from 1991–2006.

MATERIALS AND METHODS

Field Sampling

Water samples for bacteriological analyses were collected at fixed shore and offshore sampling sites throughout the year (**Figure 3.1A**). Weekly sampling was performed at 8 shore stations

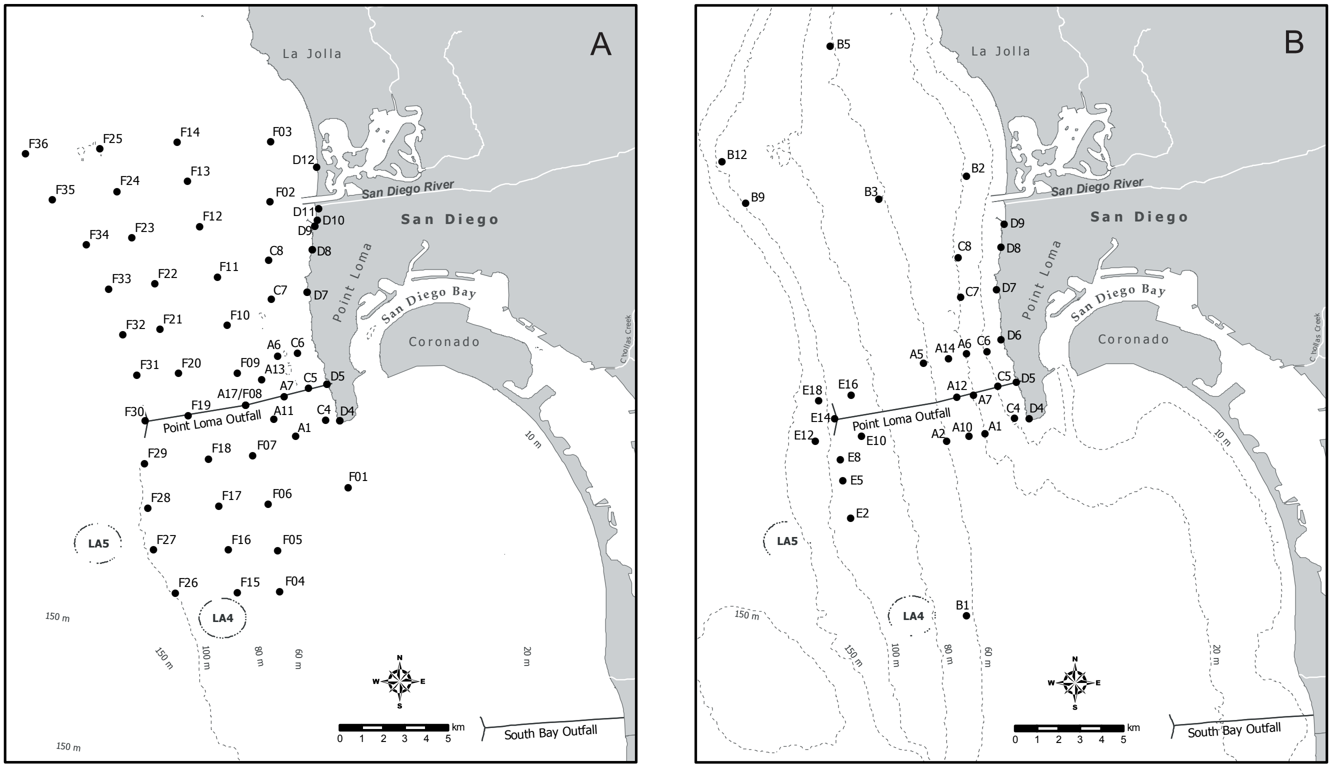

Figure 3.1

Water quality monitoring stations where bacteriological samples were collected, Point Loma Ocean Outfall Monitoring Program. (A) Current stations sampled in 2006. (B) Stations sampled from 1991–2003. Monthly offshore stations were sampled through July 2003. Shore station D6 was discontinued after July 31, 2003.

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 Offshore	x			x	x				
60-m Offshore	x					x	x		
80-m Offshore	x					x	x	x	
98-m Offshore	x					x	x	x	x

(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, surfing, fishing, 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.

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 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 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. In addition, 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 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 analysis of total coliforms, fecal coliforms, and enterococcus bacteria. Visual observations of weather, sea state, and human or animal activity in the area 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 2006 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 SBOO plume's turbidity signature by differentiating between the wastewater plume and coastal turbidity. The depth penetration of the radiance detected by this sensor varies between 8 and 15 m, depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 m. Sixteen overflights were

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 5 samples.

done in 2006, which consisted of 2 overflights per month during the winter when the outfall plume had the greatest surfacing potential and one per month during spring and summer.

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to the standard membrane filtration techniques (see APHA 1992). 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, APHA 1992).

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 statistical analyses in this report.

Shore and kelp bed station compliance with 2001 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. Mean densities (±standard error) were calculated by month or quarter, station, depth, and time period (pre-outfall extension discharge and post-outfall extension discharge). Monthly sampling at the offshore stations (see Figure 3.1B) ended after July 2003 when a quarterly schedule at a new suite of stations began. Bacteriological data from February 2, 1992 through April 8, 1992 was not used because of the extremely high values that resulted from the outfall pipe break, which would have skewed the results.

Bacterial data were evaluated relative to 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. Normality was determined graphically and homogeneity of variances was tested using the F-test. Bacteriological, oil and grease, and suspended solid data were log(x+1) transformed to improve conformity to normality for use in parametric statistical analyses.

COP and AB 411 (CDHS 2000) bacteriological benchmarks were used as reference points to distinguish elevated bacteriological values in receiving water samples discussed in this report. These are >1000 CFU/100 mL for total coliforms, >400 CFU/100 mL for fecal coliforms, and >104 CFU/100 mL for enterococcus bacteria. Furthermore, contaminated water samples were identified as those with total coliform concentrations ≥1000 CFU/ 100 mL and a fecal:total (F:T) ratio ≥0.1 (see CDHS 2000). Samples from quarterly 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 and processed according to method requirements to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in the Quality Assurance Report (City of San Diego 2007).

The distribution of the PLOO waste field was estimated from maps of total coliform densities collected at the offshore stations. These maps were generated using the Spatial Analyst extension for ArcGIS 9.1. The Inverse Distance Weighting algorithm was used with the power set to 3, a neighborhood of 5, and default values for all other parameters. Bacterial densities from samples shallower than 60 m were not used because contaminated water was detected in only 1 such sample: the 12 m depth sample collected at station F01 on April 14. Interpolations of deep water total coliform concentrations are meant for simplified data visualization purposes only and are not statistically significant.

RESULTS AND DISCUSSION

Compliance with California Ocean Plan Standards

Compliance with COP bacterial standards for the shore and kelp stations was very high in 2006 (**Appendices A.1, A.2**). Shore station D11 was the only station to fall below 100% compliance. The few exceedances of the 30-day total coliform standard occurred at station D11 during March, the wettest month of the year. All kelp stations were 100% compliant with each COP bacterial standard.

Spatial and Temporal Trends

Shore stations

In 2006, a total of 2496 samples were collected for bacteriological analyses, including 495 from the shoreline stations, 1437 at the kelp stations, and 564 at the quarterly offshore stations. Of these, only 49 had total coliform concentrations greater than or equal to the 1000 CFU/100 mL benchmark. Five of these samples were collected at the shore stations and 44 at the offshore stations, while none were collected at the kelp stations. Forty of these 44 offshore samples also had F:T ratios ≥0.1 and were used as possible indicators of plume movement.

Bacterial densities were generally low at the shore stations in 2006 (**Table 3.2**). Monthly total coliform densities during the year averaged from 2 to 1264 CFU/100 mL. Although rainfall was below average for the year, the highest mean densities occurred during the wet months (e.g., February through May; see Chapter 2). For example, total coliform densities were highest in February as a result of one sample collected from station D11 on February 21 following a rain event (NOAA/NWS 2007; **Table 3.3**). Of the 5 shore samples with total coliforms ≥1000 CFU/100 mL, 2 were collected in February and May during rain events, and one occurred in March when trace amounts of rain fell prior to sampling. Two samples from station D8 were not associated with rain events but did contain bacterial levels that exceeded the benchmark values for total and fecal coliforms and were indicative

Table 3.2

Shore station bacterial densities and rainfall data for the PLOO region during 2006. Mean total coliform, fecal coliform, and enterococcus bacteria densities are expressed as CFU/100 mL. Rain is measured at Lindbergh Field, San Diego, CA (see NOAA/NWS 2007). Sample size (n) for each station is given in parentheses.

Month	**Rain** (in.)		**D4** (61)	**D5** (62)	**D7** (62)	**D8** (62)	**D9** (62)	**D10** (62)	**D11** (62)	**D12** (61)	**All stations**
Jan	0.36	*Total*	5	4	5	274	96	132	141	22	85
		Fecal	6	2	3	140	6	15	14	3	24
		Entero	3	2	3	24	10	11	16	5	9
Feb	1.11	*Total*	57	6	59	61	8	77	1264	5	195
		Fecal	6	3	70	21	2	16	37	4	20
		Entero	3	5	7	8	2	6	17	2	6
Mar	1.36	*Total*	2	3	6	54	16	256	668	90	137
		Fecal	2	2	4	20	3	20	25	4	10
		Entero	3	2	2	16	4	12	10	6	7
Apr	0.88	*Total*	2	57	3	58	10	72	230	10	55
		Fecal	2	17	3	23	4	6	17	4	9
		Entero	2	6	2	6	2	3	4	3	4
May	0.77	*Total*	85	43	23	176	10	286	319	6	119
		Fecal	4	12	6	46	3	24	42	2	17
		Entero	3	9	7	94	2	29	54	3	25
Jun	0.00	*Total*	49	56	24	76	24	40	76	115	56
		Fecal	2	6	4	9	3	11	18	10	8
		Entero	2	2	5	4	2	7	7	38	8
Jul	0.04	*Total*	13	20	128	32	13	53	116	21	49
		Fecal	2	2	7	14	2	49	28	8	14
		Entero	2	2	4	2	2	9	31	2	7
Aug	0.01	*Total*	52	16	92	28	13	180	96	52	66
		Fecal	3	4	5	4	2	19	17	9	8
		Entero	2	2	2	2	2	12	29	7	8
Sep	0.00	*Total*	6	15	124	80	10	48	32	7	40
		Fecal	2	4	4	28	3	12	14	10	10
		Entero	2	6	8	9	2	3	4	2	5
Oct	0.76	*Total*	17	24	57	137	21	61	29	16	45
		Fecal	2	3	10	53	4	24	11	5	14
		Entero	4	2	18	22	2	15	6	7	10
Nov	0.15	*Total*	11	32	136	360	16	81	49	61	93
		Fecal	6	6	29	113	4	22	30	33	30
		Entero	9	6	10	84	8	7	7	39	21
Dec	0.71	*Total*	7	10	13	164	52	66	64	22	50
		Fecal	4	6	6	92	20	30	40	7	26
		Entero	2	30	2	287	18	38	142	14	67
Annual means		**Total**	**24**	**24**	**55**	**128**	**25**	**112**	**251**	**34**	
		Fecal	**3**	**5**	**12**	**48**	**5**	**21**	**24**	**8**	
		Entero	**3**	**6**	**6**	**46**	**5**	**13**	**27**	**11**	

Table 3.3

Elevated total coliform, fecal coliform, and enterococcus bacteria (Entero) densities (CFU/100 mL) at PLOO shore stations in 2006. Fecal to total coliform ratios (F:T) ≥0.1(see text) are bolded. Rain was measured at Lindbergh Field, San Diego, CA (see NOAA/NWS 2007).

Date	72-Hour rain (in.)	Station	Total	Fecal	Entero	F:T
January 18	0.00	D8	1200	740	38	**0.62**
February 21	0.19	D11	6200	100	48	0.02
March 5	0.05	D11	2600	78	28	0.03
May 22	0.77	D11	1000	120	220	**0.12**
November 18	0.00	D8	1000	420	220	**0.42**

of contaminated water (F:T ratio ≥0.1). However, high counts of indicator bacteria have also been present during dry periods at station D8 in previous years (City of San Diego 2005, 2006g) and the relationship between rainfall and monthly mean fecal coliform concentrations was not significant (Spearman correlation; n=12, p=0.32).

Other potential sources of contamination that may have contributed to elevated bacterial densities at shore stations D8 and D11 include kelp and seagrass beach wrack (see Martin and Gruber 2005) and shorebirds, all of which were present during the collection of many of the samples (City of San Diego 2006a–f). There is also a tidally influenced storm drain at station D8, which may accumulate organic debris (kelp and surfgrass) and amplify bacterial densities (Martin and Gruber 2005). In contrast, the beach around station D11 is a designated dog recreation area and has a population of transient people living along the San Diego River upstream of the sampling site. Contamination from both sources is suspected in the elevated bacterial counts at this station.

Kelp bed and offshore stations

Only 2% of the offshore station samples (n=40) collected in 2006 were indicative of contaminated waters (total coliform density ≥1000 CFU/100 mL and an F:T ratio ≥0.1; **Appendix A.3**). Total coliform densities in shallow depths (1–25 m) ranged from <2 to 1400 CFU/100 mL throughout the year, while densities of fecal coliforms ranged from <2 to 160 CFU/100 mL. Only one shallow water sample, station F01 in April, was indicative of contaminated water. The highest mean densities of indicator bacteria 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 2006. For example, none of the bacteriological samples collected from the kelp bed stations had elevated bacterial densities. Mean bacterial densities were highest at stations along the 80 and 98-m transects of quarterly offshore stations (Figure 3.2B). Thirty-five of the 40 samples indicative of contaminated water were collected from sites along these transects. The other 5 samples came from station F01 (18-m depth contour) and stations F05, F06, F09, and F10 (60-m depth contour). The relatively high bacterial densities in samples collected at station F01 may be related to the release of over 10 million gallons of sewage during 2005–2006 from Naval Base San Diego into San Diego Bay (US Navy 2006). Mean bacterial densities were generally highest at the 80 m stations in April, the 98 m stations in July, and the 80 m and 98 m stations in October (**Table 3.4**) The lowest densities were in January with elevated samples in only one sample (see Appendix A.3).

The spatial distribution of the wastefield varied by quarter in 2006 (**Figure 3.3**). Interpolation of the bacteriological data from 60 m and below indicates that there was a possible offshore movement in January, as evidenced by the lack of elevated bacterial densities around and inshore of the PLOO diffusers. The only January sample containing bacterial densities indicative of contaminated water occurred 5.6 km north of the PLOO at station F33 (60 m depth sample). MODIS imagery showed offshore flows of surface waters that occurred up to 1 week before the January quarterly sampling (Ocean Imaging 2007a).

In April, the wastefield was detected along the 80 and 60 m contours, mostly to the north and inshore of the outfall. Although the wastefield appeared to have moved eastward in April, it was not detected at special study stations A11 and A13 or at any of the kelp bed stations (City of San Diego 2006c). MODIS imagery indicated that surface waters were flowing north in early April, but had switched back to a southward flow right before the April quarterly sampling (Ocean Imaging 2007b). Elevated bacterial densities were found up to 7.5 km south of the PLOO along the 60 m contour in April and may have been due to discharge from the San Diego Bay and Tijuana River following several rain events. MODIS imagery revealed turbidity plumes from the San Diego Bay and Tijuana River in the sampling area before the April sampling (Ocean Imaging 2007b).

In July and October, contaminated water was detected up to 12.5 km (7.8 mi) north of the PLOO (stations F36 and F25) along the 80 m and 98 m contours. Data from an acoustic doppler current profiler (ADCP) also indicated that the dominant direction of current flow for bottom waters (42–98 m depths) around the PLOO diffusers in October was north with some movement east and west (City of San Diego, unpublished data).

Historical Analyses

The extension of the PLOO was designed to eliminate bacterial contamination in the Point Loma kelp bed and nearshore waters. To evaluate the effectiveness of the outfall extension, mean bacterial densities for pre-discharge (1/1/1991–11/23/1993) and post-discharge (11/24/1993–12/31/2006) periods were compared for shore, kelp, and offshore station surveys (see Materials and Methods). The results

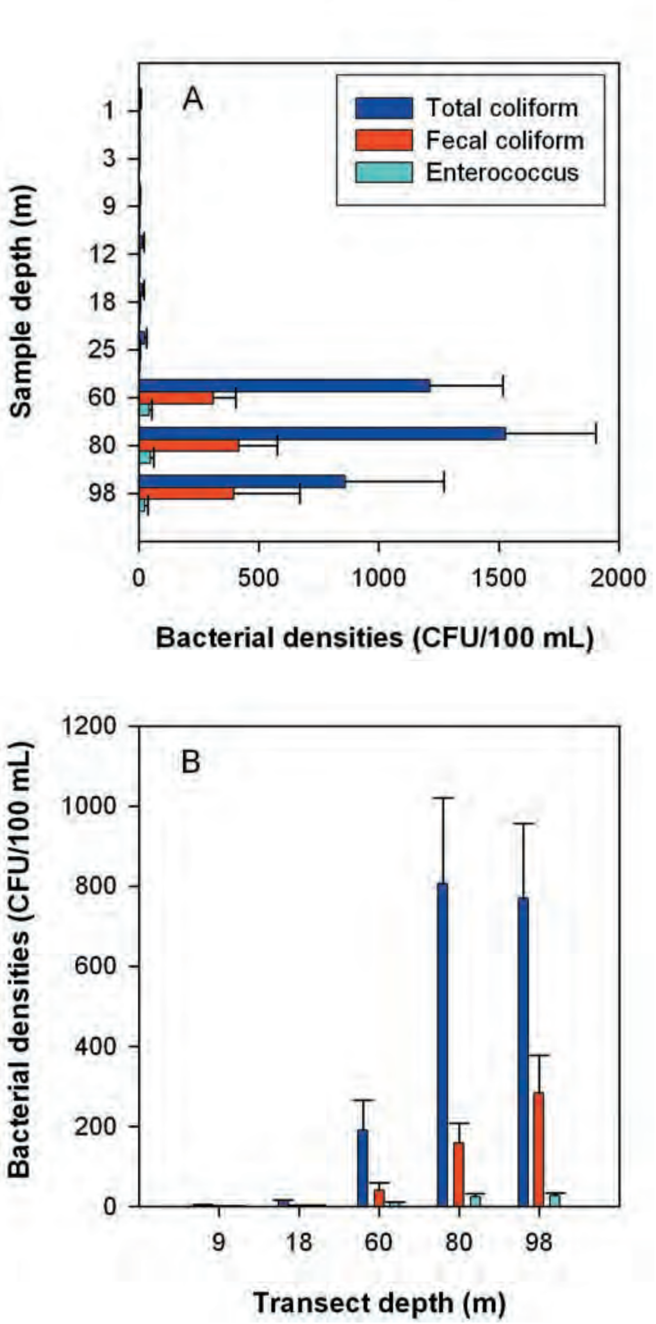

Figure 3.2
Kelp and quarterly offshore station bacterial densities for the PLOO region during 2006. Total coliform, fecal coliform, and enterococcus bacterial densities (mean±SD; CFU/100 mL) by (A) sample depth and (B) transect depth.

Table 3.4

Mean bacterial densities (CFU/100 mL) for quarterly sampling events in 2006 at PLOO kelp bed and offshore stations. n=number of samples collected quarterly. Sample size for 9-m kelp bed stations in January=42.

Assay	Contour	n	January	April	July	October
Total	9-m kelp bed	45	3	2	3	4
	18-m kelp bed	75	10	13	3	11
	18-m offshore	9	8	184	109	2
	60-m offshore	33	109	584	34	37
	80-m offshore	44	123	1362	451	1284
	98-m offshore	55	150	6	1809	1110
Fecal	9-m kelp bed	45	2	2	2	2
	18-m kelp bed	75	3	3	2	2
	18-m offshore	9	3	27	28	3
	60-m offshore	33	20	127	9	4
	80-m offshore	44	23	331	91	193
	98-m offshore	55	35	3	754	345
Entero	9-m kelp bed	45	2	2	2	2
	18-m kelp bed	75	2	2	2	2
	18-m offshore	9	2	2	24	2
	60-m offshore	33	9	23	4	2
	80-m offshore	44	11	61	10	18
	98-m offshore	55	14	2	60	33

indicate that the PLOO extension has greatly reduced the flow of the wastewater plume into the Point Loma kelp bed such that it is rarely, if ever, detected along the shoreline or the kelp beds (see **Figures 3.4–3.5**). Mean total and fecal coliform densities from samples collected at the shore stations, and all 3 indicator bacteria at the kelp stations, were significantly lower once discharge through the extended outfall began (**Table 3.5**). Station D5, located along the shoreline where the outfall pipe meets the shore, had the largest decline in fecal coliform densities during the post-discharge period. The largest overall decrease at the kelp stations occurred in total coliform densities, while fecal coliform densities declined at all depths in the post-discharge period.

Mean densities of indicator bacteria at the offshore samples were also significantly lower and samples indicative of contaminated water have been restricted to deeper waters since discharge began through the extended outfall (**Figure 3.6**, Table 3.5). For example, the highest fecal coliform densities occurred in samples taken from 24 to 43 m during the pre-discharge period, but occurred in samples from 80 m during the post-discharge period (**Figure 3.7**). Similarly, fecal densities greater than 400 CFU/100 mL have not been found shallower than 12 m during the post-discharge period. Finally, total coliforms densities during the post-discharge period have fallen below 1000 CFU/100 mL at stations along the 60 m contour near the old outfall as well as those stations farther inshore, with densities >1000 CFU/100 mL limited to stations along the 80 m contour (Figure 3.7). Overall these results suggest that the extension of the outfall pipe has suppressed the surfacing potential and significantly reduced the onshore movement of the PLOO wastefield.

SUMMARY AND CONCLUSIONS

There was no evidence that the Point Loma Ocean Outfall (PLOO) wastewater plume reached the shoreline or recreational waters in 2006. Elevated

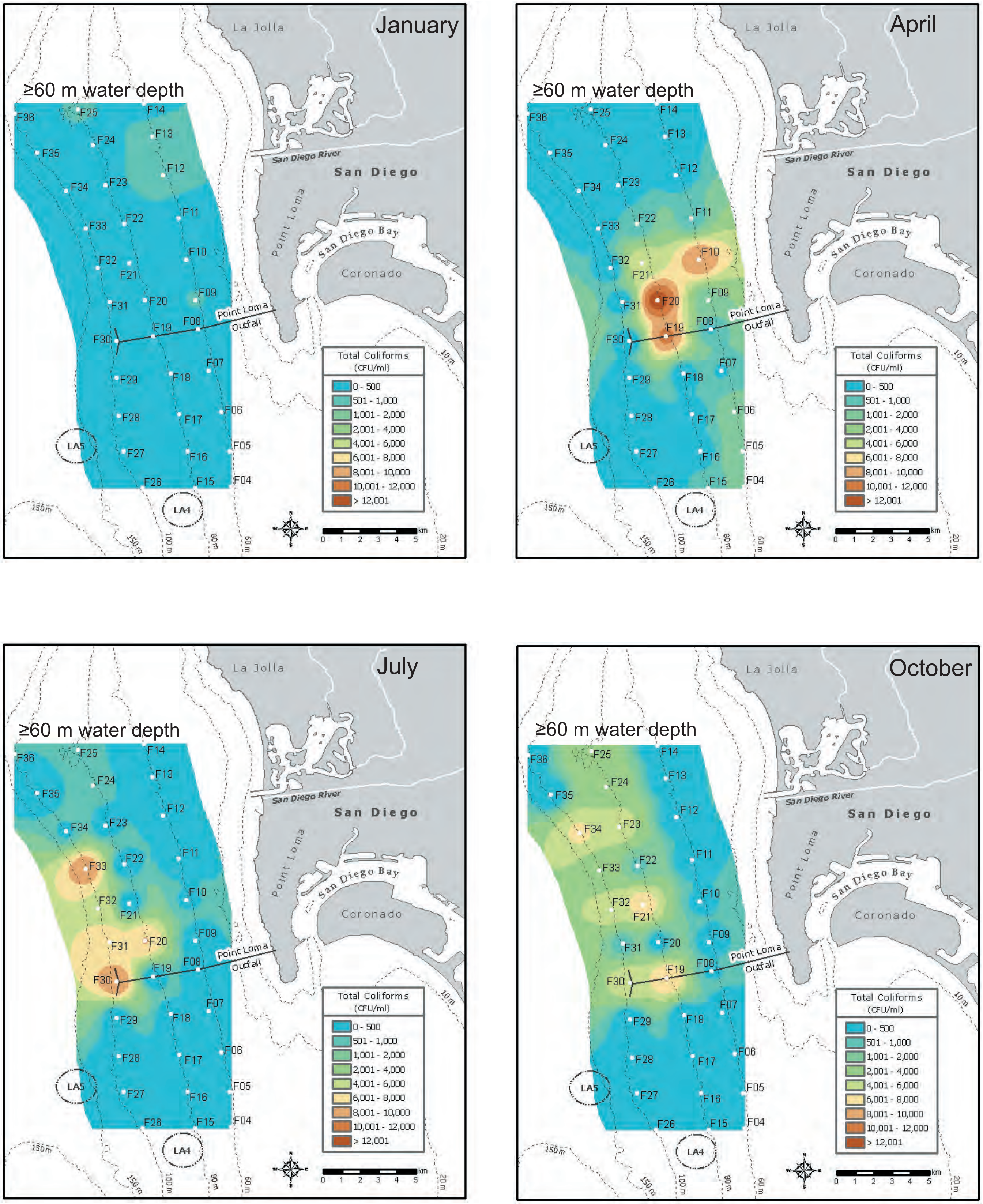

Figure 3.3
Distribution of mean total coliform counts from depths of 60 m and below collected during quarterly offshore surveys in 2006. Contaminated water (see text) was generally not detected in samples shallower than 60 m depth.

Table 3.5

Independent sample t-test results for pre-extension discharge versus post-extension discharge periods from PLOO shore, kelp, and monthly offshore stations. Data are log(x+1) transformed. The pre-extension discharge period is from January 1991 to November 1993, while post-extension data used in this analysis is from November 1993 to December 2006 (Shore and Kelp) and November 1993 to July 2003 (Offshore).

	Variable	t	df	P
Shore	Total coliform	-2.243	1319	0.025
	Fecal coliform	-3.967	1294	<0.001
	Enterococcus	-1.698	5786	0.089
Kelp	Total coliform	-68.360	13,356	<0.001
	Fecal coliform	-59.411	11,668	<0.001
	Enterococcus	-55.091	12,281	<0.001
Offshore	Total coliform	-28.937	6735	<0.001
	Fecal coliform	-27.340	6131	<0.001
	Enterococcus	-25.688	6430	<0.001

bacterial densities along the shore were limited to stations D8 and D11 where the source of contamination may have been heavy recreational use or decaying kelp and surfgrass wrack material. Despite a below average amount of rainfall in 2006, most of these elevated bacterial densities came during the wettest months of February through May. All of the kelp bed stations had low densities of all indicator bacteria. Furthermore, all 7 kelp bed stations and all but one shore station were 100% compliant with the 4 COP standards. Shore station D11, located near the mouth of the San Diego River, was 95% compliant with the 30-day total coliform standard and 100% compliant with the other 3 COP standards. All of the exceedances at station D11 occurred during March when rains were heaviest; however, an analysis of rainfall and shore station bacterial densities showed that there was no significant correlation between rain and fecal coliforms.

It is also unlikely that the PLOO wastewater ever reached surface waters in 2006. Bacteriological evidence of contaminated water at the offshore stations was predominantly limited to samples collected from depths of 60 m and deeper. The only shallow water sample indicative of contaminated water was taken from station F01 (12 m depth) in April, and may have been due to sewage discharge from Naval Base San Diego into the San Diego Bay.

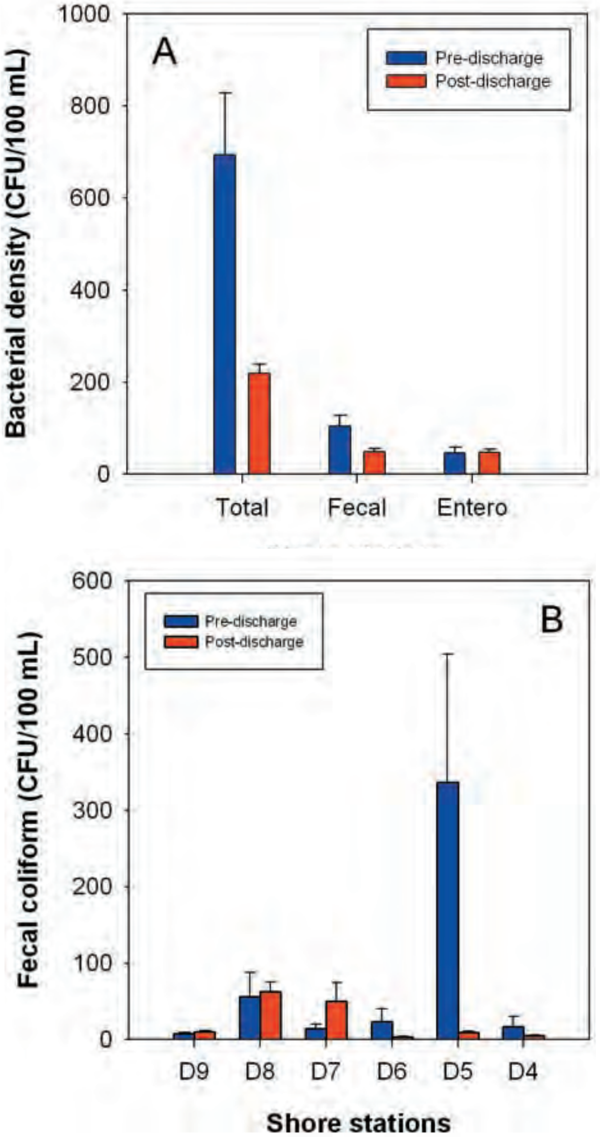

Figure 3.4

Mean bacterial densities (mean±SE) for PLOO shore stations from 1991–2006. The pre-extension period is from January 1991 to November 1993 while post-extension is from November 1993 to December 2006. Sample size indicated as Pre/Post. (A) Mean densities by parameter. Total=total coliform (n=1007/4768), Fecal=fecal coliform (n=1007/4781), Entero=enterococcus (n=1008/4780). (B) Mean fecal coliform densities by station (n=212–556). Stations are arranged from north to south on the x-axis.

