# Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant) 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
9174 Sky Park Court, Suite 100
San Diego, CA 92123

Attention: POTW Compliance Unit

Dear Sir:

Enclosed is the 2006 Annual Receiving Waters Monitoring Report for NPDES Permit No. CA0109045, Order No. 2000-129, for the City of San Diego South Bay Water Reclamation Plant (SBWRP) discharge through the South Bay 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, macrobenthic communities, demersal fishes and megabenthic invertebrates, and bioaccumulation of contaminants in fish tissues. These data are also presented in the International Boundary and Water Commission's annual report for discharge from the International Wastewater Treatment Plant (NPDES Permit No. CA0108928, Order No. 96-50).

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 the 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

cc: Department of Environmental Health, County of San Diego
U.S. Environmental Protection Agency, Region 9
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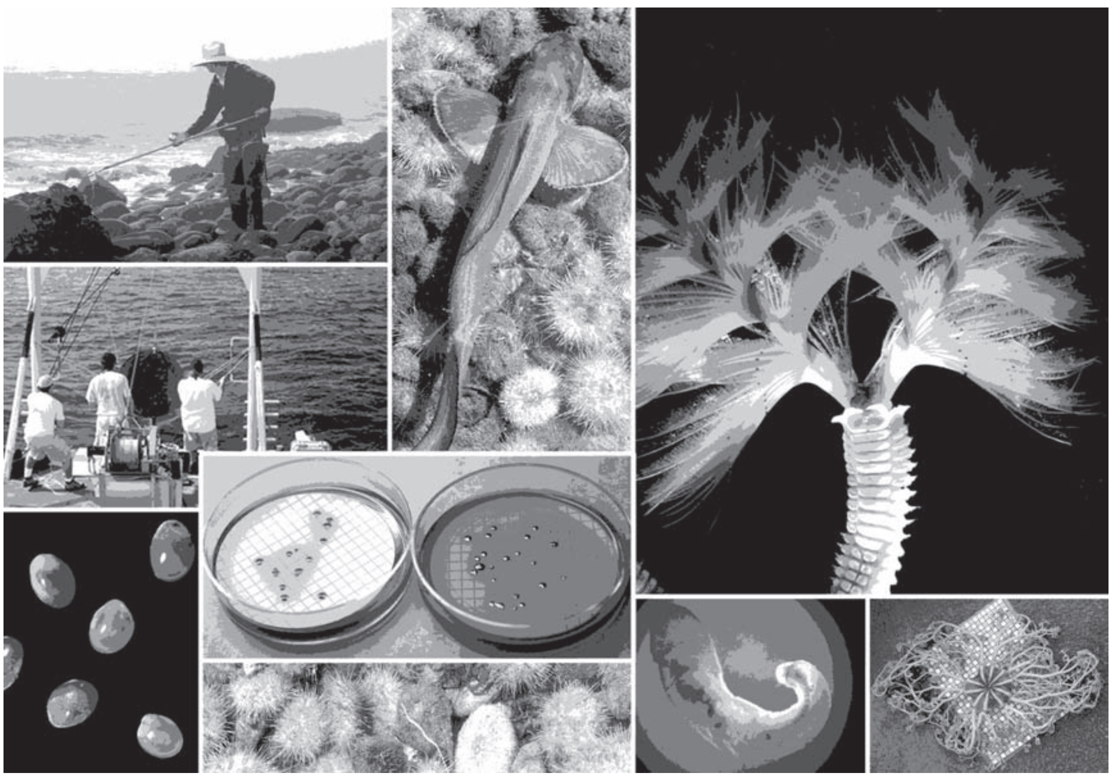
# *Annual Receiving Waters Monitoring Report*

for the

# South Bay Ocean Outfall

## (South Bay Water Reclamation Plant)

## 2006




Prepared by:

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Environmental Monitoring and Technical Services Division Laboratory
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Ocean Monitoring Program



June 2007

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# *Executive Summary*

The monitoring and reporting requirements for the City of San Diego (City) South Bay Water Reclamation Plant (SBWRP) and International Boundary and Water Commission (IBWC) International Wastewater Treatment Plant (IWTP) are outlined in NPDES Permits Nos. CA0109045 and CA0108928, respectively. Since effluent from the SBWRP and IWTP commingles as it is discharged through the South Bay Ocean Outfall (SBOO), the receiving water monitoring requirements are similar and a single ocean monitoring program is conducted by the City to comply with both permits. The main objective of the South Bay ocean monitoring program is to assess the impact of wastewater discharged through the SBOO on the marine environment off southern San Diego, including effects on water quality, sediment conditions, and marine organisms. The study area centers around the SBOO discharge site, which is located approximately 5.6 km offshore at a depth of 27 m. Monitoring at sites along the shore extends from Coronado southward to Playa Blanca, northern Baja California, while offshore monitoring occurs in an adjacent area overlying the coastal continental shelf at sites ranging in depth from 9 to 55 m.

Prior to the initiation of wastewater discharge in 1999, the City of San Diego conducted a 3½-year baseline study designed to characterize background environmental conditions in the South Bay region in order to provide information against which post-discharge data could be compared. Additionally, a region-wide survey of benthic conditions is typically conducted each year at randomly selected sites from Del Mar to the US/Mexico border. Such 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 are presented herein.

The receiving waters monitoring effort for the South Bay region may be 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 various physical and chemical oceanographic parameters are evaluated to characterize water mass transport potential in the region. Water quality monitoring along the shore and in offshore waters includes the measurement of bacteriological indicators to assess the potential effects of both natural and anthropogenic inputs, and determine compliance with 2001 California Ocean Plan (COP) bacteriological standards for water contact areas. Benthic monitoring includes sampling and analyses of soft-bottom macrofaunal communities and their associated sediments, while communities of demersal fish and megabenthic invertebrates are the focus of trawling activities. Bioaccumulation studies to determine whether contaminants are present in the tissues of local species supplement the monitoring of fish populations. In addition to the above activities, the City and the International Boundary and Water Commission support 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. These results are incorporated herein into the interpretations of oceanographic and microbiological data (see Chapters 2 and 3).

The present report focuses on the results of all ocean monitoring activities conducted in the South Bay region during 2006. An overview and summary of the main findings for each of the major components of the monitoring program are included below.

## OCEANOGRAPHIC CONDITIONS

Although the seasonal transition for water temperatures occurred relatively early in the year (June–July rather than August–September), oceanographic conditions in the South Bay region were generally similar to previous patterns. Thermal stratification of the water column followed the typical cycle with maximum stratification in mid-summer and reduced stratification during winter. Relatively low annual rainfall generated less stormwater runoff in 2006 than in the previous year. Aerial imagery from the remote sensing study indicated that the outfall plume was present in shallow sub-surface waters from January through April and in December when the water column was well-mixed, and was deeply submerged during May–November when the water column was stratified. In general, data from both oceanographic measurements and aerial imagery provide no evidence that any water quality parameter (e.g., dissolved oxygen, pH) changed significantly due to wastewater discharge via the SBOO. In addition, a historical review of oceanographic data did not reveal any changes in water parameters related to the beginning of discharge in January 1999. Instead, these data indicate that natural events such as stormwater runoff and large scale oceanographic events explain most of the observed temporal and spatial variability in water quality parameters in the South Bay region.

## MICROBIOLOGY

The greatest effects on nearshore water quality conditions in the South Bay region in 2006 appeared to be associated with river discharge and runoff during storm events. For example, despite a lower annual rainfall, annual mean concentrations of fecal coliform bacteria along the shoreline near the Tijuana River in 2006 were similar to levels seen during 2005, a year with much heavier rain. However, bacterial densities at individual shore and kelp stations were lower overall, resulting in rates of compliance with 2001 COP standards that were much higher. Data from the offshore sites suggested that the wastewater plume was confined to sub-surface waters from March through November when the water column was stratified. In contrast, bacterial counts indicative of wastewater were evident in surface waters near the SBOO only during January when the water column was well-mixed. Overall, various water quality data suggest that elevated bacterial counts detected along the shore in 2006 were not caused by the shoreward transport of wastewater from the outfall. Instead, bacterial levels in nearshore waters correspond more to inputs and the transport of materials from the Tijuana River and Los Buenos Creek.

Historical analyses of various water quality parameters support the above results. Overall mean densities of total and fecal coliforms were lower at shore stations during the post-discharge period (1999–present) relative to the pre-discharge period (1995–1998). However, differences between these periods varied widely by station, with station S5, located nearest to the Tijuana River, demonstrating the greatest decline during the post-discharge period. At the kelp stations, mean total coliform density also declined during the post-discharge period while fecal coliform and enterococcus densities increased slightly. In contrast, post-discharge mean bacteriological densities at the offshore stations increased and were highest nearest the SBOO discharge site.

## SEDIMENT QUALITY

The composition and quality of ocean sediments in the South Bay area were similar in 2006 to those observed during previous years. Sediments at most sites were dominated by fine sands with grain size tending to increase with depth. Stations located offshore and southward of the SBOO discharge area consisted of very coarse sediments, while sites located in shallower water and north of the outfall towards San Diego Bay had finer sediments.

Mean concentrations of total organic carbon (TOC) in South Bay sediments were higher in 2006 than in previous surveys, whereas total nitrogen (TN) values declined slightly. The increase in TOC was due mostly to an unusually high value at one station in July, along with increases of ~25% relative to 2005 values at several other shallow water sites. Trace metal concentrations decreased relative to 2005 with most values below pre-discharge levels. However, arsenic was present in concentrations above the Effects-Range-Low

(ERL) sediment quality threshold at one site north of the outfall while copper concentrations were above the ERL at one location south of the SBOO. Other contaminants (e.g., pesticides, PCB, PAH) were detected infrequently or at low levels during the year. Overall analyses of particle size and sediment chemistry data collected in 2006 provide no indication of contamination attributable to wastewater discharge.

## MACROBENTHIC INVERTEBRATE COMMUNITIES

Benthic communities in the SBOO region included macrofaunal assemblages that varied along gradients of sediment structure and depth. Assemblages surrounding the SBOO in 2006 were similar to those that occurred during previous years. Most sites contained high abundances of the spionid polychaete *Spiophanes bombyx*, a species characteristic of other shallow-water assemblages in the Southern California Bight (SCB). This shallow water group was represented by several distinct sub-assemblages according to differences in sediment structure (i.e., either more fines or more coarse materials). Another type of assemblage occurred at sites from slightly deeper water where the sediments contained finer particles, and probably represents a transition between assemblages occurring in shallow sandy habitats and those occurring in finer mid-depth sediments off southern California. This assemblage also contained relatively high numbers of *S. bombyx*, but was distinguished from the shallow-water assemblages by denser populations of the polychaetes *S. duplex* and *Prionospio jubata*, the amphipod *Ampelisca agassizi*, and the tanaid *Leptochelia dubia*. Finally, sites with sediments composed of relict red sands or varied amounts of other coarse sand or shell hash were characterized by unique assemblages.

Species richness and abundance also varied with depth and sediment type in the region, although there were no clear patterns with respect to distance from the outfall. The range of values for most community parameters was similar in 2006 to that seen in previous years, and most environmental disturbance indices such as the BRI and ITI were characteristic of undisturbed sediments. In addition, changes in benthic community structure in the South Bay region that occurred during the year were similar in magnitude to those that have occurred previously and elsewhere off southern California. Such changes often correspond to large-scale oceanographic processes or other natural events. Overall, benthic assemblages in the region remain similar to those observed prior to wastewater discharge and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf. There was no evidence that the SBOO wastewater discharge has caused degradation of the benthos in the area.

## DEMERSAL FISH AND MEGABENTHIC INVERTEBRATE COMMUNITIES

As in previous years, speckled sanddabs continued to dominate South Bay fish assemblages in 2006. Although the numbers of speckled sanddabs have declined markedly from their peak in 2004, this species occurred at all stations and accounted for 49% of the total catch in 2006. Other characteristic, but less abundant, species included the California lizardfish, yellowchin sculpin, longfin sanddab, hornyhead turbot, California tonguefish, roughback sculpin, and English sole. Although fish assemblages varied among stations, these differences were mostly due to variations in speckled sanddab and California lizardfish populations.

The sea star *Astropecten verrilli,* dominated the large (megabenthic) trawl-caught invertebrate assemblages. Although community structure of these organisms also varied between sites, low species richness, abundance, biomass, and diversity generally characterized these assemblages.

Overall, results of the 2006 trawl surveys provide no evidence that the discharge of wastewater has affected either fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of species were similar at stations located near the outfall and further away. Finally, the absence of physical abnormalities or evidence of disease on local fishes suggests that populations remain healthy in the region.

## CONTAMINANTS IN FISH TISSUES

There was no clear evidence to suggest that tissue contaminant loads in fish tissues were affected by the discharge of wastewater in 2006. Although various contaminants were detected in both liver and muscle tissues, concentrations of most contaminants were not substantially different from those reported prior to discharge.

The occurrence of both metals and chlorinated hydrocarbons in the tissues of South Bay fishes may be due to many factors, including the ubiquitous distribution of many contaminants in coastal sediments off southern California. Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. Exposure to contaminants can vary greatly between species and even among individuals of the same species depending on migration habits. Fish may be exposed to pollutants in a highly contaminated area and then move into a region that is less contaminated. This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many other point and non-point sources that may contribute to contamination in the region.

## SAN DIEGO REGIONAL SURVEY

In the summer of 2006, the City revisited 40 randomly chosen sites initially selected for 1996 survey in order to compare conditions 10 years later. Thirty-four sites ranging in depth from 12–197 m were successfully sampled during the 2006 survey. In addition, 7 repeat sites were sampled in 1995, 1996, 1997, 2005, and 2006.

Overall, the sediments reflect the diverse and patchy habitats common to the SCB. Stations between 31 and 120 m in depth were composed primarily of 63% sands and 36% fine particles and represent most of the mid-shelf region off San Diego. By comparison, sites occurring at shallow depths contained 81% sands and 19% fines, while sediments at deeper sites contained 57% sands and 41% fines. Stations with the most coarse sediments occurred in shallow waters offshore of the SBOO, and along the Coronado Bank, a southern rocky ridge located offshore of Point Loma. Relict sediments typical of the area offshore of the Tijuana River were found west of the SBOO. Sediment composition at shallow water sites from this survey and those included in the regular semi-annual sampling grid surrounding the SBOO were generally similar. In contrast, stations from the deeper semi-annual transects were composed of more sand and less fine materials than comparable mid-shelf samples.

Higher values for TOC and TN occurred in sediments from the deep and mid-shelf stations. For example, mean TOC values increased from the shallow-shelf to the deep water sites following the progression of increased percent fines. In contrast, the highest average concentrations of sulfides occurred among the shallow-shelf stations. In general, average concentrations of TOC and TN from the 2006 survey were slightly higher than 1996 values, and were indicative of a trend towards increased organics through time. Concentrations of several metals correlated with increasing percentage of fines or appeared to be associated with nearby sources of anthropogenic inputs such as ocean outfalls and dredge spoils disposal sites. Average concentrations for most metals were higher in deep shelf sediments where fine particles were more prevalent. Concentrations of trace metals in sediments were relatively similar between the 1996 and 2006 surveys. Concentrations of other contaminants (e.g., pesticides, PAHs, PCBs) were also greater in the sediments containing more fine particles. Contaminant levels at the shallow stations included in the SBOO semi-annual sampling grid contained higher TOC and lower sulfide concentrations, but similar metals concentrations relative to the shallow water samples from the regional survey. In contrast, sediments at the deeper stations had lower levels of organics and trace metals than comparable mid-shelf samples. Overall, the 2006 regional survey data did not show any pattern of impact relative to wastewater discharge from the SBOO, although patterns associated with other anthropogenic sources (e.g., dredge spoils disposal) were evident.

The SCB benthos has long been considered a heterogeneous habitat, with the distribution of species and communities varying in space and time. The SCB shelf consists largely of an *Amphiodia* mega-community with other sub-communities representing simple variations determined by differences in substrate type and microhabitat. Results of the 2006 and previous regional surveys off San Diego generally support this characterization. The 2006 benthic assemblages were very similar to those sampled at the same sites 10 years previously (1996) and segregated mostly due to differences in habitat type (e.g., depth and sediment grain size). There was little evidence of anthropogenic impact. One assemblage characterized over 60% of the benthos off San Diego, with the ophiuroid *Amphiodia urtica* representing the dominant species. Co-dominant species within this assemblage included other taxa common to the region, such as the polychaetes *Prionospio jubata* and *Spiophanes duplex*, and the bivalve mollusc *Axinopsida serricata*. This group occurred along the mainland shelf at depths from 44 to 94 m, and in sediments containing a relatively high percentage of fine particles (e.g., 43% fines).

In contrast, the dominant species of other assemblages occurring in the region varied according to the sediment type or depth. Shallow water assemblages (<30 m) were generally composed of more coarse sediments and highly variable depending upon their sediment composition. At many of the stations comprising these assemblages, polychaete species such as *Monticellina siblina, Spiophanes bombyx*, and *Scoletoma* sp were numerically dominant. These assemblages were largely similar to other shallow, sandy sediment communities in the SCB. A deep-water assemblage located at depths >180 m was dominated by the polychaetes *S. kimballi* and *Paradiopatra parva,* and the mollusc *Compressidens stearnsi*. These sites had the highest percentage of fine particles and the second highest concentration of organic carbon were low in species richness.

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# Chapter 1. General Introduction

## INTRODUCTION

The South Bay Ocean Outfall (SBOO) discharges treated effluent to the Pacific Ocean that originates from 2 separate sources: the City of San Diego's South Bay Water Reclamation Plant (SBWRP) and the International Wastewater Treatment Plant (IWTP) operated by the International Boundary and Water Commission (IBWC). Wastewater discharge from the IWTP began on January 13, 1999 and is presently performed under the terms and conditions set forth in Order No. 96–50, Cease and Desist Order No. 96–52 for NPDES Permit No. CA0108928. Discharge from the SBWRP began on May 6, 2002 and was performed under Order No. 2000-129, NPDES Permit No. CA0109045 through December 31, 2006; this order has been replaced by Order No. R9-2006-0067 effective January 1, 2007. The Monitoring and Reporting Programs (MRPs) included in the above permits define the requirements for monitoring receiving waters in the region, including sampling plans, compliance criteria, laboratory analyses, and data analyses and reporting guidelines.

All receiving waters monitoring for the South Bay region with respect to the above referenced permits has been performed by the City of San Diego since discharge began in 1999. The City also conducted a baseline monitoring program for 3½-years before discharge began in order to characterize background environmental conditions for the SBOO region (City of San Diego 2000a). The results of this baseline study provide background information against which the post-discharge data may be compared. In addition, the City has conducted annual region-wide surveys off the coast of San Diego since 1994 either as part of regular South Bay monitoring requirements (e.g., City of San Diego 1998, 1999, 2000b, 2001, 2002, 2003, 2006) or as part of larger, multi-agency surveys of the entire Southern California Bight (e.g., Bergen et al. 1998, 2001, Noblet et al. 2002, Ranasinghe et al. 2003, 2007, Schiff et al. 2006). Such regional surveys are useful in characterizing the ecological health of diverse coastal areas and may help to identify and distinguish reference sites from those impacted by wastewater discharge, stormwater input or other sources of contamination.

Finally, the City of San Diego and the IBWC also contract with Ocean Imaging Corporation (Solana Beach, CA) to conduct a remote sensing program for the San Diego/Tijuana region as part of the ocean monitoring programs for the Point Loma and South Bay areas. Imagery from satellite data and aerial sensors produces a synoptic look at surface water clarity that is not possible using shipboard sampling alone. However, a major limitation of aerial and satellite images is that they only provide information about surface or near-surface waters (~0–15 m) without providing any direct information regarding the movement, color, or clarity of water in deeper layers. In spite of these limitations, one objective of this ongoing project is to ascertain relationships between the various types of imagery and data collected in the field. With public health issues being a paramount concern of ocean monitoring programs, any information that helps to provide a clearer and more complete picture of water conditions is beneficial to the general public as well as to program managers and researchers. Having access to a large-scale overview of surface waters within a few hours of image collection also has the potential to bring the monitoring program closer to real-time diagnosis of possible contamination conditions and add predictability to the impact that natural events such as storms and heavy rains may have on shoreline water quality.

This report presents the results of all receiving waters monitoring conducted as part of the South Bay monitoring program in 2006, including sampling at both regular fixed sites around the SBOO and randomly selected sites for the annual benthic survey of the entire San Diego region. The results of the remote sensing surveys conducted during the year are also considered and integrated into interpretations of oceanographic and water quality data (e.g., bacteria levels, total suspended solids, oil and grease). Comparisons are also made to conditions present during previous years in order to evaluate any changes that may have occurred related to the outfall or natural events. The major components of the monitoring program are covered in the following chapters: Oceanographic Conditions, Microbiology, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, Bioaccumulation of Contaminants in Fish Tissues, Regional Sediment Conditions, and Regional Macrobenthic Communities. Some general background information and procedures for the regular fixed-grid and regional monitoring programs and associated sampling designs are given below and in subsequent chapters and appendices.

## REGULAR FIXED-GRID MONITORING

The South Bay Ocean Outfall is located just north of the border between the United States and Mexico. The outfall terminates approximately 5.6 km offshore at a depth of about 27 m. Unlike other southern California outfalls that are located on the surface of the seabed, the pipeline first begins as a tunnel on land and then continues under the seabed to a distance of about 4.3 km offshore. From there it connects to a vertical riser assembly that conveys effluent to a pipeline buried just beneath the surface of the seabed. This subsurface pipeline then splits into a Y-shaped multiport diffuser system, with the 2 diffuser legs extending an additional 0.6 km to the north and south. The outfall was originally designed to discharge and disperse effluent via a total of 165 diffuser risers, which included one riser located at the center of the "Y" and 82 others spaced along each diffuser leg. However, low flows have required closure of all ports along the northern diffuser leg and many along the southern diffuser since discharge began in order to maintain sufficient back pressure within the drop shaft so that the outfall can operate in accordance with the theoretical model. Consequently, discharge during 2006 and previous years have been generally limited to the distal end of the southern diffuser leg, with the exception of a few intermediate points at or near the center of the diffusers.

The regular SBOO sampling area extends from the tip of Point Loma southward to Playa Blanca, Mexico, and from the shoreline seaward to a depth of about 61 m. The offshore monitoring stations are arranged in a fixed grid that spans the terminus of the outfall, with each site being monitored in accordance with NPDES permit requirements. Sampling at these fixed stations includes monthly seawater measurements of physical, chemical, and bacteriological parameters in order to document water quality conditions in the area. Benthic sediment samples are collected semiannually to monitor macrofaunal communities and sediment conditions. Trawl surveys are performed quarterly to monitor communities of demersal fish and large, bottom-dwelling invertebrates. Additionally, analyses of fish tissues are performed semiannually to monitor levels of chemical constituents that may have ecological or human health implications.

## RANDOM SAMPLE REGIONAL SURVEYS

In addition to the regular fixed grid monitoring around the SBOO, the City typically conducts a summer benthic survey of sites distributed throughout the entire San Diego region as part of the monitoring requirements for the South Bay outfall. These annual surveys are based on an array of stations that are randomly selected by the United States Environmental Protection Agency (USEPA) using the probability-based EMAP design. Surveys conducted in 1994, 1998, and 2003 involved other major southern California dischargers, were broader in scope, and included sampling sites representing the entire Southern California Bight (SCB), from Cabo Colonet, Mexico to Point Conception, USA. These regional surveys were the Southern California Bight 1994 Pilot Project (SCBPP), and the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight′98 and Bight′03, respectively). Results of these 3 bightwide surveys are available in Bergen et al. (1998, 2001), Noblet et al. (2002), Ranasinghe et al. (2003, 2007), and Schiff et al. (2006). A separate regional survey was not conducted in 2004 in order to conduct a special "sediment mapping" study pursuant to an agreement with the San Diego Regional Water Quality Control Board and USEPA (see Stebbins et al. 2004, City of San Diego 2005).

The 2006 summer survey of randomly selected sites off San Diego covered an area from Del Mar south to the Mexican border and extending offshore from depths of 12 m to about 197 m. This survey revisited the same randomly selected sites targeted in 1996 (see City of San Diego 1998). Although 40 sites were targeted each year, only 34 were successfully sampled for benthic infauna and sediments in 2006 compared to 33 originally in 1996. Unsuccessful sampling was due to the presence of rocky substrates that made it impossible to collect benthic grab samples.

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# *Chapter 2. Oceanographic Conditions*

## INTRODUCTION

The City of San Diego regularly monitors oceanographic conditions of the water column to assess possible impacts from the outfall discharge as well as the effects of the local oceanic events on the fate of the discharge. The South Bay Ocean Outfall (SBOO) discharges treated wastewater approximately 5.6 km offshore at a depth of about 27 m. The average daily flow rate during 2006 was 24.5 mgd$^{-1}$. Water quality in the South Bay region is naturally variable, but is also subject to various anthropogenic sources of contamination, including discharge from the SBOO and outflows from sources such as San Diego Bay and the Tijuana River. These latter 2 non-point sources are fed by 415 and 1731 square miles of watershed, respectively, and contribute significantly to nearshore turbidity, sedimentation, and bacteriological densities (Largier et al. 2004).

The fate of SBOO wastewater discharged into 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 thus are important components of ocean monitoring programs (Bowden 1975). Analysis of the spatial and temporal variability of these 3 parameters in addition to transmissivity, dissolved oxygen, pH, and chlorophyll can elucidate patterns of water mass movement. Taken together, analyses of these measurements for the receiving waters surrounding the SBOO can help (1) describe deviations from expected patterns, (2) reveal the impact of the wastewater plume relative to other inputs such as from San Diego Bay and the Tijuana River, (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. The combination of physical parameter measurements, assessments of bacteriological concentrations and distributions (see Chapter 3), and remote sensing via satellite and aerial imagery provides further insight into the mass transport potential surrounding the SBOO throughout the year.

This chapter describes the oceanographic conditions that occurred during 2006 and is referenced in subsequent chapters to explain patterns of bacteriological occurrence (see Chapter 3) or other effects of the SBOO discharge on the marine environment (see Chapters 4–7).

## MATERIALS AND METHODS

### Field Sampling

Oceanographic measurements were collected at 40 fixed sampling stations located from 3.4 km to 14.6 km offshore (**Figure 2.1**). These stations form a grid encompassing an area of approximately 450 square kilometers and were situated along 9, 19, 28, 38, 55, and 60-m depth contours. Three of these stations (I25, I26, I39) are considered kelp bed stations, which are subject to 2001 California Ocean Plan (COP) water contact standards. The 3 kelp stations were selected for their proximity to suitable substrates for the Imperial Beach kelp bed; however, this kelp bed has been historically transient and inconsistent in terms of size and density (North 1991, North et al. 1993). Thus, these 3 stations are located in an area where kelp is only occasionally found.

Oceanographic measurements were collected at least once per month over a 3–5 day period. Data for temperature, salinity, density, pH, transmissivity (water clarity), chlorophyll *a*, and dissolved oxygen were recorded by lowering a SeaBird conductivity, temperature, and depth (CTD) instrument through the water column. Profiles of each parameter were constructed for each station by batch process

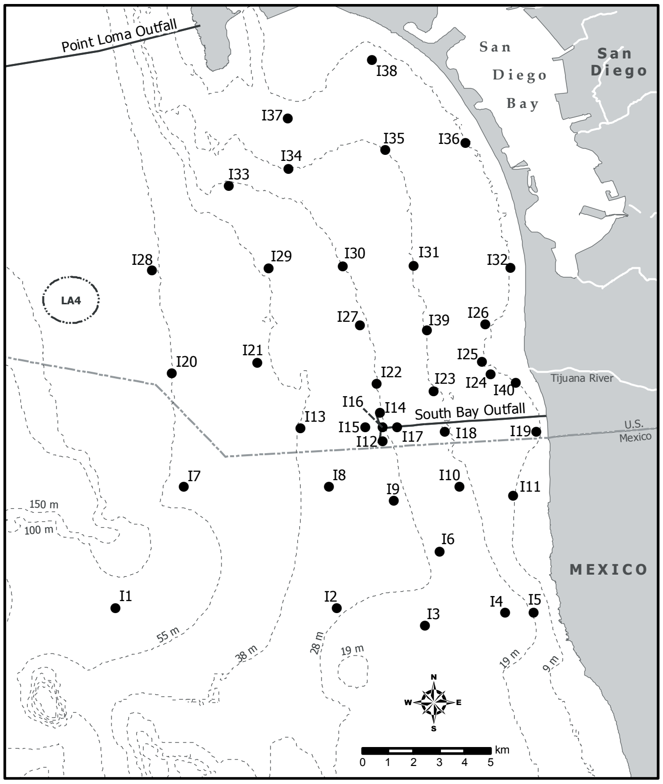



**Figure 2.1**
Water quality monitoring stations where CTD casts are taken, South Bay Ocean Outfall Monitoring Program.

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. To meet the COP sampling frequency requirements for kelp bed areas, CTD casts were conducted at the kelp stations an additional 4 times each month. Visual observations of weather and water conditions were recorded just prior to each CTD sampling event.

### Remote Sensing

Monitoring of the SBOO area and neighboring coastline also included aerial and satellite image analyses 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 quality Landsat Thematic Mapper (TM) images were purchased. High resolution 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 maximizes the detection of the SBOO 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 and one per month during spring and summer.

### Historical Data Analyses

Mean data were determined for surface depths (≤2 m), mid-depths (10–20 m), bottom depths (≥27 m), and all depths combined for stations I9, I12, I22, and I27. 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 11 years at all depths for each CTD parameter. Means and standard deviations for surface, mid, and bottom depths were calculated separately and are included in **Appendix A.1**. Additionally, CTD profile plots consisting of means ±1 SD at 5 m depth increments for 1995–2005 were compared with the 2006 mean profile data for temperature and salinity for these 4 stations.

## RESULTS AND DISCUSSION

### Expected Seasonal Patterns of Physical and Chemical Parameters

Southern California weather can be classified into 2 basic seasons: wet (winter) and dry (spring through fall) (NOAA/NWS 2007), and certain patterns in oceanographic conditions 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 of homogeneity within the water column is the normal signature for all physical parameters from December through February (**Figure 2.2**). Stormwater runoff however, may intermittently influence density profiles during these times by causing a low

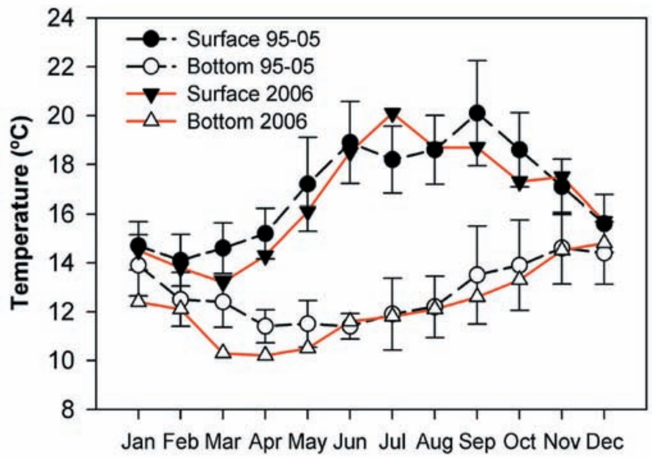



**Figure 2.2**
Mean monthly surface and bottom temperatures (°C) and standard deviations for 1995–2005 are compared to mean temperatures for 2006.

salinity lens within nearshore surface waters. The chance that the wastewater plume from the SBOO 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 has historically averaged 2.06 and 1.96 inches respectively for these months. Rainfall returned to normal levels in March, while above average rainfall occurred in May with 0.77 inches compared to the historical average of 0.21

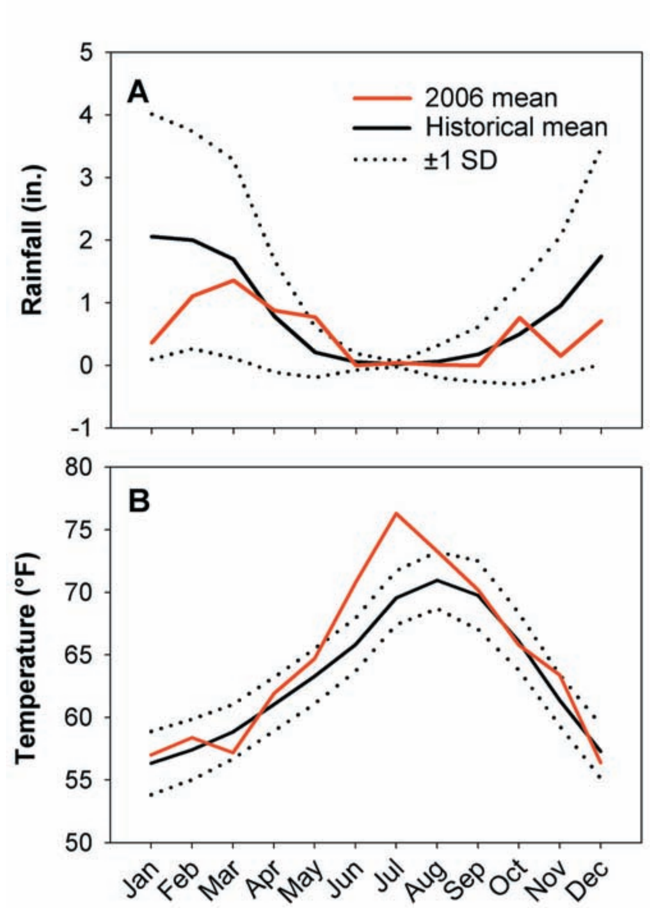



**Figure 2.3**
Total monthly rainfall (A) and monthly mean air temperature (B) at Lindbergh Field (San Diego, CA) for 2006 compared to monthly mean rainfall and air temperature (±1 SD) for the historical period 1914 through 2005.

inches. Thereafter, only 1.62 inches of rain fell from September through December, resulting in a total annual rainfall of 6.15 inches, well below the annual average of 10.26 inches. During March, average air temperature approached the lower confidence limit of the 91-year historical average limit, while near record warm air temperatures occurred in June–August (Figure 2.3B). Annual ocean surface temperatures peaked during these same months. Despite these circumstances, thermal stratification of the water column followed normal seasonal patterns at the nearshore and offshore sampling areas.

Temperature is the main factor affecting water density and stratification of southern California ocean waters (Dailey et al. 1993, Largier et al. 2004) and provides the best indication of the surfacing potential of the wastewater plume. This is particularly true of the South Bay where waters are shallow and salinity is relatively constant. Average temperatures from all depths for stations I9, I12, I22, and I27 (28-m depth contour) for the period 1995–2005 were compared with mean data for 2006 (**Table 2.1**). Overall, water temperatures during the winter, summer, and fall months in 2006 were similar to historical values from 1995–2005. Monthly differences between these 2 periods ranged from -0.6 to 1.0 °C, well within their respective standard deviations. However, water column temperatures were colder than normal from March through May, when temperatures ranged between 11.6 and 12.0 °C, approximately 1.4–1.6 °C lower than historical values. These differences were also true for temperatures at surface, mid, and bottom depths over the same period (see Appendix A.1). January also had cooler bottom waters than normal with a difference of -1.5 °C from the historical mean, and mid-depth and surface waters were warmer than average in June and July, respectively. The peak in surface water temperature during July was coincident with the second highest recorded July air temperature since 1914.

Although temperatures at kelp stations were below average early in the year, thermal stratification of the water column generally followed normal seasonal patterns (**Figures 2.4**, **Table 2.2)**. Below average bottom temperatures during January resulted in a stronger than normal stratification near the bottom of the water column (**Figure 2.5**). More typical seasonal stratification began to develop in March and April with temperature differences between surface and bottom waters of 2.9 °C and 4.1 °C, respectively (Table 2.2). In April, thermal stratification was relatively strong, and low temperatures were outside the confidence limits for the historical averages. Thermoclines of ~1 °C over less than 1 meter of depth developed between 5–13 m in March and April. Stratification was strongest in June and July with 7−8 °C differences between surface and bottom water temperatures. The thermoclines were observed at an average depth of 13 m in June and became much shallower in July with an average depth of 6 m. A weaker shallow thermocline persisted into November, but became undetectable by December.

Localized upwelling can transport colder deeper water and nutrients from below the thermocline to surface waters and may also cause onshore transport of wastewater plumes (Roughan et al. 2005). In the South Bay, topographic features such as the Point Loma headland create a divergence of the prevailing southerly flow as it encounters shallower isobaths (see Roughan et al. 2005). This creates a vorticity that transports deeper water to the surface where it is subsequently swept southward within the South Bay. Satellite imagery of the SBOO region using AVHRR thermal sensors and infrared TM sensors showed patterns that are consistent with this description on June 28 and July 14 (**Figure 2.6**). Colder upwelled water, light to dark blue in the AVHRR images and white features in the TM imagery, appears to flow south from the Point Loma headland. In August 2006, localized upwelling was apparent from a marked decline of water temperatures at kelp and monthly stations (Table 2.2, Figure 2.4).

Salinity values for stations I9, I12, I22, and I27 averaged from 33.34 to 33.64 ppt per month, with the lowest values occurring in January and the highest in March–May (Table 2.1). Mean mid-depth and bottom water salinities for the same period ranged from 33.68 to 33.82, respectively, and were near or slightly higher than the standard deviation (Appendix A.1b,c). These values were coincident with the occurrence of the coldest bottom temperatures of ~10 °C, the influx of which is normal for this period (Figures 2.4, 2.5). The unusual occurrence of heavy rainfall in May (i.e., 0.77 inches) did not cause a reduction in surface water salinities at kelp or monthly stations. Overall, the greatest differences between surface and bottom water salinity at all stations occurred from March through May during 2006.

Density, a product of temperature, salinity, and pressure, is influenced primarily by temperature in the South Bay region where depths are shallow and salinity profiles are relatively uniform. Therefore, changes in density typically mirror changes in

## Table 2.1

Mean data at all depths for 2006 compared to historical mean data and standard deviations (±1 SD) for 1995–2005 at stations I9, I12, I22, and I27, and difference (Δ) between 2006 and 1995–2005 mean data. Data includes temperature (°C), salinity (ppt), density (δ/θ), dissolved oxygen (mg/L), pH, transmissivity (%), and chlorophyll *a* (µg/L).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Temperature* | | | | | | | | | | | | |
| 2006 | 14.3 | 13.3 | 12.0 | 11.6 | 11.9 | 15.0 | 15.1 | 13.9 | 16.0 | 14.9 | 16.4 | 14.9 |
| 1995–2005 | 14.4 | 13.4 | 13.4 | 13.1 | 13.5 | 14.1 | 14.1 | 14.0 | 15.6 | 15.5 | 15.5 | 14.9 |
| SD | 1.2 | 1.2 | 1.4 | 1.7 | 2.7 | 3.1 | 2.8 | 2.6 | 3.2 | 2.5 | 1.7 | 1.3 |
| Δ | -0.1 | -0.1 | -1.4 | -1.5 | -1.7 | 0.9 | 1.0 | -0.1 | 0.4 | -0.6 | 0.9 | -0.0 |
| *Salinity* | | | | | | | | | | | | |
| 2006 | 33.34 | 33.41 | 33.51 | 33.64 | 33.61 | 33.61 | 33.53 | 33.43 | 33.44 | 33.38 | 33.39 | 33.48 |
| 1995–2005 | 33.48 | 33.52 | 33.50 | 33.61 | 33.63 | 33.66 | 33.61 | 33.55 | 33.50 | 33.44 | 33.42 | 33.46 |
| SD | 0.20 | 0.18 | 0.20 | 0.14 | 0.11 | 0.15 | 0.15 | 0.15 | 0.12 | 0.12 | 0.15 | 0.46 |
| Δ | -0.14 | -0.11 | 0.01 | 0.03 | -0.02 | -0.05 | -0.07 | -0.12 | -0.06 | -0.06 | -0.03 | 0.02 |
| *Density* | | | | | | | | | | | | |
| 2006 | 24.85 | 25.09 | 25.42 | 25.60 | 25.51 | 24.88 | 24.78 | 24.97 | 24.53 | 24.73 | 24.42 | 24.82 |
| 1995–2005 | 24.92 | 25.15 | 25.15 | 25.28 | 25.19 | 25.08 | 24.99 | 25.02 | 24.66 | 24.65 | 24.60 | 24.82 |
| SD | 0.27 | 0.28 | 0.38 | 0.41 | 0.60 | 0.70 | 0.65 | 0.57 | 0.75 | 0.55 | 0.39 | 0.46 |
| Δ | -0.07 | -0.06 | 0.27 | 0.32 | 0.32 | -0.20 | -0.21 | -0.05 | -0.13 | 0.08 | -0.18 | 0.00 |
| *Dissolved oxygen* | | | | | | | | | | | | |
| 2006 | 8.0 | 8.6 | 7.0 | 6.0 | 6.5 | 7.6 | 7.4 | 7.1 | 8.2 | 7.9 | 7.7 | 6.9 |
| 1995–2005 | 7.7 | 7.5 | 7.6 | 7.3 | 7.1 | 7.6 | 8.1 | 8.3 | 8.1 | 8.4 | 7.8 | 7.8 |
| SD | 0.7 | 1.0 | 1.4 | 1.7 | 1.8 | 1.7 | 1.5 | 1.5 | 1.4 | 1.5 | 0.8 | 0.7 |
| Δ | 0.3 | 1.1 | -0.6 | -1.3 | -0.6 | -0.0 | -0.7 | -1.2 | 0.2 | -0.5 | -0.1 | -0.9 |
| *pH* | | | | | | | | | | | | |
| 2006 | 8.1 | 8.2 | 8.0 | 8.0 | 8.0 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 |
| 1995–2005 | 8.0 | 8.0 | 8.0 | 7.9 | 8.0 | 8.0 | 8.0 | 8.0 | 8.1 | 8.1 | 8.1 | 8.1 |
| SD | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Δ | 0.1 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | -0.0 |
| *Transmissivity* | | | | | | | | | | | | |
| 2006 | 85 | 81 | 81 | 84 | 87 | 79 | 84 | 89 | 87 | 87 | 87 | 80 |
| 1995–2005 | 83 | 80 | 82 | 81 | 83 | 82 | 84 | 84 | 85 | 86 | 85 | 85 |
| SD | 7 | 12 | 10 | 8 | 5 | 7 | 6 | 5 | 5 | 6 | 4 | 6 |
| Δ | 2 | 1 | -1 | 3 | 4 | -3 | -0 | 5 | 2 | 1 | 2 | -5 |
| *Chlorophyll a* | | | | | | | | | | | | |
| 2006 | 4.6 | 11.0 | 10.3 | 4.0 | 5.8 | 10.1 | 4.1 | 2.7 | 3.4 | 4.0 | 2.4 | 1.8 |
| 1995–2005 | 4.8 | 5.7 | 4.9 | 8.1 | 6.2 | 7.4 | 4.6 | 5.5 | 5.1 | 4.3 | 4.4 | 5.6 |
| SD | 2.2 | 4.4 | 2.1 | 6.2 | 3.9 | 6.5 | 3.6 | 3.9 | 3.6 | 3.5 | 2.9 | 3.3 |
| Δ | -0.2 | 5.4 | 5.4 | -4.1 | -0.4 | 2.7 | -0.5 | -2.8 | -1.7 | -0.3 | -2.0 | -3.8 |

temperature. This relationship was true for 2006 as indicated by CTD data collected at the kelp and offshore water quality stations (Figure 2.4). Offshore surface water density was lowest in July when these waters were warmest. The difference between surface and bottom water densities was greatest from April through September, with the resulting pycnocline contributing to the stratification of the upper column at the time.

Mean chlorophyll *a* values in surface waters ranged from a low of 1.8 µg/L in November at the offshore

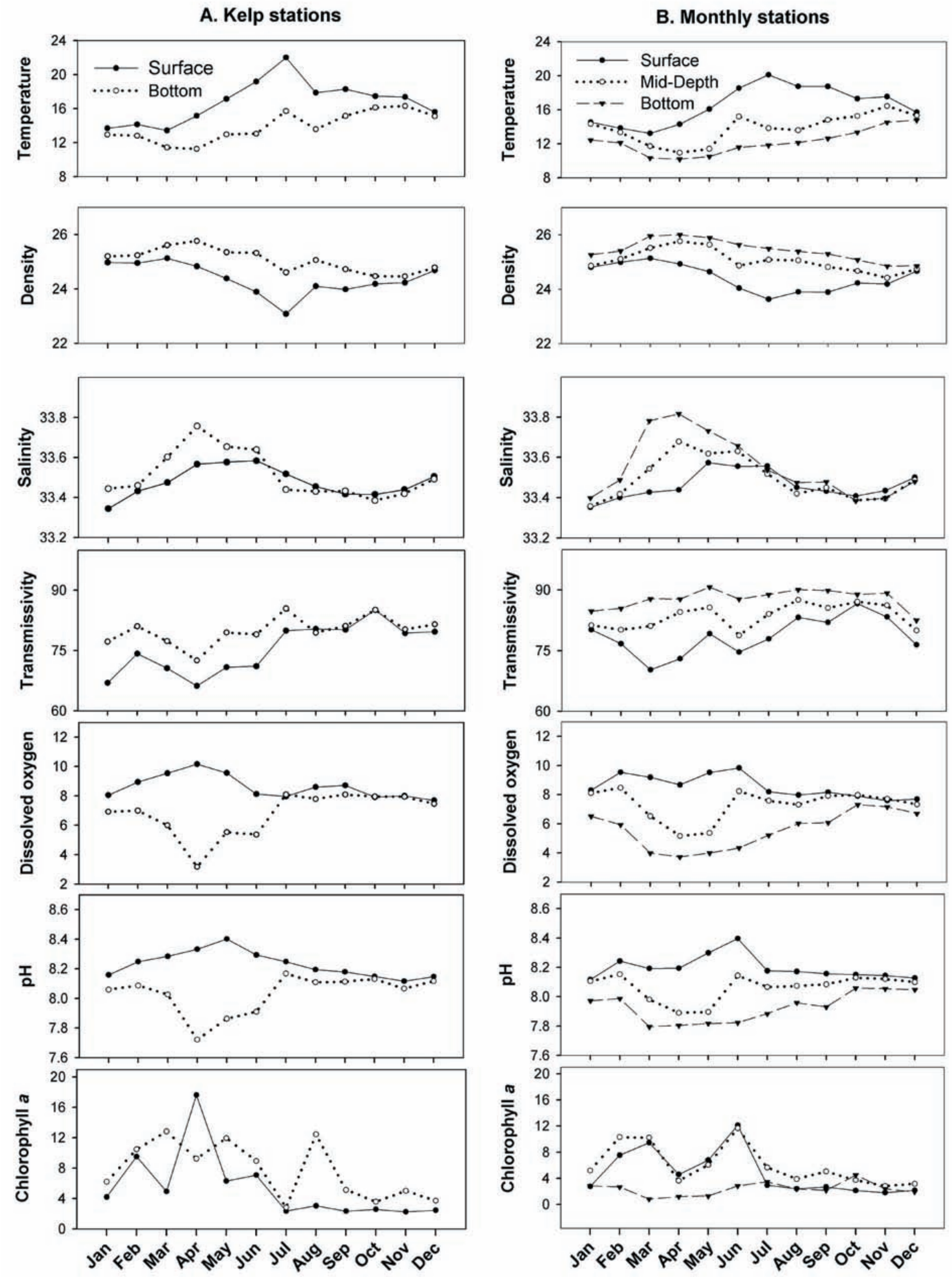



**Figure 2.4**
Monthly mean temperature (°C), density (δ/θ), salinity (ppt), transmissivity (%), dissolved oxygen (mg/L), pH, and chlorophyll *a* (µg/L) values for (A) surface (≤2m) and bottom (≥27m) waters at the kelp water quality stations and (B) surface (≤2m), mid-depth (10–20 m) and bottom (≥88m) waters at the monthly water quality stations during 2006.