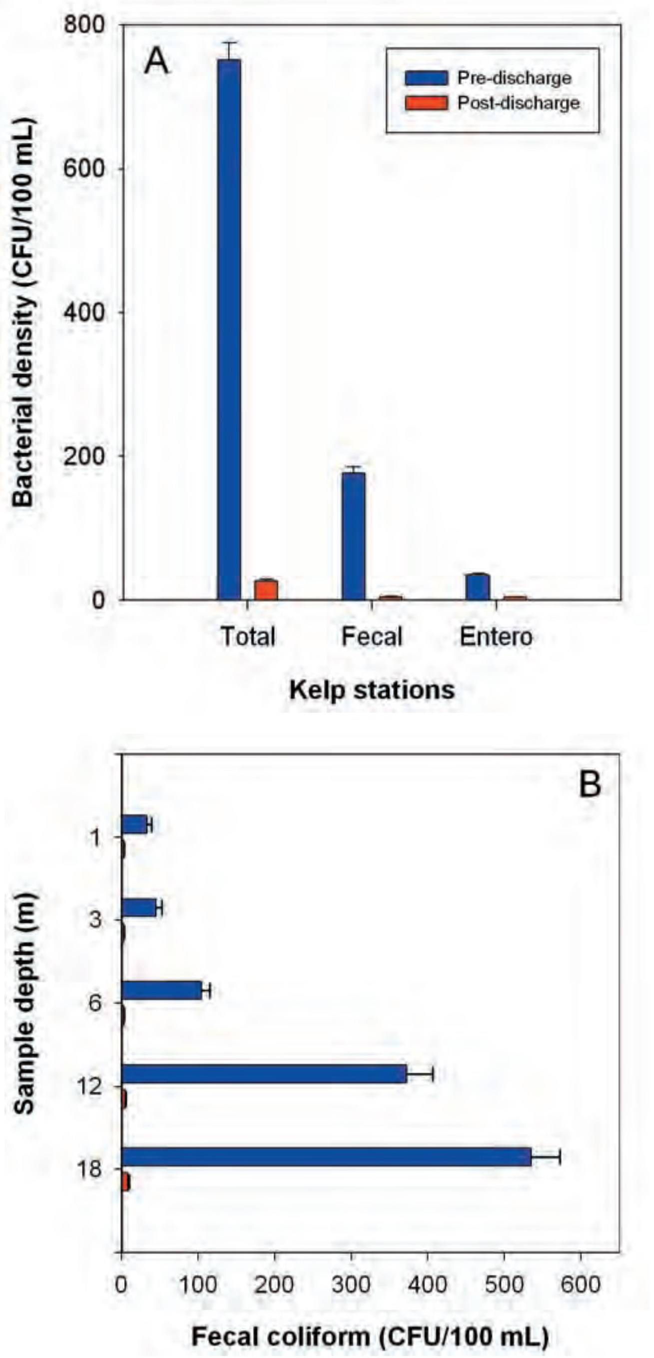

Figure 3.5
PLOO kelp station mean bacterial densities (mean±SE) collected by (A) parameter and (B) depth from 1991–2006. The pre-discharge period is from January 1991 to November 1993 while post-discharge is from November 1993 to December 2006. Sample size indicated as Pre/Post. Total=total coliform (n=10,550/17,883), Fecal=fecal coliform (n=10,540/17,925), Entero=enterococcus (n=10,531/17,924).

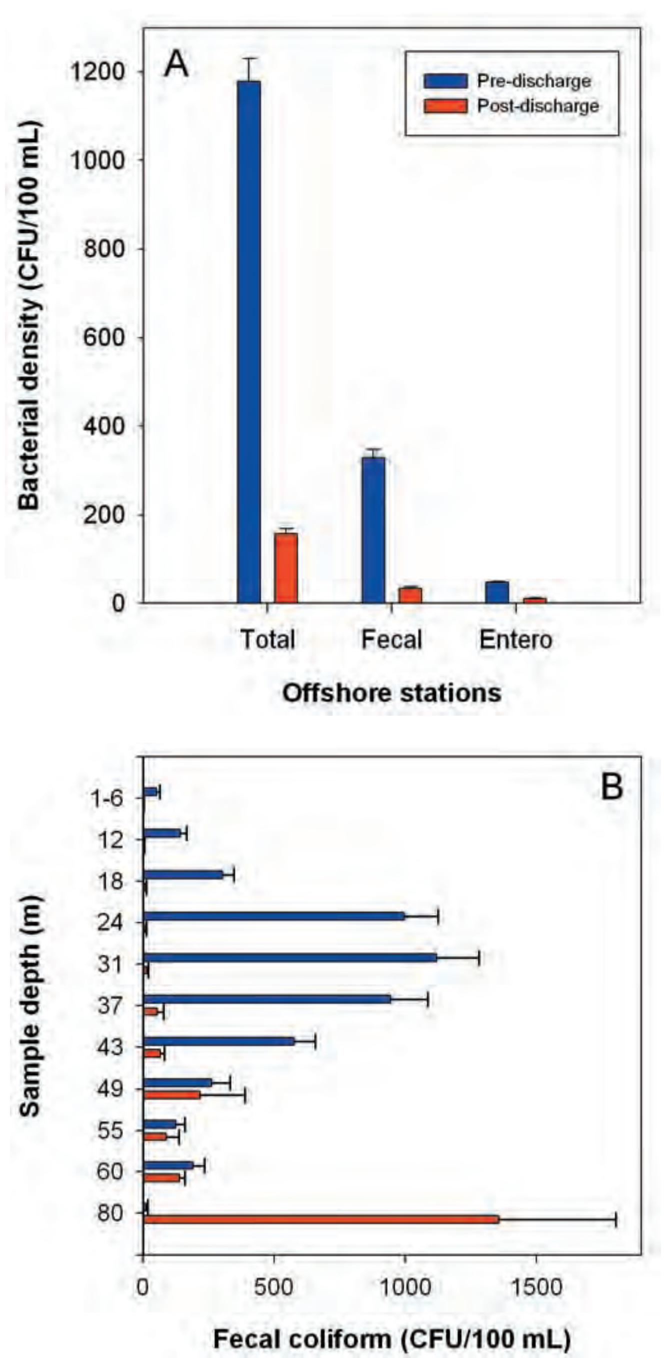

Figure 3.6
PLOO monthly offshore station mean bacterial densities (mean±SE) collected by (A) parameter and (B) depth from 1991–2006. The pre-discharge period is from January 1991 to November 1993 while post-discharge is from November 1993 to July 2003. Sample size indicated as Pre/Post. Total=total coliform (n=4444/6977), Fecal=fecal coliform (n=4477/6980), Entero=enterococcus (n=4476/6980).

The discharge depth (~98 m) may be the dominant factor that keeps the plume from reaching the surface. Wastewater is released into cold, dense seawater that does not appear to mix with the top 25 m of the water column. Physical parameters suggest that the water column was strongly

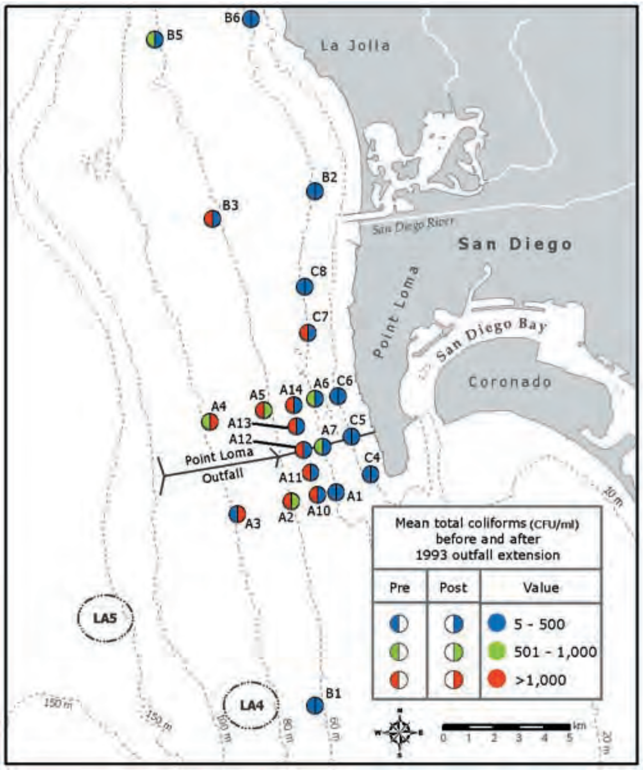

Figure 3.7
Comparison of pre- and post-discharge mean total coliform densities (CFU/100 mL) for PLOO water quality monitoring stations where monthly bacteriological samples were collected from 1991–2003.

stratified during the spring through fall months (see Chapter 2). However, the absence of evidence for bacteriological contamination in the surface waters in January, when the water column was well mixed, suggests that stratification may not be the only factor limiting the depth of the plume to 60 m and deeper.

The dominant direction of the PLOO waste field flow appeared to be northward in 2006. High bacterial densities were detected at the northern limits of the quarterly sampling grid during most quarters, and were detected at the southern limits only in April. There was also evidence that the plume moved inshore to the 60-m depth contour in April. It also appears that the plume may have dispersed farther offshore than most of the sampling stations in January, when contaminated water was only detected well north of the PLOO in the 60 m sample from station F33. There did not appear to be one consistent pattern for the distribution of the wastefield.

Analyses of historical data indicated that since the extension of the PLOO, the wastefield is no longer reaching the shoreline. Mean coliform densities at shore stations significantly decreased during the post-discharge period. Similarly, all kelp bed station indicator bacterial densities decreased significantly during the post-discharge period. The largest decreases were detected in the 12 and 18-m depth samples. There is no bacteriological evidence that the PLOO wastefield has reached the Point Loma kelp bed since the outfall extension went into operation. Similarly, all indicator bacterial densities from the monthly offshore stations significantly decreased during the post-discharge period. The highest mean fecal coliform densities shifted from 24–43 m depth samples during the pre-discharge period to 80 m samples during the post-discharge period. These results, combined with recent results from quarterly station samples, indicate that the wastewater plume is remaining below the thermocline and offshore of the Point Loma kelp bed.

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Chapter 4. Sediment Characteristics

INTRODUCTION

Soft bottom ocean sediments provide important habitat to benthic invertebrate and demersal fishes. 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 these processes. The geological history of an area can shape the chemical composition of sediments. 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). Similarly, primary productivity in nearshore waters, as well as terrestrial plant debris originating from bays, estuaries, and rivers greatly affects the organic content of sediments (Mann 1982, Parsons et al. 1990). Finally, sediment particle size influences concentrations of various constituents within sediments. 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, 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 the subsequent substrate composition in the immediate area (see Shepard 1973). Consequently, monitoring sediment conditions is important to understand natural and anthropogenic impacts to the sediments in the region surrounding the Point Loma Ocean Outfall (PLOO).

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2006 at stations surrounding the 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

Sediment samples were collected at 22 stations in the PLOO region (**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 north of the outfall. Each sample was collected from one grab of a double chain-rigged 0.1 m^2 Van Veen grab sampler; the other grab sample was used for macrofaunal community analysis (see Chapter 5). Sub-samples for various analyses were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (USEPA 1987).

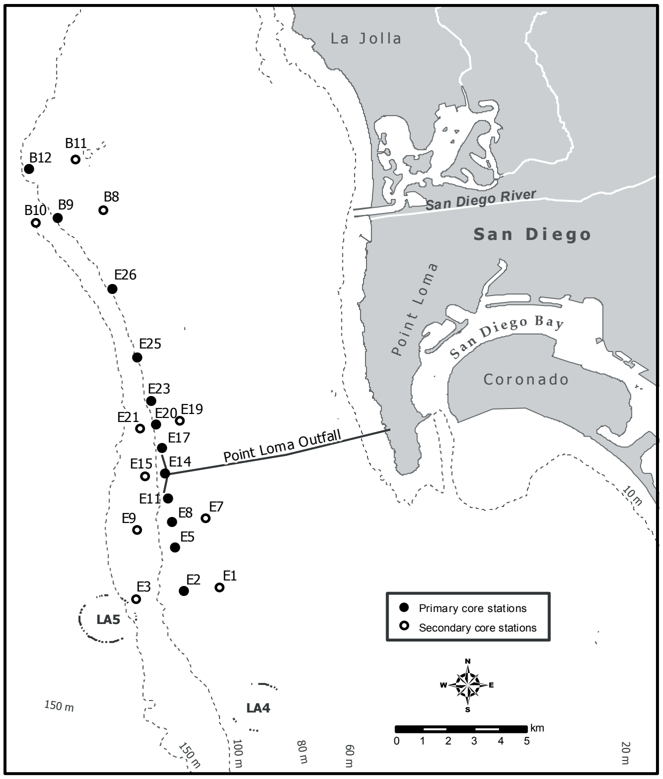

Figure 4.1
Benthic sediment station locations sampled for the Point Loma Ocean Outfall Monitoring Program.

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Laboratory. 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. These data were expressed as the percent "Coarse" of the total sample sieved.

Data output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles from >0.0625 to 2.0 mm in size, silt as particles from 0.0625 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 totaling 100%. The coarse fraction was included with the ≥2.0 mm fraction in the calculation of various particle size parameters, which were determined using a normal probability scale (see Folk 1968). The parameters included mean and median particle size in millimeters, phi size, standard deviation of phi (sorting coefficient), skewness, kurtosis, and percent sediment type (i.e., coarse, sand, silt, clay).

Chemical parameters analyzed for each sediment sample included total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl compounds (PCBs) (see **Appendix B.1**). These data were generally limited to values above the method detection limit (MDL). However, concentrations below the MDL were reported as "estimated" values if their presence could be verified by mass-spectrometry (i.e., spectral peaks confirmed), or as "not detected" (i.e., null) if not confirmed. Zeroes were substituted for all null values when calculating mean values. Annual mean concentrations are reported as the mean ± the standard deviation of station-quarter values.

Concentrations of the sediment constituents detected in 2006 were compared to average results from previous years. In addition, values for trace metals, TOC, TN, and pesticides (i.e., DDT) were compared to median values for the Southern California Bight (SCB). These medians were based on the cumulative distribution function (CDF) calculated for each parameter using data from the SCB region-wide survey in 1994 (see Schiff and Gossett 1998). They are presented as the 50% CDF in the tables included herein. Levels of contamination were further evaluated by comparing the results of this study to the Effects-Range-Low (ERL) sediment quality guideline of Long et al. (1995). The National Status and Trends Program of the National Oceanic and Atmospheric Administration originally calculated the ERL to provide a means for interpreting monitoring data. 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 SBOO 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	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: $D(phi) = -3.3219\log_{10}D(mm)$

RESULTS AND DISCUSSION

Particle Size Distribution

During 2006, ocean sediments collected off Point Loma were predominantly composed of very fine sand and coarse silt with a mean particle size of 0.079 mm or 3.9 phi (**Table 4.2**). Fine sediments (silt and clay fractions combined) averaged about 39% of the sediments overall, while sands accounted for approximately 58%. Coarser materials such as shell hash and gravel comprised the remaining 3%. 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 2007). This also suggests that these sites are subject to slow moving currents, reduced water motion, or some type of disturbance (e.g., storm surge, rapid suspension/deposition of materials). For example, 17 of the 44 samples collected in 2006 contained some measure of both coarse materials and fine particles (silt and clay), while 4 others included observations of rock, gravel, or coarse sand within the sample (see **Appendix B.2**). Mean particle size at all but 3 stations was ≤0.08 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 0.039 mm) occurred at the north station B8 located along the 88-m depth contour, while the coarsest sediments (>0.1 mm) occurred at stations near the PLOO (E14) and southward (E2 and E9). Each of these stations averaged over 12% coarse materials, with station E14 averaging about 25%. Stations along the 98 and 116-m contours, from E17 southward to E2, were composed of sandy sediments that were slightly more coarse than the surrounding area. In addition, observations of the field samples collected at stations E9, E14, and E15 revealed the presence of coarse, black sand used as stabilizing

Table 4.2

Summary of particle size parameters and organic loading indicators at PLOO sediment stations during 2006. Data are expressed as annual means. CDF=cumulative distribution functions (see text); na=not available. Area mean=mean for 2006. Values that exceed the median CDF are in bold type.

		Particle size						Organic indicators				
Station	**Depth (m)**	**Mean (mm)**	**Mean (phi)**	**SD (phi)**	**Coarse (%)**	**Sand (%)**	**Fines (%)**	**BOD (mg/kg)**	**Sulfides (ppm)**	**TN (wt%)**	**TOC (wt%)**	**TVS (wt%)**
North reference stations												
B11	88	0.055	4.2	2.0	2.0	52.7	**45.4**	517	0.7	**0.102**	**2.870**	3.94
B8	88	0.039	4.7	1.6	0.0	40.9	**59.2**	475	3.0	**0.086**	**0.995**	3.87
B12	98	0.075	3.8	1.9	1.1	65.6	33.4	516	1.0	**0.063**	**3.600**	3.45
B9	98	0.059	4.1	1.8	2.0	58.4	**39.6**	342	1.5	**0.060**	**0.979**	3.13
B10	116	0.068	3.9	1.6	1.5	69.5	29.0	411	1.6	**0.053**	**1.585**	3.14
Stations north of the outfall												
E19	88	0.054	4.3	1.5	0.6	54.9	**44.6**	368	3.6	**0.063**	**0.740**	2.67
E20	98	0.062	4.0	1.4	0.0	63.7	36.4	339	3.2	**0.051**	**0.612**	2.25
E23	98	0.057	4.2	1.5	0.0	59.6	**40.4**	360	3.5	**0.054**	**0.647**	2.40
E25	98	0.059	4.1	1.6	0.0	61.7	38.4	469	1.7	**0.055**	**0.766**	2.38
E26	98	0.053	4.3	1.5	0.0	57.0	**43.1**	371	1.6	**0.060**	**0.768**	2.77
E21	116	0.062	4.0	1.5	0.0	66.3	33.8	288	1.2	0.050	**0.647**	2.30
Outfall stations												
E11	98	0.073	3.8	1.4	0.0	69.1	31.0	242	16.2	0.049	**0.613**	2.11
E14	98	0.283	2.4	1.8	24.9	42.8	32.4	418	5.9	0.048	**0.652**	1.85
E17	98	0.065	4.0	1.5	0.0	66.4	33.6	294	6.6	0.049	**0.655**	2.09
E15	116	0.064	4.0	1.5	0.0	67.3	32.8	339	3.9	0.048	**0.835**	2.38
Stations south of the outfall												
E1	88	0.057	4.2	1.9	2.0	53.9	**44.1**	357	2.4	**0.059**	**0.659**	2.38
E7	88	0.057	4.1	1.5	0.0	59.2	**40.8**	342	0.7	**0.061**	**0.662**	2.35
E2	98	0.150	3.1	1.9	12.5	44.5	**43.0**	282	5.6	**0.053**	**0.777**	2.42
E5	98	0.067	3.9	1.5	1.0	65.9	33.2	256	1.0	0.049	**0.627**	2.27
E8	98	0.066	4.0	1.5	0.2	66.9	33.0	270	1.3	0.050	**0.687**	2.20
E3	116	0.080	3.7	2.1	2.8	62.3	34.9	323	2.9	0.040	0.515	2.14
E9	116	0.144	2.8	1.8	14.8	26.0	**59.3**	303	0.9	**0.061**	**1.510**	2.50
Area mean		0.079	3.9	1.6	3.0	57.9	39.1	358	3.2	0.057	1.018	2.59
50% CDF							38.5	na	na	0.050	0.597	na

material for the outfall pipe, suggestive of the potential spread of this ballast material (see Appendix B.2).

Organic Indicators

Generally, the distribution of organic indicators in PLOO sediments during 2006 was similar to that seen prior to discharge (see City of San Diego 1995a). The north reference stations had higher concentrations of organic indicators than most stations farther south (Table 4.2). For example, the north reference sites included the 3 highest values of TOC, TN, BOD, and TVS, and all 5 sites contained TOC values of ~1.0% or higher and TVS above 3.0%. In contrast, just one southern station (E9) had comparable TOC values. Concentrations of organic indicators at sites within the vicinity of the PLOO (i.e., E11, E14, E15, E17) were relatively low; however, TOC concentrations at these sites were above the median CDF. In addition, station E11 had elevated sulfides (16.2 ppm) and stations E14 and E25 had slightly elevated BOD values (418 and 469 mg/kg, respectively).

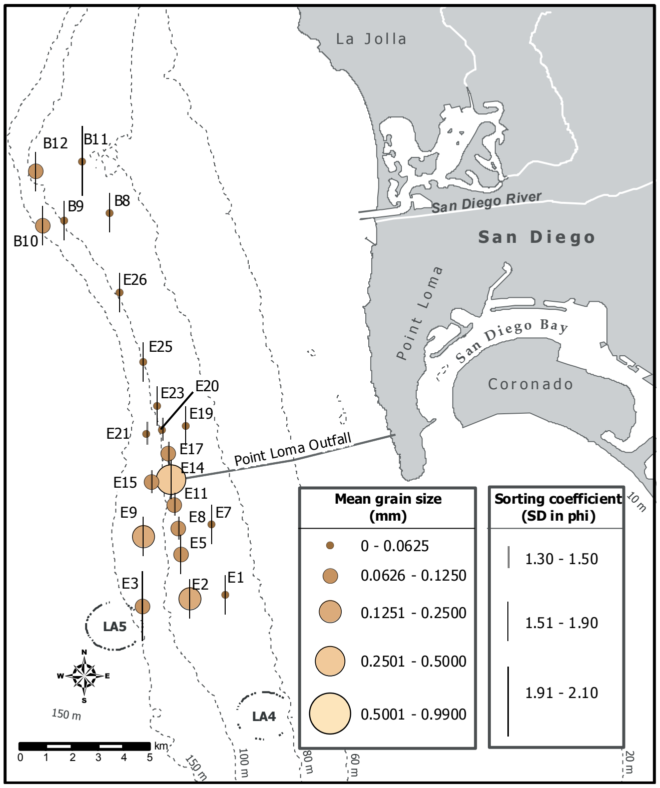

Figure 4.2

Annual mean particle size (mm) distribution and sorting coefficient (standard deviation in phi units) for PLOO sediment stations sampled during 2006.

Overall, these patterns are consistent with the spatial pattern observed in historical data from stations along the 98-m contour (**Figure 4.3**). Conversely, average TOC concentrations increased by over 50% in 2006 (see **Appendix B.3**). This change was not due to the relatively high values at stations B10, B11, B12, and E9; similarly high values have been encountered previously at these stations (see City of San Diego 1995b–1997). Instead, the high 2006 area mean is consistent with a region-wide increase in TOC values (see City of San Diego 2007). Mean BOD also reached a maximum value in 2006, but, in contrast to TOC, BOD values have been consistently higher during the entire post-discharge period (**Figure 4.4**). Overall, the concentrations of organics in sediments surrounding the PLOO during 2006 were within range of those found regionally for the mid-shelf strata (see City of San Diego 2007).

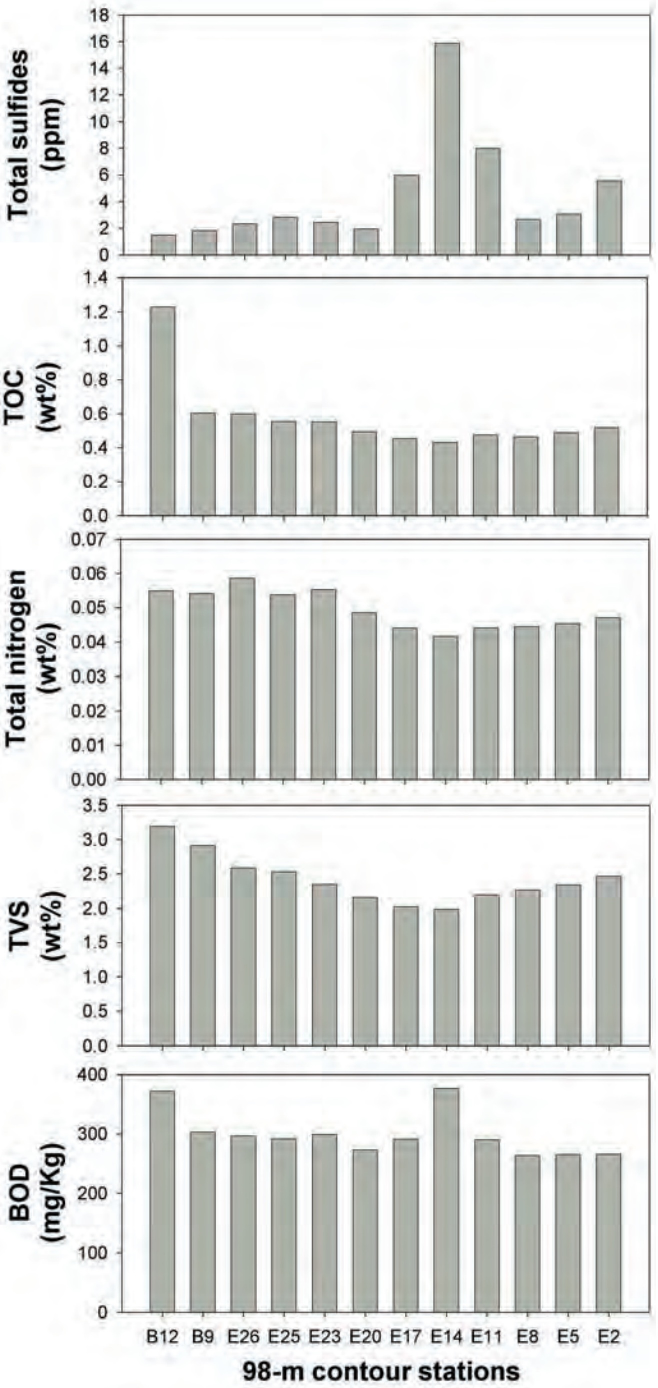

Figure 4.3

Means of organic indicators for 98-m contour stations, 1991–2006, listed from north to south (left to right).

Trace Metals

Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc were detected at concentrations above their MDLs in all sediments off Point Loma (**Table 4.3**). Silver was detected in

Table 4.3

Annual mean concentrations of trace metals (ppm) detected at each PLOO sediment station during 2006. CDF=cumulative distribution function; ERL=effects range-low-threshold value; nd=not detected; na=not available. Bolded values exceed the CDF value. Area mean=mean for 2006. See Appendix A.1 for metal names represented by the periodic table symbols.

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	**9820**	**0.3**	4.21	50.2	0.10	0.11	23.6	8.4	**20400**	10.3	120	0.028	9.5	0.00	**0.32**	nd	0.6	24.4
B-8	88	**11700**	**0.3**	4.32	53.6	0.07	0.08	22.5	**12.9**	**17100**	11.5	129	**0.047**	10.6	**0.29**	**0.67**	nd	1.0	25.8
B-12	98	7110	**0.7**	**5.04**	27.1	0.11	0.16	25.5	4.0	**22900**	9.6	70	0.016	6.9	0.14	nd	nd	0.8	20.1
B-9	98	9025	**0.5**	3.54	54.3	0.11	0.12	22.6	8.0	**19350**	8.4	107	0.024	8.0	nd	**0.28**	nd	0.7	23.6
B-10	116	7440	0.2	2.51	31.7	0.05	0.10	17.6	7.4	13850	6.9	73	0.022	6.0	nd	**0.21**	0.19	0.5	19.0
Stations north of the outfall																			
E-19	88	**9990**	0.1	3.14	48.2	0.05	0.10	18.7	8.5	13950	9.7	111	**0.046**	8.7	nd	**0.52**	0.10	0.9	19.9
E-20	98	8105	0.2	2.37	35.0	0.04	0.11	15.5	6.4	11400	7.4	88	0.025	7.0	nd	**0.33**	0.19	0.7	17.0
E-23	98	8415	**0.3**	3.11	37.2	0.05	0.11	16.1	6.4	12350	7.8	93	0.023	7.6	nd	**0.40**	nd	0.7	16.5
E-25	98	8180	**0.3**	2.90	35.1	0.05	0.10	15.9	5.9	12100	7.8	90	0.027	7.3	0.17	**0.30**	nd	0.9	15.5
E-26	98	8370	0.2	2.46	38.3	0.05	0.09	16.3	6.8	12350	8.0	96	0.028	7.6	0.00	**0.45**	nd	0.6	18.9
E-21	116	6945	0.2	2.78	27.9	0.04	0.12	14.3	4.9	10600	6.9	75	0.022	6.6	0.14	**0.22**	nd	0.8	13.7
Outfall stations																			
E-11	98	6715	**0.4**	2.97	28.5	0.04	0.11	13.2	4.7	9790	6.3	69	0.026	6.0	nd	**0.22**	0.18	0.8	15.0
E-14	98	6990	**0.4**	3.79	32.4	0.03	0.16	14.5	7.0	11100	6.2	93	0.019	8.0	0.14	**0.20**	0.16	0.6	16.7
E-17	98	7610	**0.3**	3.81	32.9	0.04	0.12	14.9	4.9	11450	7.1	83	0.022	7.0	0.12	**0.36**	0.19	0.9	15.3
E-15	116	7050	**0.4**	2.32	27.9	0.04	0.12	14.6	5.2	10445	6.8	72	0.025	6.5	0.13	**0.30**	0.20	0.8	15.2
Stations south of the outfall																			
E-1	88	**9690**	**0.3**	3.10	52.0	0.08	0.08	16.5	9.9	13650	7.8	101	**0.054**	7.4	0.07	nd	nd	1.3	26.9
E-7	88	8890	**0.3**	3.22	42.4	0.05	0.10	16.7	6.7	12450	8.7	94	0.027	8.0	0.12	**0.45**	0.26	0.9	17.6
E-2	98	**10700**	**0.4**	2.23	53.8	0.08	0.07	17.6	**14.5**	14850	6.6	108	**0.041**	7.4	nd	nd	nd	1.2	27.3
E-5	98	7025	0.2	2.58	31.0	0.04	0.05	13.5	6.5	10500	6.6	73	0.028	5.9	nd	**0.32**	0.36	0.7	14.2
E-8	98	7000	0.2	2.66	29.2	0.04	0.07	14.0	5.0	10350	6.1	72	0.024	6.2	nd	**0.29**	0.21	1.0	14.4
E-3	116	**9375**	**0.4**	2.24	68.8	0.07	0.08	15.2	**13.2**	13650	9.4	106	**0.051**	5.8	nd	nd	nd	1.5	27.5
E-9	116	7905	**0.5**	3.63	32.5	0.05	0.13	18.1	9.6	13550	8.7	80	0.028	7.1	nd	**0.32**	nd	0.8	24.6
Area mean		8366	0.3	3.13	39.5	0.06	0.10	17.1	7.6	13552	7.9	91	0.029	7.3	0.06	0.30	0.10	0.8	19.5
Detection (%)		100	100	100	100	100	100	100	100	100	100	100	100	100	41	82	45	100	100
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

Annual mean concentrations for pesticides (ppt), total PCBs (ppt), and total PAHs (ppb) in PLOO sediments during January and July 2006. CN=*cis*-Non-achlor; CDF=cumulative distribution function (see text); nd=not detected; na=not available; ERL=Effects-range-low threshold value. Bolded values exceed the CDF value.