## Table 2.2

Differences between the surface (≤2 m) and bottom (≥27 m) waters for mean values of temperature (Temp, °C), density (δ/θ), salinity (ppt), dissolved oxygen (DO, mg/L), pH, transmissivity (XMS, %), and chlorophyll *a* (Chl *a*, µg/L) at all monthly SBOO stations during 2006.

| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temp** | *Surface* | 14.5 | 13.8 | 13.2 | 14.3 | 16.1 | 18.5 | 20.1 | 18.7 | 18.7 | 17.3 | 17.5 | 15.7 |
| | *Bottom* | 12.4 | 12.1 | 10.3 | 10.2 | 10.5 | 11.6 | 11.8 | 12.1 | 12.6 | 13.3 | 14.5 | 14.8 |
| | Δ | 2.1 | 1.7 | 2.9 | 4.1 | 5.6 | 6.9 | 8.3 | 6.6 | 6.1 | 4.0 | 3.0 | 0.9 |
| **Density** | *Surface* | 24.80 | 24.99 | 25.13 | 24.92 | 24.64 | 24.04 | 23.63 | 23.90 | 23.89 | 24.22 | 24.19 | 24.66 |
| | *Bottom* | 25.26 | 25.40 | 25.95 | 26.00 | 25.88 | 25.63 | 25.49 | 25.38 | 25.29 | 25.07 | 24.84 | 24.85 |
| | Δ | -0.46 | -0.41 | -0.82 | -1.08 | -1.24 | -1.59 | -1.86 | -1.48 | -1.40 | -0.85 | -0.65 | -0.19 |
| **Salinity** | *Surface* | 33.35 | 33.40 | 33.43 | 33.44 | 33.57 | 33.56 | 33.56 | 33.45 | 33.43 | 33.41 | 33.43 | 33.50 |
| | *Bottom* | 33.40 | 33.49 | 33.78 | 33.82 | 33.73 | 33.66 | 33.54 | 33.48 | 33.48 | 33.38 | 33.40 | 33.48 |
| | Δ | -0.05 | -0.09 | -0.35 | -0.38 | -0.16 | -0.10 | 0.02 | -0.03 | -0.05 | 0.03 | 0.03 | 0.02 |
| **DO** | *Surface* | 8.3 | 9.5 | 9.2 | 8.7 | 9.5 | 9.8 | 8.2 | 8.0 | 8.2 | 7.9 | 7.6 | 7.7 |
| | *Bottom* | 6.5 | 5.9 | 4.0 | 3.7 | 4.0 | 4.3 | 5.2 | 6.0 | 6.1 | 7.3 | 7.2 | 6.7 |
| | Δ | 1.8 | 3.6 | 5.2 | 5.0 | 5.5 | 5.5 | 3.0 | 2.0 | 2.1 | 0.6 | 0.4 | 1.0 |
| **pH** | *Surface* | 8.1 | 8.2 | 8.2 | 8.2 | 8.3 | 8.4 | 8.2 | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 |
| | *Bottom* | 8.0 | 8.0 | 7.8 | 7.8 | 7.8 | 7.8 | 7.9 | 8.0 | 7.9 | 8.1 | 8.1 | 8.0 |
| | Δ | 0.1 | 0.2 | 0.4 | 0.4 | 0.5 | 0.6 | 0.3 | 0.2 | 0.3 | 0.1 | 0.0 | 0.1 |
| **XMS** | *Surface* | 80 | 77 | 70 | 73 | 79 | 75 | 78 | 83 | 82 | 87 | 83 | 76 |
| | *Bottom* | 85 | 85 | 88 | 88 | 91 | 88 | 89 | 90 | 90 | 89 | 89 | 82 |
| | Δ | -5 | -9 | -18 | -15 | -12 | -13 | -11 | -7 | -8 | -2 | -6 | -6 |
| **Chl *a*** | *Surface* | 2.8 | 7.5 | 9.4 | 4.6 | 6.8 | 12.1 | 3.0 | 2.4 | 2.7 | 2.1 | 1.8 | 2.2 |
| | *Bottom* | 2.9 | 2.7 | 0.8 | 1.2 | 1.3 | 2.9 | 3.5 | 2.4 | 2.2 | 4.5 | 2.4 | 1.9 |
| | Δ | -0.1 | 4.9 | 8.6 | 3.4 | 5.5 | 9.2 | -0.5 | 0.0 | 0.5 | -2.4 | -0.6 | 0.3 |

stations to a high value of 17.6 µg/L in April at the kelp stations (Table 2.2, Appendix A.2). Generally, chlorophyll *a* was consistently elevated from February through June at surface and mid-depths at the offshore stations, and at surface and bottom depths at the kelp stations. Increases in plankton density, as estimated using chlorophyll *a*, likely influenced some of the declines in transmissivity and increases in oxygen and pH that occurred during these periods. Plankton blooms were also observed throughout the year in the aerial imagery (Ocean Imaging 2006, 2007a, b).

### Historical Analyses of CTD Data

A review of historical oceanographic data for 4 stations surrounding the SBOO does not reveal a measurable impact from the wastewater discharge that began in 1999. Instead, these data were consistent with changes within the California Current System observed by CalCOFI (Peterson et al. 2006) (**Figure 2.7**). Three significant events have affected the California Current System during the last decade: (1) the 1997–1998 El Niño event; (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 beginning in October 2002. Temperature and salinity data for the South Bay region are consistent with the first 2 events, although recent data show a trend of cooler water beginning in 2005. This trend varies from other surveys of the California Current System and 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 within the South Bay region were also below the mean from late 2002–2006. However, recent CalCOFI data showed an increase

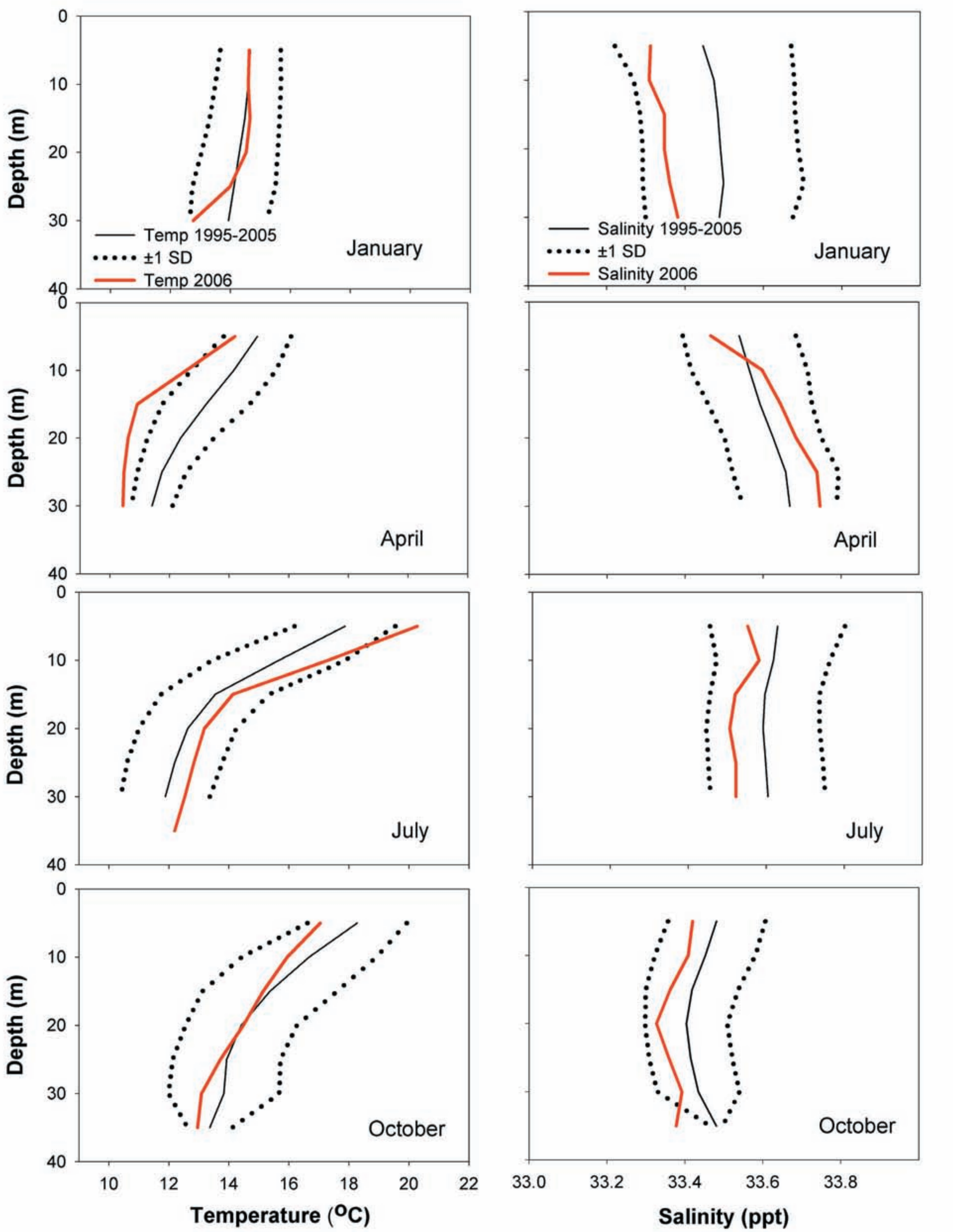
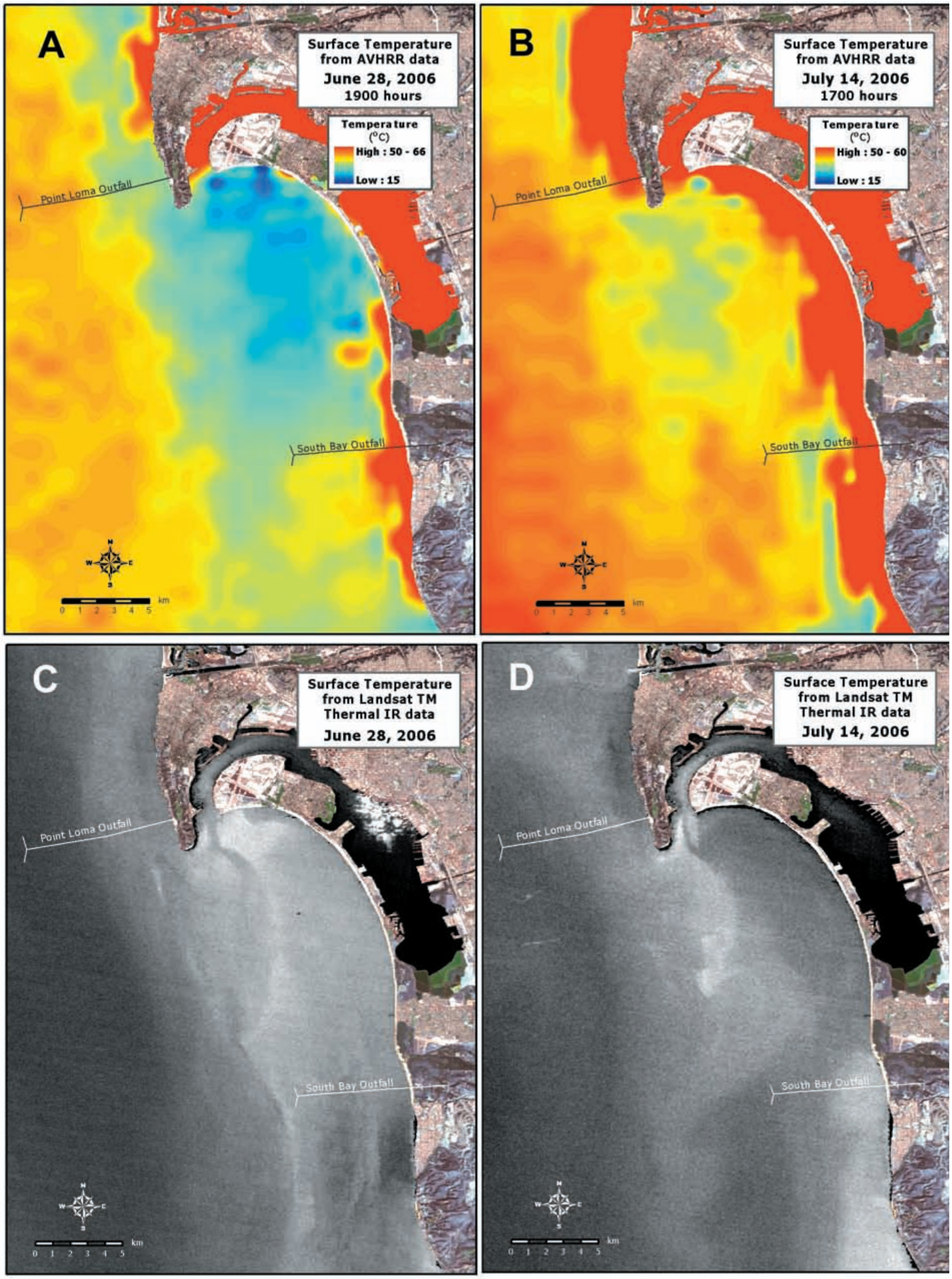
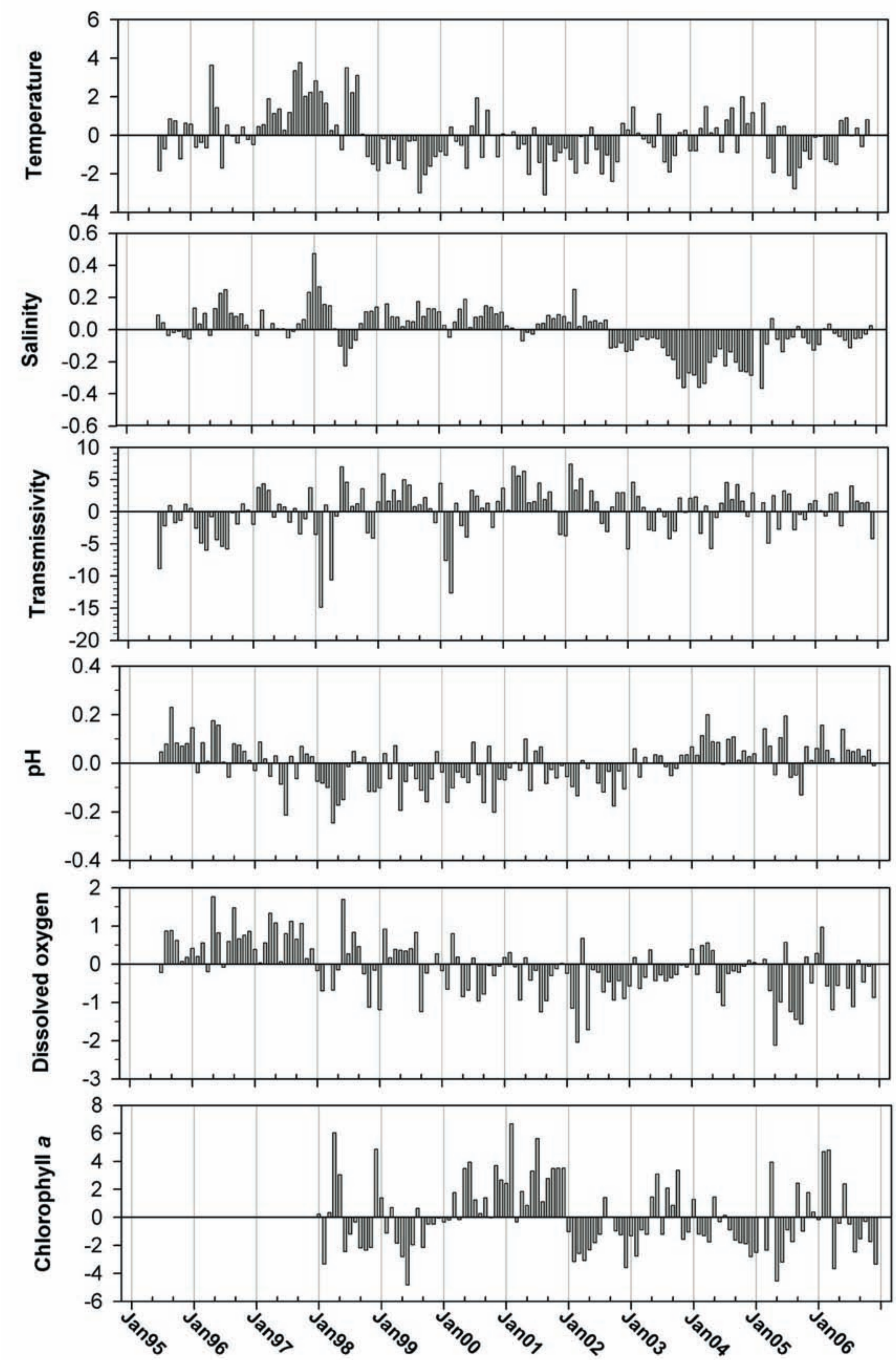



**Figure 2.5**
Mean quarterly temperature and salinity data for 2006 compared to mean temperature and salinity (±1 SD) for the historical period 1994 through 2005 at stations I9, I12, I22, and I27.




## Figure 2.6

Satellite imagery showing the San Diego 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 the historical monthly means for 1995–2006 for temperature (°C), salinity (ppt), transmissivity (%), pH, dissolved oxygen (mg/L), and chlorophyll a (μg/L).

in 2006 in portions of the Southern California and northern Baja California regions.

Overall water clarity (transmissivity) has generally increased in the South Bay since initiation of discharge in 1995, but several intermittent decreases in clarity were 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 at LA-5, leaving large, visible plumes of sediment throughout the region (see City of San Diego 2006). Several large decreases during winter periods such as those in 1998 and 2000 appear to be the result of increased amounts of suspended sediments caused by strong storm activity when monthly total rainfall ranged from one to nearly 8 inches (NOAA/NWS 2007). Smaller decreases in spring and early summer are probably related to plankton blooms such as those observed throughout the region in 2005 (City of San Diego 2006).

Although chlorophyll *a* concentrations have mostly increased in southern California during recent years (Peterson et al. 2006), the South Bay data are more consistent with those observed in northern Baja California where chlorophyll *a* mostly decreased. Occasional increases within the South Bay region occurred as a result of red tides blooms caused by the dinoflagellate *Lingulodinium polyedra*. 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).

Trends in relation to the outfall were not apparent for pH and dissolved oxygen. These 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 which make temporal changes difficult to evaluate.

## Remote Sensing

Imagery from the remote sensing studies generally confirmed water column stratification that was apparent from CTD data. For example, DMSC aerial imagery detected the outfall plume's near-surface signature on several occasions when the water column was mixed including January through April and in December (**Figure 2.8**); however the size and intensity of the plume tended to be significantly less than in previous years (Ocean Imaging 2006, 2007a, b). Subsequent aerial imagery suggested that the outfall plume remained deeply submerged from May through November when the water column was stratified.

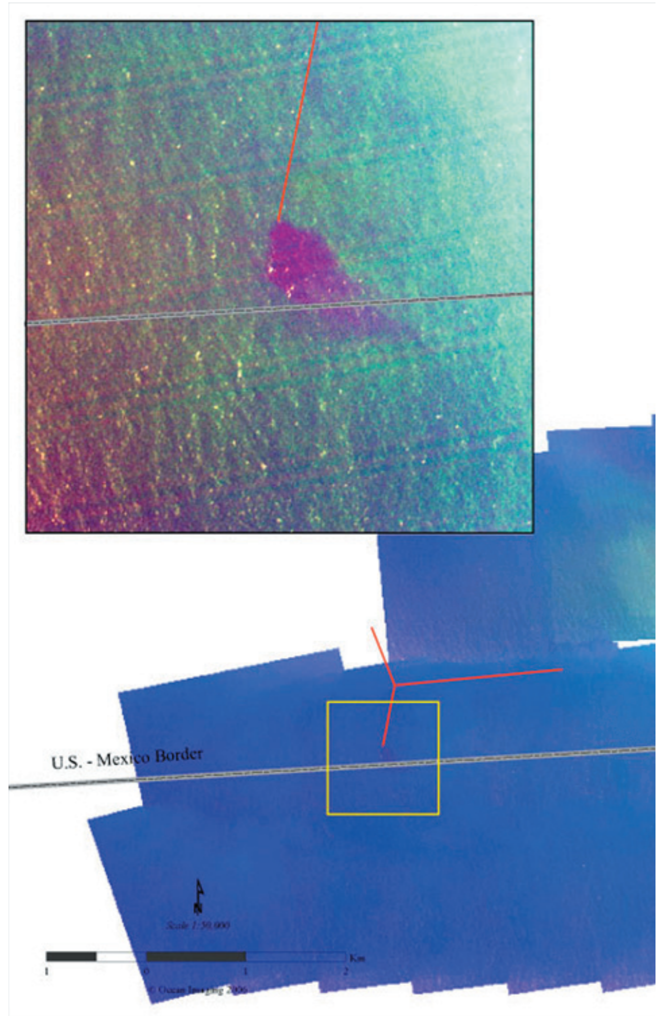



**Figure 2.8**
DMSC image composite of the SBOO outfall and coastal region acquired on January 31, 2006. Effluent from the south riser indicates a southerly flow.

The relatively few storms during 2006 resulted in decreased runoff and smaller than normal sedimentary plumes from the Tijuana River during winter thereby reducing coastal contamination during the first 3 months (Ocean Imaging 2006).

Generally, runoff plumes from the river remained within 3–4 km of the coastline and did not extend over the SBOO outfall wye region as observed in previous years (City of San Diego 2006). Northward flows during the first 3 months of 2006 resulted in 3 Coronado beach closures as discharge from the Tijuana River moved north past the Imperial Beach pier. In April a northward flow of effluent from Los Buenos Creek crossed into the South Bay. During the late spring, summer, and early fall dominant southward currents generally limited beach contamination to areas south of the river mouth. Additionally, MODIS imagery indicated the presence of shoreline turbidity throughout the period from wave and longshore current activity.

## SUMMARY AND CONCLUSIONS

Oceanographic conditions in 2006 were generally within expected seasonal variability. Water temperatures at all depths were below average from March through May, but returned to normal during the remainder of the year. Maximum surface temperatures were above historical means in July, coincident with record monthly air temperatures. Although the seasonal transition for water temperatures occurred in early summer (June and July) rather than late summer (August and September) as seen in prior years, thermal stratification of the water column followed typical patterns.

Water column stratification began to develop in March and persisted through November, and remote sensing data generally confirmed this pattern. A weak outfall plume signature was detected near the surface by aerial imagery on several occasions during the winter months when the water column was mixed. Otherwise, remote sensing observations suggested that the outfall plume remained deeply submerged from May through November (Ocean Imaging 2006, 2007a, b).

With the exception of a slight decline in August temperatures, upwelling appeared to occur rarely in 2006 based on CDT data. A few South Bay upwelling events in June and July were visible in infrared satellite imagery. Aerial and satellite remote sensors also detected the presence of plankton blooms for much of 2006 that were confirmed as increases in chlorophyll *a* concentrations in CTD data. Plankton blooms in South Bay are complex, stimulated by localized upwelling, and occasionally influenced by large red tides created when the river is flowing and nutrients are more readily available.

Long-term analysis of CTD data for 1995–2006 did not reveal changes in water parameters relative to the discharge of wastewater that began in 1999. However, temperature and salinity data for South Bay did correspond to 2 of 3 significant climate events that occurred within the California Current System during this period: 1) the 1997–1998 El Niño event, and 2) 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 beginning in October 2002, was not observed. Instead, ocean conditions during that time were more consistent with coastal survey data from 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 SBOO region since initiation of wastewater discharge from the SBOO. Chlorophyll *a* levels in the South Bay have mostly decreased through time a trend consistent with water conditions in northern Baja California. Changes in pH and dissolved oxygen did not exhibit any apparent trends related to wastewater discharge. Changes in these parameters are complex, dependent on temperature and depth, and are sensitive to physicochemical and biological processes including carbon cycling. Moreover, both parameters are subject to diurnal and seasonal variations making it difficult to decipher temporal trends.

Rainfall was well below average during 2006 and drought conditions existed during January and February. Consequently there was a reduction in ocean contamination during the winter months as a result of the decreased precipitation and absence of large runoff plumes as seen in previous years.

Aerial imagery indicated that current flow was primarily directed south during 2006. However, northward flow of effluent from Los Buenos Creek into the sampling region was observed once in aerial imagery. Finally, data from the region's water column, together with remote sensing data, revealed no evidence of impact from the SBOO along the coastline in 2006.

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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 South Bay Ocean Outfall (SBOO). This is designed to assess general water quality conditions, evaluate patterns in movement and dispersal of the wastewater plume, and monitor compliance with the 2001 California Ocean Plan according to NPDES permit specifications (see Chapter 1). The final results of bacteriological and individual station compliance data are submitted to the International Boundary and Water Commission and San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Bacteriological densities, together with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged through the outfall. Analyses of these data may also help identify point or non-point sources other than the outfall as contributing to bacterial contamination events in the region. This chapter summarizes and interprets patterns in bacterial concentrations collected for the South Bay region during 2006.

## MATERIALS AND METHODS

### Field Sampling

Water samples for bacteriological analyses were collected at fixed shore and offshore sampling sites during 2006 (**Figure 3.1**). Sampling was performed weekly at 11 shore stations to monitor bacterial levels along public beaches. Three shore stations (S0, S2, S3) located south of the US/Mexico border are not subject to California Ocean Plan (COP) water contact standards. Eight other shore stations (S4–S6, S8–S12) located between the border and Coronado are subject to the COP standards (see **Box 3.1**). In addition, 28 offshore stations were sampled monthly, usually over a 3-day period. These 28 offshore sites are located in a grid surrounding the outfall along the 9, 19, 28, 38, and 55-m depth contours. Three of these stations (I25, I26, I39) are considered kelp bed stations and are subject to the COP water contact standards. The kelp stations were sampled for bacterial analysis 5 times each month, such that each day of the week is represented over a 2-month period. The 3 kelp stations were selected because of their proximity to suitable substrates for the Imperial Beach kelp bed; however, this kelp bed is transient with variable size and density (North 1991, North et al. 1993). Thus, these 3 stations are located in an area where kelp is only occasionally found.

Seawater samples from the 11 shore stations were collected from the surf zone 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 collection. The samples were then

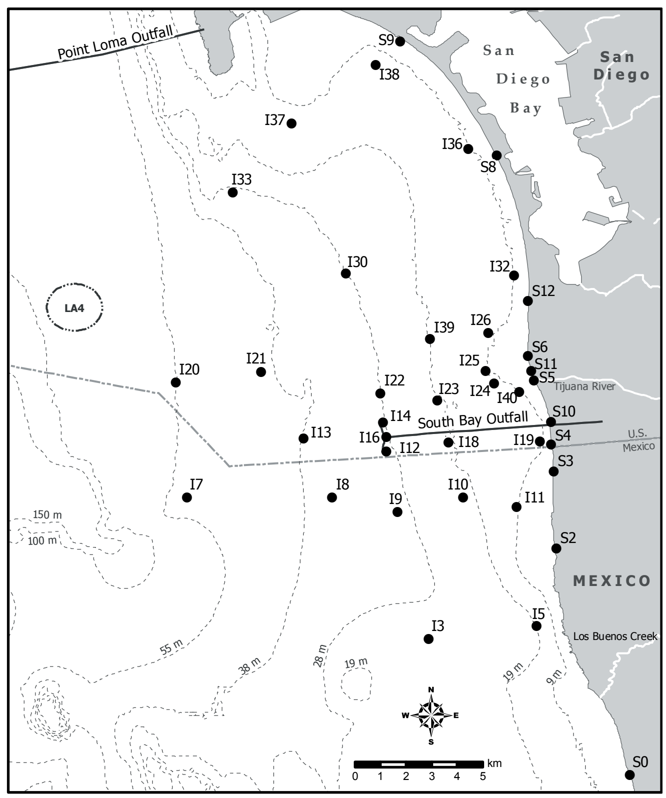



**Figure 3.1**
Water quality monitoring stations where bacteriological samples were collected, South Bay Ocean Outfall Monitoring Program.

**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.

transported on blue ice to the City's Marine Microbiology Laboratory and analyzed to determine concentrations of total coliform, fecal coliform, and enterococcus bacteria.

Seawater samples were collected at 3 discrete depths at each of the offshore sites and analyzed for total coliform, fecal coliform, and enterococcus bacteria, as well as total suspended solids and oil and grease during the monthly sampling. These samples were collected using either a series of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Aliquots for each analysis were drawn into appropriate sample containers. The bacteriological samples were refrigerated on board ship and then transported to the City's Marine Microbiology Laboratory for analyses. The total suspended solids and oil and grease samples were taken to the City's Wastewater Chemistry Laboratory for analyses. Visual observations of weather, sea state, and human or animal activity in the area were also recorded at the time of sampling. Monitoring of the SBOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging Corporation (see Chapter 2).

### Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to 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 guidelines established by the EPA (see Bordner et al. 1978) and APHA (1992). According to these guidelines, 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 COP standards and mean values.

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 Laboratory's Quality Assurance Report (City of San Diego 2007).

Shore and kelp bed station compliance with COP bacteriological standards were summarized according to the number of days that each station was out of compliance (see Box 3.1). 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. Spatial and temporal patterns in bacteriological contamination were determined from mean densities of total coliform, fecal coliform, and enterococcus bacteria. Mean densities (±standard error) were calculated by month, station, depth, and time period (pre-discharge and post-discharge); compliance resamples were not considered for these calculations. Bacteriological, oil and grease and suspended solid data were log(x+1) transformed to improve conformity to normality for use in parametric statistical analyses. Normality was determined graphically and homogeneity of variances was tested using the F-test. Monthly rainfall and oceanographic conditions (see Chapter 2), as well as other events (e.g., stormwater flows and turbidity plumes, nearshore and surface water circulation patterns) identified through remote sensing data were evaluated relative to the bacterial data.

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 were >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 samples containing total coliform concentrations ≥1000 CFU/mL and a fecal:total (F:T) ratio ≥0.1 (see CDHS 2000). Samples from offshore monthly water quality stations that met these criteria were used as indicators of the SBOO waste field, while those with total coliform concentrations ≥1000 CFU/mL and a fecal:total (F:T) ratio <0.1 were identified as stormwater discharge from the Tijuana River and San Diego Bay.

## RESULTS AND DISCUSSION

Bacteriological densities in 2006 were generally high in the South Bay region, despite a relatively small amount of rainfall over the year. For example, annual mean concentrations of fecal coliform bacteria along the shoreline near the Tijuana River (stations S5, S6, S11) were similar to levels seen during 2005, a year with much heavier rainfall (**Figure 3.2**). Overall, 10% of the samples (n=201) analyzed in 2006 had total coliform concentrations greater than or equal to the 1000 CFU/100 mL benchmark. Of these high values, 111 were collected at shore sites, 9 were collected during the kelp station surveys, and 81 were collected during the monthly offshore surveys. Thirty-eight of these monthly offshore samples and one of the kelp survey samples had F:T ratios ≥0.1, which are indicative of contaminated water (n=39). These samples were further evaluated to assess possible patterns in plume movement (see below).

### Temporal Variability

February through May, October, and December were the wettest months of the year and had the highest densities of indicator bacteria in shoreline samples (**Table 3.1**). Twenty-two of the 24 samples with total coliform concentrations that exceeded the 10,000 CFU/100 mL standard occurred during these wet months, with the 2 other exceedances occurring in January. Although January was not a wet month, the January exceedances correspond to a 4-day period (January 1–4) when all of the rainfall for the month occurred. The Tijuana River was flowing at 16.2±5.6 million gallons/day (mean±SE) during this period (IBWC, unpublished data).

Fecal coliform concentrations along the shoreline also corresponded to the pattern of rainfall in 2006 (**Figure 3.3A**), and were significantly correlated with monthly rainfall (Spearman correlation; n=12, p=0.006). This pattern has also been observed since 1995 when shoreline sampling began (Figure 3.3B) and the relationship between fecal coliform concentrations and annual rainfall was significant (Spearman correlation; n=12, p=0.001). However, deviations from this trend occurred on 2 occasions in 2006: (1) relatively low densities of fecal coliforms were detected in March despite fairly heavy rainfall; and (2) in July, high densities of fecal coliforms occurred with little rainfall. The

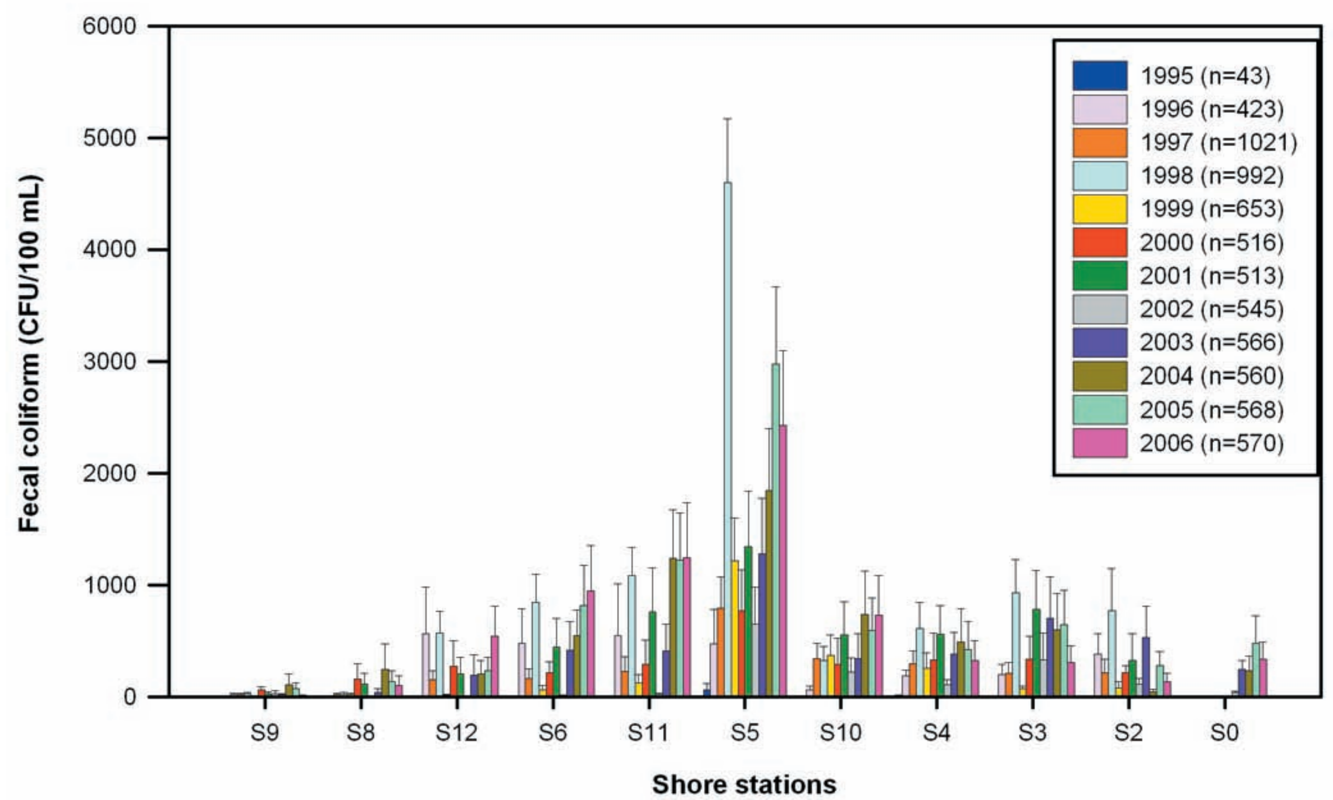



**Figure 3.2**
Mean annual fecal coliform densities (mean±SE) for each SBOO shore station from 1995–2006. Stations are arranged from north to south on the x-axis. Stations S5, S6, and S11 are all within 1 km of the Tijuana River. Sampling for stations S10–S12 started in October 1996 and sampling for station S0 started in August 2002.

elevated bacterial densities in July were collected at shore stations S5, S6, S8, S11, and S12 on July 18 and may have been caused by a sewage spill from Mexico that flowed into the Tijuana River around July 15. After the sewage spill, the Tijuana River had a mean flow of 10.5±8.4 million gallons/day from July 16–17.

Samples with high densities of indicator bacteria were collected from the kelp stations during most months of 2006. However, as with the shore stations, most of the kelp station samples (71%) with total coliform concentrations ≥1000 CFU/100 mL were collected during February through May, October, and December (**Appendix B.1, B.2**). Three of these samples had F:T ratios ≥0.1, but the fecal coliform densities were low and the samples were probably not indicative of contaminated wastewater from the SBOO.

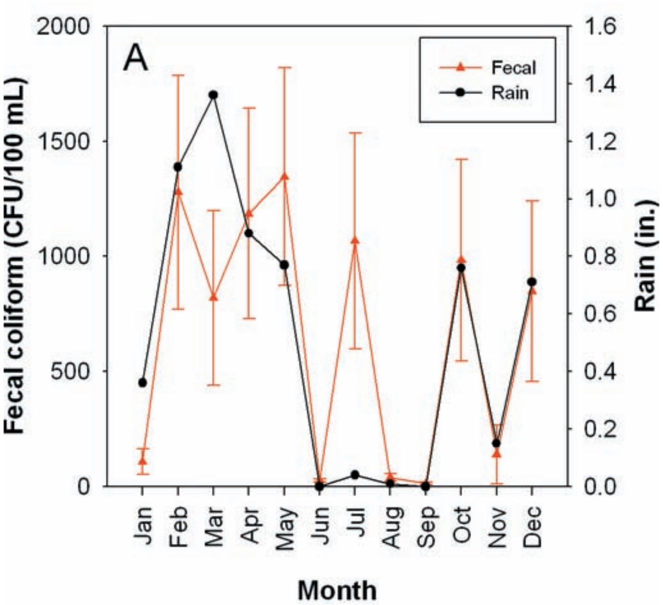
Monthly sampling of indicator bacteria at the other offshore sites also showed distinct seasonal trends related to rainfall and storm discharge (**Figure 3.4**). Two-thirds of the 81 samples with total coliform concentrations ≥1000 CFU/100 mL occurred during February through May, October, and December (**Appendices B.2, B.3**). Additionally, 13 of the 17 samples collected at the stations along the 9 and 19-m contours that were representative of contaminated water occurred during those months. Most, if not all, of these inshore samples were likely related to discharge from the Tijuana River and Los Buenos Creek. During periods of northward current flows, discharge from the Tijuana River and Los Buenos Creek is carried up the coast towards Imperial Beach and may affect water quality at inshore stations (Largier et al. 2004, Ocean Imaging 2005, City of San Diego 2006).

Water column stratification was seasonal and this was apparent in the offshore monthly water quality samples. The wastewater plume remained sub-surface most of the year, but was detected in surface waters at stations along the 28-m contour

## Table 3.1

Shore station bacterial densities and rainfall data for the SBOO 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. Sample size (n) for each station is given parenthetically and excludes resamples. Stations are listed north to south in order from left to right.

| Month | Rain (in.) | | S9 (52) | S8 (52) | S12 (52) | S6 (52) | S11 (52) | S5 (52) | S10 (51) | S4 (51) | S3 (52) | S2 (52) | S0 (52) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Jan** | 0.36 | *Total* | 22 | 842 | 771 | 42 | 194 | 241 | 3250 | 3272 | 3284 | 244 | 6480 |
| | | *Fecal* | 8 | 26 | 24 | 12 | 7 | 81 | 54 | 54 | 608 | 76 | 236 |
| | | *Entero* | 3 | 42 | 34 | 25 | 10 | 141 | 94 | 105 | 528 | 59 | 143 |
| **Feb** | 1.11 | *Total* | 37 | 7 | 1553 | 4853 | 6102 | 8009 | 15 | 30 | 4459 | 8004 | 1315 |
| | | *Fecal* | 7 | 2 | 183 | 1197 | 3087 | 6003 | 3 | 2 | 1661 | 1151 | 119 |
| | | *Entero* | 9 | 4 | 212 | 72 | 1696 | 3156 | 2 | 3 | 2760 | 412 | 49 |
| **Mar** | 1.36 | *Total* | 909 | 8 | 4490 | 4780 | 6200 | 13300 | 8525 | 6400 | 3725 | 4768 | 525 |
| | | *Fecal* | 36 | 4 | 417 | 467 | 216 | 6265 | 852 | 337 | 126 | 281 | 20 |
| | | *Entero* | 53 | 2 | 15 | 88 | 40 | 6043 | 151 | 83 | 68 | 211 | 11 |
| **Apr** | 0.88 | *Total* | 16 | 7 | 4061 | 4770 | 7012 | 6950 | 6062 | 8033 | 4710 | 225 | 111 |
| | | *Fecal* | 2 | 7 | 709 | 2520 | 3075 | 3110 | 1317 | 1553 | 711 | 10 | 21 |
| | | *Entero* | 3 | 2 | 8 | 188 | 248 | 3029 | 30 | 31 | 15 | 9 | 8 |
| **May** | 0.77 | *Total* | 43 | 65 | 3216 | 3241 | 6611 | 9764 | 2746 | 201 | 137 | 745 | 2984 |
| | | *Fecal* | 2 | 5 | 2004 | 1646 | 3013 | 7210 | 746 | 12 | 11 | 13 | 135 |
| | | *Entero* | 4 | 8 | 76 | 75 | 244 | 5299 | 12 | 10 | 10 | 22 | 32 |
| **Jun** | 0.00 | *Total* | 140 | 65 | 140 | 225 | 135 | 110 | 42 | 43 | 90 | 201 | 555 |
| | | *Fecal* | 44 | 7 | 14 | 19 | 14 | 14 | 4 | 7 | 10 | 73 | 82 |
| | | *Entero* | 39 | 4 | 4 | 12 | 10 | 21 | 2 | 9 | 14 | 25 | 17 |
| **Jul** | 0.04 | *Total* | 200 | 4105 | 1810 | 4105 | 4015 | 4065 | 312 | 782 | 1829 | 1261 | 847 |
| | | *Fecal* | 28 | 1207 | 793 | 3026 | 3006 | 3010 | 32 | 138 | 163 | 94 | 237 |
| | | *Entero* | 5 | 9 | 13 | 25 | 11 | 29 | 8 | 16 | 19 | 23 | 11 |
| **Aug** | 0.01 | *Total* | 16 | 13 | 68 | 16 | 10 | 13 | 16 | 32 | 162 | 10 | 4244 |
| | | *Fecal* | 3 | 2 | 55 | 2 | 2 | 6 | 4 | 25 | 155 | 3 | 169 |
| | | *Entero* | 2 | 2 | 142 | 2 | 2 | 3 | 2 | 13 | 42 | 2 | 34 |
| **Sep** | 0.00 | *Total* | 75 | 17 | 20 | 16 | 16 | 11 | 16 | 17 | 11 | 359 | 1354 |
| | | *Fecal* | 5 | 3 | 9 | 3 | 3 | 3 | 3 | 7 | 4 | 9 | 99 |
| | | *Entero* | 5 | 2 | 3 | 3 | 2 | 4 | 2 | 2 | 4 | 2 | 28 |
| **Oct** | 0.76 | *Total* | 28 | 18 | 3217 | 3212 | 3207 | 3210 | 3205 | 81 | 92 | 61 | 3384 |
| | | *Fecal* | 7 | 3 | 1886 | 2403 | 2403 | 882 | 3003 | 40 | 26 | 17 | 139 |
| | | *Entero* | 4 | 4 | 75 | 683 | 126 | 24 | 110 | 6 | 5 | 10 | 98 |
| **Nov** | 0.15 | *Total* | 11 | 26 | 22 | 98 | 11 | 13 | 12 | 22 | 13 | 57 | 7010 |
| | | *Fecal* | 9 | 2 | 3 | 62 | 2 | 4 | 2 | 3 | 4 | 5 | 1437 |
| | | *Entero* | 7 | 2 | 5 | 15 | 2 | 6 | 8 | 5 | 11 | 6 | 443 |
| **Dec** | 0.71 | *Total* | 14 | 40 | 21 | 29 | 40 | 4167 | 5528 | 5470 | 6305 | 1407 | 5038 |
| | | *Fecal* | 7 | 42 | 9 | 6 | 8 | 3008 | 2361 | 1952 | 376 | 39 | 1521 |
| | | *Entero* | 2 | 22 | 7 | 13 | 7 | 3253 | 41 | 41 | 38 | 34 | 127 |
| **Annual means** | | | | | | | | | | | | | |
| | | **Total** | **118** | **419** | **1631** | **2078** | **2774** | **4089** | **2512** | **1982** | **1980** | **1354** | **2932** |
| | | **Fecal** | **12** | **101** | **546** | **952** | **1245** | **2434** | **732** | **326** | **312** | **138** | **337** |
| | | **Entero** | **11** | **9** | **52** | **107** | **192** | **1721** | **40** | **28** | **281** | **64** | **83** |



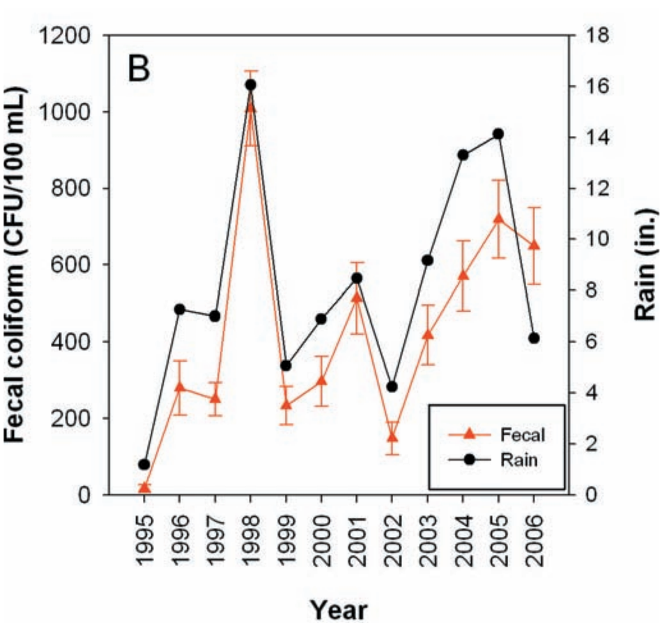




**Figure 3.3**
Mean fecal concentrations (mean±SE) at shore stations vs. rain by (A) month in 2006 and (B) year. See Figure 3.2 for sample sizes. Shoreline sampling began in October 1995. Rain for 1995 includes only October–December. Rain was measured at Lindbergh Field, San Diego, CA.

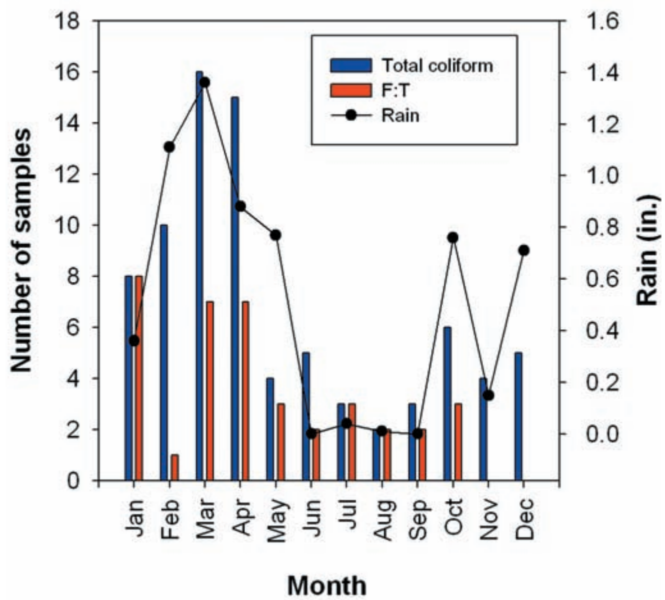



**Figure 3.4**
SBOO monthly offshore water quality samples with high bacterial densities collected in 2006. Total coliform=number of samples with total coliform densities ≥1000 CFU/100 mL; F:T=number of samples with total coliform densities ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T)≥0.1. Rain was measured at Lindbergh Field, San Diego, CA.

in January (**Figure 3.5**; Appendix B.2). Seasonal stratification did not begin to develop until March/April (see Chapter 2).