	Pesticides					
Station	**CN**	**HCB**	**Total DDT**	**Total PAH**	**No. PAH**	**Total PCB**
North reference stations						
B-11	nd	nd	**31790**	182	13	nd
B-8	nd	nd	nd	191	10	nd
B-12	1000	nd	285	112	7	nd
B-9	nd	nd	nd	114	7	nd
B-10	nd	nd	nd	103	6	nd
Stations north of the outfall						
E-19	nd	nd	nd	159	9	nd
E-20	nd	nd	nd	133	8	nd
E-23	nd	nd	nd	138	9	nd
E-25	nd	nd	205	140	9	nd
E-26	nd	nd	nd	123	7	nd
E-21	nd	nd	nd	124	7	nd
Outfall stations						
E-11	nd	nd	nd	103	5	nd
E-14	nd	nd	nd	111	6	nd
E-17	nd	228	nd	123	8	nd
E-15	nd	nd	nd	112	7	nd
Stations south of the outfall						
E-1	nd	nd	612	190	13	535
E-7	nd	nd	230	93	7	nd
E-2	nd	nd	252	146	9	**2715**
E-5	nd	nd	215	92	6	nd
E-8	nd	nd	180	126	6	nd
E-3	nd	nd	nd	255	12	**3769**
E-9	nd	nd	nd	140	9	**9355**
CDF	na	na	10000	na		2600
ERL			1580	4022		22700

82% of the samples and selenium and thallium were detected in just over 40% of the samples.

Sediments at most stations contained concentrations of metals below their respective CDF and ERL values. For example, only antimony and silver frequently occurred in concentrations above the median CDF. Generally, metal concentrations were highest in 2 general locations: (1) at the north reference stations, particularly B8 and B11, and (2) at the 3 southernmost stations located east of the LA-5 dredge disposal site (i.e., E1, E2, E3). The highest values for aluminum, barium, copper, lead, manganese, mercury, nickel, selenium, silver, tin, and zinc were collected at one or more of these stations. Several of these stations, along with station E19 located northeast of the PLOO, also included concentrations of 3 or more metals above the CDF. Some of the lowest metal concentrations actually occurred at the 4 stations surrounding the PLOO discharge area (i.e., E11, E14, E15, E17). The high levels of barium, copper, mercury, and zinc at the southern stations near LA-5 may be related to the deposition of dredged sediments that originated from San Diego Bay, where such metals are known to occur in high concentrations (see City of San Diego 2003).

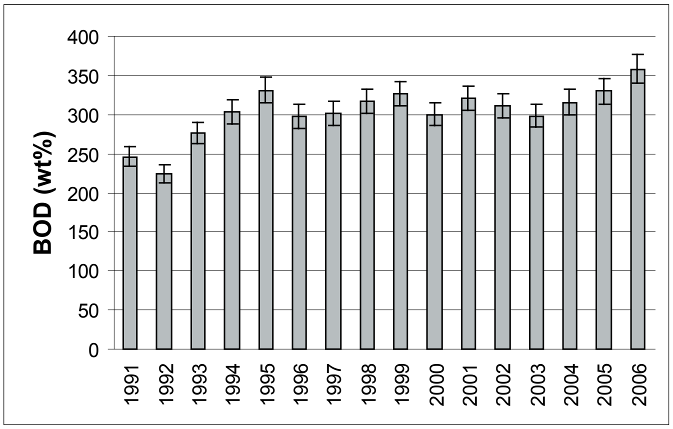

Figure 4.4

Annual mean concentrations of BOD (1991–2006) with 95% confidence limit.

Overall, the average concentrations of trace metals in local sediments decreased in 2006 relative to prior years (**Appendix B.4**). In particular, the 2006 levels of aluminum, beryllium, iron, and manganese detected in Point Loma sediments were much lower than 2005, when increased runoff and sedimentation resulting from record rainfall increased concentrations of these metals region-wide (City of San Diego 2006). Reduced runoff and drought conditions that persisted throughout much of 2006 may have contributed to the decline in metals contamination found region-wide (see City of San Diego 2007).

Pesticides, PCBs, and PAHs

Three chlorinated pesticides were detected at 9 PLOO sediment stations in 2006: cis-Nonachlor, hexachlorobenzene (HCB), and DDT (the sum of several metabolites) (**Table 4.4**). Cis-Nonachlor was found in the sediments from station B12, along with low levels of DDT, while low concentrations of HCB were detected at station E17. In contrast, DDT was detected as its final metabolic degradation product (p,p-DDE) at stations E1, E2, E5, E7, E8, E25, B11, and B12. All but one of these samples were collected in January. Sediments at station E1 contained similar concentrations of p,p-DDE in January and July. The extraordinarily high mean concentration at station B11 (31,790 ppt) — a result of the January sample with a concentration of 63,580 ppt and a non-detect in July — exceeded the median CDF for the SCB (10,000 ppt) and the ERL (1580 ppt). Similarly high values (e.g., >40,000 ppt) have been found only twice before, once at station B9 and once at E2 (see City of San Diego 1996, 2000). The previous high total DDT concentration at station B11 was 6400 ppt in 1996 (City of San Diego 1997). Pesticide contamination along the San Diego shelf appears to result from sources unrelated to the PLOO discharge. For example, region-wide total DDT concentrations 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, City of San Diego 2006). Similarly, discharges from Mission Bay and the San Diego River during periods of heavy rainfall may affect those more northern sites (e.g., B9, B11).

PCBs were detected in sediments from only 4 stations in 2006, all of which are located south of the PLOO (Table 4.4). Three stations (E2, E3, E9) had values above the median CDF of 2600 ppt, but still well below the ERL of 22,700 ppt. Fifteen different congeners comprised the highest total PCB concentration (9355 ppt) at station E9, while 8 were detected at stations E2 and E3. PCBs 110 and 153/168 were detected at all 4 sites, while PCBs 52, 101, 118, and 149 were found at stations E2, E3, and E9. PCBs have historically occurred at these and other southern stations relatively near the LA-5 disposal site. In contrast, PAH compounds were detected in low concentrations at all stations in 2006 with no values exceeding the ERL of 4022 ppb (Table 4.4).

SUMMARY and CONCLUSIONS

Ocean sediments at stations surrounding the PLOO in 2006 were comprised primarily of very fine sands and coarse silt. Overall, these 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. Very coarse sediments were found at stations E14 located nearest the PLOO and stations E2 and E9 located southward of the outfall. 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, the region's sediment composition reflects multiple anthropogenic input (e.g., outfall construction, dredge materials disposal) and natural influences (e.g., Pleistocene and recent detrital deposits; see Emery 1960).

The overall distribution of organic indicators was generally similar to previous surveys; however the concentrations of TOC and BOD were generally high in 2006 than in the previous year. 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. Sediments at station E14, nearest the outfall, had elevated TOC concentrations and relatively high BOD values, but very low sulfides compared to previous years. However, concentrations of organics in sediments surrounding the PLOO during 2006 were within range of those found regionally (see City of San Diego 2007).

Fifteen trace metals were detected frequently in sediments surrounding the PLOO during 2006, with the lowest concentrations occurring near the discharge site. Most metals were present at concentrations below median CDF values for the SCB and other sediment quality guidelines. Only antimony and silver occurred in concentrations frequently above median CDF values. Metal concentrations were highest at the north reference stations, particularly B8 and B11, and several stations located east of the LA-5 dredge disposal site (i.e., E1, E2, E3). The highest values for 11 different metals were collected at one or more of these 5 sites. 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 2003). Their presence at sites south of the PLOO and near LA-5 may be related to the disposal of materials dredged from the Bay. The lowest metal concentrations occurred at sites near the PLOO. Region-wide, average concentrations of trace metals decreased in 2006 relative to prior years. In particular, concentrations of metals associated with storm-related runoff in 2005 (e.g., aluminum, beryllium, iron, manganese) were significantly lower than in 2006.

PAH compounds were detected in low concentrations at all stations in 2006, and no value exceeded the ERL. In contrast, PCB values above the median CDF were detected in sediments from 3 stations south of the PLOO. The total PCB load at these stations included from 8 to 15 different PCB congeners, with 6 congeners common to each station. 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 2003; 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. Three chlorinated pesticides were detected in PLOO sediments from 9 stations in 2006. An extraordinarily high concentration of DDT that exceeded both the median CDF and the ERL was collected at station B11 in January. Similarly high values were found only twice before (see City of San Diego 1996, 2000). Generally, pesticide contamination along the San Diego shelf has been low and appears to be the result of sources unrelated to the PLOO discharge.

Overall, data from the sediment composition and chemistry indicate that impact from the PLOO wastewater discharge appears to be limited to slight increases in mean sediment grain size and moderately elevated levels of BOD and sulfides in nearby sediments. Instead, natural events (e.g., storms and plankton blooms) and anthropogenic sources (e.g., pollution from stormwater discharge and dredging activities) are more likely than the PLOO to contribute measurable changes to sediments off Point Loma.

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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 prey 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 important 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, 2005).

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 2006 at fixed stations surrounding the PLOO discharge site off San Diego, California are presented in this chapter. Descriptions and comparisons of the different macrofaunal 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 range from 8 km south to 11 km north of the outfall terminus and are located along the 88, 98, and 116-m depth contours (**Figure 5.1**). A total of 88 benthic grabs were taken during 2 surveys in

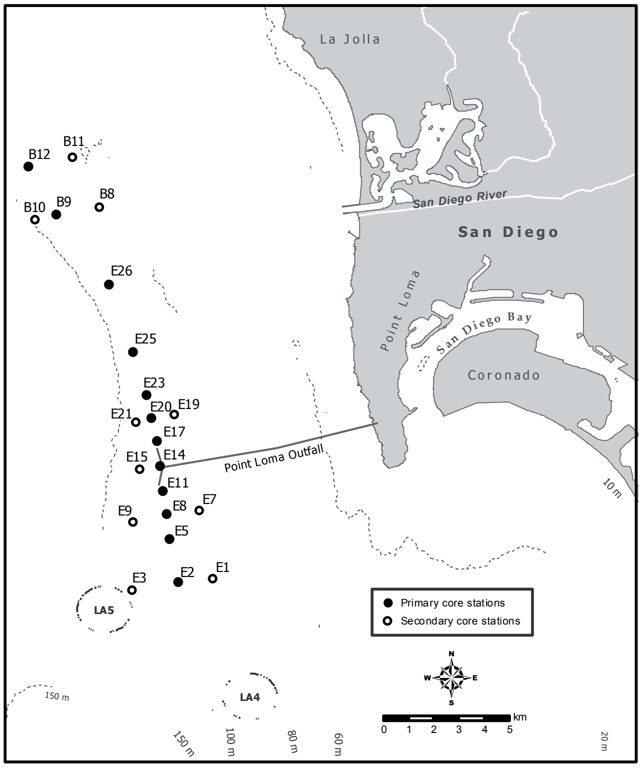


Figure 5.1
Benthic stations surrounding the City of San Diego's Point Loma Ocean Outfall.

2006. All 22 benthic stations were sampled in both January and July.

Samples for benthic community analysis were collected from 2 replicate grabs per station during each survey using a modified 0.1-m^2 chain-rigged, double van Veen grab. 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. After a minimum of 72 hours, each sample was rinsed with freshwater and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups by a subcontractor, 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 v6 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 44 combined samples among 22 stations.

Annual means for the following community parameters were calculated for each station and cluster group: species richness (number of species); total number of species per site (i.e., cumulative of 2 replicate samples); abundance (number of individuals); Shannon diversity index (H'); Pielou's evenness index (J'); Swartz dominance index (minimum number of species accounting for 75% of the total abundance in each grab; see Swartz et al. 1986, Ferraro et al. 1994); 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 have been no changes in select 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 2006) an impact 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 13 years (45 quarterly or semi-annual surveys) of after impact data.

The E stations, located within 8 km of the outfall, are considered most likely to be affected by wastewater discharge. Station E14 was selected as the impact site for all analyses; this station is located nearest the Zone of Initial Dilution (ZID) and probably is 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, BRI) and abundances of 3 taxa that are considered sensitive to organic enrichment. These indicator taxa include 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 α=0.05.

RESULTS AND DISCUSSION

Community Parameters

Number of species

A total of 621 macrofaunal taxa were identified during the 2006 PLOO surveys. Mean values of species richness ranged from 63 to 147 species per 0.1 m^2 (**Table 5.1**). Stations E3, E9, and E25 and northern reference stations B10, B11, and B12 were characterized by the most species, averaging 119–137 species per 0.1 m^2 (City of San Diego 2005, 2006a). This pattern is consistent with previous high species richness values for these sites (e.g., City of San Diego 2005, 2006a) In contrast, the lowest species richness was found at stations E1, E7, E11, E19, E20, and E23, all of which averaged fewer than 90 species per 0.1 m^2. In addition, species richness at approximately half of the stations showed a large decrease compared to 2005 (see City of San Diego 2006a).

Polychaetes were the most diverse of the major taxa in the region, accounting for 46% of all species collected during 2006. Crustaceans accounted for 24% of the species, molluscs 15%, echinoderms 6%, and all other taxa combined for 9% of the species.

Macrofaunal abundance

Mean macrofaunal abundance averaged 169–586 animals per 0.1 m^2 in 2006 (Table 5.1). The largest number of animals occurred at stations E9, E14, and B12, each of which averaged >450 animals per 0.1 m^2. The fewest animals (<300 per 0.1 m^2) were collected at stations E1, E19, E20, and E23, which were also low in species richness. The remaining sites had abundances ranging from 305 to 434 animals per 0.1 m^2. There was a 22% decline in overall abundance region wide in 2006 versus 2005, with the largest difference occurring at stations B11 and B8 (see City of San Diego 2006a). These sites averaged 1074 and 606 individuals per 0.1 m^2 respectively in 2005 but <350 in 2006.

Polychaetes were the most numerous animals, accounting for 57% of the total abundance. Crustaceans accounted for 23%, echinoderms 11%, molluscs 7%, and all other phyla combined 2%. The most apparent change in community structure was a decrease in polychaete abundances compared to 2005. Polychaete numbers decreased by 5% region wide. The largest decreases in polychaete abundance occurred at northern stations B11 (20%) and B8 (10%), which accounted for most of the decrease in the total abundances at these 2 stations in 2006. In contrast, mean abundances of echinoderms, molluscs, and crustaceans increased at station B11. The largest increase in echinoderm mean abundances was seen at station E1 (12%).

Species diversity, dominance, and evenness

Species diversity (H') ranged from 4.3 to 5.1 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 (H' ≥5.0) occurred at the northern stations B10–B12 and stations E3 and E9, while the lowest (≤4.5) occurred at stations E1, E7, E17, and E19.

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 2006 were characterized by relatively high numbers of evenly distributed species (Table 5.1). The dominance index averaged 38 species per station, which is similar to that observed in 2005 (see City of San Diego 2006a). The highest values (≥50) occurred at stations E3 and E9, and station B11 while the lowest values (≤30) were seen at stations E7, E17, and E19. Evenness (J') varied little in 2006, with mean values ranging from 0.95 to 1.07.

Environmental disturbance indices

Mean Benthic Response Index (BRI) values ranged from 2 to 23 in 2006. These values suggest that

Table 5.1

Benthic community parameters from PLOO stations sampled in 2006. Data are expressed as annual means (±SE) for: Species richness, no. species/0.1 m^2 (SR); total cumulative no. species for the year (Tot spp); Abundance, no. individuals/0.1 m^2 (Abun); Shannon diversity index (H'); Evenness (J'); Swartz dominance, no. species comprising 75% of a community by abundance (Dom); Benthic Response Index (BRI); Infaunal Trophic Index (ITI). n=4. Minima and maxima represent values from all replicates.

Station	SR	Tot spp	Abun	H'	J'	Dom	BRI	ITI
88-m contour								
B11	137	281	418	5.1	1.03	53	6	79
B8	98	197	334	4.7	1.06	35	6	85
E19	82	153	287	4.5	0.99	27	6	86
E7	87	164	310	4.5	1.00	30	9	87
E1	89	190	293	4.4	0.96	31	7	89
98-m contour								
B12	132	239	504	5.0	1.02	45	9	76
B9	103	198	346	4.8	1.05	40	5	81
E26	99	178	341	4.8	1.03	37	7	79
E25	119	202	434	4.9	1.02	40	8	80
E23	89	164	294	4.7	1.06	35	7	81
E20	85	157	279	4.7	1.03	34	9	80
E17	95	175	393	4.5	0.98	30	12	77
E14	110	224	452	4.7	1.00	34	19	73
E11	87	167	305	4.6	1.02	31	12	79
E8	95	181	323	4.7	1.04	33	7	80
E5	100	185	344	4.7	1.01	33	7	82
E2	96	188	318	4.7	1.01	37	6	83
116-m contour								
B10	121	230	391	5.0	1.06	45	8	78
E21	97	180	338	4.7	1.02	35	9	80
E15	113	211	386	4.9	1.03	42	8	80
E9	132	243	451	5.0	1.00	50	8	79
E3	127	234	370	5.1	1.03	55	5	81
All stations								
Mean	104	197	359	4.7	1.02	38	8	81
Min	63	153	169	4.3	0.95	21	2	68
Max	147	281	586	5.1	1.07	61	23	90

benthic communities in the region are relatively undisturbed as BRI values below 25 are considered indicative of reference conditions (Smith et al. 2001). The highest mean values (≥12) were measured at stations E11, E14, and E17, located nearest the PLOO discharge site. Mean ITI values ranged from 68 to 90 per station in 2006 (Table 5.1), and were similar to those reported in previous years (see City of San Diego 2005, 2006a). These values are also indicative of undisturbed sediments or reference environmental conditions (see Bascom et al. 1979).

Dominant Species

Macrofaunal communities in the Point Loma region were dominated by polychaete worms (**Table 5.2**). For example, 8 polychaetes species, 2 crustaceans,

Table 5.2

Dominant macroinvertebrates at the PLOO benthic stations sampled during 2006. 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 occurrence	Percent occurrence
Most abundant				
Amphiodia urtica	Echinodermata: Ophiuroidea	20.4	20.4	100
Prionospio jubata	Polychaeta: Spionidae	20.0	20.0	100
Euphilomedes producta	Crustacea: Ostracoda	12.9	13.2	98
Mediomastus sp	Polychaeta: Capitellidae	12.5	12.5	100
Euphilomedes carcharodonta	Crustacea: Ostracoda	11.9	11.9	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.4	8.4	100
Spiophanes duplex	Polychaeta: Spionidae	8.3	8.3	100
Phisidia sanctaemariae	Polychaeta: Terebellidae	8.1	8.3	98
Proclea sp A	Polychaeta: Terebellidae	7.9	8.5	93
Paradiopatra parva	Polychaeta: Onuphidae	7.6	7.6	100
Most abundant per occurrence				
Amphiodia urtica	Echinodermata: Ophiuroidea	20.4	20.4	100
Prionospio jubata	Polychaeta: Spionidae	20.0	20.0	100
Euphilomedes producta	Crustacea: Ostracoda	12.9	13.2	98
Mediomastus sp	Polychaeta: Capitellidae	12.5	12.5	100
Euphilomedes carcharodonta	Crustacea: Ostracoda	11.9	11.9	100
Caecum crebricinctum	Mollusca: Gastropoda	1.1	11.9	9
Proclea sp A	Polychaeta: Terebellidae	7.9	8.5	93
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.4	8.4	100
Phisidia sanctaemariae	Polychaeta: Terebellidae	8.1	8.3	98
Spiophanes duplex	Polychaeta: Spionidae	8.3	8.3	100
Most frequently collected				
Amphiodia urtica	Echinodermata: Ophiuroidea	20.4	20.4	100
Prionospio jubata	Polychaeta: Spionidae	20.0	20.0	100
Mediomastus sp	Polychaeta: Capitellidae	12.5	12.5	100
Euphilomedes carcharodonta	Crustacea: Ostracoda	11.9	11.9	100
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.4	8.4	100
Spiophanes duplex	Polychaeta: Spionidae	8.3	8.3	100
Paradiopatra parva	Polychaeta: Onuphidae	7.6	7.6	100
Amphiuridae	Echinodermata: Ophiuroidea	6.9	6.9	100
Amphiodia sp	Echinodermata: Ophiuroidea	6.6	6.6	100

1 echinoderm, and 1 mollusc were among the dominant macroinvertebrates. The 2 most abundant species were the ophiuroid *Amphiodia urtica* and the spionid *Prionospio jubata*, 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 of *Amphiodia* present off Point Loma in 2006 was *A. digitata*, which accounted for 3% of ophiuroids in the family Amphiuridae that could be identified to species (i.e., *A. urtica* = 97%). If values for these taxa are adjusted accordingly, then the estimated

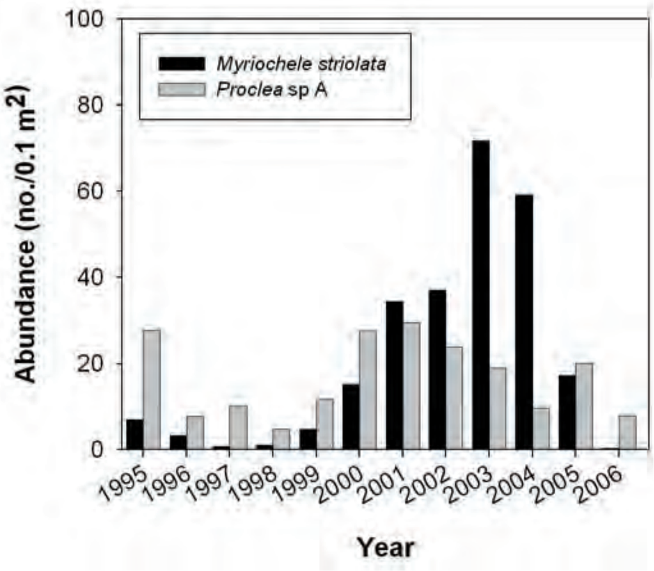


Figure 5.2
Mean annual abundance of *Myriochele striolata* and *Proclea* sp A at the PLOO benthic stations from 1995–2006.

population size for *A. urtica* becomes 28 animals per 0.1 m^2 off Point Loma.

Many of these abundant species were dominant prior to discharge and have remained so ever since (e.g., City of San Diego 1995, 1999, 2004, 2005, 2006a). 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, both *Myriochele striolata* and *Proclea* sp A were among the most abundant polychaetes in 2005, but their densities were much lower in 2006 and have varied considerably over time (**Figure 5.2**). Such variation can have significant effects on other descriptive statistics (e.g., dominance, diversity, abundance) and environmental indices such as BRI and ITI that use the abundance of indicator species in their equations.

BACIP Analyses

BACIP t-tests indicate that there has been a net change in the mean difference of species richness, BRI values, and *Amphiodia* spp abundance between the impact site E14 and both control sites since the onset of discharge from the PLOO (**Table 5.3**). There was also a net change in abundance between E14 and control site B9. The change 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 2006 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 reflect a decrease in the number of these ophiuroids collected at E14 and an increase at the control stations since discharge began (Figure 5.3e). *Amphiodia urtica* densities declined at E14 in 2006 relative to July 2005 and remain similar to the low densities that occurred from 1999–2003, while densities at the 2 control stations are more similar to pre-discharge values. Differences in BRI are generally due to increased index values at station E14 since 1994 (Figure 5.3C). These increased BRI values may in part be explained by the historically lower numbers of *Amphiodia*.

Table 5.3
Results of BACIP t-tests for number of species (SR), infaunal abundance, BRI, and the abundance of several representative taxa around the Point Loma Ocean Outfall (1991–2006). Control sites=far-field station E26 or reference station B9. Impact site=near-ZID station E14; Before Impact period=July 1991 to October 1993 (n=10); After Impact period=January 1994 to July 2006 (n=45). Critical t value=2.007 for =0.05 (two-tailed t-tests, df=53). ns=not significant.

Variable	Control vs. Impact	t	p
SR	E26 v E14	-3.08	0.002
	B9 v E14	-3.51	<0.001
Abundance	E26 v E14	-1.42	ns
	B9 v E14	-2.70	0.005
BRI	E26 v E14	-14.60	<0.001
	B9 v E14	-9.93	<0.001
Amphiodia spp	E26 v E14	-6.99	<0.001
	B9 v E14	-4.94	<0.001
Ampelisca spp	E26 v E14	-1.57	ns
	B9 v E14	-1.04	ns
Rhepoxynius spp	E26 v E14	-0.95	ns
	B9 v E14	-0.99	ns

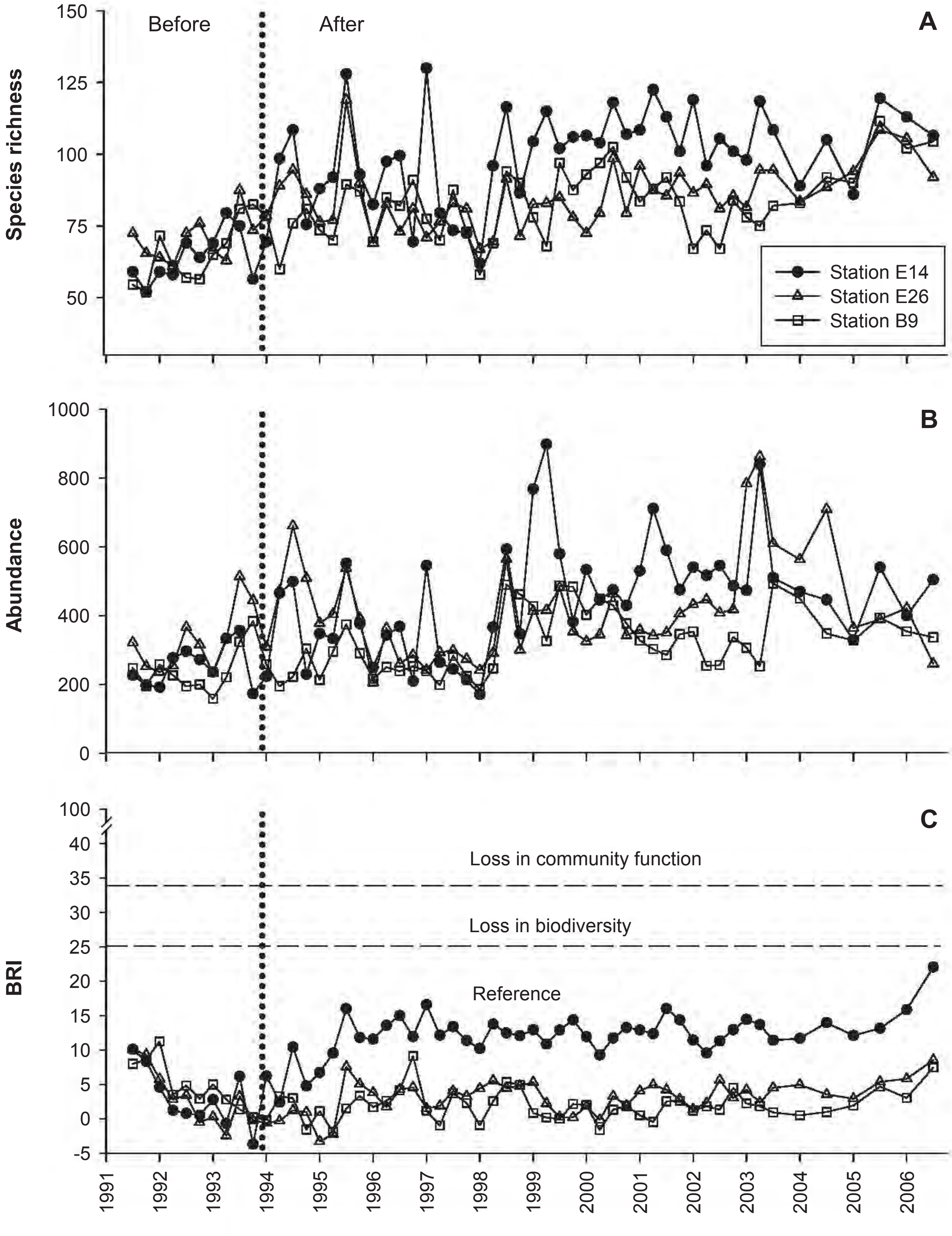


Figure 5.3

Comparison of several parameters at the "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.3). Before and After signify the onset of discharge through the PLOO outfall extension on November 24, 1993. 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) benthic response index (BRI); (D) abundance of *Ampelisca* spp (Amphipoda); (E) abundance of *Amphiodia* spp (Ophiuroidea).