### Spatial Variability

Elevated bacterial densities along the shoreline and in shallow, nearshore waters appeared to be related to sources other than the SBOO. Proximity to the Tijuana River and Los Buenos Creek discharges appeared to have greater influence on bacteriological levels along the shoreline. For example, the highest densities of indicator bacteria occurred along the shore at the 6 stations closest to the Tijuana River (i.e., S4–S6, S10–S12) and station S0 located south of Los Buenos Creek in Mexico (Table 3.1). Station S5, located adjacent to the mouth of the Tijuana River, had the highest mean bacterial levels of all of the shore stations sampled in 2006. Station S0, the southernmost shore station, was likely impacted by discharge from the nearby Los Buenos Creek and/or southerly alongshore flow carrying Tijuana River discharge. Contaminants from upstream sources (e.g., sod farms and runoff not captured by the canyon collector system) and the Tijuana estuary (e.g., decaying plant material) are released during increased river flow and extreme tidal exchanges and are a likely bacterial source for the stations closest to the Tijuana River (Largier et al. 2004). The San Antonio de los Buenos Wastewater Treatment Plant, Mexico releases its partially treated effluent

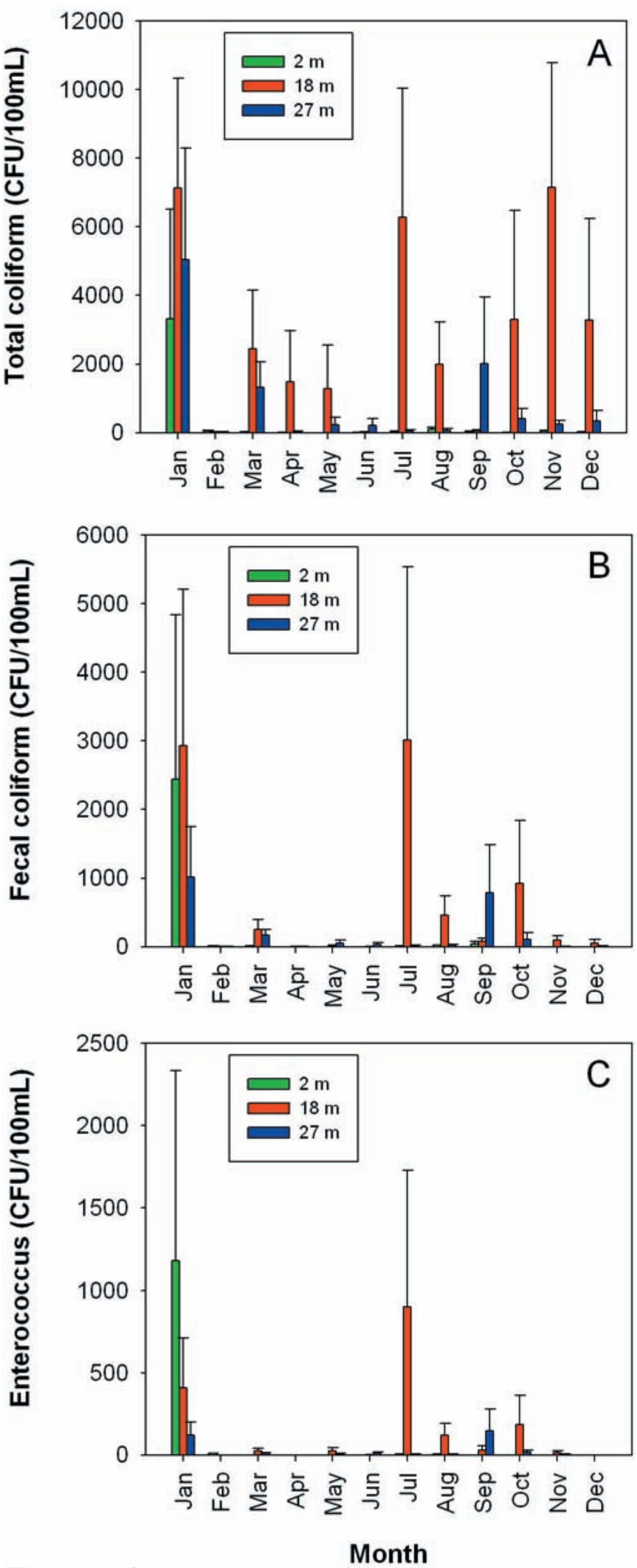



**Figure 3.5**
Bacterial concentrations at monthly offshore SBOO stations (I9, I12, I14, I16, I22) along the 28-m contour for surface (2 m), mid-depth (18 m), and bottom waters (27 m) during 2006: (A) total coliform, (B) fecal coliform, and (C) enterococcus bacteria. Values are means±SE; n=5.

through Los Buenos Creek and this flow may have affected total and fecal coliform levels both south and north of the international border.

Discharge from the Tijuana River also affected water quality at various stations along the 9 and 19-m contours (Ocean Imaging 2006 a, b, c). Stormwater discharge from the Tijuana River from February through May, and during October and December was likely responsible for elevated bacterial densities at these nearshore stations. For example, there were 28 monthly offshore water samples from these stations representative of stormwater (i.e., total coliforms ≥1000 CFU/100 mL and F:T ratios <0.1) taken during these months (Appendix B.3). Except for those samples collected from stations nearest the outfall (I12, I14, I16), most of the contaminated water samples taken during wet months came from stations near the Tijuana River mouth (Appendix A.2). The July sewage spill into the Tijuana River that impacted the shore stations was not detected in the kelp station samples.

Contaminated water samples considered indicative of the wastewater plume (i.e., total coliforms ≥1000 CFU/100 mL and F:T ratios ≥0.1) were detected most frequently at stations along the 28-m depth contour, which is the depth of the SBOO discharge (**Figure 3.6A**). Nineteen of the 39 samples identified as representing contaminated water occurred along or near the 28-m contour: 15 at the stations nearest the outfall (I12, I14, I16), one at northern station I30, and 3 at southern stations I3 and I9. Only 2 samples were collected farther offshore than the 28-m depth contour (I20, I21). The rest of the samples indicative of contaminated water came from stations along the 9–19 m depth contours.

There was limited evidence that the wastewater plume reached surface waters in 2006, as only 7 of the 39 contaminated water samples occurred in surface waters (2 m) (Figure 3.6B). These samples were collected in January, March, April, June, and October (Appendix A.2). The January sample was collected from outfall station I12 when there was no thermocline. The March sample was collected

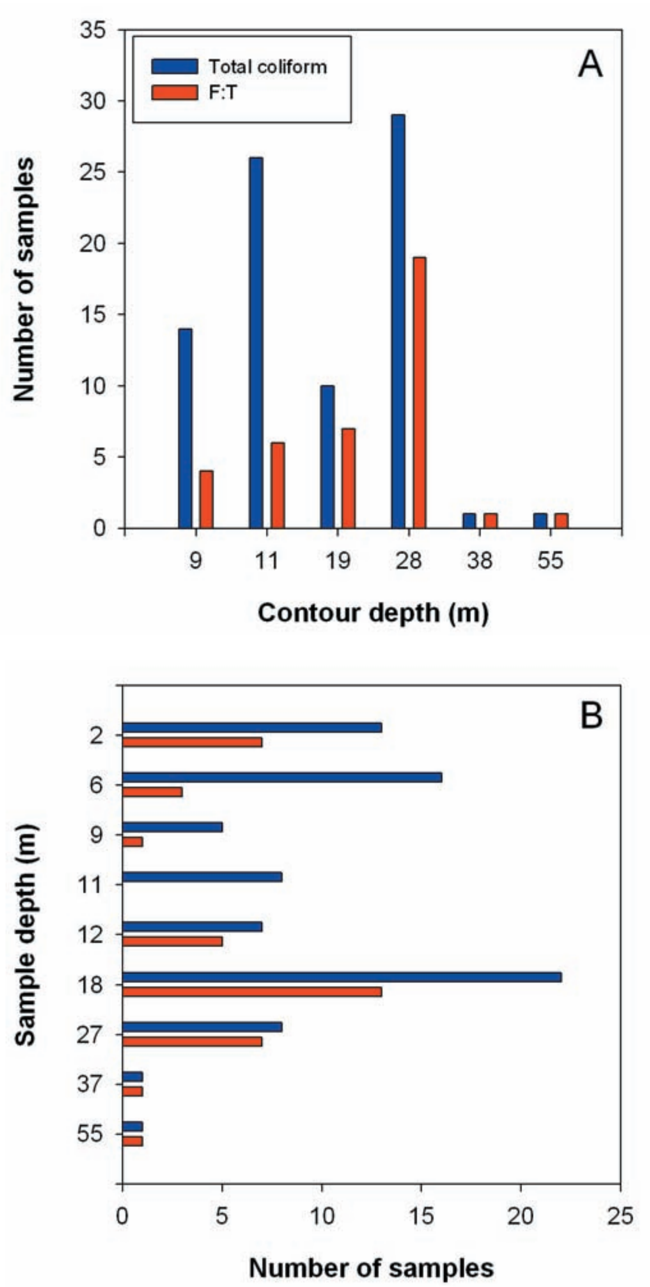



**Figure 3.6**
SBOO monthly offshore water quality samples with high bacterial densities depicted by (A) contour and (B) depth in 2006. Total coliform=number of samples with total coliform densities ≥1000 CFU/100 mL (n=81); F:T=number of samples with total coliform densities ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥0.1 (n=38).

at station I40 after the Tijuana River began flowing following later February rainfall. The April samples occurred at stations I19 and I40 and may have been affected by the Tijuana River and Los Buenos Creek, Mexico turbidity plumes. These plumes were probably the result of 0.5 inches of rain from the previous 2 days and were visible in MODIS imagery taken on April 6 (**Figure 3.7**). The cause of the contaminated samples at inshore stations I5 and I11 in June and I5 in October was not apparent.

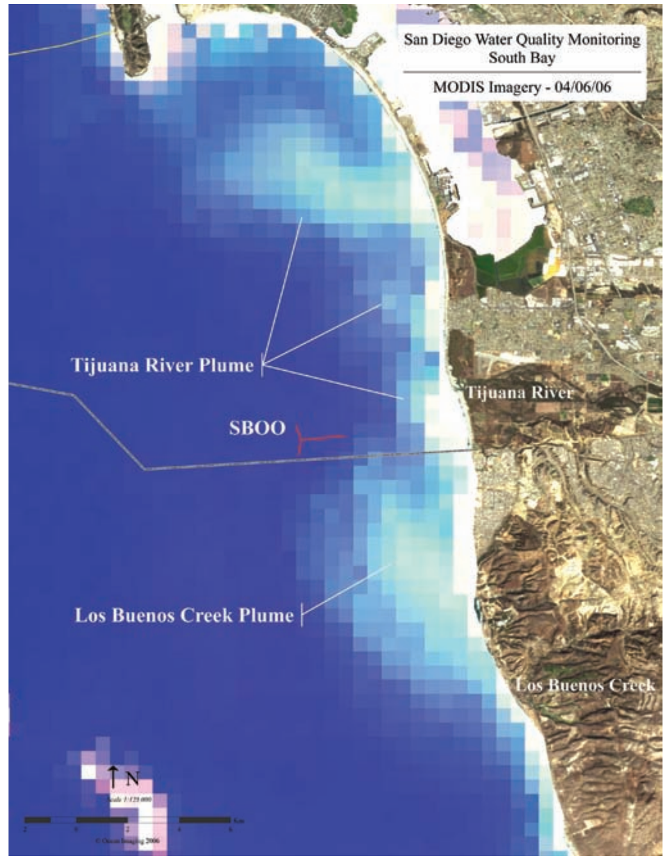



**Figure 3.7**
MODIS satellite image showing the San Diego water quality monitoring region on April 6, 2006. White pixels represent areas obscured by cloud cover.

## Compliance with California Ocean Plan Standards

Compliance with COP bacterial standards in 2006 for shore and kelp bed stations in the U.S. is summarized in **Tables 3.2** and **3.3**. Overall, compliance was higher in 2006 than in 2005, which was probably related to the lower rainfall during the past year (City of San Diego 2006). For example, compliance with the 30-day total coliform standard at the shore stations ranged from 49 to 95% in 2006 versus 36 to 81% in 2005. In addition, the number of days that samples at the shore stations were out of compliance with the 10,000 total coliform standard decreased from 41 in 2005 to 28 in 2006. The frequency of compliance

**Table 3.2**
Summary of compliance with 2001 California Ocean Plan water contact standards for SBOO shore and kelp bed stations during 2006. Values reflect the number of days that each station exceeded the 30-day and 10,000 total coliform standards (see Box 3.1). Shore stations are listed north to south in order from left to right.

| **30-day Total coliform standard** | | **Shore stations** | | | | | | | | **Kelp stations** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **# days** | **S9** | **S8** | **S12** | **S6** | **S11** | **S5** | **S10** | **S4** | **I25** | **I26** | **I39** |
| *January* | 31 | 0 | 20 | 20 | 0 | 0 | 0 | 28 | 28 | 0 | 0 | 0 |
| *February* | 28 | 0 | 0 | 0 | 1 | 7 | 7 | 1 | 1 | 0 | 0 | 0 |
| *March* | 31 | 2 | 0 | 26 | 31 | 31 | 31 | 25 | 25 | 0 | 0 | 0 |
| *April* | 30 | 18 | 0 | 30 | 30 | 30 | 30 | 30 | 30 | 0 | 0 | 0 |
| *May* | 31 | 0 | 0 | 10 | 8 | 31 | 31 | 31 | 24 | 0 | 0 | 0 |
| *June* | 30 | 0 | 0 | 0 | 0 | 1 | 28 | 26 | 0 | 0 | 0 | 0 |
| *July* | 31 | 0 | 0 | 10 | 0 | 0 | 13 | 5 | 5 | 0 | 0 | 0 |
| *August* | 31 | 0 | 0 | 9 | 0 | 0 | 16 | 14 | 14 | 0 | 0 | 0 |
| *September* | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *October* | 31 | 0 | 0 | 0 | 14 | 14 | 14 | 0 | 0 | 0 | 0 | 0 |
| *November* | 30 | 0 | 0 | 0 | 15 | 15 | 15 | 0 | 0 | 0 | 0 | 0 |
| *December* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 19 | 0 | 0 | 0 |
| Percent compliance | | **95%** | **95%** | **71%** | **73%** | **65%** | **49%** | **51%** | **60%** | **100%** | **100%** | **100%** |
| **10,000 Total coliform standard** | | | | | | | | | | | | |
| *January* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| *February* | 28 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| *March* | 31 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | 1 | 0 | 0 | 0 |
| *April* | 30 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 2 | 0 | 0 | 0 |
| *May* | 31 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 |
| *June* | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *July* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *August* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *September* | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *October* | 31 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| *November* | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *December* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| Total | | **0** | **0** | **1** | **3** | **5** | **10** | **4** | **5** | **0** | **0** | **0** |

with standards based on running means (i.e., the 30-day total, 60-day fecal, and geometric mean standards) was lowest from March through June, when cumulative rainfall was greatest. In contrast, the 3 kelp stations were 100% compliant with all COP standards.

As in the previous years, rainfall caused low compliance rates for the shore stations closest to the Tijuana River. Only the 2 northernmost shore stations (S8 and S9) were compliant with the 30-day total and 60-day fecal coliform standards over 90% of the time. By contrast, percent compliance at the more southern stations ranged from 33 to 73% for these same standards. The proximity of these shore stations to the Tijuana River may explain the frequency with which they were out of compliance. Lower runoff volumes and the absence of frequent and persistent northward currents probably attributed to the increased compliance at stations north of the Tijuana River relative to previous years (City of San Diego 2006, Ocean Imaging 2006a).

## Table 3.3

Summary of compliance with 2001 California Ocean Plan water contact standards for SBOO shore and kelp bed stations during 2006. Values reflect the number of days that each station exceeded the 60-day fecal coliform and geometric mean standards (see Box 3.1). Shore stations are listed north to south in order from left to right.

| 60-day Fecal coliform standard | | Shore stations | | | | | | | | Kelp stations | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **# days** | **S9** | **S8** | **S12** | **S6** | **S11** | **S5** | **S10** | **S4** | **I25** | **I26** | **I39** |
| *January* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 0 | 0 | 0 |
| *February* | 28 | 0 | 0 | 1 | 4 | 4 | 8 | 13 | 13 | 0 | 0 | 0 |
| *March* | 31 | 0 | 0 | 31 | 16 | 9 | 31 | 29 | 29 | 0 | 0 | 0 |
| *April* | 30 | 0 | 0 | 30 | 30 | 30 | 30 | 30 | 30 | 0 | 0 | 0 |
| *May* | 31 | 0 | 0 | 31 | 31 | 31 | 31 | 31 | 31 | 0 | 0 | 0 |
| *June* | 30 | 0 | 0 | 18 | 14 | 30 | 30 | 30 | 24 | 0 | 0 | 0 |
| *July* | 31 | 0 | 7 | 24 | 19 | 19 | 31 | 23 | 7 | 0 | 0 | 0 |
| *August* | 31 | 0 | 12 | 31 | 12 | 12 | 12 | 0 | 31 | 0 | 0 | 0 |
| *September* | 30 | 0 | 5 | 15 | 5 | 5 | 5 | 0 | 22 | 0 | 0 | 0 |
| *October* | 31 | 0 | 0 | 7 | 15 | 15 | 15 | 7 | 0 | 0 | 0 | 0 |
| *November* | 30 | 0 | 0 | 12 | 30 | 30 | 30 | 12 | 0 | 0 | 0 | 0 |
| *December* | 31 | 0 | 0 | 6 | 16 | 16 | 23 | 26 | 20 | 0 | 0 | 0 |
| Percent compliance | | **100%** | **93%** | **44%** | **47%** | **45%** | **33%** | **42%** | **40%** | **100%** | **100%** | **100%** |
| **Geometric mean standard** | | | | | | | | | | | | |
| *January* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *February* | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *March* | 31 | 0 | 0 | 0 | 0 | 0 | 31 | 11 | 3 | 0 | 0 | 0 |
| *April* | 30 | 0 | 0 | 5 | 24 | 26 | 30 | 5 | 10 | 0 | 0 | 0 |
| *May* | 31 | 0 | 0 | 0 | 0 | 14 | 31 | 10 | 11 | 0 | 0 | 0 |
| *June* | 30 | 0 | 0 | 0 | 0 | 0 | 22 | 5 | 0 | 0 | 0 | 0 |
| *July* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *August* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *September* | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *October* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *November* | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *December* | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Percent compliance | | **100%** | **100%** | **99%** | **93%** | **89%** | **69%** | **92%** | **93%** | **100%** | **100%** | **100%** |

### Bacterial Patterns Compared to Other Wastewater Indicators

Results from the oil and grease and total suspended solids (TSS) sampling suggest that both have limited utility as indicators of the waste field in 2006. Oil and grease concentrations were mostly below the detection limit (<1.4 mg/L) in 2006 (**Table 3.4**). The only exception was an oil and grease value of 2.23 mg/L of an uncertain cause that occurred in May at station I30, located over 5 km north of the SBOO. Data from bacteria samples suggest that the plume was traveling southward at the time since concentrations of indicator bacteria were low (<2 CFU/100 mL) in the samples from I30 but high in samples at depths of 6 m and below at stations I10, I11, and I12. Monthly mean TSS concentrations ranged from 5.2 to 10.2 mg/L (Table 3.4). Individual values varied considerably, ranging between <1.6 and 74.3 mg/L, and were not significantly correlated with total or fecal coliform concentrations or F:T (**Table 3.5**). Of the 183 TSS samples with elevated concentrations (≥10.0 mg/L), only 81 (44%) corresponded to samples with total coliform densities ≥1000 CFU/100 mL, and only 38 (21%) of these had F:T ratios ≥0.1.

## Table 3.4

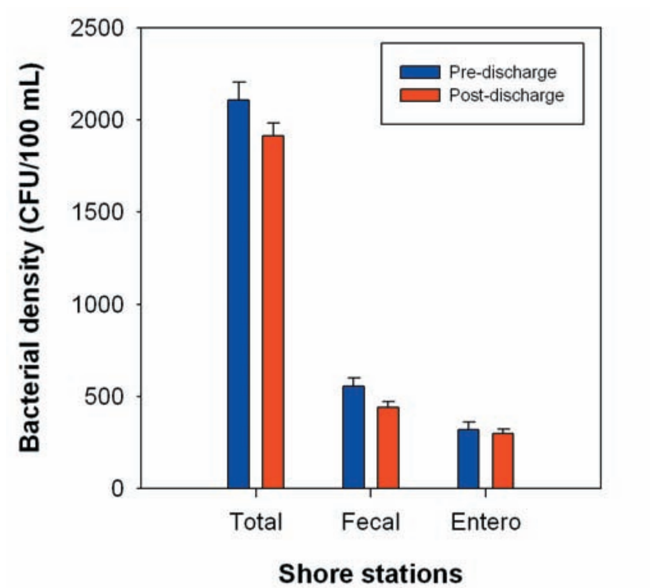
Means (±SE) for total suspended solids (TSS; 3 depths) and detected oil and grease (O&G; 2 m depth) for each SBOO monthly water quality station during 2006. Ranges are given in parentheses; n=84. nd= not detected. The minimum levels of detection are 1.4 mg/L. (O&G) and 1.6 mg/L (TSS).

| Month | O&G mg/L | TSS mg/L |
|---|---|---|
| *January* | nd | 6.4±0.8 (<1.6–52.0) |
| *February* | nd | 6.5±0.5 (2.5–32.7) |
| *March* | nd | 6.6±0.4 (2.0–18.1) |
| *April* | nd | 7.5±1.0 (2.0–74.3) |
| *May* | 2.23 | 6.1±0.5 (1.9–23.3) |
| *June* | nd | 6.4±0.5 (2.2–25.5) |
| *July* | nd | 9.2±0.4 (4.6–27.8) |
| *August* | nd | 10.2±0.7 (<1.6–30.5) |
| *September* | nd | 7.9±0.4 (2.8–20.7) |
| *October* | nd | 5.2±0.2 (1.7–13.2) |
| *November* | nd | 7.6±0.3 (2.0–14.6) |
| *December* | nd | 7.4±0.4 (3.0–32.9) |

## Table 3.5

Spearman rank correlation results for total suspended solids from SBOO monthly offshore stations from 1995–2006.

| Correlation | Period | $r_s$ | n | P |
|---|---|---|---|---|
| Total coliform | 2006 | -0.019 | 1006 | 0.54 |
| Fecal coliform | 2006 | <-0.001 | 1007 | 0.99 |
| Fecal:total coliform | 2006 | 0.006 | 1006 | 0.86 |
| Total coliform | 95–06 | 0.019 | 11,359 | <0.001 |
| Fecal coliform | 95–06 | 0.153 | 11,373 | <0.001 |
| Fecal:total coliform | 95–06 | -0.173 | 11,358 | <0.001 |



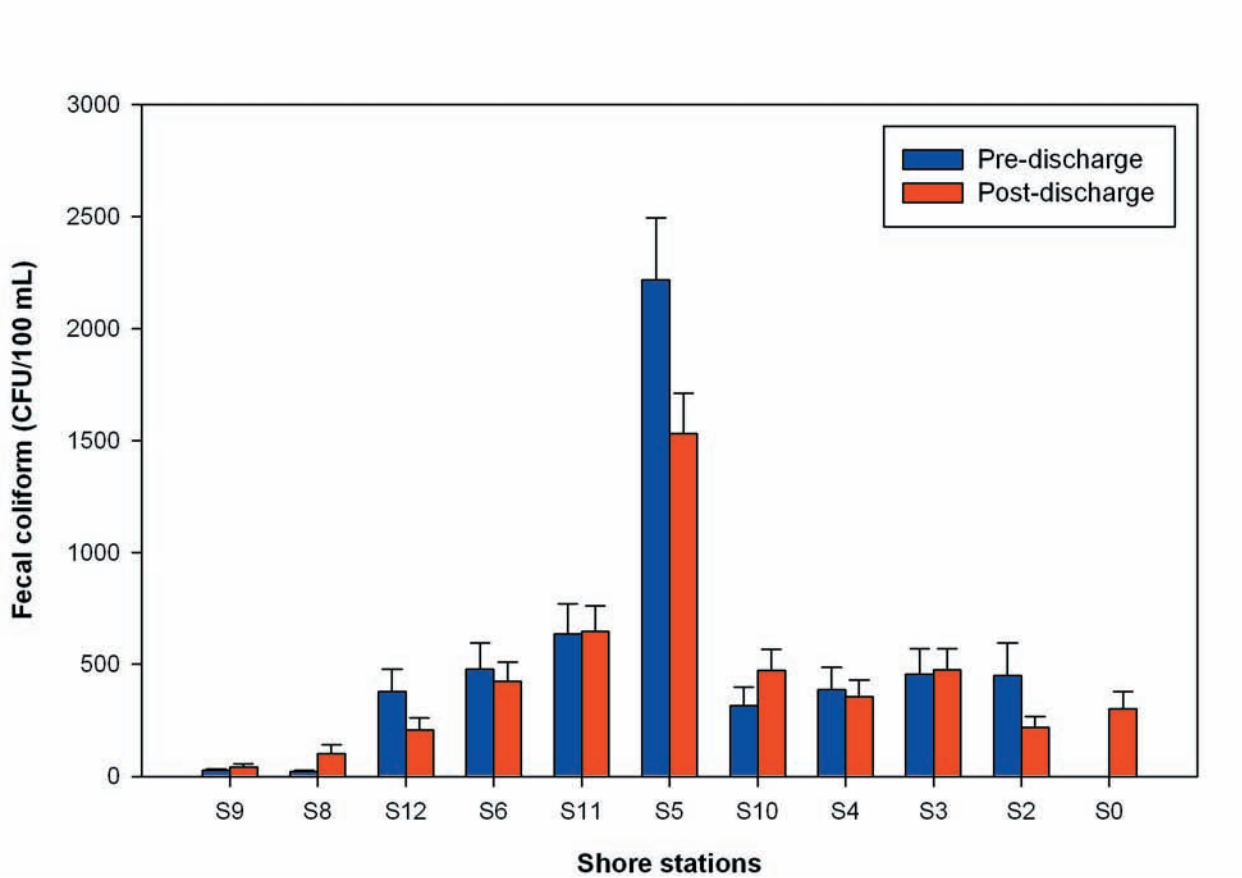

## Figure 3.8

Mean bacterial densities (mean±SE) for SBOO shore stations from 1995–2006. The pre-discharge period is from October 2, 1995 to January 12, 1999 while post-discharge is from January 13, 1999 to December 31, 2006. Sample size=Pre/Post. Total=total coliform (n=2471/4445), Fecal=fecal coliform (n=2515/4455), Entero=enterococcus (n=1388/4343).

### Historical Analyses

Mean total and fecal coliform densities along the shore have been lower since discharge began in January 1999 **(Figure 3.8).** The differences in the transformed data were slight, but significant (**Table 3.6**), some of which was caused by differences in bacterial densities at specific stations. For example, the largest decline in mean fecal coliform densities occurred at station S5 (**Figure 3.9**), which is likely related to diverting discharge that flowed into the Tijuana River to the SBOO.

Kelp station mean total coliform densities declined during the post-discharge period, while fecal coliform and enterococcus densities increased slightly (**Figure 3.10A**). Despite a lot of variation during the pre-discharge period, the difference in mean total coliform densities was significantly lower during the post-discharge period (Table 3.6).




## Figure 3.9

Mean fecal coliform densities (mean±SE) for SBOO shore stations from 1995–2006. The pre-discharge period is from October 2, 1995 to January 12, 1999 (n=147–297) while post-discharge is from January 13, 1999 to December 31, 2006 (n=226–430). Stations are arranged from north to south on the x-axis. Stations S5, S6, and S11 are all within 1 km of the Tijuana River. Sampling for stations S10–S12 started in October 1996 and station S0 in August 2002.

The pre- and post-discharge differences in the other bacterial indicators were not significant. Post-discharge fecal coliform densities show the greatest increase from the 12-m depth samples, all of which were collected from station I39 (Figure 3.10B). However, all of the mean fecal coliform densities for each depth and period were low.

In contrast to the shore stations, the mean bacteriological densities from monthly offshore stations increased during the post-discharge period (**Figure 3.11**, Table 3.6). The highest pre-discharge fecal coliform densities were detected at along the 9 and 11-m depth contours (**Figure 3.12A**) and were most likely caused by stormwater and river discharge from the Tijuana River. During the post-discharge period, mean fecal coliform densities increased dramatically along the 28-m depth contour, the depth at which treated effluent is discharged from the SBOO. The highest mean fecal coliform densities came from the 18 m depth samples, mostly from stations I12, I14, and I16 near the SBOO diffuser wye (Figure 3.12B).

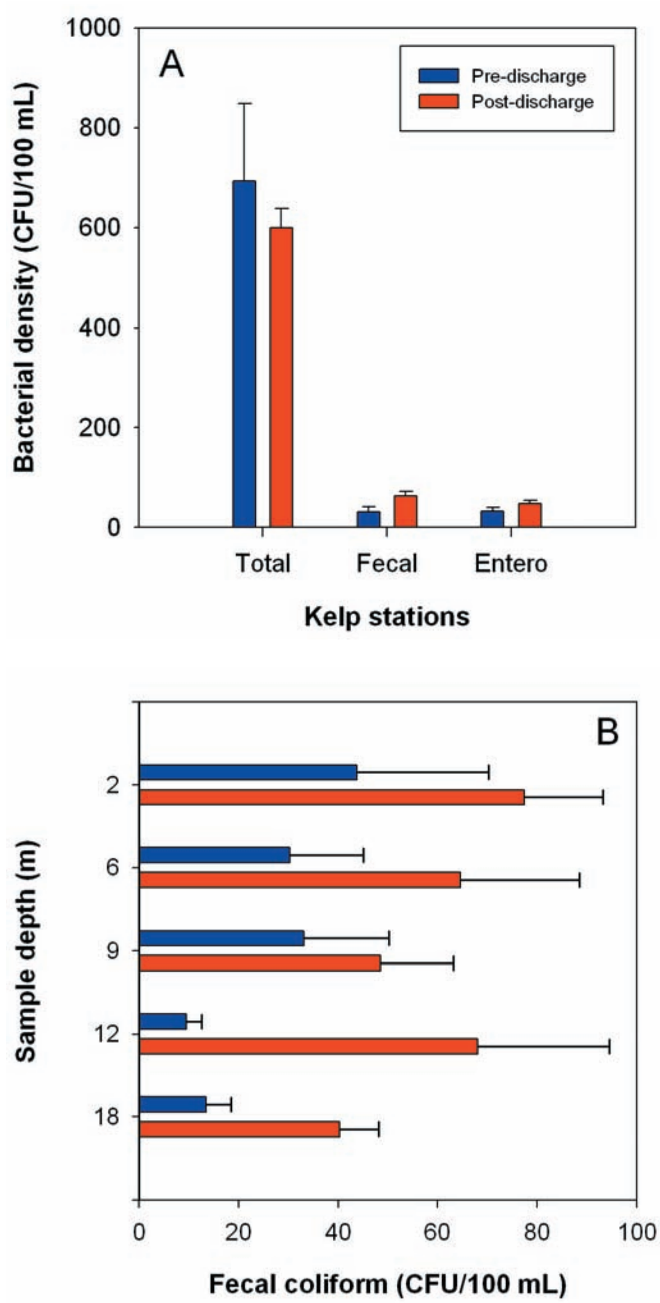
The percent of oil and grease detected in offshore station water samples increased during the post-discharge period (**Figure 3.13**). However, the difference in measured oil and grease concentrations was not significant (independent sample t-test: t=0.65; df=68; P=0.516). Oil and grease were detected in only 0.35% of the pre-discharge samples versus 2.49% of the post-discharge samples. Oil and grease were never detected in any samples from the 9-m, 38-m, and 55-m contours during the pre-discharge period, whereas during the post-discharge

## Table 3.6
Independent sample t-test results for pre-discharge versus post-discharge periods from SBOO shore (Shore), biweekly kelp (Kelp), and monthly offshore (Offshore) stations. Data are log(x+1) transformed. The pre-discharge period is from October 2, 1995 to January 12, 1999 while post-discharge is from January 13, 1999 to December 31, 2006.

| | Variable | t | df | P |
|---|---|---|---|---|
| **Shore** | Total coliform | -3.85 | 6914 | <0.001 |
| | Fecal coliform | -6.47 | 5002 | <0.001 |
| | Enterococcus | -3.99 | 2255 | <0.001 |
| **Kelp** | Total coliform | 3.12 | 4579 | 0.002 |
| | Fecal coliform | 1.89 | 412 | 0.060 |
| | Enterococcus | -0.01 | 4625 | 0.989 |
| **Offshore** | Total coliform | 13.63 | 7554 | <0.001 |
| | Fecal coliform | 14.81 | 9357 | <0.001 |
| | Enterococcus | 4.02 | 7314 | <0.001 |

period, they were distributed across all contours, with the highest detection rate occurring at the 38-m contour.

Measured levels of TSS in offshore station water samples also increased during the post-discharge period. While the difference in mean levels was significant (independent sample t-test: t=15.60; df=6875; P<0.001), the actual difference was small (mean±SE: pre-discharge=5.04±0.07 mg/L; post-discharge=6.13±0.05 mg/L). Mean levels of TSS increased along all sampled contours during the post-discharge period (**Figure 3.14A**). In addition, post-discharge mean levels of TSS were higher from most sample depths (Figure 3.14B). The 1995–2006 data showed a significant correlation between TSS and total and fecal coliforms, including F:T, in the offshore station water samples (Table 3.5). While these relationships are significant, little of the variation is explained. This is shown in **Figure 3.15**, where water samples contain a range of TSS values that coincide with elevated total fecal coliforms.




## Figure 3.10
SBOO kelp station mean bacterial densities (mean±SE) collected by (A) period and (B) depth from 1995–2006. The pre-discharge period is from October 2, 1995 to January 12, 1999 while post-discharge is from January 13, 1999 to December 31, 2006. Sample size=Pre/Post. Total=total coliform (n=342/4239), Fecal=fecal coliform (n=342/4285), Entero=enterococcus (n=342/4285).

## SUMMARY AND CONCLUSIONS

Bacterial concentrations in shore station samples that exceeded COP standards in 2006 appear to have been caused by contamination from either river discharge or from runoff during and after storm events. Bacterial concentration and visible satellite imagery data indicate that flows from the Tijuana River, Los Buenos Creek, and non-point source

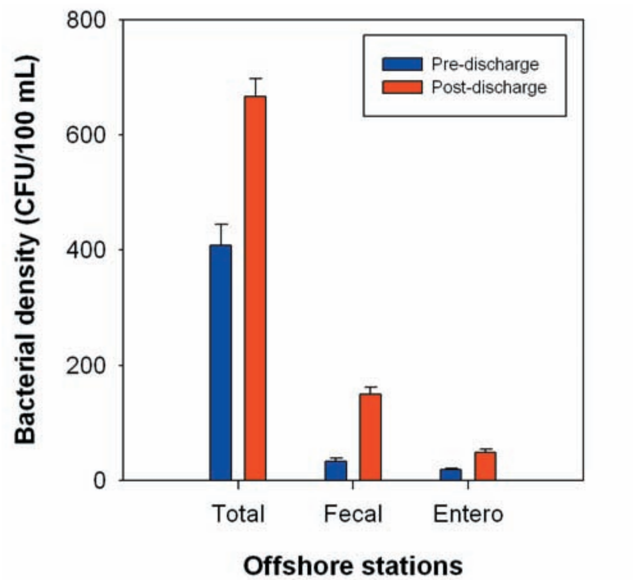



**Figure 3.11**
Mean bacterial densities (mean±SE) for SBOO monthly offshore stations from 1995–2006. The pre-discharge period is from October 2, 1995 to January 12, 1999 while post-discharge is from January 13, 1999 to December 31, 2006. Sample size=Pre/Post. Total=total coliform (n=3421/7962), Fecal=fecal coliform (n=3428/7969), Entero=enterococcus (n=3428/7970).

stormwater runoff are more likely than wastewater discharge to impact water quality along and near the shore.

Data from the bacterial analyses indicate that the wastewater plume from the SBOO rarely reached surface waters in 2006. Thermal stratification that began in March/April likely prevented the wastewater plume from surfacing through most of the year. Most elevated bacterial counts evident of contamination near the surface in January, March, April, June, and October occurred during periods of rainfall or when turbidity plumes from the Tijuana River or Los Buenos Creek reached the affected stations. Results highly indicative of wastewater reaching the surface occurred only in January near the outfall diffusers (station I12). The majority of the subsurface (>2 m depth) monthly water quality samples indicative of the wastewater plume occurred at depths of 18 m and below. Stations near the outfall had the highest incidences of samples indicative of wastewater, which were collected throughout the year.

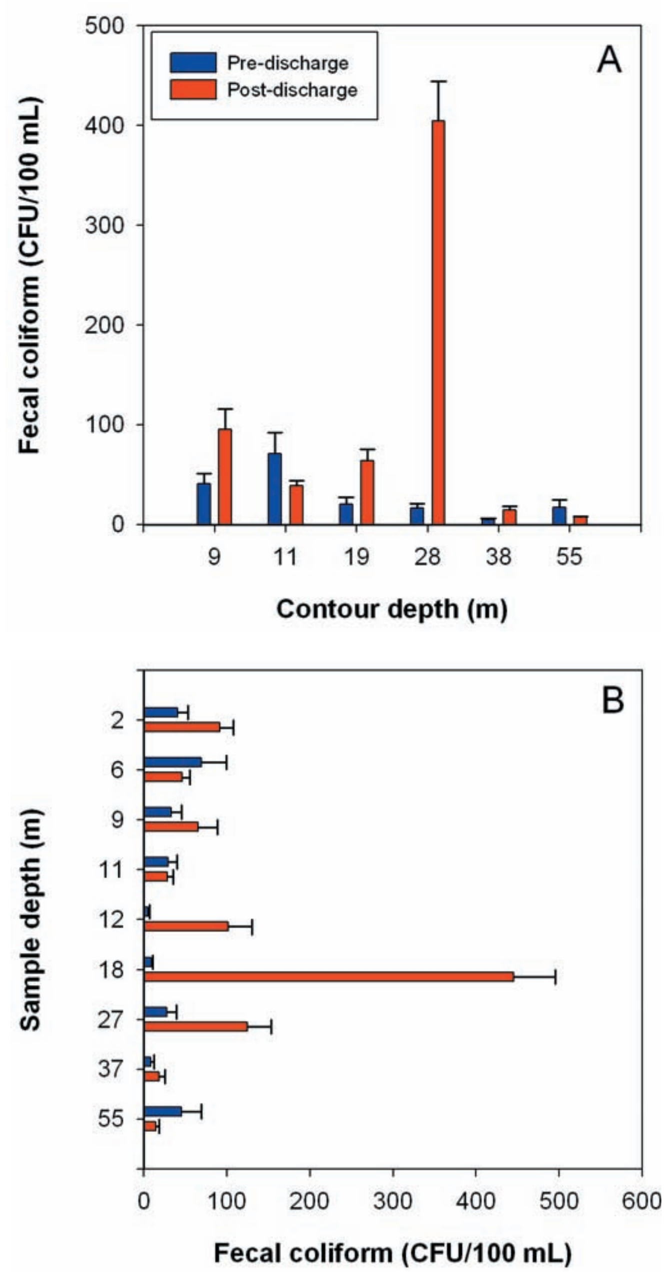
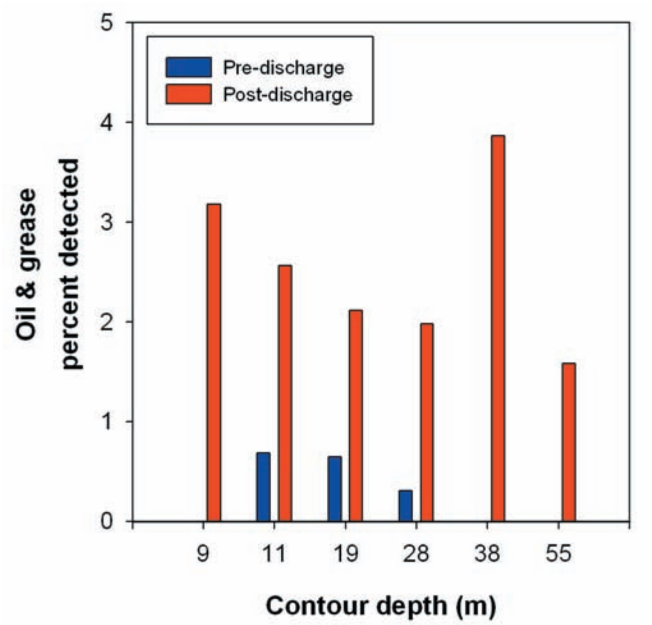



**Figure 3.12**
SBOO monthly offshore mean fecal coliform densities (mean±SE) collected by (A) transect and (B) depth from 1995–2006. The pre-discharge period is from October 2, 1995 to January 12, 1999 (n=3428) while post-discharge is from January 13, 1999 to December 31, 2006 (n=7969).

Rain and flows from the Tijuana River and Los Buenos Creek appear to be the primary sources of the nearshore bacteriological contamination. These conditions had the largest impact on water quality in the South Bay region during 2006. Although elevated bacterial densities were detected at the 9 to 19-m depth contour stations and shore stations



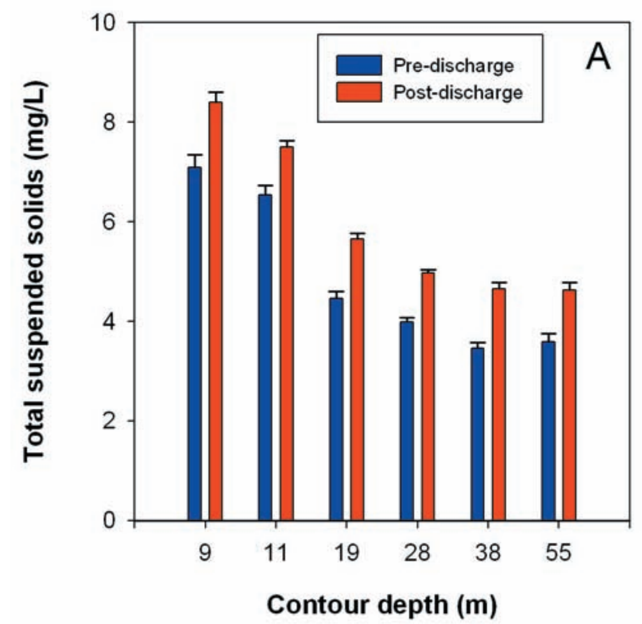




**Figure 3.13**
Percent of water samples where oil and grease were detected for SBOO monthly offshore stations from 1995–2006. The pre-discharge period is from October 2, 1995 to January 12, 1999 (n=1143) while post-discharge is from January 13, 1999 to December 31, 2006 (n=2653). The O&G detection level changed from 0.2 to 1.4 mg/L in January 2003.

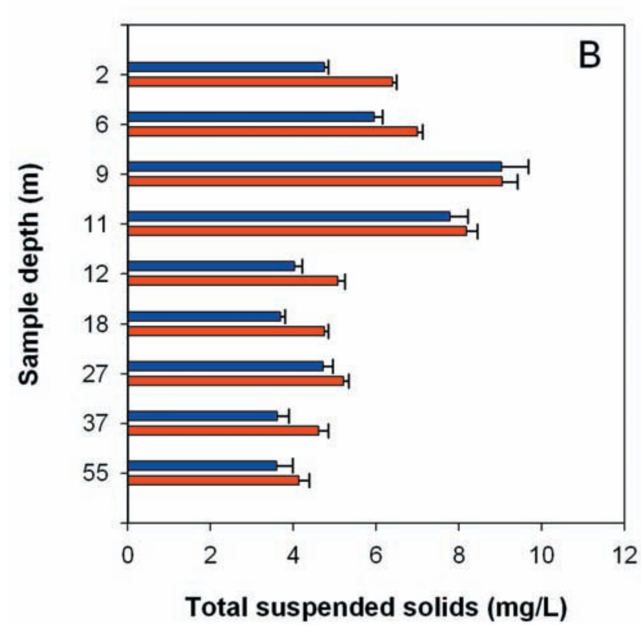



**Figure 3.14**
SBOO monthly offshore mean total suspended solids (mean±SE) collected by (A) transect and (B) depth from 1995–2006. The pre-discharge period is from October 2, 1995 to January 12, 1999 (n=3413) while post-discharge is from January 13, 1999 to December 31, 2006 (n=7975).

throughout the year, these data do not indicate a shoreward transport of the SBOO discharge plume.

A historical analysis indicated that mean coliform bacteriological densities at shore stations were slightly lower during the post-discharge period. While the mean total coliform density from the kelp stations was lower during the post-discharge period, all mean bacteriological densities at kelp stations were low during both periods. In contrast, offshore station mean bacteriological densities increased during the post-discharge period and were highest at the stations nearest the SBOO diffusers. Measured levels of oil and grease were detected more frequently and total suspended solids were slightly higher during the post-discharge period. While total suspended solids are not a consistent indicator of the waste field, there is a significant relationship which explains little of the variability between total coliforms and total suspended solids for the period from 1995–2006.

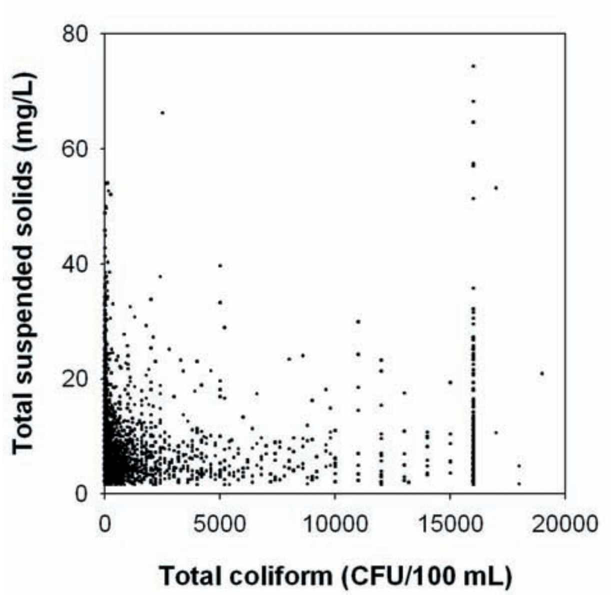



**Figure 3.15**
SBOO monthly offshore total suspended solids and total coliform densities from 1995–2006 (n=11,359).

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# Chapter 4. Sediment Characteristics

## INTRODUCTION

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

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

The chemical composition of sediments can also be affected by the geological history of an area. For example, sediment erosion from cliffs and shores, and the flushing of sediment particles and terrestrial debris from bays, rivers and streams, contribute to the composition of metals and organic content within an area. Additionally, nearshore primary productivity by marine plankton contributes to organic input in marine sediments (Mann 1982, Parsons et al. 1990). Finally, concentrations of various constituents within sediments are often affected by sediment particle size. For example, the levels of organic materials and trace metals within ocean sediments generally rise with increasing amounts of fine particles (Emery 1960, Eganhouse and Vanketesan 1993).

Ocean outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of ocean 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 discharged via outfalls are trace metals, pesticides and various organic compounds (e.g., organic carbon, nitrogen, sulfides) (Anderson et al. 1993). Moreover, the presence of large outfall pipes and structures associated can alter the hydrodynamic regime in the immediate area.

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2006 in the vicinity of the South Bay Ocean Outfall (SBOO). The primary goals are to: (1) assess possible impact of wastewater discharge on the benthic environment by analyzing spatial and temporal variability of various sediment parameters, and (2) determine the presence or absence of sedimentary and chemical footprints near the discharge site.

## MATERIALS AND METHODS

Sediment samples were collected during January and July 2006 at 27 stations surrounding the SBOO (**Figure 4.1**). These stations range in depth from 18 to 60 m and are distributed along 4 main depth contours. Listed from north to south along each contour, these stations include: I35, I34, I31, I23, I18, I10, and I4 (19-m contour); I33, I30, I27, I22, I14, I16, I15, I12, I9, I6, I2, and I3 (28-m contour); I29, I21, I13, and I8 (38-m contour); I28, I20, I7, and I1 (55-m contour). Each sample was collected from one-half of a chain-rigged 0.1 $m^2$ double Van Veen grab; 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).

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Laboratory. Particle size analysis was

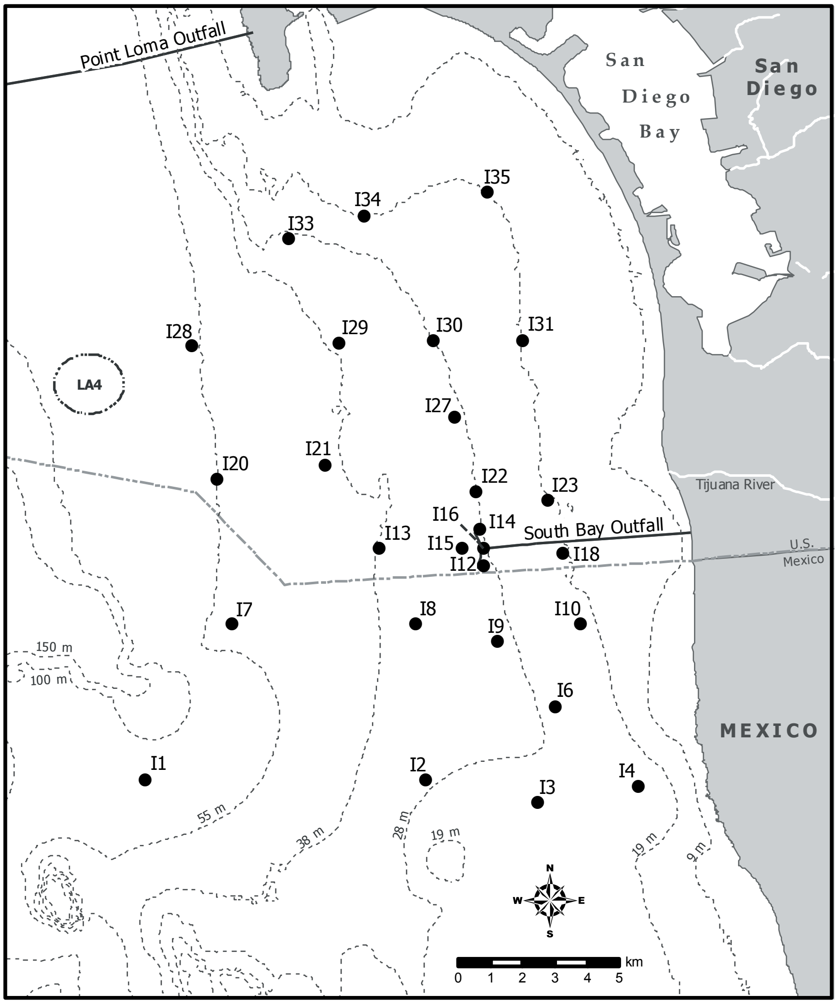



**Figure 4.1**
Benthic sediment station locations sampled for the South Bay Ocean Outfall Monitoring Program.

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 C.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

## 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: $D(phi) = -3.3219\log_{10}D(mm)$

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±standard deviation of station-quarter values.