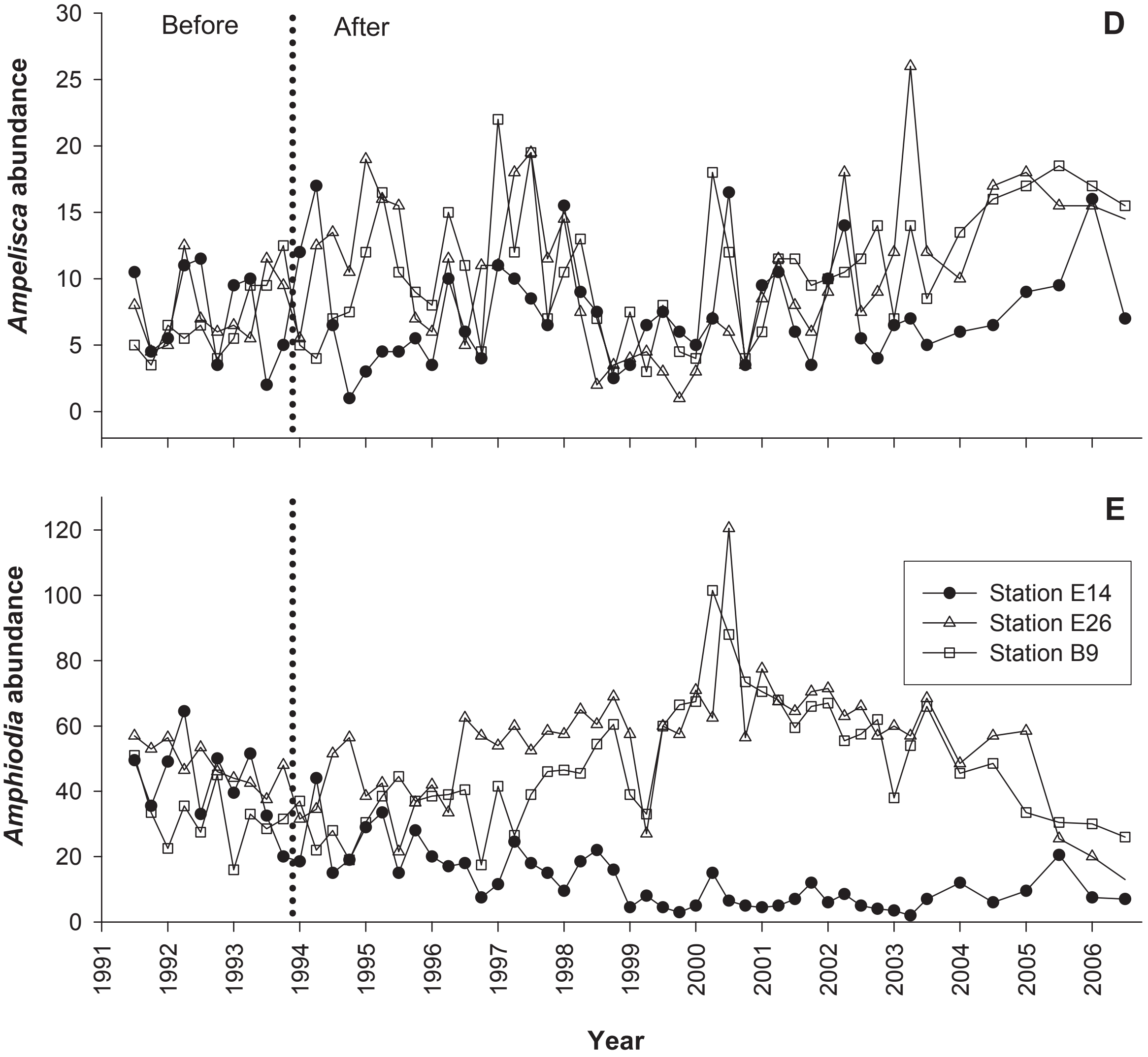


Figure 5.3 Continued

The results for total infaunal abundances were more ambiguous (Figure 5.3B, Table 5.3). While the difference in mean abundances between station B9 and the impact site has changed since discharge began, no such pattern is apparent regarding the second control site (E26). Finally, there were no post-discharge changes in the mean abundances of ampeliscid or phoxocephalid amphipods between impact and control sites.

Classification of Benthic Assemblages

Classification analyses discriminated differences between 5 main benthic assemblages (cluster groups A–E) in the Point Loma Region during 2006 **(Figures 5.4, 5.5)**. These assemblages differed in terms of 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 the assemblage from the July survey of E14, located nearest the PLOO discharge. The spionid polychaete *Prionospio jubata* was the dominant species characterizing this assemblage. The next 2 most abundant species were the ostracod *Euphilomedes carcharodonta* and the bivalve *Axinopsida serricata*. This assemblage had the highest mean abundance (504 per 0.1 m^2) compared to the other cluster groups. Species

Table 5.4

Summary of the most abundant taxa composing cluster groups A–E from the PLOO benthic stations surveyed in 2006. 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 indicated in bold type.

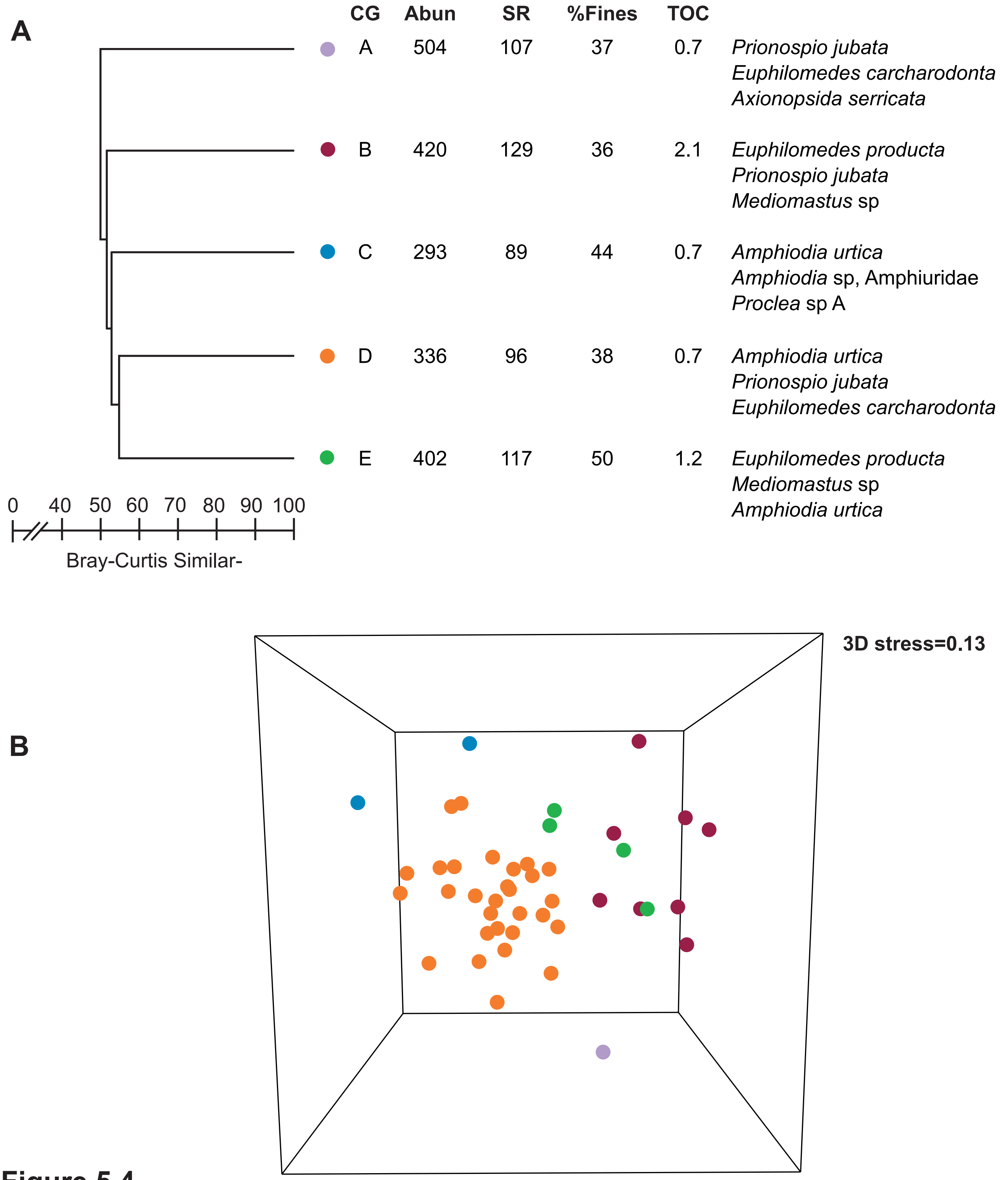
		Cluster group				
Species/Taxa	**Higher taxa**	**A** (n=1)	**B** (n=8)	**C** (n=2)	**D** (n=29)	**E** (n=4)
Ampelisca brevisimulata	Crustacea: Amphipoda	0.5	1.1	3.8	1.0	0.3
Ampelisca careyi	Crustacea: Amphipoda	0.5	4.4	4.0	1.5	3.0
Amphiodia sp	Echinodermata: Ophiuroidea	1.5	2.8	**25.5**	6.7	5.8
Amphiodia urtica	Echinodermata: Ophiuroidea	5.0	6.5	**59.5**	**22.3**	**18.6**
Amphiuridae	Echinodermata: Ophiuroidea	4.5	2.7	**13.8**	8.1	4.1
Axinopsida serricata	Mollusca: Bivalvia	**21.0**	3.6	4.3	2.0	1.9
Caecum crebricinctum	Mollusca: Gastropoda	—	5.9	—	—	—
Chaetozone hartmanae	Polychaeta: Cirratulidae	13.0	7.3	2.8	8.8	9.8
Decamastus gracilis	Polychaeta: Capitellidae	13.0	4.0	0.3	3.6	1.6
Euphilomedes carcharodonta	Crustacea: Ostracoda	**27.5**	5.5	5.8	**14.5**	5.1
Euphilomedes producta	Crustacea: Ostracoda	16.5	**21.4**	0.5	9.5	**26.1**
Glycera nana	Polychaeta: Glyceridae	18.5	5.6	5.0	4.5	5.3
Lanassa venusta venusta	Polychaeta: Terebellidae	—	3.1	3.5	4.2	7.3
Mediomastus sp	Polychaeta: Capitellidae	17.5	**13.4**	2.8	11.5	**21.4**
Nuculana elenensis	Mollusca: Bivalvia	13.5	0.9	2.0	2.1	1.0
Paradiopatra parva	Polychaeta: Onuphidae	4.5	10.6	5.0	6.8	9.6
Paraprionospio pinnata	Polychaeta: Spionidae	6.5	6.1	3.0	5.2	5.5
Parvilucina tenuisculpta	Mollusca: Bivalvia	19.0	1.6	0.3	0.9	0.3
Phisidia sanctaemariae	Polychaeta: Terebellidae	0.5	5.5	3.3	8.7	13.8
Prionospio dubia	Polychaeta: Spionidae	5.0	4.5	3.0	3.6	6.0
Prionospio jubata	Polychaeta: Spionidae	**41.5**	**19.6**	3.5	**21.2**	15.3
Proclea sp A	Polychaeta: Terebellidae	—	1.8	12.8	9.8	5.8
Spiophanes berkeleyorum	Polychaeta: Spionidae	4.5	7.3	0.8	5.9	4.3
Spiophanes duplex	Polychaeta: Spionidae	8.0	12.9	2.0	7.7	6.0
Spiophanes kimballi	Polychaeta: Spionidae	5.0	5.1	2.3	4.5	10.0

richness averaged 107 taxa per 0.1 m^2. Sediments at this site were mixed with 37% fine particles and 50% coarse materials including some coarse black sand, shell hash, and pebbles (see appendix B.2). Total organic carbon (TOC) concentration was 0.7%.

Cluster group B included animals from 3 northern reference stations and 1 southern station. The dominant species in this assemblage included the ostracod *Euphilomedes producta, P. jubata*, and the capitellid polychaete *Mediomastus* sp. Species richness was relatively high (129 species per 0.1 m^2) while abundance averaged 420 individuals. Sediments associated with this group contained 36% fine particles. The mean TOC value (2.1%) for this cluster group was higher than those from the other cluster groups.

Cluster group C represented animals from the southern station E1, along the 88-m contour. Dominant taxa included ophiuroids (*Amphiodia urtica*, *Amphiodia* sp, and Amphiuridae) and the terebellid polychaete *Proclea* sp A. This assemblage averaged 293 individuals and 89 species per 0.1 m^2. Sediments at E1 were mixed, composed of 44% fines, and coarse sands with some shell hash and gravel. TOC at stations within this group averaged 0.7%.

Cluster group D encompassed the largest assemblage in 2006, comprising animals collected



	CG	Abun	SR	%Fines	TOC	
●	A	504	107	37	0.7	*Prionospio jubata* *Euphilomedes carcharodonta* *Axionopsida serricata*
●	B	420	129	36	2.1	*Euphilomedes producta* *Prionospio jubata* *Mediomastus* sp
●	C	293	89	44	0.7	*Amphiodia urtica* *Amphiodia* sp, Amphiuridae *Proclea* sp A
●	D	336	96	38	0.7	*Amphiodia urtica* *Prionospio jubata* *Euphilomedes carcharodonta*
●	E	402	117	50	1.2	*Euphilomedes producta* *Mediomastus* sp *Amphiodia urtica*

Figure 5.4
(A) Cluster results of the macrofaunal abundance data for the PLOO benthic stations sampled during 2006. Data are expressed as mean values per 0.1 m^2 grab over all stations in each group. CG=cluster group; SR=number of species; Abun=number of individuals. Ranges in parentheses are for individual grab samples. **(B)** MDS ordination of PLOO benthic stations sampled during 2006. Plot based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between major faunal assemblages.

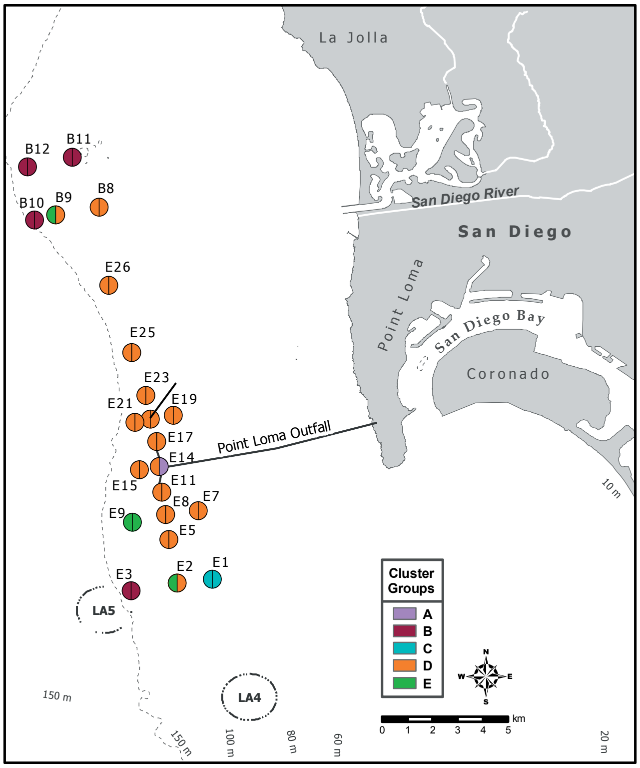


Figure 5.5
Summary of ordination and classification analyses results for macrofaunal abundance data during 2006. Cluster groups are color-coded on the map to reveal spatial patterns in the distribution of benthic assemblages.

from 66% of the samples from 16 stations. The dominant species in this group were *A. urtica*, *P. jubata*, and *E. carcharodonta*. Infauna averaged 336 individuals and 96 species per 0.1 m^2, the second lowest among all cluster groups. The January survey of station E14 was included in this group The sediments collected with this assemblage were characterized by silty sand with 38% fines and 0.7% TOC.

Cluster group E included animals collected from 3 sites primarily located along the 98 and 116-m depth contours. The numerically dominant species in this group were *E. carcharodonta*, *Mediomastus* sp, and *A. urtica*. This assemblage averaged 402 individuals and 117 taxa per 0.1 m^2. The stations associated with this assemblage had the highest percentage of fines (50%), and the second highest TOC (1.2%).

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, 2006a). Ophiuroids and polychaetes continue to be the most abundant and diverse infauna in the region. Although many of the 2006 assemblages were dominated by similar species, the relative abundance of these species varied between sites. In contrast to 2004 and 2005, the oweniid polychaete *Myriochele striolata* was not among the most abundant or widespread invertebrates in the PLOO region. Instead, the brittle star *Amphiodia urtica* (adults and juveniles combined) was the most abundant and widespread taxon. The Spionid polychaete *Prionospio jubata* was the second most widespread benthic invertebrate in the region, being dominant or co-dominant in most assemblages. 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, 2006a). In addition, values for these parameters in 2006 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 during the post-discharge period (see City of San Diego 1995, 2006a). The increase in species has been most pronounced near the outfall, which suggests that significant environmental degradation has not occurred in the region. In addition, the observed decreases in abundance at most stations in 2006 were not accompanied by changes in dominance, a pattern inconsistent with predicted pollution effects. Whatever the cause of such changes, benthic communities around the PLOO are not dominated by a few pollution tolerant species. For example, the opportunistic polychaete *Capitella capitata*, which is often associated with degraded soft bottom habitats, continues to occur only in low numbers off Point Loma. A total of 16 individual *C. capitata* were collected off Point Loma in 2006, with 6 occurring at the 3 stations nearest the PLOO (E17, E14, E11). In contrast, this species can reach densities >500 individuals per 0.1 m^2 and constitute as much as 85% of the total abundance in heavily polluted sediments (Swartz et al. 1986).

A few changes near the outfall suggest some effects are coincident with anthropogenic activities. Benthic response index (BRI) values are higher at stations nearest the outfall (E17, E14, E11) than at other sites in the region In addition, increased values of the BRI at station E14 after discharge began may be considered indicative of organic enrichment or some other type of disturbance. However, BRI values at all sites remain characteristic of undisturbed areas (see City of San Diego 1995, 2006a). The increased variability in number of species and infaunal abundance at station 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. 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. This difference is due mostly to a decrease in numbers of ophiuroids near the outfall and a corresponding increase at the control sites during the post-discharge period. These differences have decreased over the past 2 years. Although long term changes in *Amphiodia* populations at E14 may likely be related to organic enrichment, altered sediment composition, or some other factor, abundances for the Point Loma region 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, Diener et al. 1995). Further complicating the picture, stable patterns in populations of pollution sensitive amphipods (i.e., *Rhepoxynius*, *Ampelisca*) and a limited presence of a pollution tolerant species (e.g., *C. capitata*) do not offer evidence of strong outfall-related effects.

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., station E14). Because of the minimal extent of these changes, it has not been possible to determine whether observed effects are due to habitat alteration related to the physical structure of the outfall pipe, organic enrichment, or another related factor. 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

INTRODUCTION

Demersal fishes and megabenthic invertebrates 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 over 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 the sea urchins *Lytechinus pictus* and *Allocentrotus fragilis*, and the sea stars *Luidia foliata* and *Astropecten verrilli*.

The structure of these communities may be influenced by both anthropogenic and natural factors. Demersal fishes and megabenthic invertebrates live in close proximity to sediments potentially altered by anthropogenic influences such as inputs from ocean outfalls and storm drain runoff. 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). The mobile nature of many species (e.g., schools of fish or aggregations of urchins) can result in population fluctuations that affect diversity and abundance measures. All of these influences affect the structure of these communities, making them inherently variable.

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 2006. A long-term analysis of changes in these communities from 1991 through 2006 is also presented.

MATERIALS AND METHODS

Field Sampling

A total of 12 trawls were performed during 2 surveys off Point Loma in 2006. The area of study 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 of bottom time at about 2.5 knots along a predetermined heading.

Each trawl catch was brought on board ship for sorting and inspection. All captured 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 size class (standard length). For invertebrates, the total number of individuals

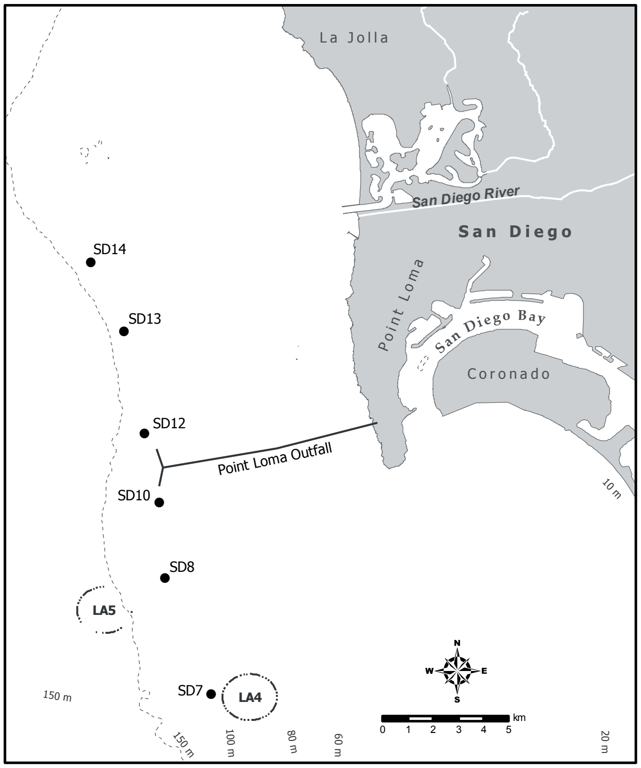

Figure 6.1
Otter trawl station locations, Point Loma Ocean Outfall Monitoring Program.

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 characterized 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 using data from only the July surveys over the past 16 years (1991-2006). PRIMER software was used to examine spatio-temporal patterns in the overall similarity of fish assemblages in the region (see Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking, and ordination by non-metric multidimensional scaling (MDS). The fish abundance data were limited to species that occurred in at least 10 hauls, or had a station abundance of 5 or greater. These data were square root transformed, and the Bray-Curtis measure of similarity was used as the basis for classification. Because the species composition was sparse at some stations, a dummy species with a value of 1 was added to all samples prior to computing similarities (see Clarke and Gorley 2006). The SIMPER ("similarity percentages") routine was used to describe inter- and intra- group species differences.

RESULTS

Fish Community

Thirty-nine species of fish were collected in the area surrounding the PLOO during 2006 (**Table 6.1**). The total catch for the year was 6243 fishes representing an average of 520 individuals per haul. Pacific sanddab was the most abundant fish comprising 44% of the total catch (n=2734). This species, as well as halfbanded rockfish, Dover sole, longspine combfish, shortspine combfish, pink seaperch, English sole, hornyhead turbot, and greenstriped rockfish, occurred in every haul. Other common fishes present in at least half of the hauls were yellowchin sculpin, plainfin midshipman, stripetail rockfish, California lizardfish, California tonguefish, greenblotched rockfish, bigmouth sole, and pink rockfish. All of these 17 species were relatively small with average lengths <20 cm (**Appendix C.1**).

In 2006, average abundances of demersal fish ranged from a low of 395 individuals at station SD13 to 793 at station SD10 (**Table 6.2**). These values are generally lower and represent less station variability than was observed in 2005 (City of San Diego 2006). The greatest abundance at station SD10 was due to high numbers of yellowchin

Table 6.1

Demersal fish species collected in 12 trawls in the PLOO region during 2006. Data for each species are expressed as: percent abundance (PA); frequency of occurrence (FO); mean abundance per occurrence (MAO).

Species	PA	FO	MAO
Pacific sanddab	44	100	228
Halfbanded rockfish	20	100	107
Dover sole	9	100	45
Yellowchin sculpin	8	67	63
Longspine combfish	5	100	27
Shortspine combfish	3	100	13
Pink seaperch	1	100	7
Plainfin midshipman	1	92	8
English sole	1	100	7
Stripetail rockfish	1	83	6
California lizardfish	1	92	4
Roughback sculpin	1	42	9
Hornyhead turbot	1	100	4
Greenstriped rockfish	1	100	3
California tonguefish	1	67	4
Spotfin sculpin	<1	25	9
Slender sole	<1	33	5
Greenblotched rockfish	<1	67	2
Bigmouth sole	<1	58	3
Pink rockfish	<1	50	3
Blackbelly eelpout	<1	42	3
Pacific argentine	<1	25	5
California scorpionfish	<1	33	2
California skate	<1	42	1
Blacktip poacher	<1	42	1
Spotted cuskeel	<1	17	2
Spotted ratfish	<1	17	2
Bluebanded ronquil	<1	17	1
Bluespotted poacher	<1	17	1
Flag rockfish	<1	17	1
Pygmy poacher	<1	17	1
Starry skate	<1	17	1
White croaker	<1	17	1
Bluebarred prickleback	<1	8	1
Chub mackerel	<1	8	1
Greenspotted rockfish	<1	8	1
Lingcod	<1	8	1
Shortbelly rockfish	<1	8	1
Squarespot rockfish	<1	8	1

sculpin and halfbanded rockfish (**Appendix C.2**). On average, the smallest haul occurred north of the PLOO at station SD13, which contrasts the typical pattern of lower abundances at the southernmost stations SD 7 and SD8 (e.g., see Figure 6.2).

Table 6.2

Summary of demersal fish community parameters for PLOO stations sampled during 2006. Data are presented for cumulative (total) and mean number of species, abundance (abund), diversity (H'), and biomass (BM; kg, wet weight); n=2 surveys.

	No. of Species				
Station	Total	Mean	Abund	H'	BM
SD7	28	22	431	1.94	6.4
SD8	30	23	462	1.72	9.2
SD10	21	18	793	1.39	11.9
SD12	19	16	516	1.81	10.3
SD13	22	18	395	1.36	12.9
SD14	24	21	525	1.44	14.2

The total biomass of fishes captured at each station was also lower and less variable in 2006 relative to prior years. Biomass values ranged from 6.4 kg at the southernmost station (SD7) to 14.2 kg at the northernmost station (SD14). The highest biomass did not always coincide with the largest hauls, but instead reflected the collection of larger fish. For example, station SD13 had the fewest individuals on average, but the second highest biomass. In contrast, station SD10 averaged the most fish per haul, but had only the third highest biomass. This difference is due, in part, to larger Pacific sanddabs collected at SD13 in July. These fish averaged 50 g at SD13, 40 g at SD14, and ≤20 g at the all other stations (**Appendix C.3**).

As in previous years, values for species richness and diversity (H') varied little during 2006 (Table 6.2). The mean number of species ranged from 16 to 23 per haul, while the (cumulative) total number of species was 30 or less at all stations over the year. These species richness values are higher than those found for the shallower stations sampled as part of the South Bay monitoring program (City of San Diego 2007), but are similar to median SCB values for the same depths (Allen et al. 1998). Average diversity (H') values for the PLOO region ranged from 1.36 to 1.94, with stations SD7, SD8, and SD12 having values >1.5, which is

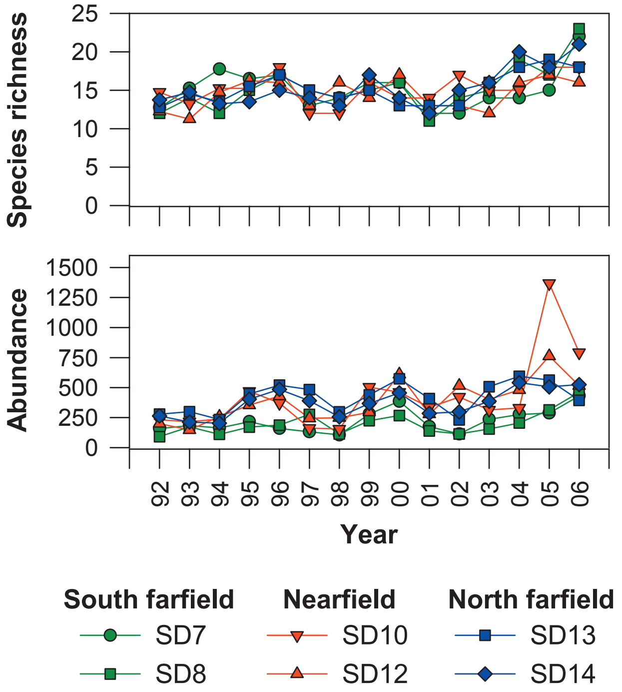

Figure 6.2
Annual mean species richness (number of species) and abundance (number of individuals) per PLOO station of demersal fish collected from 1992 through 2006; n=4 1992–2002, n=3 in 2003, and n=2 during 2004–2006.

the median for the SCB region (see Allen et al. 1998, 2002). These diversity values are typical for the southern region of the SCB, and are a result of the predominance of a few species such as Pacific sanddabs, halfbanded rockfish, and yellowchin sculpin.

Large fluctuations in populations of a few dominant species have been the primary factor contributing to the high variation in fish community structure off Point Loma since 1992 (**Figure 6.2, Figure 6.3**). For example, species richness has consistently averaged from 10 to 23 species per station, while mean abundances have varied between 93 and 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). These 4 stations also had fairly similar patterns of change in the dominant species through time. None of the observed changes appear to be associated with wastewater discharge from the Point Loma outfall.

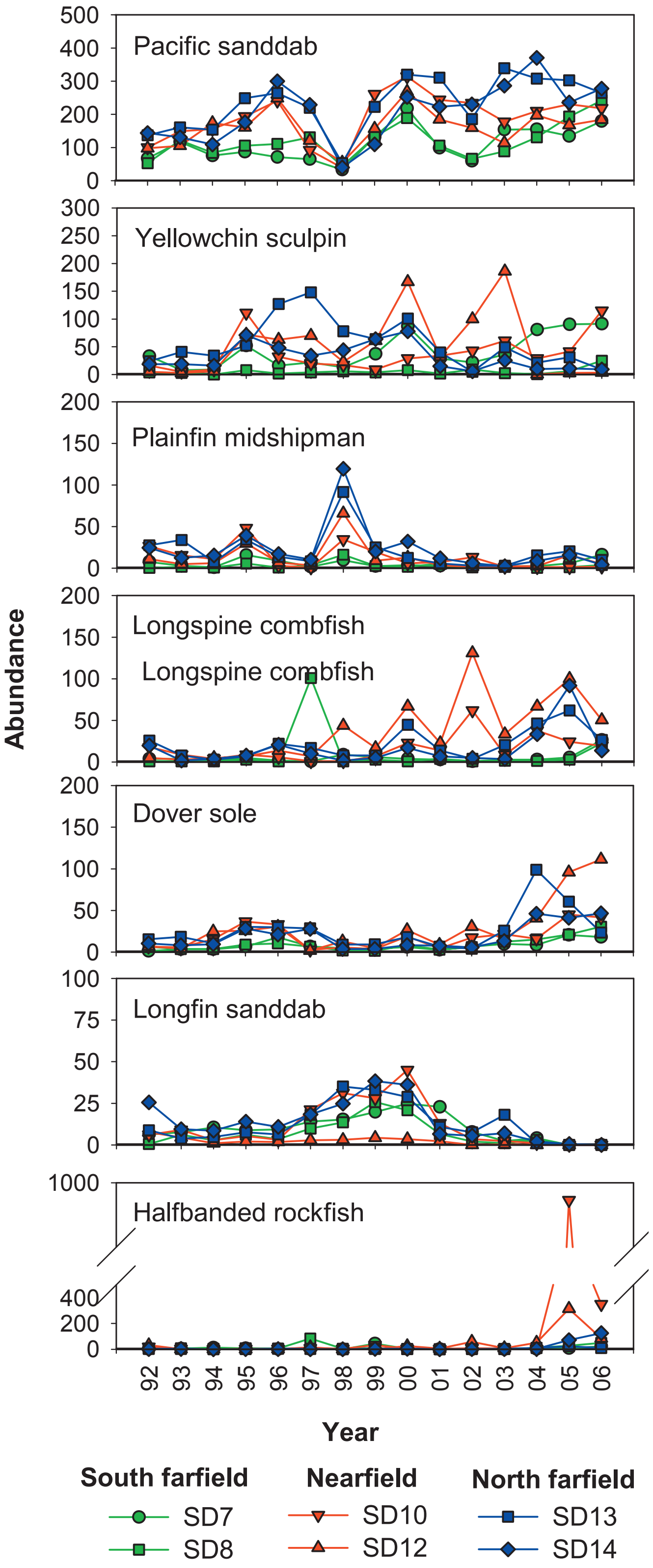

Figure 6.3
Annual mean abundance (number of individuals) per PLOO station for the 7 most abundant fish species collected from 1992 through 2006; n=4 1992–2002, n=3 in 2003, and n=2 during 2004–2006.

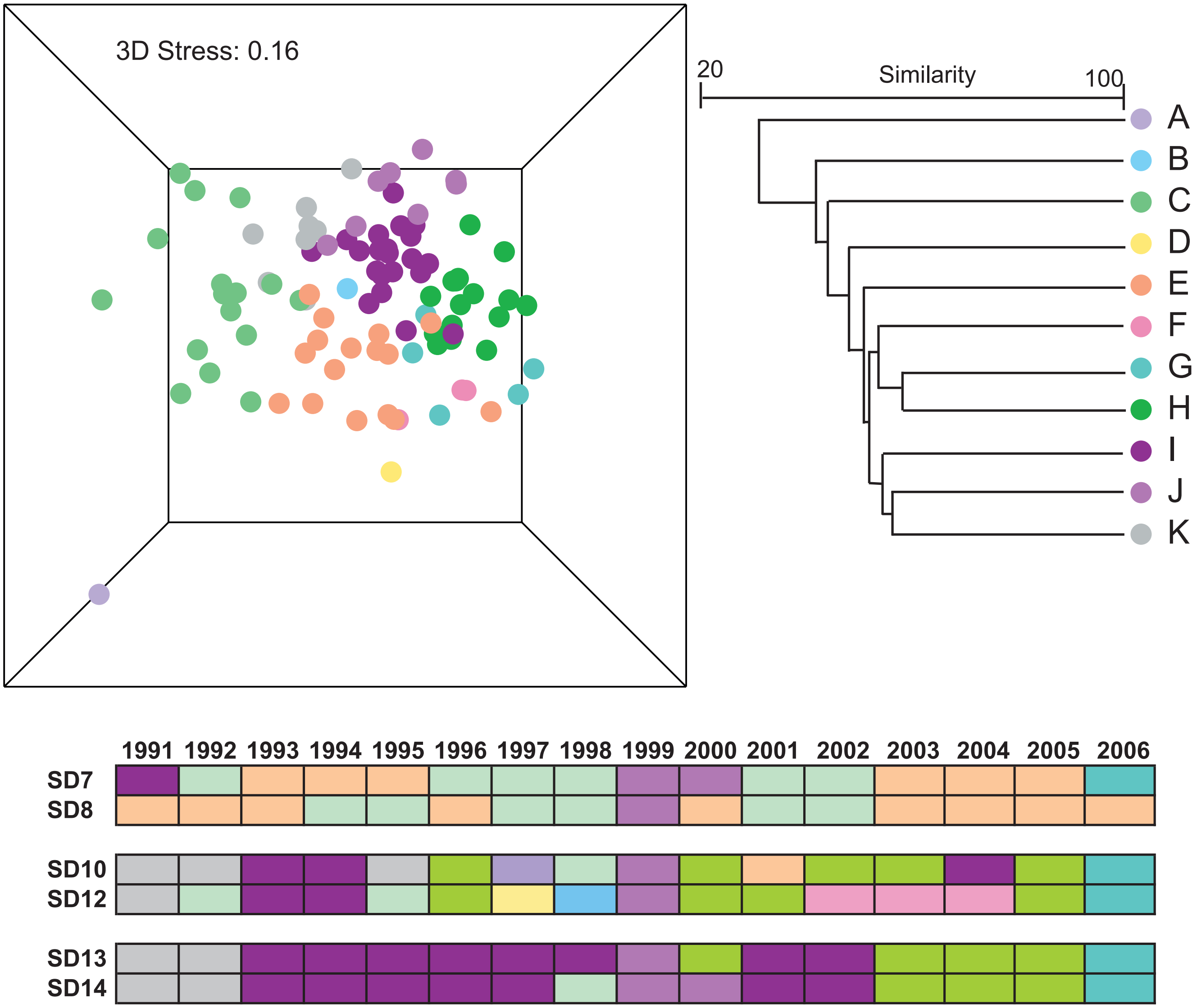

Figure 6.4
Results of ordination and classification analysis of demersal fish collected at PLOO stations SD7–SD14 between 1991 and 2006 (July surveys only). Data are also presented as a matrix showing distribution over time.

Ordination and classification analyses of fish abundance data from the July surveys between 1991 and 2006 indicate that the demersal fish community in the Point Loma area is dominated by Pacific sanddabs, with differences in relative abundances of this and other common species discriminating various sub-assemblages (station groups A–K; see **Figure 6.4**). No patterns of change in fish assemblages were associated with the onset of discharge from the PLOO; the composition of fish that occurred at stations SD10 and SD12 in 1994 was present prior to discharge and was similar to the composition at northern reference stations (SD13, SD14). However, the sub-assemblages occurring at SD10 and SD12 have varied more over time than has either pair of reference sites, particularly during the period 1995–1998. For example, 11 different sub-assemblages were identified from stations SD10 and SD12 from 1997–2006, while 6 or fewer were identified from the northern and southern sites. The differences between these sub-assemblages are slight however, and are likely related to site-specific topography, sediments, or the occasional collection of atypical species (e.g., rockfish) at stations SD10 and SD12. The overriding causes of differences between assemblages through time relate more to

Table 6.3

Description of station groups A–K defined in Figure 6.4. Data include mean abundance of species that together account for 90% of the similarity (or 90% of total abundance when groups have n <2). Values in bold type indicate the species that are most representative of a station group (i.e., 3 species with the highest similarity/SD values >2 for station 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	Group K
Number of hauls	1	1	16	1	16	3	5	16	21	8	8
Overall similarity	NA	NA	62	NA	66	69	57	72	75	67	65
Mean species richness	7	14	11	17	16	13	17	16	14	14	11
Mean abundance	44	259	92	224	222	312	482	471	293	375	220
Species	**Mean abundance**										
Pacific sanddab	**23**	**75**	**58**	**110**	**153**	**131**	**197**	**308**	**204**	**227**	**116**
Halfbanded rockfish	**16**			**60**		39	180				
Dover sole		**36**	8		**15**	**31**	**40**	**49**	24		**15**
Longspine combfish		**7**				46	9	**30**			
Shortspine combfish					7						
Spotfin sculpin					6						
Longfin sanddab			5							**26**	
Plainfin midshipman		**116**									**44**
Slender sole						**24**					
Stripetail rockfish										47	
Yellowchin sculpin			4						10	30	
Squarespot rockfish				**23**							
Greenblotched rockfish				8							

oceanographic events (e.g., El Niño conditions in 1998) or location (i.e., station) than to discharge through the PLOO. For example, station groups G, J, and K represent assemblages impacted by shifting ocean temperatures (see Chapter 2), while groups C and E are indicative of the different assemblages at stations SD7 and SD8 relative to those around the outfall and northward. Station group G comprised all but one station surveyed in 2006 (see below) and may be a response to cooler bottom water temperatures (see Chapter 2).

Overall, the 11 major cluster groups consisted of fishes from 1 to 21 hauls comprised of only 7 to 17 species per assemblage. Abundances among the station groups varied widely, with 44 to 482 individuals per assemblage. The species that characterized each assemblage (see **Table 6.3**) and the species that differentiated between assemblages (see **Appendix C.4**) are detailed below.

Station group A: The fishes identified from a single trawl at station SD10 in July 1997 formed a group. This trawl included only 7 species and a total of 44 fishes, 87% of which were Pacific sanddabs and halfbanded rockfish. The low number of fishes present may have been due to the amount of time the net was in contact with the bottom during the 10 minutes it was being towed. Reduced catches such as this one can occur if the net bounces along the bottom.

Station group B: Group B comprised a single trawl conducted at station SD12 in 1998. Relatively high numbers of plainfin midshipman and the presence of gulf sanddabs differentiated this assemblage from the others. However, an analysis of all 4 quarters of the 1998 data did not distinguish this as a unique assemblage during that year (see City of San Diego 1999).

Station group C: This assemblage of fishes occurred over several surveys at stations SD7 and/or SD8, at 4 of 6 stations surveyed during the 1998 El Niño, and at station SD12 in 1992 and 1995. Relatively low numbers of species and low abundances, including the second lowest number of Pacific sanddabs, characterized the group. The low numbers of Pacific sandabs and absence of other cold water species (e.g., Dover sole) differentiated this group of fishes. Lower numbers of Pacific sanddabs are common at stations SD7 and SD8 but not at other stations comprising this station group (i.e., SD10, SD12, SD14) (see Figure 6.3). The low numbers of Pacific sanddabs and Dover sole differentiated the assemblages at stations SD10, SD12, and SD14 during these years from most other surveys conducted at these stations (i.e., groups F, G, H, I, K).

Station group D: As with station groups A and B, group D was comprised of a single trawl: station SD12 sampled in 1997. Group D had considerably higher species richness and numbers of fishes than group A and was dominated by Pacific sanddabs and halfbanded rockfish. This collection of fish was unique in the relatively high numbers of squarespot rockfish and greenblotched rockfish.

Station group E: This assemblage occurred at stations SD7 and SD8 almost exclusively. This group, in combination with group C, characterized all but one survey at SD8, and all but 4 surveys at SD7. Moderate numbers of Pacific sanddabs and Dover sole characterized group E. The relative abundance of these 2 species, together with the shortspine combfish, differentiated these hauls from the others.

Station group F: Moderate numbers of Pacific sanddabs and Dover sole and relatively high numbers of slender sole represented 3 hauls taken at SD12 during 2002, 2003, and 2004. lowchin sculpin and halfbanded rockfish also helped differentiate this assemblage.

Station group G: With the exception of station SD8, fishes present at most stations sampled during July 2006 formed Group G. This group was characterized by high species richness and the highest mean abundance of all the groups, the latter due to large catches of Pacific sanddab and halfbanded rockfish. Comparatively large numbers of Dover sole and the presence of pink seaperch differentiated this station group from the others.

Station group H: This assemblage generally occurred at stations located around the outfall (SD10, SD12) and/or to the north (SD13, SD14) sampled during 1996 and between 2000 and 2005. This collection of fish averaged the highest numbers of Pacific sanddab and Dover sole, and was also characterized by longspine combfish.

Station group I: The species comprising group I occurred over several years of surveys at stations SD13 and/or SD14 and a few years at SD10 and SD12. Dover sole was also fairly abundant in this group, which helped differentiate it from other similar assemblages (e.g., groups A, B, D, F).

Station group J: Group J occurred at all stations sampled in 1999, and at stations SD7 and SD14 sampled in 2000. This assemblage had the second highest numbers of Pacific sanddab, but the presence of longfin sanddabs differentiated this group from all others. Longfin sanddabs are typically considered a shallower, warmer water species than Pacific sanddabs. The higher abundance of longfin sanddabs in 1999 was likely due to the warmer waters associated with the El Niño that had occurred the previous year.

Station group K: This assembly of fishes occurred in the summers of 1991 and 1992 at station SD10 north to SD14. It was characterized by moderate numbers of Pacific sanddabs, Dover sole, and relatively high numbers of plainfin midshipman.

Physical Abnormalities and Parasitism

Occurrences of disease or other physical abnormalities were generally low (<1%) in fish populations off Point Loma during 2006. For example, there were no incidences of fin rot, while only 3 Dover soles (less than 1% of the sampled Dover sole population) were found to

Table 6.4

Megabenthic invertebrate species collected in 12 trawls in the PLOO region during 2006. 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	89	100	1491
Allocentrotus fragilis	5	75	103
Acanthoptilum sp	4	58	105
Luidia foliolata	1	92	10
Parastichopus californicus	<1	83	6
Sicyonia ingentis	<1	92	8
Ophiura luetkenii	<1	58	5
Astropecten verrilli	<1	58	4
Octopus rubescens	<1	75	2
Florometra serratissima	<1	50	3
Pleurobranchaea californica	<1	50	2
Spatangus californicus	<1	42	2
Rossia pacifica	<1	42	2
Paguristes turgidus	<1	42	1
Platymera gaudichaudii	<1	33	2
Tritonia diomedea	<1	25	2
Brissopsis pacifica	<1	17	3
Armina californica	<1	17	2
Luidia asthenosoma	<1	8	3
Megasurcula carpenteriana	<1	17	2
Thesea sp B	<1	25	1
Metridium farcimen	<1	17	1
Ophiothrix spiculata	<1	17	1
Suberites suberea	<1	17	1
Cancellaria cooperii	<1	8	1
Cancellaria crawfordiana	<1	8	1
Hemisquilla californiensis	<1	8	1
Henricia leviuscula	<1	8	1
Nassarius insculptus	<1	8	1
Neocrangon zacae	<1	8	1
Neosimnia barbarensis	<1	8	1
Paralithodes californiensis	<1	8	1
Philine auriformis	<1	8	1
Platydoris macfarlandi	<1	8	1
Podochela hemphillii	<1	8	1
Podochela lobifrons	<1	8	1

have any tumors. These tumors were likely from a Dover specific infection, and have not been associated with degraded environments (Dr. M. J. Allen, SCCWRP, personal communication). The copepod eye parasite *Phrixocephalus cincinnatus* occurred on 2% of the Pacific sanddabs collected and was present at all stations during all surveys.

Table 6.5

Summary of megabenthic invertebrate community parameters for PLOO stations sampled during 2006. Data are presented for cumulative (total) and mean number of species, abundance (abund), and diversity (H'); n=2 surveys.

	No. of species			
Station	Total	Mean	Abund	H'
SD7	23	16	1890	0.24
SD8	13	9	3551	0.08
SD10	15	11	2021	0.13
SD12	18	13	1493	0.76
SD13	17	13	706	0.80
SD14	16	12	339	0.92

Invertebrate Community

A total of 19,994 megabenthic invertebrates, representing 36 species, were collected during 2006 (**Table 6.4**, **Appendix C.4**). The white sea urchin *Lytechinus pictus* was the most abundant and most frequently captured species. It was the only species present in all trawls and accounted for 89% of the total invertebrate catch. Other common species that occurred in more than half of the hauls included the sea urchin *Allocentrotus fragilis*, the sea pen *Acanthoptilum* sp, the sea stars *Astropecten verrilli* and *Luidia foliolata*, the brittle star *Ophiura luetkenii,* the sea cucumber *Parastichopus californicus*, the shrimp *Sicyonia ingentis*, and the octopus *Octopus rubescens*.

Abundance, species richness, and diversity values for the megabenthic invertebrate assemblages varied among stations and between surveys (**Table 6.5, Appendix C.5**). For example, abundance per station averaged from 339 to 3551 individuals. Stations SD13 and SD14 had much lower abundances than the other 4 stations, due to relatively small catches of *Lytechinus pictus.* Diversity values were extremely low (<1) for the entire area due to the numerical dominance of this sea urchin. Dominance of *L. pictus* is typical for these types of habitats throughout the SCB (e.g., Allen et al. 1998).

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

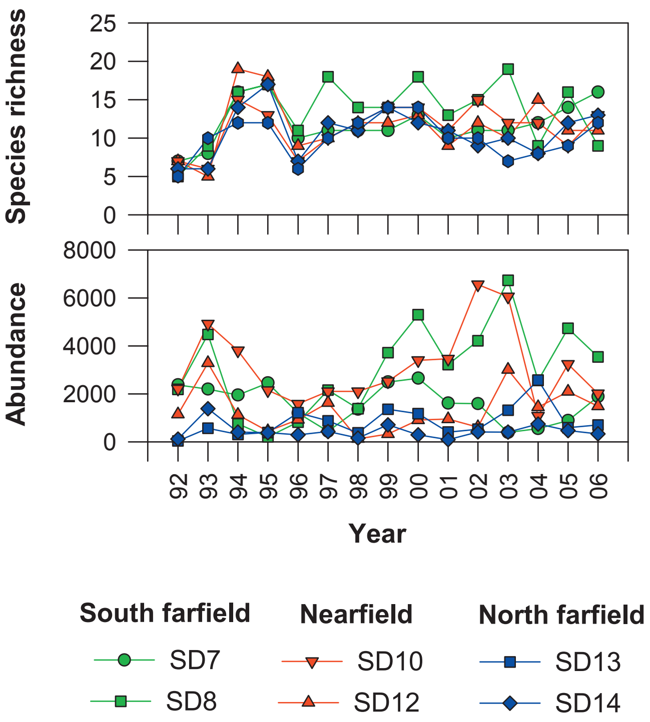

Figure 6.5
Annual mean species richness (number of species) and abundance (number of individuals) per PLOO station of megabenthic invertebrates collected from 1992 through 2006; n=4 1992–2002, n=3 in 2003, and n=2 during 2004–2006.

the patterns of change have been similar among stations. In contrast, changes in abundance have differed greatly among stations. The average annual invertebrate catches have been consistently low at stations SD13 and SD14, while the remaining stations have demonstrated large fluctuations in abundance. These fluctuations typically reflect changes in *L. pictus* populations, as well as the urchin *Allocentrotus fragilis*, and, to a lesser degree, the sea pen *Acanthoptilum* sp (**Figure 6.6**). The abundances of these 3 taxa are much lower at the 2 northern sites, which likely reflects differences in sediment composition (e.g., fine sands vs. mixed coarse/fine sediments, see Chapter 4). None of the observed variability in the invertebrate community could be attributed to the discharge of wastewater from the PLOO.

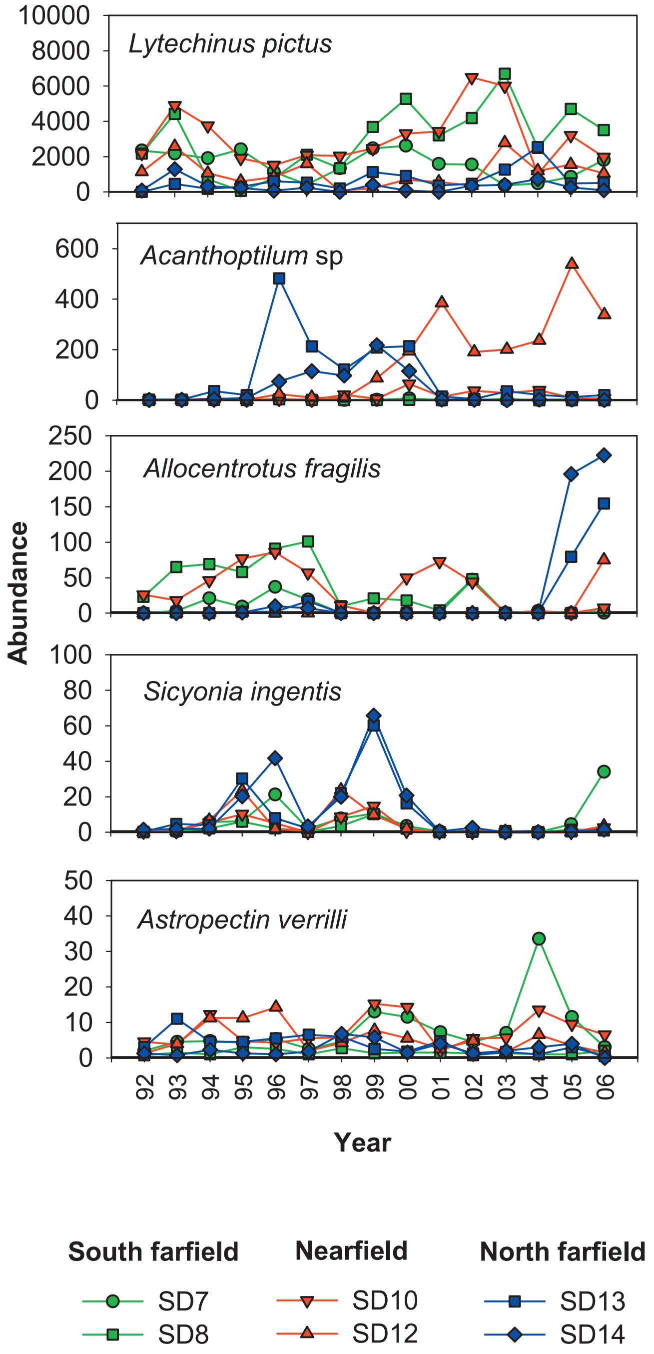

Figure 6.6
Annual mean abundance (number of individuals) per PLOO station for the 5 most abundant megabenthic invertebrate species collected from 1992 through 2006; n=4 1992–2002, n=3 in 2003, and n=2 during 2004–2006.

SUMMARY AND CONCLUSIONS

As in previous years, Pacific sanddabs continued to dominate fish assemblages surrounding the Point Loma Ocean Outfall during 2006. These fish were present in relatively high numbers at all stations. Other characteristic, but less abundant species, included halfbanded rockfish, Dover sole, longspine combfish, shortspine combfish, pink seaperch, English sole, hornyhead turbot, greenstriped rockfish, yellowchin sculpin, plainfin midshipman, stripetail rockfish, California lizardfish, California tonguefish, greenblotched rockfish, bigmouth sole, and pink rockfish. Although the composition and structure of the fish assemblages varied among stations, most differences were due to fluctuations in Pacific sanddab populations.

Assemblages of megabenthic invertebrates were also dominated by a single prominent species, the white sea urchin *Lytechinus pictus.* Other common species included the sea urchin *Allocentrotus fragilis*, the sea pen *Acanthoptilum* sp, the sea stars *Astropecten verrilli* and *Luidia foliolata*, the brittle star *Ophiura luetkenii,* the sea cucumber *Parastichopus californicus*, the shrimp *Sicyonia ingentis*, and the octopus *Octopus rubescens*. Although megabenthic community structure varied between sites, these assemblages were generally characterized by low species richness and diversity. Abundance was proportional to the number of *L. pictus* collected in each haul.

Overall, results of the trawl surveys conducted in 2006 provide no strong 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 distribution 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 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

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. The bioaccumulation of contaminants in a 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 uptake of dissolved chemical constituents from the water and the ingestion and assimilation of pollutants from food sources. Because of their proximity to the sediments, they also accumulate pollutants by ingesting pollutant-containing suspended particulate matter or sediment particles. For this reason, levels of contaminants in tissues of demersal fish are often related to those found in the environment (Schiff and Allen 1997), thus making them useful in biomonitoring programs.

The bioaccumulation portion of the PLOO monitoring program consists of 2 components: (1) analysis of liver tissues from trawl-caught fishes; (2) analysis of muscle tissues 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 at rig fishing sites 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 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 environmental quality of our 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 for fish collected in the Point Loma region during 2006.

MATERIALS AND METHODS

Collection

Pacific sanddabs (*Citharichthys sordidus*) and English sole (*Parophrys vetulus*) were collected from 4 trawling zones, while various species of rockfish (*Sebastes* spp) were collected at 2 rig fishing stations (RF1 and RF2) in October 2006 (**Figure 7.1,**

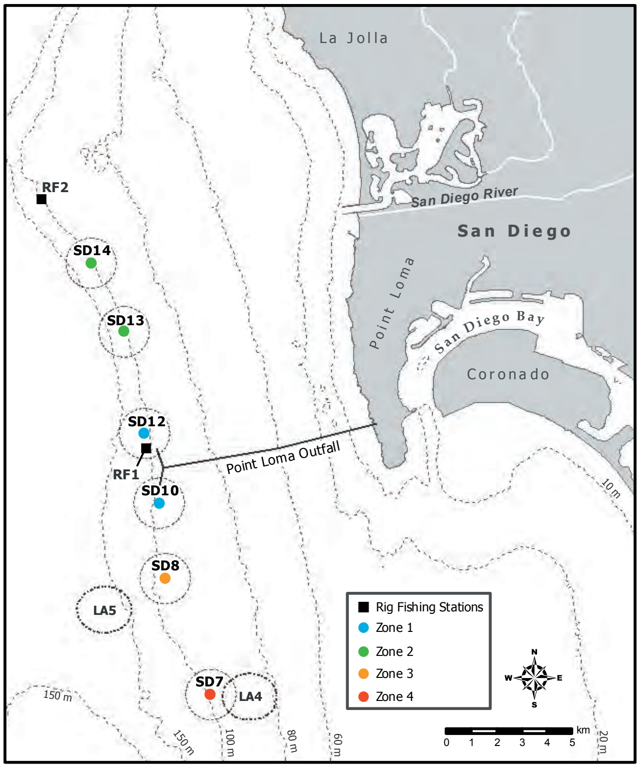

Figure 7.1
Otter trawl stations with 1-km diameter zones and rig fishing stations for the Point Loma outfall monitoring region.

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 2006. Pacific sanddab=PS; English sole=ES; copper rockfish=CRF; starry rockfish=SRF; yellowtail rockfish=YRF.

Station	Rep 1	Rep 2	Rep 3
Zone 1	PS	PS	PS
Zone 2	PS	PS	PS
Zone 3	PS	PS	PS
Zone 4	PS	PS	ES
RF1	CRF	CRF	CRF
RF2	SRF	YRF	YRF

Table 7.1). Zone 1 includes nearfield trawl stations SD10 and SD12, located just south and just north of the PLOO, respectively; Zone 2 includes northern farfield trawl stations SD13 and SD14; Zone 3 is trawl station SD8, located relatively near the LA-5 dredged materials disposal site; Zone 4 is trawl station SD7, located several kilometers to the south of the outfall near the LA-4 dredge materials disposal site. Trawl-caught fishes were collected, measured, and weighed following guidelines described in Chapter 6 of this report. Fishes were collected at the rig fishing sites using rod and reel fishing tackle, and then also measured and weighed. The species that were analyzed from each station/zone are summarized in Table 7.1. Only fish greater than 13 cm standard length were retained for tissue analyses. These fish were sorted into no more than 3 composite samples per station or zone, each containing a minimum of 3 individuals. Composite samples were typically made up of a single species; the only exceptions occurred when multiple species of rockfish were required to obtain the minimum number of fish for a sample. Fishes were then wrapped in aluminum foil, labeled, sealed in plastic bags, placed on dry ice, transported to the Marine Biology Laboratory, and held in the freezer at -80˚C until dissected.