Concentrations of the sediment constituents that were detected in 2006 were compared to average results from previous years, including the pre-discharge period (1995–1998). 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.

## RESULTS AND DISCUSSION

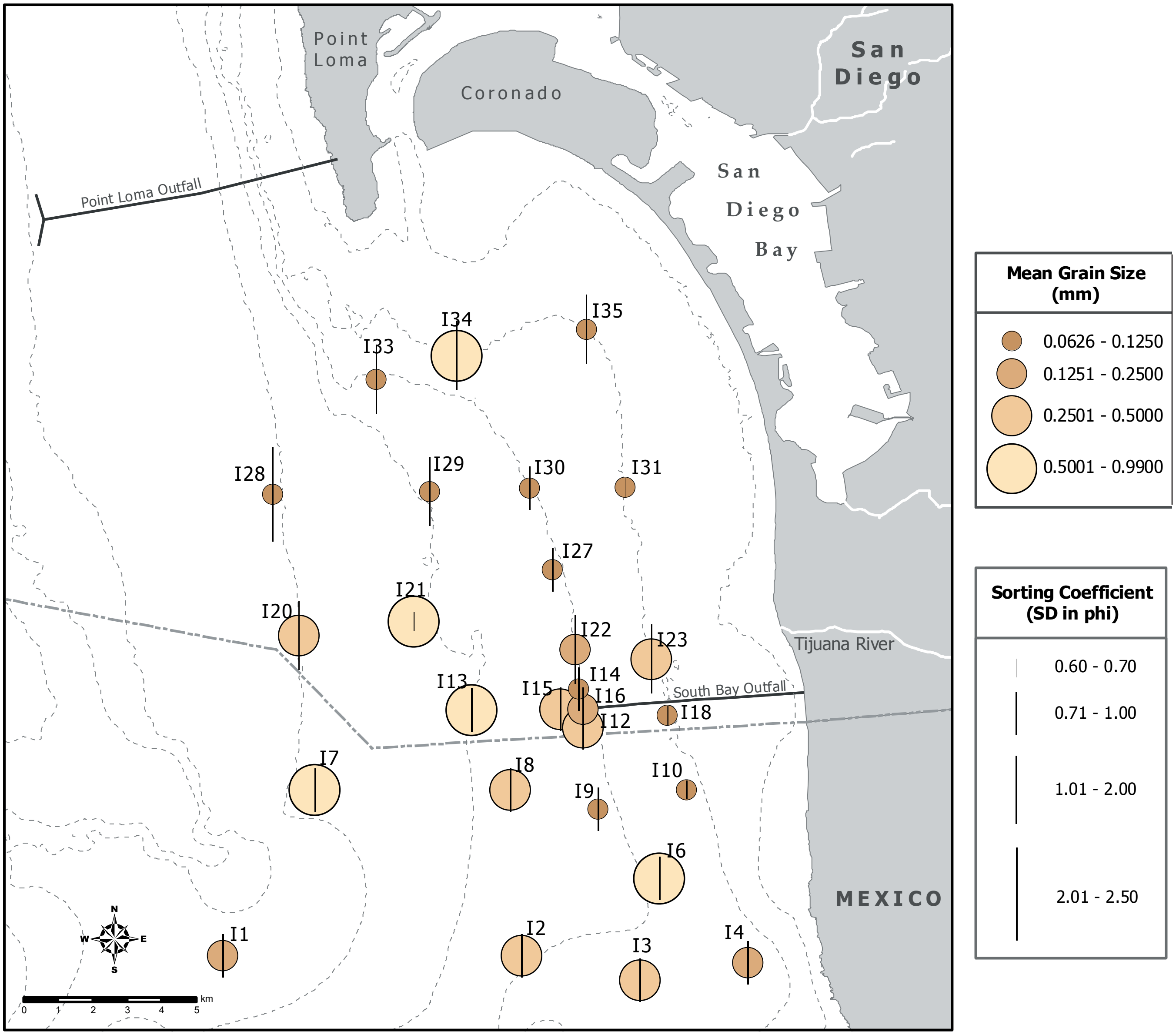
### Particle Size Distribution

Sediment composition at sites surrounding the SBOO ranged from very fine to coarse sands (0.064–0.609 mm) in 2006 with an area-wide mean of 0.258 mm (**Table 4.2**). Generally, stations located farther offshore and southward of the SBOO had coarser sediments than those located inshore and to the north of the outfall (**Figure 4.2**). This pattern is primarily due to deposits of coarse red relict sands found at several of these stations (e.g., I6, I7, I13, I20, I21; see **Appendix C.2**). Stations located along the shallower 19 and 28-m contours and towards the mouth of San Diego Bay typically had finer sediments (diameter <0.125 mm), with samples collected at stations I23 and I34 being notable exceptions (see below). The higher silt content at

## Table 4.2

Annual means (n=2) for particle size parameters and organic loading indicators at SBOO stations during 2006. CDF=cumulative distribution functions (see text); na=not available. MDL=method detection limit. Area Mean=mean for all stations. Pre-discharge period = 1995–1998. Bolded values exceed the median CDF.

| | Particle Size | | | | | | Organic Indicators | | |
|---|---|---|---|---|---|---|---|---|---|
| **Station** | **Mean (mm)** | **Mean (phi)** | **SD (phi)** | **Coarse (%)** | **Sand (%)** | **Fines (%)** | **Sulfides ppm** | **TN WT%** | **TOC WT%** |
| **CDF** | | | | | | 38.5 | na | 0.051 | 0.748 |
| **MDL** | | | | | | | 0.14 | 0.005 | 0.010 |
| *19 m stations* | | | | | | | | | |
| I35 | 0.064 | 4.0 | 1.45 | 0.0 | 59.5 | **40.5** | 32.15 | 0.037 | 0.415 |
| I34 | 0.511 | 1.1 | 1.10 | 19.8 | 79.3 | 0.9 | 0.15 | 0.000 | **0.800** |
| I31 | 0.124 | 3.0 | 0.60 | 0.2 | 92.4 | 7.5 | 1.17 | 0.021 | 0.210 |
| I23 | 0.457 | 1.8 | 1.10 | 19.0 | 73.4 | 7.7 | 1.44 | 0.015 | **3.487** |
| I18 | 0.111 | 3.2 | 0.65 | 0.2 | 90.0 | 9.9 | 2.12 | 0.014 | 0.123 |
| I10 | 0.118 | 3.1 | 0.65 | 0.2 | 91.5 | 8.4 | 1.09 | 0.017 | 0.143 |
| I4 | 0.135 | 2.9 | 0.85 | 0.2 | 92.2 | 7.7 | 3.01 | 0.019 | 0.282 |
| *28 m stations* | | | | | | | | | |
| I33 | 0.124 | 3.1 | 1.05 | 0.4 | 86.6 | 13.0 | 14.06 | 0.023 | 0.544 |
| I30 | 0.102 | 3.3 | 1.00 | 0.4 | 83.8 | 15.8 | 6.48 | 0.020 | 0.190 |
| I27 | 0.109 | 3.2 | 0.75 | 0.2 | 88.0 | 11.9 | 1.15 | 0.019 | 0.174 |
| I22 | 0.156 | 2.8 | 1.05 | 0.5 | 89.1 | 10.5 | 7.28 | 0.019 | 0.162 |
| I16 | 0.160 | 2.7 | 1.00 | 0.2 | 91.6 | 8.3 | 1.37 | 0.017 | 0.138 |
| I15 | 0.323 | 1.7 | 1.00 | 3.7 | 92.5 | 3.8 | 0.24 | 0.012 | 0.084 |
| I14 | 0.111 | 3.2 | 1.00 | 0.2 | 85.7 | 14.2 | 10.89 | 0.023 | 0.225 |
| I12 | 0.262 | 2.2 | 0.80 | 2.4 | 93.1 | 4.6 | 0.39 | 0.009 | 0.105 |
| I9 | 0.093 | 3.5 | 1.00 | 0.2 | 80.5 | 19.4 | 9.19 | 0.028 | 0.280 |
| I6 | 0.519 | 1.0 | 0.75 | 8.6 | 91.3 | 0.2 | 0.09 | 0.013 | 0.152 |
| I3 | 0.400 | 1.4 | 0.80 | 5.6 | 94.5 | 0.0 | 0.78 | 0.006 | 0.052 |
| I2 | 0.343 | 1.5 | 0.80 | 4.3 | 95.7 | 0.0 | 0.30 | 0.006 | 0.063 |
| *38 m stations* | | | | | | | | | |
| I29 | 0.080 | 3.7 | 1.15 | 0.1 | 70.0 | 30.0 | 5.08 | 0.036 | 0.500 |
| I21 | 0.609 | 0.7 | 0.60 | 10.8 | 89.2 | 0.0 | 0.08 | 0.005 | 0.068 |
| I13 | 0.528 | 1.0 | 0.75 | 8.3 | 91.1 | 0.7 | 0.24 | 0.008 | 0.148 |
| I8 | 0.478 | 1.1 | 0.80 | 7.4 | 91.3 | 1.3 | 0.24 | 0.008 | 0.080 |
| *55 m stations* | | | | | | | | | |
| I28 | 0.084 | 3.7 | 2.05 | 3.9 | 61.5 | 34.7 | 11.00 | 0.041 | **0.788** |
| I20 | 0.302 | 1.9 | 1.80 | 7.4 | 78.3 | 14.4 | 0.19 | 0.013 | 0.123 |
| I7 | 0.550 | 0.9 | 0.80 | 10.4 | 88.5 | 1.1 | 0.19 | 0.011 | 0.099 |
| I1 | 0.131 | 3.0 | 0.90 | 0.0 | 91.2 | 8.8 | 0.74 | 0.022 | 0.250 |
| **Area Mean** | 0.258 | 2.4 | 0.97 | 4.2 | 85.6 | 10.2 | 4.11 | 0.017 | 0.359 |
| **Pre-discharge** | 0.213 | 2.3 | 0.80 | 1.4 | 87.7 | 10.2 | 4.59 | 0.019 | 0.143 |




## Figure 4.2

Mean particle size distribution for SBOO sediment chemistry stations sampled during January and July 2006. Mean particle size is based on diameter in millimeters, with sorting coefficient (standard deviation) in phi units.

most shallower stations is probably due to sediment deposition from the Tijuana River and to a lesser extent from San Diego Bay (see City of San Diego 1988, 2003a).

Several stations experienced relatively large differences in sediment composition between the January and July surveys. The greatest difference occurred at stations I23 and I34 where mean particle size differed by approximately 0.7 and 0.4 mm, respectively (Appendix C.2). Station I34 is located just south of the channel that enters San Diego Bay, and maintenance dredging of the harbor entrance channel may occasionally affect sediments in the area. The last documented dredging in the area occurred in September 2004 (www.portofsandiego.org/projects/harbordredging/). Station I23 is located in shallow water offshore of the Tijuana River, where increased runoff from storms may impact sediment deposition or removal. Substantial (~30%) differences in the amount of coarse materials between surveys occurred at both stations (I23 and I34). Red relict sands, cobble, and coarse sands were collected at station I34 in January, but not in July. In contrast, large amounts of coarse sands were collected at station I23 in July

## Table 4.3

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 | Phi | mm | SD | % Fines | % Coarse | Sulfides | TN | TOC |
|---|---|---|---|---|---|---|---|---|
| 1995 | 2.6 | 0.212 | 0.8 | 12.0 | 2.6 | 2.88 | 0.019 | 0.148 |
| 1996 | 2.6 | 0.206 | 0.9 | 11.2 | 0.8 | 3.23 | 0.022 | 0.149 |
| 1997 | 2.5 | 0.219 | 0.7 | 9.5 | 0.7 | 6.32 | 0.019 | 0.147 |
| 1998 | 2.5 | 0.214 | 0.7 | 9.0 | 2.1 | 5.11 | 0.017 | 0.132 |
| 1999 | 2.5 | 0.237 | 0.7 | 8.8 | 0.9 | 2.39 | 0.017 | 0.129 |
| 2000 | 2.5 | 0.208 | 0.8 | 8.8 | 1.0 | 4.32 | 0.021 | 0.130 |
| 2001 | 2.3 | 0.254 | 0.8 | 8.4 | 1.5 | 0.91 | 0.015 | 0.149 |
| 2002 | 2.4 | 0.259 | 0.8 | 9.8 | 2.3 | 0.78 | 0.016 | 0.139 |
| 2003 | 2.3 | 0.243 | 0.9 | 8.8 | 3.3 | 2.61 | 0.015 | 0.119 |
| 2004 | 2.3 | 0.263 | 1.1 | 9.1 | 4.5 | 2.93 | 0.018 | 0.135 |
| 2005 | 2.2 | 0.265 | 1.1 | 10.1 | 4.8 | 1.43 | 0.023 | 0.186 |
| 2006 | 2.4 | 0.258 | 1.0 | 10.2 | 4.2 | 4.11 | 0.017 | 0.234 |

that were not present in January. Other sites that experienced differences of at least 0.2 mm in mean grain size between surveys include station I15 near the SBOO discharge site and station I20 located further offshore along the 55-m contour.

The sorting coefficient reflects the range of grain sizes comprising sediments and is calculated as the standard deviation of the grain size in phi (see Table 4.1). Generally, areas composed of similarly sized particles are considered to have well-sorted sediments (SD ≤ 0.5 phi) suggestive of strong wave and current activity within an area (see Gray 1981). In contrast, particles of varied sizes have poorly sorted sediments (SD ≥1.0 phi) indicative of low wave and current activity. South Bay sediments were moderately to poorly sorted, suggesting either reduced wave and current velocity or some disturbance. Mean sorting coefficients in the area surrounding the SBOO ranged from 0.6–2.1 phi during the 2006 surveys, while individual sites averaged 0.9±0.4 phi (Table 4.2, Appendix C.2). Thirteen of the 27 stations had poorly sorted sediments (i.e., SD ≥1.0 phi), including 3 sites along the 19-m contour, 7 sites along the 28-m contour, 1 site along the 38-m contour, and 2 sites along the 55-m contour (see Figure 4.2). Station I35 near the mouth of San Diego Bay, and stations I20 and I28 along the 55-m contour had the highest mean sorting coefficients (>1.4 phi). The sorting coefficients for I28 and I35, along with station I29, have consistently been >1.0 (see City of San Diego 2006).

Overall mean particle size for the South Bay has increased over time (see **Table 4.3**). For example, mean particle size during the 1995–1998 period was <0.22 mm but has ranged from 0.243 to 0.265 mm since 2001. Particle size began to increase after 1998 when El Niño conditions produced powerful storms and heavy surf that eroded beaches along the San Diego coastline (City of San Diego 2003b, U.S. Army Corp of Engineers 2002). Drought conditions that persisted in San Diego from 1999 through early 2004 resulted in a reduction of runoff from rivers and bays that most likely caused a decrease in deposition of terrestrial fine particles onto the ocean shelf. In addition, record rainfall from October 2004 through February 2005 and associated heavy surf resulted in severe loss of beach sand from Imperial Beach as well as other beaches in San Diego County (Zúñiga 2005). Overall, the increase in particle size in the South Bay appears to be in part the result of accretion of coarser sediments lost from the Silver Strand littoral cell.

### Indicators of Organic Loading

Mean concentrations of total organic carbon (TOC) in South Bay sediments in 2006 were higher than in previous surveys, whereas total nitrogen (TN) values declined slightly (see Table 4.3). For example, the area mean for TOC was 0.359% in 2006 compared to the previous high of 0.186% in 2005. This increase was due primarily to an abnormally high value (6.85%) measured at station I23 in July, along with 8 other stations (I4, I6, I14, I22, I23, I31, I33, I34, I35) that increased 25% or more in mean TOC concentration relative to 2005 (see City of San Diego 2006). All of these 9 stations are located in shallow waters or near San Diego Bay, the Tijuana River, and the SBOO. TOC concentrations at 3 sites (I23, I28, I34) were above the SCB median value. Although high compared to the surrounding deeper sites, these TOC values are similar to those located at similar depths from the July 2006 regional benthic survey (see Chapter 8). The higher TOC concentrations at these stations may represent a carry-over of persistent discharge from San Diego Bay and the Tijuana River during the winter of 2004–2005 that was laden with organic material, or die-off from the extensive 2004–2005 plankton bloom (see City of San Diego 2006). Although high concentrations of TOC typically correspond to higher concentrations of fine sediments (Emery 1960, Eganhouse and Venkatesan 1993), this was not necessarily true of samples collected in 2006. Of the above 9 sites, only 4 averaged percent fines above 10%, including just one of 3 sites with the highest average TOC concentration.

Sulfide concentrations averaged from 0.08 to about 32 ppm during the year. The area mean of 4.11 ppm in 2006 was higher than in 2005, and is due primarily to an exceptionally high value at station I35 (32.15 ppm). Unlike TOC or TN, higher sulfide concentrations tended to co-occur with sediments containing >10% fine particles. These stations included several sites north of the SBOO and (i.e., I14, I22, I27, I28, I29, I30, I33, I35) and only one southern site (I9). Overall, concentrations of organic loading indicators were similar to those of the random survey results and there was no pattern in relative to wastewater discharge.

### Trace Metals

Aluminum, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, nickel, tin, and zinc were detected at 100% of the South Bay area stations in 2006 (**Table 4.4**). In contrast, antimony, mercury, silver, and thallium were detected less frequently, while selenium was not detected at all. Area means for most metals were lower in 2006 compared to prior years. For example, concentrations of 11 trace metals exceeded pre-discharge means in 2005 (see City of San Diego 2006), whereas only 5 metals did so in 2006. Moreover, 2006 mean concentrations of 8 metals (aluminum, arsenic, beryllium, chromium, iron, manganese, thallium, zinc) were equal to or lower than pre-discharge means.

Stations composed of coarse materials and red relict sands (I7, I13, I21) contained concentrations of arsenic above the median CDF. In addition, station I10, located along the 19-m contour south of the SBOO had concentrations of copper and zinc above the median CDF, while stations I29 and I35 had concentrations of antimony above the median. These high values were a result of significant increases between January and July of 4.2 to 99.2 ppt and 57.6 to 95.6 ppt for copper and zinc, respectively. Nearly all trace metal concentrations were below the ERL sediment quality thresholds for metals of concern (i.e., cadmium chromium, copper, lead, mercury, nickel, silver, zinc); exceptions were for arsenic at station I21 and copper at station I10.

Generally, there was no pattern in trace metal contamination related to proximity to the SBOO. Instead, metal concentrations were typically highest in sediments composed of high percentages of fine materials. Three stations (i.e., I28, I29, I35) containing 30% or more of fine materials contained nearly all of the highest or second highest concentrations of individual metals. Arsenic, which

## Table 4.4

Annual mean concentrations of trace metals (parts per million) detected at each station during 2006. CDF=cumulative distribution function. MDL=method detection limit. ERL=effects range low threshold value. nd=not detected. Pre-discharge values (1995–1998). See Appendix A.1 for metal names represented by the periodic table symbols. Bolded values exceed the median CDF.

| | Al | Sb | As | Ba | Be | Cd | Cr | Cu | Fe | Pb | Mn | Hg | Ni | Ag | Tl | Sn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MDL** | 1.15 | 0.13 | 0.33 | 0.002 | 0.001 | 0.01 | 0.016 | 0.028 | 0.75 | 0.142 | 0.004 | 0.003 | 0.036 | 0.013 | 0.022 | 0.059 | 0.052 |
| **CDF** | 9400 | 0.2 | 4.80 | na | 0.26 | 0.29 | 34.0 | 12.0 | 16800 | na | na | 0.040 | na | 0.17 | na | na | 56.0 |
| **ERL** | na | na | 8.2 | na | na | 1.2 | 81 | 34 | na | 46.7 | na | 0.15 | 20.9 | 1.0 | na | na | 150 |
| *19 m stations* | | | | | | | | | | | | | | | | | |
| I35 | 9365 | **0.3** | 2.23 | 47.50 | 0.07 | 0.08 | 14.5 | 8.2 | 10550 | 5.31 | 101.0 | 0.019 | 5.7 | 0.12 | 0.14 | 1.0 | 26.2 |
| I34 | 1405 | 0.1 | 1.58 | 6.85 | 0.01 | 0.01 | 4.1 | 2.9 | 3250 | 2.35 | 23.1 | nd | 0.7 | nd | 0.19 | 1.1 | 4.7 |
| I31 | 3295 | 0.2 | 0.80 | 16.65 | 0.02 | 0.03 | 6.6 | 2.1 | 3140 | 1.64 | 35.5 | nd | 1.5 | 0.02 | 0.18 | 0.6 | 6.1 |
| I23 | 3335 | 0.1 | 1.48 | 22.98 | 0.03 | 0.06 | 6.4 | 3.2 | 4115 | 2.02 | 40.8 | nd | 1.7 | 0.02 | 0.00 | 0.7 | 7.0 |
| I18 | 4755 | 0.1 | 1.56 | 39.70 | 0.03 | 0.02 | 9.3 | 3.7 | 5695 | 2.04 | 55.7 | nd | 2.3 | nd | 0.12 | 0.6 | 10.6 |
| I10 | 6140 | 0.2 | 1.36 | 50.25 | 0.03 | 0.02 | 8.9 | **51.7** | 6715 | 1.93 | 76.6 | nd | 2.8 | 0.03 | nd | 0.7 | **74.1** |
| I4 | 3740 | 0.2 | 1.04 | 23.50 | 0.02 | 0.03 | 7.7 | 3.0 | 4045 | 2.22 | 41.8 | nd | 2.6 | 0.03 | nd | 0.6 | 8.8 |
| *28 m stations* | | | | | | | | | | | | | | | | | |
| I33 | 4800 | 0.1 | 1.89 | 23.65 | 0.03 | 0.04 | 8.4 | 4.1 | 6140 | 3.94 | 65.1 | 0.014 | 2.7 | 0.02 | nd | 0.9 | 14.2 |
| I30 | 6560 | 0.2 | 1.85 | 32.45 | 0.04 | 0.06 | 11.0 | 4.2 | 6780 | 2.76 | 65.3 | 0.010 | 3.5 | 0.05 | nd | 0.7 | 16.2 |
| I27 | 5690 | 0.1 | 1.28 | 28.95 | 0.03 | 0.03 | 9.3 | 3.5 | 5745 | 2.54 | 56.5 | nd | 2.9 | 0.06 | 0.12 | 0.7 | 13.0 |
| I22 | 4190 | 0.1 | 1.53 | 21.00 | 0.03 | 0.05 | 8.3 | 2.5 | 4765 | 2.62 | 43.8 | 0.002 | 2.5 | 0.03 | nd | 0.8 | 10.3 |
| I16 | 3305 | 0.1 | 1.38 | 24.35 | 0.03 | 0.06 | 7.1 | 3.1 | 4470 | 1.91 | 45.2 | 0.004 | 2.1 | 0.02 | nd | 0.9 | 10.1 |
| I15 | 2310 | 0.1 | 2.13 | 10.45 | 0.03 | 0.03 | 8.1 | 1.7 | 4215 | 1.79 | 28.5 | 0.002 | 1.6 | nd | nd | 0.6 | 8.4 |
| I14 | 6160 | 0.2 | 1.48 | 36.20 | 0.04 | 0.04 | 9.8 | 5.2 | 6575 | 2.95 | 67.4 | 0.002 | 3.3 | 0.09 | 0.15 | 0.6 | 16.3 |
| I12 | 2975 | 0.1 | 1.57 | 17.56 | 0.02 | 0.05 | 7.0 | 3.3 | 4145 | 2.09 | 36.6 | nd | 1.7 | 0.07 | 0.07 | 0.6 | 9.2 |
| I9 | 7490 | 0.2 | 1.08 | 45.35 | 0.04 | 0.03 | 12.1 | 5.9 | 7895 | 3.10 | 78.6 | 0.002 | 4.8 | 0.09 | 0.27 | 0.7 | 19.3 |
| I6 | 1047 | 0.2 | 3.70 | 4.03 | 0.01 | 0.04 | 8.2 | 1.1 | 3740 | 1.45 | 11.8 | nd | 0.8 | nd | nd | 0.7 | 3.7 |
| I3 | 589 | nd | 0.69 | 2.58 | 0.01 | 0.02 | 3.7 | 0.7 | 880 | 0.56 | 5.6 | nd | 0.5 | 0.05 | nd | 0.9 | 1.5 |
| I2 | 1225 | nd | 0.46 | 2.21 | 0.01 | 0.01 | 6.0 | 1.7 | 1270 | 1.05 | 10.5 | nd | 0.9 | 0.06 | nd | 0.8 | 2.1 |
| *38 m stations* | | | | | | | | | | | | | | | | | |
| I29 | 8680 | **0.3** | 2.71 | 46.65 | 0.07 | 0.05 | 13.8 | 7.3 | 9885 | 4.41 | 90.0 | 0.008 | 5.8 | 0.06 | 0.22 | 1.0 | 22.7 |
| I21 | 1030 | 0.1 | **10.80** | 2.10 | 0.02 | 0.09 | 10.7 | 2.5 | 8145 | 2.77 | 14.1 | nd | 0.8 | nd | nd | 0.9 | 5.8 |
| I13 | 1079 | 0.2 | **5.24** | 2.66 | 0.01 | 0.05 | 10.2 | 2.5 | 5625 | 2.27 | 15.7 | nd | 1.2 | nd | nd | 0.6 | 5.2 |
| I8 | 1395 | nd | 2.61 | 3.61 | 0.02 | 0.04 | 8.2 | 1.4 | 3790 | 1.25 | 15.5 | nd | 1.1 | 0.02 | nd | 0.6 | 6.0 |
| *55 m stations* | | | | | | | | | | | | | | | | | |
| I28 | 5315 | 0.2 | 2.89 | 27.45 | 0.06 | 0.06 | 10.5 | 6.5 | 7540 | 4.15 | 56.6 | 0.022 | 5.4 | 0.05 | nd | 1.1 | 17.1 |
| I20 | 1605 | 0.1 | 2.40 | 4.00 | 0.03 | 0.03 | 5.8 | 1.5 | 4405 | 1.75 | 16.9 | 0.002 | 1.4 | nd | nd | 0.7 | 6.6 |
| I7 | 1053 | 0.2 | **6.44** | 2.12 | 0.01 | 0.06 | 9.3 | 1.7 | 6685 | 2.16 | 14.7 | nd | 0.8 | nd | nd | 0.7 | 5.2 |
| I1 | 3080 | 0.2 | 0.94 | 11.16 | 0.03 | 0.06 | 7.4 | 3.7 | 3985 | 2.31 | 35.9 | 0.007 | 2.2 | nd | nd | 0.7 | 7.6 |
| Detection rate | 100 | 89 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 44 | 100 | 67 | 33 | 100 | 100 |
| Area mean | 3763 | 0.1 | 2.34 | 20.59 | 0.03 | 0.04 | 8.6 | 5.1 | 5340 | 2.42 | 42.5 | 0.003 | 2.3 | 0.03 | 0.05 | 0.8 | 12.5 |
| Pre-discharge | 5164 | 0.08 | 2.47 | NA | 0.13 | nd | 10.2 | 2.6 | 6568 | 0.09 | 55.4 | 0.002 | 1.9 | nd | 0.20 | nd | 12.5 |