Tissue Processing and Chemical Analyses

All dissections were performed according to standard techniques for tissue analysis. 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 NPDES permit under which this sampling was performed (see Chapter 1). These chemical constituents include the trace metals, chlorinated pesticides, and PCBs listed in **Appendix D.2**. Values for individual constituents of pollutants reported as totals (e.g., total DDT) are listed in **Appendix D.3**. This report includes estimated values 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 2007a).

RESULTS

Contaminants in Trawled Fishes

Metals

Twelve metals, including aluminum, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, selenium, tin, and zinc, occurred in over 80% of the liver samples analyzed from Pacific sanddabs and English sole collected by trawl in 2006 (**Table 7.2**). Antimony, beryllium, lead, nickel, silver, and thallium were also detected, but less frequently. Tissue concentrations of most metals were < 20 ppm. The only exceptions were iron and zinc, which had concentrations up to about 170 and 81 ppm, respectively. Comparisons of the frequently detected metals from Pacific sanddab samples collected closest to the discharge (Zone 1) to those located farther away (Zones 2–4) suggest that there was no clear

Table 7.2

Concentrations of metals, total PCB, and pesticides detected in liver tissues from trawl-caught fishes during October 2006. The number of samples per species is indicated parenthetically; n=number of detected values; nd=not detected.

	English sole (1)				Pacific sanddab (11)				Overall	
Parameter	n	Min	Max	Mean	n	Min	Max	Mean	% Detected	Max
Metals (ppm)										
Aluminum	1	1.5	1.5	1.5	9	0.6	18.6	6.3	83	18.6
Antimony	nd	—	—	—	3	1.14	2.31	1.72	25	2.31
Arsenic	1	13.3	13.3	13.3	11	0.5	2.7	1.6	100	13.3
Barium	1	0.185	0.185	0.185	11	0.055	0.112	0.080	100	0.185
Beryllium	nd	—	—	—	1	0.004	0.004	0.004	8	0.004
Cadmium	1	1.07	1.07	1.07	11	2.11	6.57	4.48	100	6.57
Chromium	1	0.374	0.374	0.374	11	0.175	0.975	0.515	100	0.975
Copper	1	15.8	15.8	15.8	11	2.7	4.9	3.6	100	15.8
Iron	1	170	170	170	11	57	146	104	100	170
Lead	1	1.76	1.76	1.76	1	1.55	1.55	1.55	17	1.76
Manganese	1	1.34	1.34	1.34	11	0.49	2.02	1.11	100	2.02
Mercury	1	0.037	0.037	0.037	11	0.043	0.153	0.084	100	0.153
Nickel	nd	—	—	—	2	0.247	0.333	0.290	17	0.333
Selenium	1	1.65	1.65	1.65	11	0.59	1.03	0.75	100	1.65
Silver	1	0.493	0.493	0.493	6	0.085	0.275	0.193	58	0.493
Thallium	nd	—	—	—	1	1.87	1.87	1.87	8	1.87
Tin	1	1.77	1.77	1.77	11	1.85	4.18	2.65	100	4.18
Zinc	1	80.8	80.8	80.8	11	16.5	32.6	22.0	100	80.8
Pesticides (ppb)										
HCB	1	0.9	0.9	0.9	11	2.1	4.0	3.1	100	4.0
Total Chlordane	1	3.3	3.3	3.3	11	9.6	24.4	18.3	100	24.4
Total DDT	1	912.7	912.7	912.7	11	235.2	457.1	364.6	100	912.7
Total PCB (ppb)	1	219.8	219.8	219.8	11	153.9	479.1	298.6	100	479.1
Lipids (%wt)	1	17.8	17.8	17.8	11	30.8	56.4	42.3	100	56.4

relationship between contaminant loads and proximity to the outfall (**Figure 7.2**).

Pesticides and PCBs

Three chlorinated pesticides (hexachlorobenzene (HCB), chlordane, DDT) were detected in all samples collected during 2006 (Table 7.2). Individual components of chlordane and DDT are listed in Appendix D.2, while their detected values are included in Appendix D.3. Total concentrations ranged from about 3 to 24 ppb for chlordane, 235 to 913 ppb for DDT, and 0.9 to 4 ppb for HCB. Total chlordane consisted primarily of trans nonachlor, alpha (cis) Chlordane, and cis nonachlor, which were present in 10 or more of the samples. In contrast, gamma (trans) Chlordane was present in just 5 of the samples (see Appendix D.3).

PCBs were also detected in all samples. Concentrations for 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 154 to 479 ppb. The 5 PCB congeners with the highest concentrations were PCB 153/168, PCB 138, PCB 118, PCB 180, and PCB 187 (Appendix D.3, **Figure 7.3**). Two of these, PCB118 and 153, were found at all 4 sediment stations where PCBs were detected. Congeners 153/168, PCB 138, PCB 180, and PCB 187 comprised a large proportion of the PCB commercial mixture Arochlor

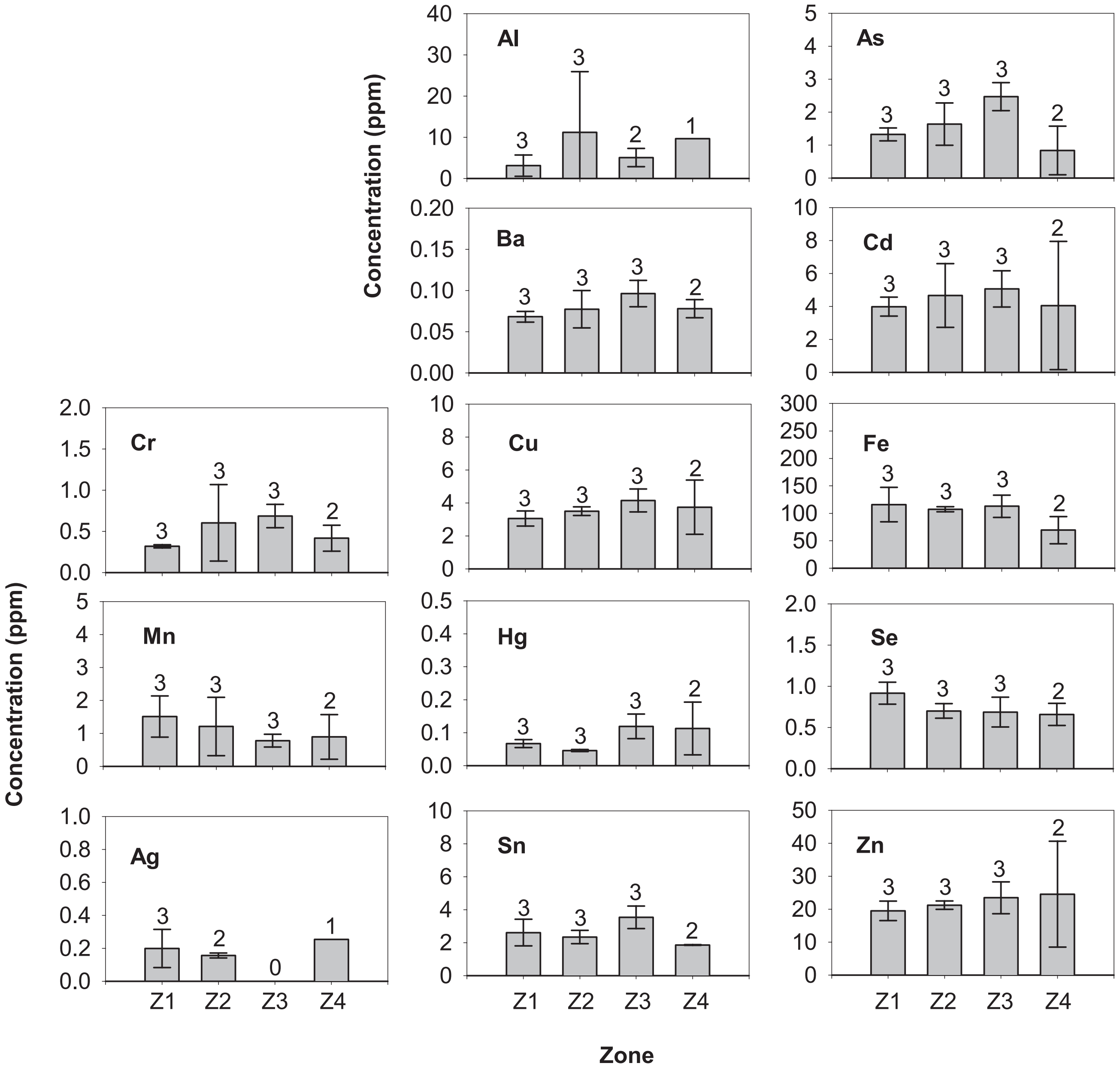

Figure 7.2

Concentrations of metals detected frequently in liver tissues of trawl-caught Pacific sanddabs collected during October 2006 at Zones 1–4 (Z1–Z4) off Point Loma. Data are expressed as means±2SE with number of samples (n) indicated above the error bars. Zone 1 represents the stations located closest to the discharge site.

1260, whereas PCB 138 and PCB 118 comprised a large proportion of Arochlor 1254 (see EPA 2006). These PCB mixtures are resistant to degradation because they are highly chlorinated; historical sources for both include electrical transformers, hydraulic fluids, synthetic resins, and de-dusting agents (Spectrum Laboratories 2003).

As with metals, there was no clear relationship between concentrations of the frequently occurring pesticides or PCBs and proximity to the outfall (**Figure 7.4**). The highest concentration of chlordane occurred in a sample of Pacific sanddabs collected in Zone 1, but the other 2 samples from this zone contained chlordane concentrations similar to those collected at other sites. Mean values of DDT and HCB appeared to be higher in samples from Zones 1 and 3 (nearest the outfall and LA-5, respectively), but these differences are only slight. On the other hand, total PCB was clearly highest for all 3 sanddab samples from Zone 3, located relatively near the LA-5 disposal site. Elevated levels of PCBs in various fish species have been demonstrated at this

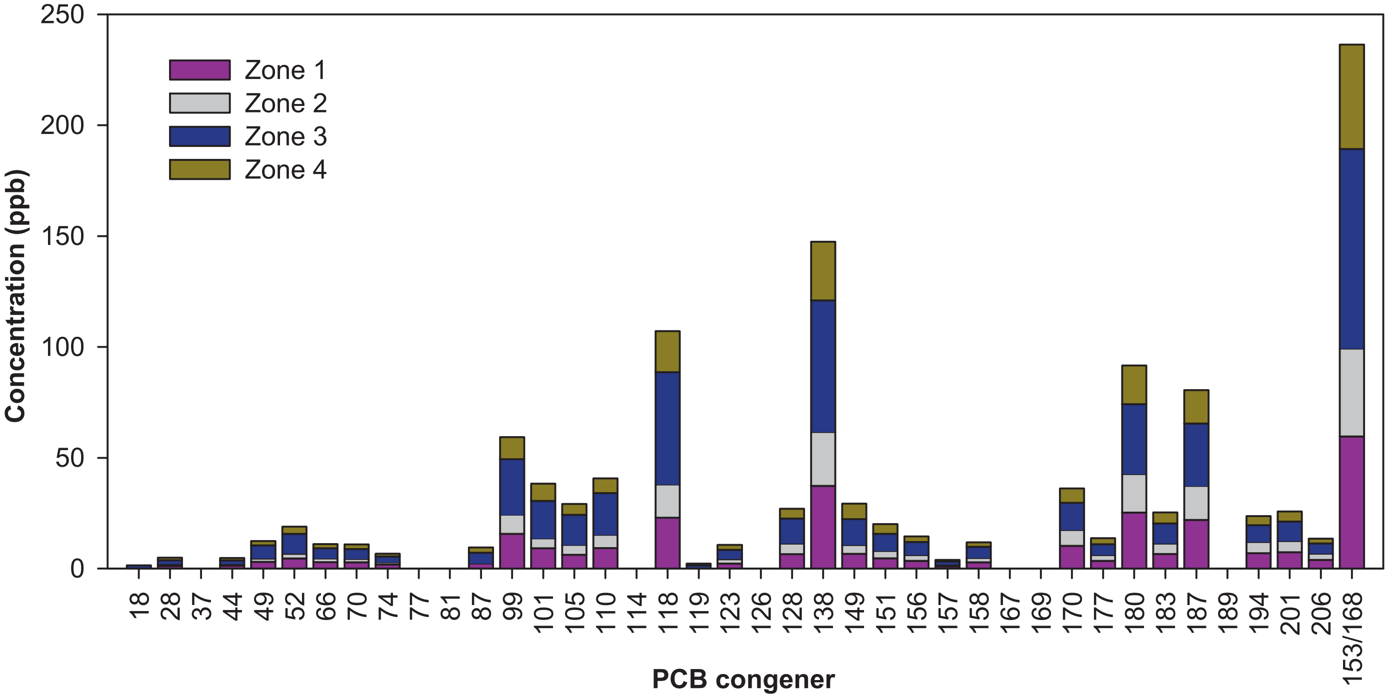

Figure 7.3

Concentrations of individual PCB congeners in liver tissues of trawl-caught Pacific sanddabs collected during October 2006 at Zones 1–4 off Point Loma. Data are expressed as means; n varies for each zone by the number of Pacific sanddab samples with detected values of each congener (see Figure 7.4).

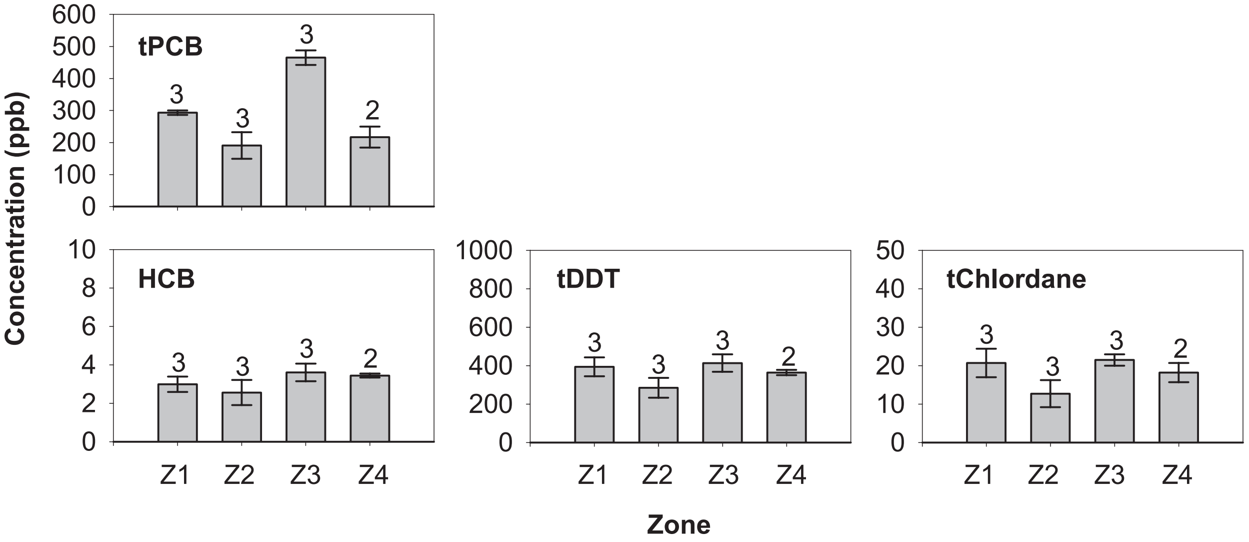

Figure 7.4

Concentrations of frequently detected chlorinated pesticides (tDDT=total DDT; HCB=hexachlorobenzene) and total PCB (tPCB) detected in liver tissues of trawl-caught Pacific sanddabs during October 2006 at Zones 1–4 (Z1–Z4) off Point Loma. Data are expressed as means±2SE with number of samples (n) indicated above the error bars. Zone 1 represents the stations located closest to the discharge site.

Table 7.3

Metals detected in muscle tissues from fishes collected at PLOO rig fishing stations during October 2006. Data are compared to USFDA action limits and median international standards (IS) when possible. Bold values exceed these standards; n=number of detected values; nd=not detected.

	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Sb	Se	Sn	Zn
Copper rockfish														
n (out of 3)	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Min	1.24	1.05	0.030	0.147	0.38	0.321	1.43	0.079	0.087	0.145	1.01	**0.35**	1.63	4.87
Max	4.75	**1.69**	0.035	0.178	0.53	0.534	2.22	0.100	0.144	0.378	1.11	**0.54**	1.77	5.73
Mean	2.84	1.28	0.034	0.158	0.44	0.431	1.93	0.088	0.107	0.234	1.05	**0.46**	1.71	5.24
Starry rockfish														
n (out of 1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Min	3.74	1.32	0.032	0.162	0.33	0.326	3.11	0.206	0.131	0.143	0.92	**0.37**	1.55	4.35
Max	3.74	1.32	0.032	0.162	0.33	0.326	3.11	0.206	0.131	0.143	0.92	**0.37**	1.55	4.35
Mean	3.74	1.32	0.032	0.162	0.33	0.326	3.11	0.206	0.131	0.143	0.92	**0.37**	1.55	4.35
Yellowtail rockfish														
n (out of 2)	2	1	2	2	2	2	2	2	2	2	2	2	2	2
Min	0.69	0.46	0.029	0.141	0.36	0.385	3.11	0.072	0.130	0.151	0.79	**0.30**	1.69	3.77
Max	8.19	0.46	0.037	0.156	0.47	0.447	4.58	0.079	0.132	0.161	0.83	**0.35**	1.71	4.28
Mean	4.44	0.46	0.033	0.149	0.42	0.416	3.85	0.076	0.131	0.156	0.81	**0.33**	1.70	4.03
% Detected	100	83	100	100	100	100	100	100	100	100	100	100	100	100
Max	8.19	**1.69**	0.037	0.178	0.53	0.534	4.58	0.206	0.144	0.378	1.11	**0.54**	1.77	5.73
USFDA Act. Limit*								1.00						
Median IS*		1.4		1.0	1.0	20		0.5				0.3	175	70

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

location before (e.g., City of San Diego 2003a). The area contains materials dredged from San Diego Bay, which is known to have elevated levels of PCBs (see City of San Diego 2003b); it is possible that the deposited San Diego Bay sediments contribute to the elevated levels of PCBs present in Zone 3 fishes.

Contaminants in Fishes Collected by Rig Fishing

Fourteen of 18 heavy metals analyzed were found in almost all of the samples from the 3 rockfish species collected at rig fishing stations during 2006 (**Table 7.3**). These metals were aluminum, arsenic, barium, cadmium, chromium, copper, iron, mercury, manganese, nickel, antimony, selenium, tin, and zinc. Beryllium, lead, silver, and thallium were not detected. The metals present in the highest concentrations were aluminum, iron, and zinc. Concentrations of each of these metals exceeded 2 ppm for at least one species of fish; however, there was little difference between species relative to mean concentrations. Other contaminants, including the pesticides HCB, chlordane, and DDT, as well as PCBs, were detected in more than 65% of the muscle samples (**Table 7.4**). The highest concentration of all 4 contaminants occurred in a single sample of starry rockfish.

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, 7.4). The United States Food and Drug Administration (USFDA) has set limits on the amount of mercury, total DDT, and chlordane in seafood that can 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

Table 7.4

Concentrations of chlorinated pesticides, PCBs, and lipids detected in muscle tissues from rockfish collected at rig fishing stations during October 2006. Data are compared to USFDA action limits (AL) and median international standards (IS) when possible. HCB=hexachlorobenzene; tChlor=chlordane. Values are expressed in ppb for all parameters except lipids, which are presented as percent weight (% wt). n=number of detected values.

	HCB	tChlor	tDDT	tPCB	Lipids
Copper rockfish					
n (out of 3)	3	2	3	3	3
Min	0.1	0.1	4.7	1.3	1.0
Max	0.1	0.2	5.3	1.7	3.4
Mean	0.1	0.2	5.0	1.5	2.3
Starry rockfish					
n (out of 1)	1	1	1	1	1
Min	0.2	0.6	19.3	7.3	1.5
Max	0.2	0.6	19.3	7.3	1.5
Mean	0.2	0.6	19.3	7.3	1.5
Yellowtail rockfish					
n (out of 2)	2	1	2	2	2
Min	0.1	0.1	3.6	0.5	0.5
Max	0.1	0.1	6.3	1.2	0.7
Mean	0.1	0.1	5.0	0.9	0.6
% Detected	100	67	100	100	100
Max	0.2	0.6	19.3	7.3	3.4
FDA -AL*		300	5000		
Median IS*		100	5000		

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

in the muscle tissues of fish collected as part of the PLOO monitoring program, only arsenic and selenium had concentrations that exceeded international standards.

In addition to addressing health concerns, spatial patterns were assessed for each contaminant that occurred frequently (i.e., each metal, pesticide, and total PCB discussed above) (**Figure 7.5**). 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. The highest values for several parameters were from the starry rockfish collected at station RF2 as discussed above. Starry rockfish are not commonly collected in this area, so it is possible that these fish recently migrated into the region.

Comparison of contaminant loads between RF1 and RF2 fishes should be considered with caution however, because different species of fish were collected at these sites. All specimens belong to the family Scorpaenidae and have similar life histories (e.g., bottom dwelling tertiary carnivores), and similar mechanisms of exposure (e.g., exposure from direct contact with the sediments and through possibly similar food sources). However, different species may have differences in physiology and food choices that could affect their accumulation of contaminants.

SUMMARY AND CONCLUSIONS

Fourteen trace metals, 3 pesticides, and a combination of PCBs were detected in over 80% of the liver samples from Pacific sanddabs and English sole collected around the Point Loma outfall region in 2006. 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 were generally similar to those reported previously by the City of San Diego for this survey area (e.g., City of San Diego 2006a), as well as the South Bay outfall monitoring area (e.g., City of San Diego 2006b). 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 local 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 addition, certain areas along the San Diego shelf (e.g., Zones 2–4, station

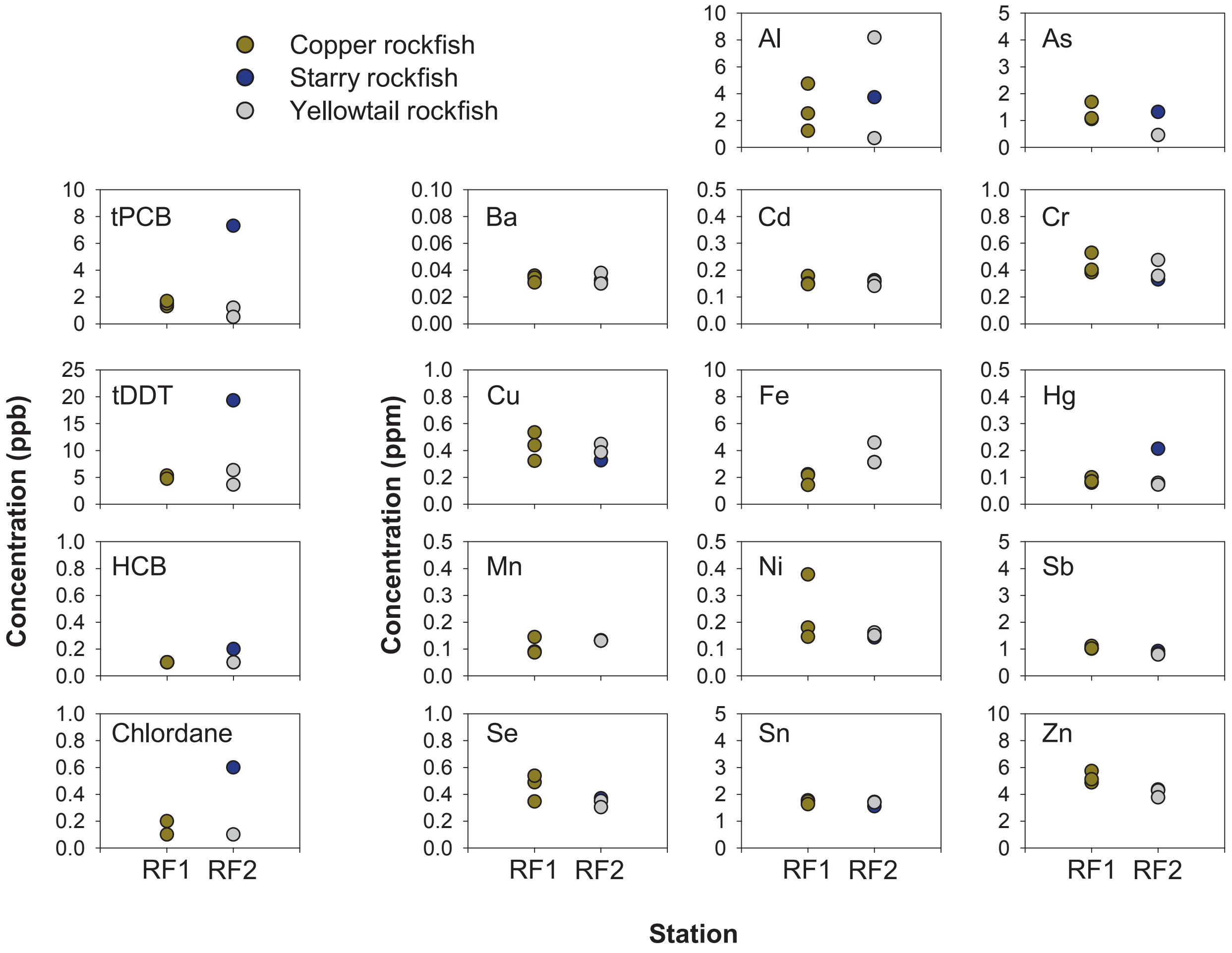

Figure 7.5

Concentrations of frequently detected metals, hexachlorobenzene (HCB), Chlordane, total DDT, and total PCB in muscle tissues of fishes collected from each PLOO rig fishing station during 2006. Missing data represent concentrations below detection limits. RF1 represents the area located closest to the discharge site.

RF2) have sediments containing relatively high concentrations of these contaminants (see Chapter 4 this report, and Chapter 8 in City of San Diego 2007b). Further, many metals (e.g., aluminum, arsenic, iron, and selenium) 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, 2002).

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 2006 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.

Despite these difficulties, there was no evidence that fishes collected in 2006 were contaminated by the discharge of wastewater from the Point Loma Ocean Outfall. Concentrations of mercury and DDT in muscle tissues from sport fish collected in the area were below USFDA 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

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

Adsorption The adhesion of dissolved substances to the surface of sediment or on the surface of an organism (e.g., a 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 becomes accumulated in tissue over time through direct intake of contaminated water, the consumption of contaminated prey, or absorption through the skin or gills.

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 3 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, shrimp, and lobster 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 dominance index) 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 (e.g., sea stars, sea urchins, and sea cucumbers).

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).

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 benthic community impacted by pollution.

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 typically 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 5 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_{12}) 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.

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 comprises 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 underwater pipe originating at the International Wastewater Treatment Plant and used to discharge treated wastewater. It extends 5.6 km (3.5 miles) offshore and discharges into about 27 m (90 ft) of water.

SBWRP (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 sample or 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 measurement that includes them (i.e., total length) is considered less reliable.

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).

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.

Appendix A

Supporting Data

2006 PLOO Stations

Microbiology

Appendix A.1

Summary of compliance with California Ocean Plan water contact standards for PLOO shore stations during 2006. 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	0	0	0	0	0	0
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	18	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
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**95%**	**100%**

60-Day fecal coliform standard

Month	**# days**	**D4**	**D5**	**D7**	**D8**	**D9**	**D10**	**D11**	**D12**
January	31	0	0	0	0	0	0	0	0
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
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Appendix A.2

Summary of compliance with California Ocean Plan water contact standards for PLOO shore stations during 2006. 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 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	0	0	0	0	0	0	0	0
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
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

60-Day fecal coliform standard

		9 m stations			**18 m stations**				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	0	0	0	0	0	0	0	0
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
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Appendix A.3

Samples where total coliform densities were ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) were ≥0.1 (see text) for the PLOO offshore and kelp water quality stations sampled in 2006. 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.

Date	Station	Transect position	Sample depth, m	Total	Fecal	Entero	F:T
January	F33	98-m – N	60	1000	240	100	0.24
April	F01	18-m – S	12	1400	160	4	0.11
	F09	60-m – N	60	1200	300	46	0.25
	F10	60-m – N	60	9400	2600	340	0.28
	F05	60-m – S	60	2000	460	98	0.23
	F06	60-m – S	60	1300	240	56	0.18
	F20	80-m – N	60	16000	5800	1200	0.36
	F20	80-m – N	80	9200	1400	160	0.15
	F21	80-m – N	60	8400	2800	420	0.33
	F21	80-m – N	80	1800	460	52	0.26
	F22	80-m – N	80	1100	200	42	0.18
	F19	80-m – O	60	16000	2600	440	0.16
	F19	80-m – O	80	4600	800	110	0.17
July	F20	80-m – N	60	16000	3200	2	0.20
	F24	80-m – N	80	1100	200	26	0.18
	F25	80-m – N	80	1300	200	28	0.15
	F31	98-m – N	60	16000	9200	640	0.58
	F31	98-m – N	80	5000	1200	100	0.24
	F32	98-m – N	60	4800	1200	160	0.25
	F32	98-m – N	80	6200	1800	180	0.29
	F32	98-m – N	98	7000	1000	60	0.14
	F33	98-m – N	60	6000	2400	240	0.40
	F33	98-m – N	80	16000	6400	740	0.40
	F33	98-m – N	98	6000	2600	60	0.43
	F34	98-m – N	98	1300	440	30	0.34
	F36	98-m – N	80	1000	340	34	0.34
	F30	98-m – O	60	13000	2600	180	0.20
	F30	98-m – O	80	16000	12000	780	0.75
October	F21	80-m – N	60	14000	2400	260	0.17
	F22	80-m – N	60	1700	340	42	0.20
	F25	80-m – N	60	2600	320	12	0.12
	F25	80-m – N	80	5000	1000	72	0.20
	F19	80-m – O	80	16000	3000	240	0.19
	F31	98-m – N	80	1000	180	8	0.18
	F32	98-m – N	80	12000	2000	140	0.17
	F32	98-m – N	98	2400	460	38	0.19
	F33	98-m – N	80	8000	1400	400	0.18
	F34	98-m – N	60	13000	1600	420	0.12
	F34	98-m – N	80	5400	780	64	0.14
	F30	98-m – O	98	16000	12000	620	0.75

Appendix B

Supporting Data

2006 PLOO Stations

Sediment Characteristics

Appendix B.1

Constituents and method detection limits (MDL) for sediment samples analyzed for the PLOO monitoring program during January and July 2006.

Parameter	Units	MDL	
		January	July
Total solids	WT%	0.24	0.24
Total volatile solids	WT%	0.11	0.11
Sulfides-total	MG/KG	0.14	0.14
Total nitrogen	WT%	0.005	0.01
Total organic carbon	WT%	0.01	0.01
Polycyclic aromatic hydrocarbons (PAHs)			
1-methylnaphthalene	UG/KG		
1-methylphenanthrene	UG/KG	41	41
2,3,5-trimethylnaphthalene	UG/KG	134	134
2,6-dimethylnaphthalene	UG/KG	106	106
2-methylnaphthalene	UG/KG		
3,4-benzo(B)fluoranthene	UG/KG	63	63
Acenaphthene	UG/KG	11	11
Acenaphthylene	UG/KG	11	11
Anthracene	UG/KG	14	14
Benzo[A]anthracene	UG/KG	34	34
Benzo[A]pyrene	UG/KG	55	55
Benzo[G,H,I]perylene	UG/KG	56	56
Benzo[K]fluoranthene	UG/KG	82	82
Benzo[e]pyrene	UG/KG	57	57
Biphenyl	UG/KG		
Chrysene	UG/KG	36	36
Dibenzo(A,H)anthracene	UG/KG	32	32
Fluoranthene	UG/KG	24	24
Fluorene	UG/KG	18	
Indeno(1,2,3-CD)pyrene	UG/KG	76	76
Naphthalene	UG/KG	21	21
Perylene	UG/KG	58	58
Phenanthrene	UG/KG	32	32
Pyrene	UG/KG	35	35

Parameter	Units	MDL	
		January	July
Polychlorinated biphenyl congeners (PCBs)			
PCB 18	NG/KG	700	700
PCB 28	NG/KG	700	700
PCB 37	NG/KG	700	700
PCB 44	NG/KG	700	700
PCB 49	NG/KG	700	700
PCB 52	NG/KG	700	700
PCB 66	NG/KG	700	700
PCB 70	NG/KG	700	700
PCB 74	NG/KG	700	700
PCB 77	NG/KG	700	700
PCB 81	NG/KG	700	700
PCB 87	NG/KG	700	700
PCB 99	NG/KG	700	700
PCB 101	NG/KG	700	700
PCB 105	NG/KG	700	700
PCB 110	NG/KG	700	700
PCB 114	NG/KG	700	700
PCB 118	NG/KG	700	700
PCB 119	NG/KG	700	700
PCB 123	NG/KG	700	700
PCB 126	NG/KG	1500	1500
PCB 128	NG/KG	700	700
PCB 138	NG/KG	700	700
PCB 149	NG/KG	700	700
PCB 151	NG/KG	700	700
PCB 153/168	NG/KG	700	700
PCB 156	NG/KG	700	700
PCB 157	NG/KG	700	700
PCB 158	NG/KG	700	700
PCB 167	NG/KG	700	700
PCB 169	NG/KG	700	700
PCB 170	NG/KG	700	700
PCB 177	NG/KG	700	700
PCB 180	NG/KG	400	400
PCB 183	NG/KG	700	700
PCB 187	NG/KG	700	700
PCB 189	NG/KG	400	400
PCB 194	NG/KG	700	700
PCB 201	NG/KG	700	700
PCB 206	NG/KG	700	700

Appendix B.1 *continued*.

		MDL	
Parameter	**Units**	**January**	**July**
Chlorinated pesticides			
BHC, Alpha isomer	NG/KG	400	400
BHC, Beta isomer	NG/KG	400	400
BHC, Delta isomer	NG/KG	400	400
BHC, Gamma isomer	NG/KG	400	400
Alpha (cis) Chlordane	NG/KG	700	700
Cis-Nonachlor	NG/KG	700	700
Gamma (trans) Chlordane	NG/KG	700	700
Heptachlor	NG/KG	700	700
Heptachlor epoxide	NG/KG	700	700
Methoxychlor	NG/KG	700	700
Oxychlordane	NG/KG	700	700
Trans Nonachlor	NG/KG	700	700
o,p-DDD	NG/KG	400	400
o,p-DDE	NG/KG	700	700
o,p-DDT	NG/KG	700	700
p,-p-DDMU	NG/KG		
p,p-DDD	NG/KG	700	700
p,p-DDE	NG/KG	400	400
p,p-DDT	NG/KG	700	700
Aldrin	NG/KG	700	700
Alpha Endosulfan	NG/KG	700	700
Beta Endosulfan	NG/KG	700	700
Dieldrin	NG/KG	700	700
Endosulfan Sulfate	NG/KG	700	700
Endrin	NG/KG	700	700
Endrin aldehyde	NG/KG	700	700
Hexachlorobenzene	NG/KG	400	400
Mirex	NG/KG	700	700

		MDL	
Parameter	**Units**	**January**	**July**
Metals			
Aluminum (Al)	MG/KG	1.15	1.2
Antimony (Sb)	MG/KG	0.13	0.13
Arsenic (As)	MG/KG	0.33	0.33
Barium (Ba)	MG/KG	0.001	0.001
Beryllium (Be)	MG/KG	0.001	0.001
Cadmium (Cd)	MG/KG	0.010	0.01
Chromium (Cr)	MG/KG	0.016	0.016
Copper (Cu)	MG/KG	0.027	0.028
Iron (Fe)	MG/KG	0.76	0.76
Lead (Pb)	MG/KG	0.142	0.142
Manganese (Mn)	MG/KG	0.003	0.003
Mercury (Hg)	MG/KG	0.003	0.003
Nickel (Ni)	MG/KG	0.036	0.036
Selenium (Se)	MG/KG	0.24	0.24
Silver (Ag)	MG/KG	0.012	0.013
Thallium (Tl)	MG/KG	0.221	0.22
Tin (Sn)	MG/KG	0.058	0.059
Zinc (Zn)	MG/KG	0.052	0.052

Appendix B.2

PLOO sediment statistics January 2006.

Station	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
North reference stations												
B11	88	0.061	4.0	2.1	3.6	0.2	1.0	3.9	54.0	38.5	3.7	Mud pea gravel, shell hash, sand, silt
B8	88	0.042	4.6	1.6	4.2	0.4	0.9	0.0	44.2	52.1	3.7	Silt, clay
B12	98	0.087	3.5	2.0	3.0	0.3	1.2	2.1	68.2	27.1	2.6	Shell hash, sand, silt
B9	98	0.063	4.0	1.8	3.5	0.3	1.3	2.0	59.9	35.1	3.0	Silt, clay
B10	116	0.069	3.9	1.6	3.1	0.6	2.0	3.0	69.3	25.2	2.5	Shell hash, silt, clay
Stations north of the outfall												
E19	88	0.056	4.2	1.5	3.9	0.3	1.2	1.2	54.5	41.7	2.7	Silt, clay
E20	98	0.062	4.0	1.4	3.7	0.4	1.2	0.0	64.1	33.5	2.4	shell hash, silt
E23	98	0.055	4.2	1.5	3.7	0.4	1.1	0.0	58.6	38.6	2.8	Shell hash, silt, clay
E25	98	0.056	4.2	1.6	3.7	0.4	1.1	0.0	60.2	36.8	3.0	Shell hash, silt, clay
E26	98	0.051	4.3	1.5	3.8	0.5	1.0	0.0	55.7	41.3	3.0	Silt, clay
E21	116	0.061	4.0	1.5	3.5	0.6	1.2	0.0	65.4	32.3	2.4	Silt
Outfall stations												
E11	98	0.076	3.7	1.3	3.4	0.5	1.4	0.0	70.5	27.6	1.9	Silt
E14	98	0.074	3.8	1.3	3.3	0.6	1.6	0.0	71.9	26.0	2.1	Silt
E17	98	0.062	4.0	1.5	3.6	0.4	1.2	0.0	65.4	32.2	2.4	Silt, clay
E15	116	0.066	3.9	1.4	3.4	0.6	1.3	0.0	67.5	29.9	2.6	Silt, clay
Stations south of the outfall												
E1	88	0.058	4.1	1.9	3.7	0.3	0.9	1.1	55.2	40.0	3.7	Shell hash, coarse and fine sand, silt
E7	88	0.057	4.1	1.5	3.8	0.4	1.1	0.0	59.5	38.0	2.5	Silt
E2	98	0.243	2.0	2.0	2.5	-0.3	0.6	23.9	31.3	44.8	0.0	Shell hash, coarse sand, silt
E5	98	0.066	3.9	1.5	3.4	0.5	1.2	0.0	66.7	31.1	2.2	Silt
E8	98	0.064	4.0	1.5	3.4	0.5	1.6	0.3	66.6	30.5	2.6	Silt, clay
E3	116	0.097	3.4	2.3	2.8	0.3	1.1	4.5	64.4	28.0	3.0	Shell hash, coarse sand, silt
E9	116	0.146	2.8	1.8	4.0	-0.9	0.6	15.4	26.1	58.5	0.0	Coarse black sand, silt

Appendix B.2 *continued*

Station	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
North reference stations												
B11	88	0.048	4.4	1.8	4.0	0.4	0.8	0.0	51.3	44.4	4.3	Rock, pea gravel, shell hash, coarse and fine sand
B8	88	0.036	4.8	1.6	4.5	0.3	0.9	0.0	37.5	58.4	4.0	Silt
B12	98	0.063	4.0	1.8	3.3	0.5	0.8	0.0	62.9	34.2	2.9	Pea gravel, shell hash, fine sand, silt
B9	98	0.054	4.2	1.7	3.8	0.4	1.0	2.0	56.9	38.1	3.1	Silt, mud pea gravel
B10	116	0.066	3.9	1.6	3.4	0.5	1.2	0.0	69.7	27.5	2.7	Coarse sand, shell hash, fine sand, silt
Stations north of the outfall												
E19	88	0.052	4.3	1.5	3.9	0.4	1.2	0.0	55.3	41.9	2.8	Shell hash, silt, clay
E20	98	0.061	4.0	1.4	3.7	0.4	1.2	0.0	63.2	34.2	2.5	Shell hash, fine sand, silt
E23	98	0.058	4.1	1.5	3.7	0.4	1.2	0.0	60.6	36.6	2.7	shell hash, silt
E25	98	0.061	4.0	1.5	3.6	0.5	1.2	0.0	63.1	34.3	2.7	shell hash, silt
E26	98	0.054	4.2	1.5	3.7	0.5	1.1	0.0	58.2	38.9	3.0	shell hash, silt
E21	116	0.063	4.0	1.4	3.6	0.5	1.2	0.0	67.1	30.5	2.4	shell hash, silt
Outfall stations												
E11	98	0.069	3.9	1.4	3.5	0.5	1.4	0.0	67.6	29.9	2.5	Fine sand, silt
E14	98	0.491	1.0	2.2	0.0	0.6	0.4	49.7	13.6	36.7	0.0	Pea gravel/gravel, shell hash, coarse black and fine sand
E17	98	0.068	3.9	1.4	3.5	0.5	1.4	0.0	67.4	30.3	2.3	Shell hash, silt, clay
E15	116	0.062	4.0	1.5	3.4	0.6	1.3	0.0	67.0	30.0	3.1	Shell hash, coarse black sand, silt, clay
Stations south of the outfall												
E1	88	0.055	4.2	1.8	3.8	0.3	0.9	2.9	52.6	41.0	3.5	Rock, pea gravel, shell hash, coarse and fine sand, silt
E7	88	0.057	4.1	1.5	3.7	0.4	1.2	0.0	58.9	38.6	2.5	Fine sand, silt
E2	98	0.056	4.2	1.7	3.7	0.4	1.0	1.1	57.7	37.8	3.4	Rock, pea gravel, shell hash, coarse sand, silt
E5	98	0.068	3.9	1.5	3.5	0.4	1.2	2.0	65.1	30.5	2.4	Fine sand, silt
E8	98	0.067	3.9	1.4	3.5	0.5	1.3	0.0	67.1	30.9	2.1	Fine sand, silt
E3	116	0.063	4.0	1.9	3.3	0.5	0.8	1.0	60.1	35.4	3.4	Rock, pea gravel, shell hash, coarse sand, silt
E9	116	0.142	2.8	1.8	4.1	-0.9	0.6	14.1	25.9	60.0	0.0	Pea gravel, shell hash, coarse black sand, silt

Appendix B.3

Summary of changes in mean particle size and organic indicators for 1995–2006. Particle size is in phi and millimeters (mm). SD=the sorting coefficient, standard deviation (phi). Coarse is the percent material greater than -1 phi or 2 mm. TN and TOC=Total nitrogen and total organic carbon expressed as percent weight (wt %).

YEAR	Particle Size				Organic Indicators				
	Mean (phi)	**Mean (mm)**	**SD (phi)**	**Fines (%)**	**BOD (mg/kg)**	**Sulfides (ppm)**	**TN (wt%)**	**TOC (wt%)**	**TVS (wt%)**
1991	4.2	0.070	2.0	36.9	246	0.4	—	—	2.36
1992	4.0	0.066	1.5	39.3	224	0.9	0.044	0.530	2.25
1993	4.2	0.057	1.7	44.3	276	2.4	0.032	0.533	2.35
1994	4.2	0.059	1.7	42.8	303	3.2	0.050	0.813	2.40
1995	4.1	0.066	1.7	40.7	331	3.2	0.034	0.652	2.65
1996	4.0	0.068	1.7	38.9	298	3.8	0.059	0.805	2.67
1997	3.9	0.072	1.7	38.4	302	6.0	0.056	0.741	2.62
1998	3.9	0.076	1.7	37.2	316	5.7	0.056	0.531	2.58
1999	3.8	0.077	1.6	34.4	327	8.7	0.055	0.514	2.78
2000	3.7	0.108	1.5	33.2	300	3.0	0.058	0.528	2.74
2001	3.9	0.078	1.7	35.2	321	2.4	0.052	0.524	2.63
2002	4.1	0.061	1.7	39.2	311	3.9	0.054	0.606	2.75
2003	4.0	0.062	1.7	38.5	298	3.5	0.063	0.617	2.48
2004	3.9	0.068	1.7	36.6	316	5.6	0.055	0.546	2.44
2005	3.9	0.066	1.6	36.1	298	3.7	0.062	0.599	2.42
2006	3.9	0.079	1.6	39.1	358	3.2	0.057	1.018	2.59

Appendix B.4

Summary of changes in mean trace metals (parts per million) for 1995–2006. CDF=cumulative distribution function. nd=not detected. “—” = not sampled. Values are adjusted for the highest MDL used over the period. Values abvoe the CDF are in bold.

Year	Al	Sb	As	B a	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
1991	—	nd	1.98	—	**0.77**	0.13	21.6	8.7	—	3.1	—	0.004	8.2	0.04	nd	nd	—	33.9
1992	—	nd	2.58	—	**0.28**	**0.37**	16.1	7.9	—	2.8	—	0.009	5.5	0.02	**0.38**	1.4	—	29.0
1993	—	**0.2**	2.98	—	0.01	**2.54**	18.3	7.9	13023	0.6	—	0.001	6.9	0.22	nd	13.1	—	27.5
1994	**9700**	nd	3.72	—	0.03	**1.71**	20.3	10.2	13880	4.0	—	0.003	8.5	0.14	nd	nd	—	31.5
1995	**10426**	**1.0**	3.95	—	0.17	0.01	19.9	9.7	14946	1.9	—	0.002	7.3	0.17	0.08	0.3	—	31.7
1996	**9744**	**1.9**	3.77	—	0.17	nd	20.2	9.3	13871	2.1	92	0.024	8.3	0.15	0.06	nd	2.1	29.0
1997	**10603**	**2.2**	3.85	—	**0.32**	0.04	19.1	10.8	13677	1.0	95	0.028	7.8	0.22	nd	nd	4.2	36.0
1998	**11847**	**3.6**	3.91	—	**0.74**	0.01	15.4	8.9	14391	2.7	105	0.009	7.9	0.13	nd	0.5	nd	33.4
1999	**11545**	**0.4**	3.88	—	**0.73**	**0.78**	16.4	8.6	14832	0.5	103	0.001	7.7	0.11	nd	0.1	nd	33.2
2000	**9714**	**0.9**	3.37	—	nd	0.01	14.8	9.4	13938	1.7	108	nd	7.2	0.17	nd	nd	0.5	30.6
2001	**10185**	**1.9**	3.43	—	0.09	0.06	17.8	10.2	14023	1.4	98	0.003	6.9	0.07	nd	0.2	nd	29.8
2002	**10206**	**1.6**	3.77	—	0.03	0.02	16.3	10.4	13902	1.0	95	0.001	5.7	0.09	0.09	0.4	nd	29.6
2003	**10164**	**0.6**	3.74	35.7	0.04	0.11	18.7	9.4	13907	1.6	98	0.015	4.8	0.04	nd	nd	nd	30.8
2004	**10389**	nd	3.04	43.0	0.12	nd	19.3	7.4	14131	3.9	143	0.011	7.3	0.01	nd	nd	nd	32.8
2005	**13941**	nd	3.48	45.1	**0.30**	nd	21.3	9.2	**17391**	5.9	216	0.006	8.1	0.02	nd	nd	nd	36.9
2006	8366	nd	3.13	39.5	0.02	nd	17.1	7.6	13552	7.7	91	0.007	7.3	0.06	nd	nd	nd	19.5
1991-2006	10447	1.1	3.47	41.6	0.23	0.43	18.0	9.2	14137	2.2	106	0.007	7.2	0.12	0.04	1.2	0.7	30.9
High MDL	5	5	0.33	0.042	0.2	0.5	3	2	3	5	0.48	0.047	3	0.24	3	10	12	4
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

Appendix C

Supporting Data

2006 PLOO Stations

Demersal Fishes and Megabenthic Invertebrates

Appendix C.1

Summary of demersal fish species captured during 2006 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 of Eschmeyer and Herald (1998) and Allen (2005).*

				Length		
Taxon/Species	**Common name**	**n**	**BM**	**Min**	**Max**	**Mean**
RAJIFORMES						
Rajidae						
Raja inornata	California skate	6	0.9	10	42	23
Raja stellulata	starry skate	2	0.2	23	24	24
CHIMAERIFORMES						
Chimaeridae						
Hydrolagus colliei	spotted ratfish	3	0.5	29	38	35
AULOPIFORMES						
Synodontidae						
Synodus lucioceps	California lizardfish	47	1.5	9	24	16
OSMERIFORMES						
Argentinidae						
Argentina sialis	Pacific argentine	15	0.3	4	7	6
OPHIDIIFORMES						
Ophidiidae						
Chilara taylori	spotted cuskeel	4	0.2	15	17	16
BATRACHOIDIFORMES						
Batrachoididae						
Porichthys notatus	plainfin midshipman	84	1.7	6	17	12
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	7	2.4	15	25	20
Sebastes chlorostictus	greenspotted rockfish	1	0.1	15	15	15
Sebastes elongatus	greenstriped rockfish	39	1.3	6	13	10
Sebastes eos	pink rockfish	18	0.6	5	11	8
Sebastes jordani	shortbelly rockfish	1	0.1	12	12	12
Sebastes hopkinsi	squarespot rockfish	1	0.1	11	11	11
Sebastes rosenblatti	greenblotched rockfish	19	0.8	7	12	10
Sebastes rubrivinctus	flag rockfish	2	0.5	9	14	12
Sebastes saxicola	stripetail rockfish	59	1.5	6	15	10
Sebastes semicinctus	halfbanded rockfish	1279	19.0	6	14	9
Hexagrammidae						
Ophiodon elongatus	lingcod	1	0.1	25	25	25
Zaniolepis frenata	shortspine combfish	159	4.1	8	17	13
Zaniolepis latipinnis	longspine combfish	320	6.8	7	17	12
Cottidae						
Chitonotus pugetensis	roughback sculpin	47	0.5	7	12	9
Icelinus quadriseriatus	yellowchin sculpin	507	2.2	4	9	7
Icelinus tenuis	spotfin sculpin	27	0.3	8	11	9
Agonidae						
Odontopyxis trispinosa	pygmy poacher	2	0.2	8	8	8
Xeneretmus latifrons	blacktip poacher	5	0.5	3	14	11
Xeneretmus triacanthus	bluespotted poacher	2	0.2	9	14	12
PERCIFORMES						
Sciaenidae						
Genyonemus lineatus	white croaker	2	0.3	19	20	20
Embiotocidae						
Cymatogaster aggregata						
Zalembius rosaceus	pink seaperch	88	1.8	5	13	9
Bathymasteridae						
Rathbunella hypoplecta	bluebanded ronquil	2	0.2	12	17	15

Appendix C.1 *continued*

Taxon/Species	Common name	n	BM	Length Min	 Max	 Mean
Zoarcidae						
Lycodopsis pacifica	blackbelly eelpout	17	0.8	16	25	21
Stichaeidae						
Plectobranchus evides	bluebarred prickleback	1	0.1	10	10	10
Scombridae						
Scomber japonicus	chub mackerel	1	0.1	20	20	20
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys sordidus	Pacific sanddab	2734	51.8	4	23	12
Hippoglossina stomata	bigmouth sole	18	1.0	10	21	14
Pleuronectidae						
Eopsetta exilis	slender sole	20	0.6	9	16	13
Microstomus pacificus	Dover sole	543	13.8	5	20	13
Parophrys vetulus	English sole	83	8.2	12	24	19
Pleuronichthys verticalis	hornyhead turbot	43	3.1	8	19	14
Cynoglossidae						
Symphurus atricauda	California tonguefish	34	0.9	8	17	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, Westminster, CA.

Appendix C.2

Summary of total abundance by species and station for demersal fish at the Point Loma Ocean Outfall trawl stations during 2006. Species abundance value is cumulative for 6 stations.

	January 2006						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species abundance by survey**
Pacific sanddab	220	181	215	241	309	280	1446
Yellowchin sculpin	162	50	224	7	18	19	480
Halfbanded rockfish	21	90	117	108	16	20	372
Dover sole	9	27	46	189	11	28	310
Longspine combfish	43	43	36	85	43	20	270
Shortspine combfish	8	17	10	25	2	5	67
Plainfin midshipman	23	8	3	8	12	8	62
English sole	2	1	21	11	16	7	58
Pink seaperch	18	5	1	24	2	6	56
Roughback sculpin	20	18			3	1	42
Stripetail rockfish	1	1	12	3	19	5	41
Hornyhead turbot	4	4	5	4	8	2	27
California tonguefish	12	5	1	4	4		26
California lizardfish	14	4		4	2	1	25
Greenstriped rockfish	1	5	4	4	3	3	20
Bigmouth sole	3	9	1		1	1	15
Spotfin sculpin	2	13					15
Blackbelly eelpout				9		4	13
Greenblotched rockfish	1		1	5	2	4	13
Pink rockfish			1	4		4	9
California scorpionfish			1	1	4	1	7
Pacific argentine	2	5					7
Blacktip poacher	1	1				1	3
California skate		1			1	1	3
Spotted ratfish	2	1					3
Bluebanded ronquil		1				1	2
Bluebarred prickleback	1						1
Flag rockfish		1					1
Greenspotted rockfish	1						1
Lingcod		1					1
Pygmy poacher		1					1
Chub mackerel	1						1
Squarespot rockfish		1					1
White croaker	1						1
QUARTER	573	494	699	736	476	422	3400

Appendix C.2 *continued*

	July 2006						
NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species abundance by survey**
Pacific sanddab	139	303	222	127	221	276	1288
Halfbanded rockfish	24	9	579	61	3	231	907
Dover sole	27	34	37	34	36	65	233
Shortspine combfish	17	26	13	30	1	5	92
Longspine combfish	10	3	3	16	10	8	50
Pink seaperch	8	3	7	4	3	7	32
Yellowchin sculpin	21		6				27
English sole	1	4	5	3	6	6	25
California lizardfish	6	7	2	1	3	3	22
Plainfin midshipman	10		1	2	8	1	22
Slender sole	5	9	1	5			20
Greenstriped rockfish	1	4	1	6	5	2	19
Stripetail rockfish	2		1		9	6	18
Hornyhead turbot	1	3	3	5	1	3	16
Spotfin sculpin		12					12
Pink rockfish				2	2	5	9
California tonguefish	1	5	2				8
Pacific argentine	8						8
Greenblotched rockfish			1		2	3	6
Roughback sculpin	5						5
Blackbelly eelpout		1			2	1	4
Spotted cuskeel	2				2		4
Bigmouth sole		2	1				3
California skate		1				2	3
Blacktip poacher		1				1	2
Bluespotted poacher	1		1				2
Starry skate		1				1	2
Flag rockfish						1	1
Pygmy poacher		1					1
Shortbelly rockfish			1				1
White croaker		1					1
QUARTER	289	430	887	296	314	627	2843
GRAND TOTAL	**862**	**924**	**1586**	**1032**	**790**	**1049**	**6243**

Appendix C.3

Summary of total biomass by species and station for demersal fish collected at the Point Loma Ocean Outfall trawl stations during 2006. Biomass is slighty overestimated due to weights less than 0.1kg.

	January 2006						
Name	SD7	SD8	SD10	SD12	SD13	SD14	Biomass by survey
Pacific sanddab	1.8	2.5	3.5	3.3	5.1	1.3	17.5
Longspine combfish	1.0	1.5	0.6	1.4	0.7	0.5	5.7
English sole	0.1	0.1	1.5	1.4	1.6	1.0	5.7
Dover sole	0.1	0.7	1.0	2.8	0.2	0.7	5.5
Halfbanded rockfish	0.2	1.4	1.5	1.5	0.4	0.3	5.3
California scorpionfish			0.4	0.2	1.2	0.6	2.4
Yellowchin sculpin	0.6	0.1	1.0	0.1	0.1	0.1	2.0
Hornyhead turbot	0.3	0.1	0.3	0.4	0.6	0.1	1.8
Shortspine combfish	0.1	0.4	0.2	0.5	0.1	0.1	1.4
Pink seaperch	0.3	0.1	0.1	0.5	0.1	0.1	1.2
Stripetail rockfish	0.1	0.1	0.2	0.1	0.3	0.1	0.9
California lizardfish	0.1	0.4		0.2	0.1	0.1	0.9
Bigmouth sole	0.1	0.4	0.1		0.1	0.1	0.8
Plainfin midshipman	0.2	0.1	0.1	0.1	0.2	0.1	0.8
California skate		0.1			0.1	0.5	0.7
California tonguefish	0.2	0.1	0.1	0.1	0.1		0.6
Greenstriped rockfish	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Spotted ratfish	0.3	0.2					0.5
Blackbelly eelpout				0.4		0.1	0.5
Greenblotched rockfish	0.1		0.1	0.1	0.1	0.1	0.5
Roughback sculpin	0.1	0.1			0.1	0.1	0.4
Blacktip poacher	0.1	0.1				0.1	0.3
Pink rockfish			0.1	0.1		0.1	0.3
Bluebanded ronquil		0.1				0.1	0.2
Pacific argentine	0.1	0.1					0.2
Spotfin sculpin	0.1	0.1					0.2
Bluebarred prickleback	0.1						0.1
Chub mackerel	0.1						0.1
Flag rockfish		0.1					0.1
Greenspotted rockfish	0.1						0.1
Lingcod		0.1					0.1
Pygmy poacher		0.1					0.1
Squarespot rockfish		0.1					0.1
White croaker	0.1						0.1
QUARTER	6.5	9.3	10.9	13.3	11.3	6.4	57.7

Appendix C.3 *continued*

	July 2006						
Name	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Biomass by survey**
Pacific sanddab	2.5	4.8	3.4	2.5	10.6	10.5	34.3
Halfbanded rockfish	0.4	0.1	5.8	1.1	0.1	6.2	13.7
Dover sole	1.0	1.1	1.2	1.0	1.5	2.5	8.3
Shortspine combfish	0.4	0.8	0.2	1.1	0.1	0.1	2.7
English sole	0.1	0.3	0.6	0.3	0.6	0.6	2.5
Hornyhead turbot	0.1	0.2	0.3	0.4	0.1	0.2	1.3
Longspine combfish	0.3	0.1	0.1	0.2	0.2	0.2	1.1
Plainfin midshipman	0.3		0.1	0.1	0.3	0.1	0.9
Greenstriped rockfish	0.1	0.1	0.1	0.2	0.1	0.1	0.7
Slender sole	0.1	0.3	0.1	0.1			0.6
California lizardfish	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Pink seaperch	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Stripetail rockfish	0.1		0.1		0.2	0.2	0.6
Flag rockfish						0.4	0.4
Blackbelly eelpout		0.1			0.1	0.1	0.3
California tonguefish	0.1	0.1	0.1				0.3
Greenblotched rockfish			0.1		0.1	0.1	0.3
Pink rockfish				0.1	0.1	0.1	0.3
Bigmouth sole		0.1	0.1				0.2
Blacktip poacher		0.1				0.1	0.2
Bluespotted poacher	0.1		0.1				0.2
California skate		0.1				0.1	0.2
Spotted cuskeel	0.1				0.1		0.2
Starry skate		0.1				0.1	0.2
White croaker		0.2					0.2
Yellowchin sculpin	0.1		0.1				0.2
Pacific argentine	0.1						0.1
Pygmy poacher		0.1					0.1
Roughback sculpin	0.1						0.1
Shortbelly rockfish			0.1				0.1
Spotfin sculpin		0.1					0.1
QUARTER	**6.2**	**9.0**	**12.8**	**7.3**	**14.4**	**21.9**	**71.6**
GRAND TOTAL	**12.7**	**18.3**	**23.7**	**20.6**	**25.7**	**28.3**	**129.3**

Appendix C.4

Summary of inter-group dissimilarity from the SIMPER procedure in PRIMER. Data are dissimilarity/standard deviation values for species that best discriminate between groups (i.e., dissimilarity/standard deviation ≥ 1.5). AD=average dissimilarity between groups.

Group1 vs	Group2	Average dissimilarity	Yellowchin sculpin	Plainfin midshipman	Longfin sanddab	Dover sole	Pink seaperch	English sole	Pacific sanddab	Gulf sanddab	Stripetail rockfish	Halfbanded rockfish	Greenblotched rockfish	Slender sole	Shortspine combfish	Squarespot rockfish	Spotfin sculpin	Bigfin eelpout
A	B	84																
A	C	62							2.1			4.4					3.0	
A	D	69																
A	E	76				2.2			4.4			2.6						
A	F	78				3.8		2.3	3.4			1.7		3.0	2.8			
A	G	83				3.2	1.6		2.9									
A	H	87				2.1			5.1									
A	I	84				2.0			5.9			3.7						
A	J	85			2.7				4.4			1.9						
A	K	78				1.9			5.1			2.8						
B	C	60	3.2	11.4		4.0	3.0			6.5								13.9
B	D	64																
B	E	59	2.7	6.5		2.1			1.6	6.5								6.4
B	F	58	1.6	5.6		2.2						1.6		2.8	2.8			
B	G	62		3.6					2.3	3.3								
B	H	65		7.1					3.8									
B	I	57	1.6	5.0		1.5			3.3									
B	J	68		3.0	3.3	3.1			2.5									
B	K	48	5.5	5.5		3.2	4.0			6.3								5.7
C	D	58							2.2		2.3	11.3	9.1			12.9		
C	E	52				1.5			2.0									
C	F	64	2.5			2.9			2.0			2.0		3.4	2.7			
C	G	70				2.6	1.8		2.4									
C	H	73				1.8			3.9									
C	I	60							3.3									
C	J	65			2.3				3.0									
C	K	49							2.0									
D	E	46		1.6		2.0					4.7	5.4	4.5			5.9		
D	F	42	1.9			6.4					1.7		2.2	3.0	2.0	5.3		
D	G	49		1.6		3.5	1.9						2.3			3.2		
D	H	60				2.1			3.1			3.3	3.7		8.5			
D	I	51				1.8			2.3			7.2	5.1			8.2		
D	J	55			3.2				1.7			3.8	3.9			4.3		
D	K	47				2.0						5.1	2.5			5.4		
E	F	46	2.2			1.9			1.5			1.6		2.7				
E	G	48				1.8		1.5										
E	H	48							1.8									
E	I	36																
E	J	44			2.6													
E	K	42																

Appendix C.4 *continued*

Group1 vs	Group2	Average dissimilarity	Yellowchin sculpin	Plainfin midshipman	Longfin sanddab	Dover sole	Pink seaperch	English sole	Pacific sanddab	Gulf sanddab	Stripetail rockfish	Halfbanded rockfish	Greenblotched rockfish	Slender sole	Shortspine combfish	Squarespot rockfish	Spotfin sculpin	Bigfin eelpout
F	G	44	1.5				2.1		1.6					2.5				
F	H	46	1.5						2.2			1.6		2.1	1.9			
F	I	46	1.9			1.5			1.7			1.8		2.9	3.0			
F	J	55	1.9		3.1	3.0			1.6			1.5		2.3	2.8			
F	K	50	2.2			2.5						1.7		3.0	2.5			
G	H	43																
G	I	42																
G	J	51			2.6	2.6	1.5											
G	K	55	1.6			2.1	2.1		1.5									
H	I	35																
H	J	41			3.1	1.8												
H	K	57							2.5									
I	J	35			2.3				1.6									
I	K	41							1.8									
J	K	49			2.6				1.7									

Appendix C5

List of megabenthic invertebrate taxa collected at PLOO stations SD7–SD14 during 2006 surveys. (N) = total number of individuals collected. Taxonomic arrangement from SCAMIT 2001.*

Taxon/Species	N
PORIFERA	
Demospongiae	
Hadromerida	
Suberitidae	
Suberites suberea	2
CNIDARIA	
ANTHOZOA	
Alcyonacea	
Muriceidae	
Thesea sp B	3
Pennatulacea	
Virgulariidae	
Acanthoptilum sp	734
Actiniaria	
Metridiidae	
Metridium farcimen	2
MOLLUSCA	
GASTROPODA	
Neotaeniglossa	
Ovulidae	
Neosimnia barbarensis	1
Neogastropoda	
Nassariidae	
Nassarius insculptus	1
Cancellariidae	
Cancellaria cooperii	1
Cancellaria crawfordiana	1
Turridae	
Megasurcula carpenteriana	3
Cephalaspidea	
Philinidae	
Philine auriformis	1
Notaspidea	
Pleurobranchidae	
Pleurobranchaea californica	14
Nudibranchia	
Platydordidae	
Platydoris macfarlandi	1
Tritoniidae	
Tritonia diomedea	6
Arminidae	
Armina california	4
CEPHALOPODA	
Sepiolida	
Sepiolidae	
Rossia pacifica	8
Octopoda	
Octopodidae	
Octopus rubescens	21

Appendix C.5 *continued*

Taxon/Species	N
HOLOTHURIODEA	
Aspidochirotida	
Stichopodidae	
Parastichopus californicus	55

*[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.6

Summary of total abundance by species and station for megabenthic invertebrates at the Point Loma Ocean Outfall trawl stations during 2006. Species abundance value is cumulative for 6 stations.

January 2006

NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species abundance by survey**
Lytechinus pictus	2025	3825	2160	740	500	42	9292
Allocentrotus fragilis				27	46	193	266
Acanthoptilum sp			15	75	11	1	102
Luidia foliolata	7	12	7	7	18	12	63
Sicyonia ingentis	40	2	1	2	1	3	49
Ophiura luetkenii	20		3		6	2	31
Astropecten verrilli	6		10	1	1		18
Parastichopus californicus	3	3	3	2	5		16
Octopus rubescens	2	5	2		4		13
Florometra serratissima	1	7					8
Rossia pacifica	3	1		2			6
Pleurobranchaea californica	1			1	2	1	5
Platymera gaudichaudii	1				3		4
Spatangus californicus	2	1				1	4
Armina californica				3			3
Luidia asthenosoma	3						3
Thesea sp B	1		1			1	3
Metridium farcimen				1			1
Nassarius insculptus			1				1
Neocrangon zacae	1						1
Ophiothrix spiculata	1						1
Paguristes turgidus						1	1
Philine auriformis				1			1
Suberites suberea						1	1
QUARTER	2117	3856	2203	862	597	258	9893

Appendix C.6 *continued*

July 2006

NAME	**SD7**	**SD8**	**SD10**	**SD12**	**SD13**	**SD14**	**Species abundance by survey**
Lytechinus pictus	1600	3200	1800	1350	508	140	8598
Allocentrotus fragilis	1	7	15	123	263	252	661
Acanthoptilum sp				600	30	2	632
Luidia foliolata	6		8	20	1	10	45
Parastichopus californicus	14	17	1	6	1		39
Sicyonia ingentis	28	1	4	5	1		39
Florometra serratissima	2	7			1	1	11
Astropecten verrilli		4	3	2			9
Pleurobranchaea californica				8	1		9
Octopus rubescens	1	2	1		2	2	8
Spatangus californicus					1	6	7
Paguristes turgidus	1	2			1	2	6
Tritonia diomedea	2		3			1	6
Brissopsis pacifica	1	4					5
Ophiura luetkenii				3	1	1	5
Megasurcula carpenteriana			1	2			3
Platymera gaudichaudii	2			1			3
Rossia pacifica	1		1				2
Armina californica					1		1
Cancellaria cooperii			1				1
Cancellaria crawfordiana				1			1
Hemisquilla californiensis		1					1
Henricia leviuscula	1						1
Metridium farcimen						1	1
Neosimnia barbarensis				1			1
Ophiothrix spiculata					1		1
Paralithodes californiensis	1						1
Platydoris macfarlandi				1			1
Podochela hemphillii						1	1
Podochela lobifrons	1						1
Suberites suberea					1		1
QUARTER	1662	3245	1838	2123	814	419	10101
GRAND TOTAL	**3779**	**7101**	**4041**	**2985**	**1411**	**677**	**19994**

Appendix D

Supporting Data

2006 PLOO Stations

Bioaccumulation of Contaminants in Fish Tissues

Appendix D.1

Lengths (L, cm) and weights (WT, g) of fishes used for each composite sample for the PLOO monitoring program during October 2006.

Station	Rep	Species	N	min L	max L	mean L	min WT	max WT	mean WT
RF1	1	Copper rockfish	3	26	32	30	494	1100	831
RF1	2	Copper rockfish	3	23	31	27	266	900	622
RF1	3	Copper rockfish	3	26	32	29	431	1000	647
RF2	1	Starry rockfish	3	21	26	24	265	459	363
RF2	2	Yellowtail rockfish	3	22	30	25	232	600	383
RF2	3	Yellowtail rockfish	3	25	27	26	383	400	393
Zone 1	1	Pacific sanddab	10	13	21	16	28	175	64
Zone 1	2	Pacific sanddab	14	12	17	14	24	68	43
Zone 1	3	Pacific sanddab	13	13	19	15	28	87	48
Zone 2	1	Pacific sanddab	12	14	17	15	37	80	52
Zone 2	2	Pacific sanddab	8	14	20	17	40	108	73
Zone 2	3	Pacific sanddab	10	15	16	15	40	59	47
Zone 3	1	Pacific sanddab	10	15	19	16	44	109	62
Zone 3	2	Pacific sanddab	4	17	23	20	63	223	122
Zone 3	3	Pacific sanddab	11	13	18	15	34	92	48
Zone 4	1	Pacific sanddab	5	15	23	17	51	103	69
Zone 4	2	Pacific sanddab	5	14	24	17	49	249	94
Zone 4	3	English sole	7	14	26	18	49	242	96

Appendix D.2

Constituents and method detection limits for fish tissue samples analyzed for the PLOO monitoring program during October 2006; na=not available.

		Method Detection Limits	
Parameter	**Units**	**Liver**	**Muscle**
Lipids	%wt	0.005	0.005
Total Solids	%wt	0.4	0.4
PCB Congeners			
PCB 101	ug/kg	13.3	1.33
PCB 105	ug/kg	13.3	1.33
PCB 110	ug/kg	13.3	1.33
PCB 114	ug/kg	13.3	1.33
PCB 118	ug/kg	13.3	na
PCB 119	ug/kg	13.3	1.33
PCB 123	ug/kg	13.3	1.33
PCB 126	ug/kg	13.3	1.33
PCB 128	ug/kg	13.3	1.33
PCB 138	ug/kg	13.3	na
PCB 149	ug/kg	13.3	1.33
PCB 151	ug/kg	13.3	1.33
PCB 153/168	ug/kg	13.3	na
PCB 156	ug/kg	13.3	1.33
PCB 157	ug/kg	13.3	1.33
PCB 158	ug/kg	13.3	1.33
PCB 167	ug/kg	13.3	1.33
PCB 169	ug/kg	13.3	1.33
PCB 170	ug/kg	13.3	1.33
PCB 177	ug/kg	13.3	1.33
PCB 18	ug/kg	33.3	1.33
PCB 180	ug/kg	13.3	na
PCB 183	ug/kg	13.3	1.33
PCB 187	ug/kg	13.3	na
PCB 189	ug/kg	13.3	1.33
PCB 194	ug/kg	13.3	1.33
PCB 201	ug/kg	13.3	1.33
PCB 206	ug/kg	13.3	1.33
PCB 28	ug/kg	13.3	1.33
PCB 37	ug/kg	13.3	1.33
PCB 44	ug/kg	13.3	1.33
PCB 49	ug/kg	13.3	1.33
PCB 52	ug/kg	13.3	1.33
PCB 66	ug/kg	13.3	1.33
PCB 70	ug/kg	13.3	1.33
PCB 74	ug/kg	13.3	1.33
PCB 77	ug/kg	13.3	1.33
PCB 81	ug/kg	13.3	1.33
PCB 87	ug/kg	13.3	1.33
PCB 99	ug/kg	13.3	1.33

Parameter	Units	Method Detection Limits	
		Liver	Muscle
Chlorinated Pesticides			
BHC, Alpha isomer	ug/kg	33.3	2
BHC, Beta isomer	ug/kg	13.3	2
BHC, Delta isomer	ug/kg	20	2
BHC, Gamma isomer	ug/kg	167	3.33
Alpha (cis) Chlordane	ug/kg	13.3	2
Cis Nonachlor	ug/kg	20	3.33
Gamma (trans) Chlordane	ug/kg	20	2
Heptachlor	ug/kg	33.3	3.33
Heptachlor epoxide	ug/kg	100	6.67
Oxychlordane	ug/kg	66.7	6.67
Trans Nonachlor	ug/kg	13.3	2
o,p-DDD	ug/kg	13.3	1.33
o,p-DDE	ug/kg	13.3	1.33
o,p-DDT	ug/kg	13.3	1.33
p,p-DDD	ug/kg	13.3	1.33
p,p-DDE	ug/kg	13.3	1.33
p,-p-DDMU	ug/kg	13.3	1.33
p,p-DDT	ug/kg	13.3	1.33
Aldrin	ug/kg	na	6.67
Alpha Endosulfan	ug/kg	167	33
Dieldrin	ug/kg	13.3	1.33
Endrin	ug/kg	13.3	1.33
Hexachlorobenzene	ug/kg	13.3	1.33
Mirex	ug/kg	13.3	1.33
Toxaphene	ug/kg	3333	333
Metals			
Aluminum (Al)	mg/kg	0.58	0.58
Antimony (Sb)	mg/kg	0.48	0.48
Arsenic (As)	mg/kg	0.38	0.38
Barium (Ba)	mg/kg	0.006	0.006
Beryllium (Be)	mg/kg	0.003	0.003
Cadmium (Cd)	mg/kg	0.029	0.029
Chromium (Cr)	mg/kg	0.08	0.08
Copper (Cu)	mg/kg	0.068	0.068
Iron (Fe)	mg/kg	0.096	0.096
Lead (Pb)	mg/kg	0.3	0.3
Manganese (Mn)	mg/kg	0.007	0.007
Mercury (Hg)	mg/kg	0.03	0.03
Nickel (Ni)	mg/kg	0.094	0.094
Selenium (Se)	mg/kg	0.06	0.06
Silver (Ag)	mg/kg	0.057	0.057
Thallium (Tl)	mg/kg	0.85	0.85
Tin (Sn)	mg/kg	0.24	0.24
Zinc (Zn)	mg/kg	0.049	0.049

Appendix D.3

Summary of constituents that make up total DDT, total PCB, and total chlordane in each sample collected as part of the PLOO monitoring program during October 2006.

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	RF1	1	Copper rockfish	Muscle	p,p-DDD	0.1	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	p,p-DDE	4.9	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	PCB 118	0.25	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	PCB 138	0.25	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	PCB 149	0.1	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	PCB 153/168	0.4	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	PCB 180	0.1	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	PCB 187	0.1	ug/kg
2006-4	RF1	1	Copper rockfish	Muscle	PCB 99	0.1	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	p,p-DDD	0.1	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	p,p-DDE	5.2	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 101	0.1	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 110	0.1	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 118	0.2	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 138	0.2	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 149	0.1	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 153/168	0.4	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 180	0.2	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 187	0.1	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	PCB 99	0.1	ug/kg
2006-4	RF1	2	Copper rockfish	Muscle	Trans Nonachlor	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	o,p-DDE	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	p,p-DDD	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	p,p-DDE	4.3	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	p,-p-DDMU	0.2	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 101	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 105	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 110	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 118	0.2	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 138	0.2	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 149	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 153/168	0.4	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 180	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 187	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 49	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 52	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	PCB 99	0.1	ug/kg
2006-4	RF1	3	Copper rockfish	Muscle	Trans Nonachlor	0.2	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	Alpha (cis) Chlordane	0.3	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	o,p-DDE	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	p,p-DDD	0.4	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	p,p-DDE	18	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	p,-p-DDMU	0.5	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	p,p-DDT	0.3	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 101	0.4	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 105	0.2	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 110	0.3	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 118	0.7	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 128	0.2	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 138	1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 149	0.4	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 151	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 153/168	1.6	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 156	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 158	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 170	0.2	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 180	0.5	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 183	0.2	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 187	0.4	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 201	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 206	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 49	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 52	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 66	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 74	0.1	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	PCB 99	0.3	ug/kg
2006-4	RF2	1	Starryl rockfish	Muscle	Trans Nonachlor	0.3	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	p,p-DDE	6.3	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	PCB 105	0.1	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	PCB 118	0.2	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	PCB 138	0.3	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	PCB 149	0.1	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	PCB 153/168	0.3	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	PCB 180	0.1	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	PCB 99	0.1	ug/kg
2006-4	RF2	2	Yellowtail rockfish	Muscle	Trans Nonachlor	0.1	ug/kg
2006-4	RF2	3	Yellowtail rockfish	Muscle	p,p-DDD	0.3	ug/kg
2006-4	RF2	3	Yellowtail rockfish	Muscle	p,p-DDE	3.3	ug/kg
2006-4	RF2	3	Yellowtail rockfish	Muscle	PCB 138	0.2	ug/kg
2006-4	RF2	3	Yellowtail rockfish	Muscle	PCB 153/168	0.2	ug/kg
2006-4	RF2	3	Yellowtail rockfish	Muscle	PCB 180	0.1	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.2	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	Cis Nonachlor	4.1	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	o,p-DDE	2.8	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	o,p-DDT	1.5	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	p,p-DDD	3.9	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	p,p-DDE	360	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	p,-p-DDMU	12	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	p,p-DDT	4.8	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 101	10	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 105	6.5	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 110	10	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 118	24	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 123	2.4	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 128	6.1	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 138	37	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 149	7.6	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 151	5	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 153/168	59	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 156	3.2	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 158	2.7	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 170	9.9	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 177	4.2	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 180	23	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 183	6.1	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 187	21	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 194	6.4	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 201	6.3	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 206	3.2	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 28	1	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 44	1.1	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 49	2.7	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 52	4	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 66	2.9	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 70	2.3	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 74	1.8	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 87	2.9	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	PCB 99	17	ug/kg
2006-4	TFZONE1	1	Pacific sanddab	Liver	Trans Nonachlor	10	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	6.9	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	Cis Nonachlor	4.8	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	Gamma (trans) Chlordane	1.7	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	o,p-DDE	3.7	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	o,p-DDT	1.4	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	p,p-DDD	5.4	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	p,p-DDE	410	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	p,-p-DDMU	14	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	p,p-DDT	6.4	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 101	8.9	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 105	6.2	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 110	7.8	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 118	23	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 123	2.4	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 128	7	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 138	39	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 149	6.8	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 151	4.3	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 153/168	61	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 156	3.9	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 157	1.1	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 158	3.2	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 170	11	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 177	2.9	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 180	29	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 183	7.3	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 187	23	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 194	7.4	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 201	7.9	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 206	4.5	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 28	1.3	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 49	2.6	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 52	3.2	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 66	2.9	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 70	2.8	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 74	1.9	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 87	2	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	PCB 99	16	ug/kg
2006-4	TFZONE1	2	Pacific sanddab	Liver	Trans Nonachlor	11	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	5	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	Cis Nonachlor	3.7	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	Gamma (trans) Chlordane	1.4	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	o,p-DDE	3.3	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	o,p-DDT	1.3	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	p,p-DDD	5.2	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	p,p-DDE	330	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	p,-p-DDMU	12	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	p,p-DDT	5.5	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 101	8.7	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 105	6.1	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 110	10	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 118	22	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 123	2.2	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 128	6.5	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 138	36	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 149	5.8	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 151	4.9	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 153/168	59	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 156	3.5	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 158	2.8	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 170	10	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 177	3.4	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 180	24	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 183	6.4	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 187	22	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 194	7.2	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 201	7.9	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 206	4.2	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 28	1.4	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 44	1.6	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 49	3.9	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 52	6.6	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 66	3.2	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 70	3.5	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 74	2	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 87	2.2	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	PCB 99	14	ug/kg
2006-4	TFZONE1	3	Pacific sanddab	Liver	Trans Nonachlor	8.4	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	3.9	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	o,p-DDE	1.8	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	p,p-DDD	3	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	p,p-DDE	220	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	p,-p-DDMU	7.3	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	p,p-DDT	3.1	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 101	3.6	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 105	3.3	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 110	4.2	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 118	11	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 123	1.6	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 128	4.1	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 138	20	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 149	3.1	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 151	2.4	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 153/168	32	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 156	2	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 157	0.7	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 158	1.4	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 170	5.7	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 177	1.8	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 180	15	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 183	3.7	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 187	13	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 194	4.5	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 201	4	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 206	2.4	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 28	0.6	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 49	1.2	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 52	1.8	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 66	1.4	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 70	1.3	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 74	0.8	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	PCB 99	7.3	ug/kg
2006-4	TFZONE2	1	Pacific sanddab	Liver	Trans Nonachlor	5.7	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	4.1	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	Cis Nonachlor	2.6	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	o,p-DDE	2.4	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	p,p-DDD	3	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	p,p-DDE	280	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	p,-p-DDMU	9.3	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE2	2	Pacific sanddab	Liver	p,p-DDT	4	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 101	4.9	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 105	4.9	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 110	7.1	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 118	17	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 123	2.1	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 128	5.6	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 138	28	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 149	4.7	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 151	3.8	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 153/168	46	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 156	3.2	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 157	0.8	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 158	2.3	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 170	9	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 177	3.7	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 180	22	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 183	6.1	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 187	19	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 194	6.4	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 201	7.1	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 206	3.5	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 28	0.8	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 49	1.4	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 52	2.1	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 66	1.6	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 70	1.4	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 74	1.1	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	PCB 99	9.7	ug/kg
2006-4	TFZONE2	2	Pacific sanddab	Liver	Trans Nonachlor	6.2	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.3	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	Cis Nonachlor	2.9	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	o,p-DDE	2.9	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	p,p-DDD	4.3	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	p,p-DDE	300	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	p,-p-DDMU	11	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	p,p-DDT	4	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 101	5.1	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 105	5.2	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 110	6.8	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 118	17	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 123	2.2	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 128	4.7	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 138	25	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 149	4.1	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 151	3.7	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 153/168	41	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 156	2.6	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 157	0.7	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 158	2	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 170	6.6	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 177	2.3	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 180	15	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 183	4.4	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 187	14	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 194	4.2	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 201	4.3	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 206	2.5	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 28	1.2	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 44	0.7	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 49	1.8	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 52	2.5	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 66	1.9	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 70	1.8	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 74	1.2	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	PCB 99	9.1	ug/kg
2006-4	TFZONE2	3	Pacific sanddab	Liver	Trans Nonachlor	7.5	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.7	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	Cis Nonachlor	4.5	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	Gamma (trans) Chlordane	1.1	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	o,p-DDE	3.6	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	p,p-DDD	5.1	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	p,p-DDE	430	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	p,-p-DDMU	14	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	p,p-DDT	4.4	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 101	13	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 105	12	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 110	17	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 118	46	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 119	1.6	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 123	3.9	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 128	12	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 138	65	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 149	10	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 151	7.9	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 153/168	98	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 156	6	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 157	1.3	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 158	5.6	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 170	14	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 177	4.9	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 180	36	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 183	11	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 187	31	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 194	9	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 201	9.8	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 206	5.4	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 28	1.8	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 44	1.5	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 49	4.1	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 52	6.3	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 66	4.2	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 70	3.4	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 74	2.6	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 87	4.2	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	PCB 99	26	ug/kg
2006-4	TFZONE3	1	Pacific sanddab	Liver	Trans Nonachlor	11	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	6.6	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	Cis Nonachlor	5.2	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	Gamma (trans) Chlordane	1.6	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	o,p-DDE	3.4	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	o,p-DDT	1.4	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	p,p-DDD	6.2	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	p,p-DDE	370	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	p,-p-DDMU	18	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	p,p-DDT	5.3	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 101	18	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 105	17	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 110	17	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 118	60	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 119	1.5	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 123	4.5	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 128	11	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 138	54	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 149	12	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 151	7.3	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 153/168	82	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 156	6.3	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 157	1.6	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 158	4.8	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 170	10	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 177	4.9	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 180	26	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 183	6.9	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 187	24	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 194	5.8	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 201	7.5	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 206	3.8	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 28	1.4	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 44	1.8	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 49	4.9	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 52	9.7	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 66	3.9	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 70	4.8	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 74	2.6	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 87	4.9	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	PCB 99	23	ug/kg
2006-4	TFZONE3	2	Pacific sanddab	Liver	Trans Nonachlor	8.8	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	5.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	Cis Nonachlor	3.95	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	Gamma (trans) Chlordane	1.3	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	o,p-DDE	2.95	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	o,p-DDT	1.25	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	p,p-DDD	5.1	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	p,p-DDE	355	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	p,-p-DDMU	11	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	p,p-DDT	4.85	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 101	19.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 105	11.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 110	22.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 118	46	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 119	1.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 123	4.15	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 128	11	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 138	59	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 149	13	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 151	7.75	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 153/168	90	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 156	5.45	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 157	1.4	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 158	4.9	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 170	13	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 177	5.05	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 18	1.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 180	32.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 183	9.25	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 187	29.5	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 194	7.95	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 201	9.05	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 206	4.6	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 28	2	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 44	1.75	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 49	8.85	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 52	11	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 66	5.75	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 70	5.4	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 74	2.85	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 87	5.4	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	PCB 99	26	ug/kg
2006-4	TFZONE3	3	Pacific sanddab	Liver	Trans Nonachlor	9.3	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	Alpha (cis) Chlordane	6.3	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	Cis Nonachlor	3.2	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE4	1	Pacific sanddab	Liver	o,p-DDE	2.3	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	p,p-DDD	3.5	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	p,p-DDE	340	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	p,-p-DDMU	8.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	p,p-DDT	3.3	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 101	7	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 105	5.4	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 110	6	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 118	20	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 119	0.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 123	2.5	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 128	5	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 138	30	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 149	6.5	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 151	4.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 153/168	54	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 156	2.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 157	0.7	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 158	2.3	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 170	7.5	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 177	2.6	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 180	20	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 183	5.7	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 187	15	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 194	4.4	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 201	4.9	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 206	2.2	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 44	0.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 49	1.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 52	2.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 66	1.6	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 70	1.8	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 74	1.2	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 87	2.3	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	PCB 99	11	ug/kg
2006-4	TFZONE4	1	Pacific sanddab	Liver	Trans Nonachlor	7.5	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	Alpha (cis) Chlordane	7.3	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	Cis Nonachlor	4.2	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	o,p-DDE	2.4	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	p,p-DDD	6.2	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	p,p-DDE	340	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	p,-p-DDMU	18	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	p,p-DDT	4.8	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 101	8.7	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 105	4.5	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 110	7.1	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 118	17	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 123	2.1	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 128	3.7	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 138	23	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 149	7.6	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 151	4.1	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 153/168	40	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 156	2.3	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 157	0.6	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 158	1.7	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 170	5.5	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 177	2.9	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 180	15	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 183	4.3	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 187	15	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 194	3.9	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 201	4.2	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 206	2.2	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 28	1.1	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 44	1.3	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 49	2.2	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 52	3.8	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 66	2.1	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 70	2.3	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 74	1.2	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 87	2.5	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	PCB 99	8.9	ug/kg
2006-4	TFZONE4	2	Pacific sanddab	Liver	Trans Nonachlor	8	ug/kg
2006-4	TFZONE4	3	English sole	Liver	o,p-DDD	1.6	ug/kg
2006-4	TFZONE4	3	English sole	Liver	o,p-DDE	47	ug/kg
2006-4	TFZONE4	3	English sole	Liver	p,p-DDD	12	ug/kg
2006-4	TFZONE4	3	English sole	Liver	p,p-DDE	780	ug/kg
2006-4	TFZONE4	3	English sole	Liver	p,-p-DDMU	70	ug/kg
2006-4	TFZONE4	3	English sole	Liver	p,p-DDT	2.1	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 101	9.7	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 105	5.1	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 110	11	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 118	20	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 119	1.2	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 123	2.6	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 128	4.2	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 138	21	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 149	14	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 151	4.4	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 153/168	36	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 156	1.8	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 158	1.9	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 170	5.3	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 177	3.8	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 180	13	ug/kg

Appendix D.3 *continued*

Date	Station	Rep	Species	Tissue	Parameter	Value	Units
2006-4	TFZONE4	3	English sole	Liver	PCB 183	3.5	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 187	14	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 194	3.9	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 201	5	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 206	2.6	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 28	2.9	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 44	1	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 49	4.3	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 52	2.7	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 66	6.3	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 70	2.3	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 74	2.3	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 87	3	ug/kg
2006-4	TFZONE4	3	English sole	Liver	PCB 99	11	ug/kg
2006-4	TFZONE4	3	English sole	Liver	Trans Nonachlor	3.3	ug/kg

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