## Table 4.5

Annual mean concentrations of pesticides and PAHs detected at each station during 2006. Beta endosulphan=(b)E; hexachlorobenzene=HCB; total DDT=tDDT; nd=not detected.

| STATION | DEPTH (m) | (b)E (ppb) | HCB (ppb) | tDDT (ppb) | tPAH (ppt) | tPAH No. |
|---|---|---|---|---|---|---|
| *19 m stations* | | | | | | |
| I35 | 19 | nd | nd | nd | 151.0 | 9 |
| I34 | 19 | nd | nd | nd | 106.7 | 11 |
| I31 | 19 | nd | nd | nd | 129.0 | 7 |
| I23 | 21 | nd | nd | nd | 110.2 | 7 |
| I18 | 19 | nd | nd | nd | 119.5 | 6 |
| I10 | 19 | nd | 300 | nd | 93.0 | 5 |
| I4 | 18 | nd | 305 | nd | 133.2 | 7 |
| *28 m stations* | | | | | | |
| I33 | 30 | 410 | nd | nd | 101.7 | 6 |
| I30 | 28 | nd | nd | nd | 119.4 | 5 |
| I27 | 28 | nd | nd | nd | 86.9 | 5 |
| I22 | 28 | nd | nd | nd | 137.5 | 9 |
| I16 | 28 | nd | 375 | nd | 110.7 | 5 |
| I15 | 31 | nd | nd | nd | 123.4 | 7 |
| I14 | 28 | nd | nd | nd | 123.4 | 6 |
| I12 | 28 | nd | 375 | nd | 109.3 | 11 |
| I9 | 29 | nd | 305 | nd | 146.4 | 5 |
| I6 | 26 | nd | nd | nd | 111.0 | 6 |
| I3 | 27 | nd | nd | nd | 135.0 | 8 |
| I2 | 32 | nd | nd | nd | 119.9 | 6 |
| *38 m stations* | | | | | | |
| I29 | 38 | nd | nd | 920 | 133.9 | 6 |
| I21 | 41 | nd | nd | nd | 102.5 | 8 |
| I13 | 38 | nd | nd | nd | 96.2 | 6 |
| I8 | 36 | nd | nd | nd | 91.6 | 5 |
| *55 m stations* | | | | | | |
| I28 | 55 | nd | nd | 845 | 79.8 | 10 |
| I20 | 55 | nd | nd | nd | 115.0 | 7 |
| I7 | 52 | nd | nd | nd | 102.9 | 7 |
| I1 | 60 | nd | nd | nd | 121.9 | 9 |

was the most prevalent trace metal at stations with coarse materials, was the single exception to this pattern.

### Pesticides

Low levels of 3 types of chlorinated pesticides were detected in sediment samples collected from just a few stations in 2006 (**Table 4.5**). Beta endosulfan was collected at station I33 at a concentration of 820 ppt in July; hexachlorobenzene (HCB) was collected at concentrations ranging from 600–750 ppt at 4 stations (I9, I10, I12, I16) in January and one station in July (I10); and p,p-DDE, a DDT derivative, was found at stations I28 and I29 during January and July with mean concentrations of 845 and 920 ppt, respectively. Two of the 4 January samples containing HCB were collected near the SBOO outfall at stations I12 and I16, while 2 others were collected at more southern stations (I9, I10). HCB has a variety of sources, including as a by-product of production of various regulated organic compounds, in the manufacture of fireworks, or the incineration of municipal wastes. Currently there are no commercial uses of HCB in the United States (DHHS—ASTDR 2002). Concentrations of DDT were lower than the median CDF value of 1200 ppt for this pesticide, and significantly lower than the ERL of 2200 ppt. Station I28 has had elevated pesticide levels in the past, which are most likely related to contamination from dredge disposal materials (see City of San Diego 2001, 2003a).

### PCBs and PAHs

PCBs were not detected in sediments from any station during 2006, while low levels of 17 PAH compounds were detected at all stations (Table 4.5). The PAH values were near or below MDL levels and should therefore be viewed with caution. The detection of low levels of PAHs at these stations appears to reflect a change in methodology where values below MDLs can be reliably estimated with qualitative identification via a mass spectrophotometer (see City of San Diego 2004). All of the values were well below the ERL of 4022 ppt for total PAH. There did not appear to be a relationship between PAH concentrations and proximity to the outfall.

## SUMMARY AND CONCLUSIONS

Sediments at the South Bay sampling sites consisted mainly of very fine to coarse sands in 2006. Spatial patterns in sediment composition within the region may be partially attributed to the multiple geological origins of red relict sands, shell hash, coarse sands, and other detrital sediments (Emery 1960). Stations located offshore and southward of the SBOO consisted of very coarse sediments. In contrast, stations located in shallower water and north of the outfall towards the mouth of San Diego Bay generally had finer sediments. Sediment deposition from the Tijuana River and to a lesser extent from San Diego Bay probably contributes to the higher content of silt at these stations (see City of San Diego 1988). Overall, mean particle size has increased over time, from pre-discharge means between 0.206–0.237 mm to post-discharge means between 0.243–0.265 mm. This increased particle size appears to be unrelated to wastewater discharge and may, in part, be the result of accretion of coarser sediments lost from the Silver Strand littoral cell or from storm-related deposition/erosion.

Although there was an overall increase in concentrations of sulfides and total organic carbon in South Bay sediments for 2006 compared to prior years, individual values generally remained low compared to the southern California continental shelf (see Noblet et al. 2003, Schiff and Gossett 1998). A relatively large increase in TOC in 2006 was related to increased concentrations at several shallow water stations located near San Diego Bay and offshore of the Tijuana River, particularly the July sediments at station I23. The TOC content at this station was 6.85%, a value typically associated with severely impacted areas (see Zeng et al 1995). Some of these increases may represent a carry-over of the persistent discharge from San Diego Bay and the Tijuana River during the winter of 2004–2005 which was laden with organic material or remnants of a lasting plankton bloom (see City of San Diego 2006).

Concentrations of most trace metals decreased in 2006 relative to previous surveys. Generally, trace metal concentrations in the SBOO sediments were near or below pre-discharge levels, and low compared to median values for southern California. Only a few stations contained trace metals concentrations above the SCB median value: stations I7, I13, I21 (arsenic); station I10 (copper and zinc); stations I29 and I35 (antimony). In addition, arsenic and copper levels were above the ERL sediment quality thresholds at stations I21 and I10, respectively. The elevated arsenic concentrations occurred where coarse materials including red relict sands were predominant. Such sediments typically contain high concentrations of arsenic. Higher concentrations of organic compounds and most trace metals were generally associated with finer sediments. This pattern is consistent with that found in other studies, in which the accumulation of fine particles has been shown to greatly influence the organic and metal content of sediments (e.g., Eganhouse and Venkatesan 1993).

Other sediment contaminants were rarely detected during 2006. For example, PCBs were not detected at all. Low levels of chlorinated pesticides were detected at only 7 stations, while PAHs were found at all stations but at concentrations near or below their respective method detection limits. Overall, there was no pattern in sediment contaminant concentrations relative to the SBOO discharge.

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# Chapter 5. Macrobenthic Communities

## INTRODUCTION

Benthic macroinvertebrates along the coastal shelf of southern California represent a diverse faunal community that is important to the marine ecosystem (Fauchald and Jones 1979, Thompson et al. 1993a, Bergen et al. 2001). These animals serve vital functions in wide ranging capacities. Some species decompose organic material as a crucial step in nutrient cycling, other species filter suspended particles from the water column, thus affecting water clarity. Many species of benthic macrofauna also are essential prey for fish and other organisms.

Human activities that impact the benthos can sometimes result in toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation. Certain macrofaunal species are highly sensitive to such changes and rarely occur in impacted areas. Others are opportunistic and can thrive under altered conditions. Because various species respond differently to environmental stress, monitoring macrobenthic assemblages can help to identify anthropogenic impact (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). Also, since the animals in these assemblages are relatively stationary and long-lived, they integrate environmental components spatially and temporally. Consequently, the assessment of benthic community structure is a major component of many marine monitoring programs which document both existing conditions and trends over time.

The structure of benthic communities is influenced by many factors including sediment conditions (e.g., particle size and sediment chemistry), water conditions (e.g., temperature, salinity, dissolved oxygen, and current velocity), and biological factors (e.g., food availability, competition, and predation). For example, benthic assemblages on the coastal shelf off San Diego typically vary along gradients in sediment particle size and/or depth. However, both human activities and natural processes can influence the structure of invertebrate communities in marine sediments. Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have documentation of background or reference conditions for an area. Such information is available for the area surrounding the South Bay Ocean Outfall (SBOO) and the San Diego region in general (e.g., City of San Diego 1999, 2000).

This chapter presents analyses and interpretations of the macrofaunal data collected at fixed stations surrounding the SBOO during 2006. Descriptions and comparisons of soft-bottom macrofaunal assemblages in the area and analysis of benthic community structure are included.

## MATERIALS AND METHODS

### Collection and Processing of Samples

Benthic samples were collected during January and July, 2006 at 27 stations surrounding the SBOO (**Figure 5.1**). These stations range in depth from 18 to 60 m and are distributed along 4 main depth contours. Listed from north to south along each contour, these stations include: I35, I34, I31, I23, I18, I10, and I4 (19-m contour); I33, I30, I27, I22, I14, I16, I15, I12, I9, I6, I2, and I3 (28-m contour); I29, I21, I13, and I8 (38-m contour); I28, I20, I7, and I1 (55-m contour).

Samples for benthic community analyses were collected from 2 replicate 0.1-$m^2$ van Veen grabs per station during the January and July surveys. An additional grab was collected at each station for sediment quality analysis (see Chapter 4). The criteria established by the United States Environmental Protection Agency (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

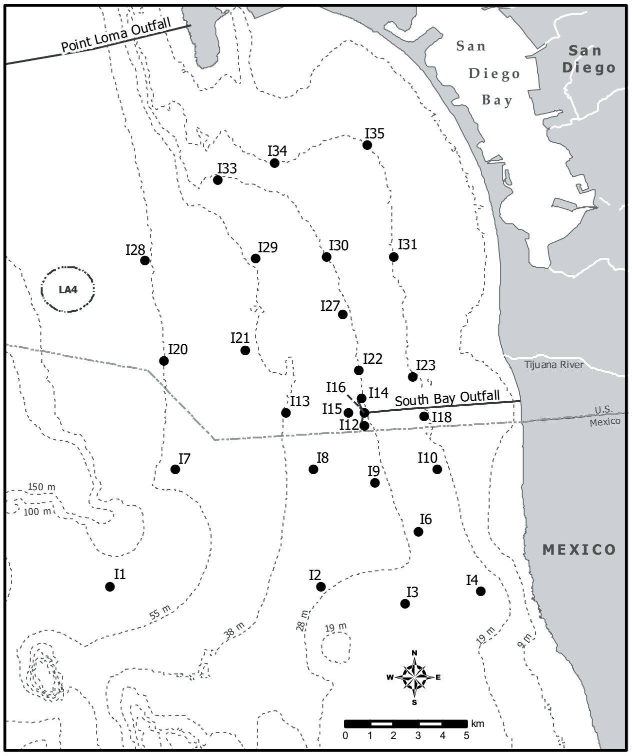



**Figure 5.1**
Macrobenthic station locations, South Bay Ocean Outfall Monitoring Program.

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 fresh water and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups by a subcontractor. Biomass was measured as the wet weight in grams per sample for each of the following taxonomic categories: Annelida (mostly polychaetes), Arthropoda (mostly crustaceans), Mollusca, Ophiuroidea, non-ophiuroid Echinodermata, and other miscellaneous phyla combined (e.g., Chordata, Cnidaria, Nemertea, Platyhelminthes, Phoronida, and Sipuncula). Values for ophiuroids and all other echinoderms were later combined to give a total echinoderm biomass. After biomassing, all animals were identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

### Data Analyses

The following community structure parameters were calculated for each station: species richness (number of species per 0.1-$m^2$ grab), annual total number of species per station, abundance (number of individuals per grab), biomass (grams per grab, wet weight), Shannon diversity index (H' per grab), Pielou's evenness index (J' per grab), Swartz dominance (minimum number of species accounting for 75% of the total abundance in each grab), Infaunal Trophic Index (mean ITI per grab, see Word 1980), and Benthic Response Index (mean BRI per grab, see Smith et al. 2001).

Multivariate analyses were performed using PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software to examine spatio-temporal patterns in the overall similarity of benthic assemblages in the region (see Clarke 1993, Warwick 1993). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). The macrofaunal abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for both classification and ordination. SIMPER analysis was used to identify individual species that typified each cluster group. Patterns in the distribution of macrofaunal assemblages were compared to environmental variables by overlaying the physico-chemical data onto MDS plots based on the biotic data (see Field et al. 1982).

## RESULTS AND DISCUSSION

### Community Parameters

***Number of species***
A total of 807 macrobenthic taxa were identified during 2006. Of these, 28% represented rare or unidentifiable taxa that were recorded only once. The average number of taxa per 0.1 $m^2$ grab ranged from 38 to 163, and the cumulative number of taxa per station ranged from 94 to 330 (**Table 5.1**). This wide variation in species richness is consistent with previous years, and can probably be attributed to different habitat types in the SBOO region (see City of San Diego 2005, 2006). Higher numbers of species, for example, are common at stations such as

## Table 5.1

Benthic community parameters at SBOO stations sampled during 2006. Data are expressed as annual means for: Species richness, no. species/0.1 $m^2$ (SR); total cumulative no. species for the year (Tot Spp); Abundance, no. individuals/0.1 $m^2$ (Abun); Biomass, g/0.1 $m^2$; 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 | Biomass | H' | J' | Dom | BRI | ITI |
|---|---|---|---|---|---|---|---|---|---|
| *19-m stations* | | | | | | | | | |
| I-35 | 72 | 147 | 302 | 4.7 | 3.4 | 0.79 | 23 | 27 | 75 |
| I-34 | 38 | 100 | 185 | 1.9 | 2.7 | 0.75 | 10 | 9 | 49 |
| I-31 | 48 | 119 | 102 | 1.6 | 3.5 | 0.90 | 23 | 21 | 74 |
| I-23 | 64 | 173 | 259 | 3.4 | 3.4 | 0.83 | 23 | 19 | 75 |
| I-18 | 43 | 101 | 96 | 1.4 | 3.4 | 0.91 | 20 | 19 | 79 |
| I-10 | 58 | 137 | 138 | 4.8 | 3.7 | 0.91 | 26 | 17 | 83 |
| I-4 | 74 | 152 | 182 | 3.9 | 3.9 | 0.91 | 32 | 20 | 77 |
| *28-m stations* | | | | | | | | | |
| I-33 | 106 | 217 | 503 | 5.0 | 3.2 | 0.69 | 24 | 27 | 73 |
| I-30 | 57 | 128 | 164 | 1.8 | 3.5 | 0.87 | 22 | 23 | 80 |
| I-27 | 57 | 133 | 138 | 1.1 | 3.6 | 0.90 | 24 | 22 | 82 |
| I-22 | 96 | 203 | 307 | 4.9 | 3.8 | 0.84 | 35 | 24 | 78 |
| I-14 | 91 | 195 | 316 | 4.1 | 3.8 | 0.85 | 31 | 23 | 82 |
| I-16 | 99 | 226 | 291 | 25.4 | 4.1 | 0.89 | 39 | 22 | 83 |
| I-15 | 71 | 166 | 270 | 3.0 | 3.5 | 0.82 | 21 | 20 | 77 |
| I-12 | 82 | 208 | 281 | 4.0 | 3.6 | 0.83 | 25 | 21 | 79 |
| I-9 | 90 | 195 | 346 | 3.0 | 3.8 | 0.84 | 28 | 23 | 82 |
| I-6 | 50 | 109 | 210 | 5.0 | 3.0 | 0.76 | 13 | 8 | 78 |
| I-2 | 49 | 104 | 158 | 3.9 | 3.2 | 0.83 | 18 | 13 | 74 |
| I-3 | 45 | 94 | 170 | 3.6 | 3.0 | 0.80 | 15 | 12 | 70 |
| *38-m stations* | | | | | | | | | |
| I-29 | 115 | 234 | 367 | 4.4 | 4.2 | 0.89 | 44 | 18 | 81 |
| I-21 | 52 | 120 | 120 | 2.4 | 3.5 | 0.89 | 23 | 11 | 86 |
| I-13 | 62 | 141 | 198 | 4.3 | 3.4 | 0.85 | 23 | 9 | 86 |
| I-8 | 62 | 134 | 186 | 4.5 | 3.6 | 0.88 | 24 | 15 | 83 |
| *55-m stations* | | | | | | | | | |
| I-28 | 163 | 330 | 536 | 7.5 | 4.5 | 0.89 | 55 | 15 | 80 |
| I-20 | 66 | 163 | 224 | 4.8 | 3.3 | 0.79 | 23 | 10 | 83 |
| I-7 | 58 | 144 | 152 | 3.2 | 3.6 | 0.89 | 26 | 10 | 88 |
| I-1 | 77 | 163 | 256 | 1.8 | 3.7 | 0.85 | 27 | 13 | 81 |
| Mean | 72 | 161 | 239 | 4.4 | 3.6 | 0.85 | 26 | 18 | 78 |
| Min | 29 | 94 | 61 | 0.6 | 2.2 | 0.58 | 5 | 2 | 18 |
| Max | 181 | 330 | 656 | 83.2 | 4.6 | 0.94 | 63 | 31 | 91 |

I28 and I29 where sediments are finer than most other sites (see Chapter 4). In addition, species richness varied between surveys, averaging about 16% higher in January than in July (see **Figure 5.2**). Although species richness varied both spatially and temporally, there were no apparent patterns relative to distance from the outfall.

Polychaete worms made up the greatest proportion of species, accounting for 35–61% of the taxa per site during 2006. Crustaceans composed 11–34% of the species, molluscs from 7 to 21%, echinoderms from 2 to 11%, and all other taxa combined about 5–19%. These percentages are generally similar to those observed during previous years, including prior to discharge (e.g., see City of San Diego 2000, 2004).

***Macrofaunal abundance***

Macrofaunal abundance ranged from a mean of 96 to 536 animals per grab in 2006 (Table 5.1). The greatest number of animals occurred at stations I33 and I28, which averaged over 500 individuals per sample. High abundances of the cirratulid polychaete, *Monticellina siblina* accounted for more than half of the individuals collected at station I33. Station I28 is typically characterized by high abundance, with a variety of different taxa accounting for the high numbers (see City of San Diego 2004). In contrast, station I18 averaged the fewest number of animals in 2006 (96 individuals per 0.1 $m^2$). Macrofaunal abundance varied between surveys, averaging about 31% higher in January than in July (Figure 5.2). Much of that increase is attributed to abundance values from stations I12, I23, I33, and I35. There were no clear spatial patterns in macrofaunal abundance relative to the outfall.

Similar to past years, polychaetes were the most abundant animals in the region, accounting for 38–75% of the different assemblages during 2006. Crustaceans averaged 5–39% of the animals at a station, molluscs from 2 to 21%, echinoderms from 1 to 10%, and all remaining taxa about 2–28% combined.

***Biomass***

Total biomass averaged from 1.1 to 25.4 grams per 0.1 $m^2$ (Table 5.1). High biomass values are often due to the collection of large motile organisms such as sea stars, crabs, and snails. For example, a single specimen of the mollusc *Kelletia kelletii* weighing 78.6 grams was collected in July 2006 and accounted for over 86% of the annual biomass at station I16. Although these large animals introduced considerable variability, overall biomass at the SBOO stations during the year was similar to historical values (Figure 5.2). Overall, polychaetes accounted for 7–72% of the biomass at a station, crustaceans 1–60%, molluscs 3–90%, echinoderms <1–60%, and all other taxa combined 0–47%. In the absence of large individual molluscs or echinoderms, polychaetes dominated most stations in terms of biomass.

***Species diversity and dominance***

Species diversity (H') varied during 2006, ranging from 2.7 at I34 to 4.5 at I28 (Table 5.1). Average diversity in the region generally was similar to previous years (Figure 5.2), and no patterns relative to distance from the outfall were apparent. The spatial patterns in evenness were similar to those for diversity and ranged from 0.69 to 0.91. Most sites with evenness values below the mean (0.85) were dominated by polychaetes.

Species dominance was measured as the minimum number of species whose combined abundance accounts for 75% of the individuals in a sample (Swartz et al. 1986, Ferraro et al. 1994). Consequently, dominance as discussed herein is inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species. Values at individual stations varied, averaging from 10 to 55 species per station during the year (Table 5.1). This range reflects the dominance of a few species at some of the SBOO stations (I34, I6, I3, and I2) versus others with many taxa contributing to the overall abundance (e.g., I28, I29). Dominance values for 2006 were similar to historical values (Figure 5.2). No clear patterns relative to the outfall were evident in dominance values.

***Environmental disturbance indices***

The benthic response index (BRI) during 2006 averaged from 8 to 27 at the various SBOO stations (Table 5.1). Index values below 25 (on a scale of 100) suggest undisturbed communities or "reference conditions," while those in the range of 25–33 represent "a minor deviation from reference conditions," which may reflect anthropogenic impact (Smith et al. 2001). Stations I33 and I35 were the only 2 stations that had a BRI value above 25 (BRI=27). There was no gradient of BRI values

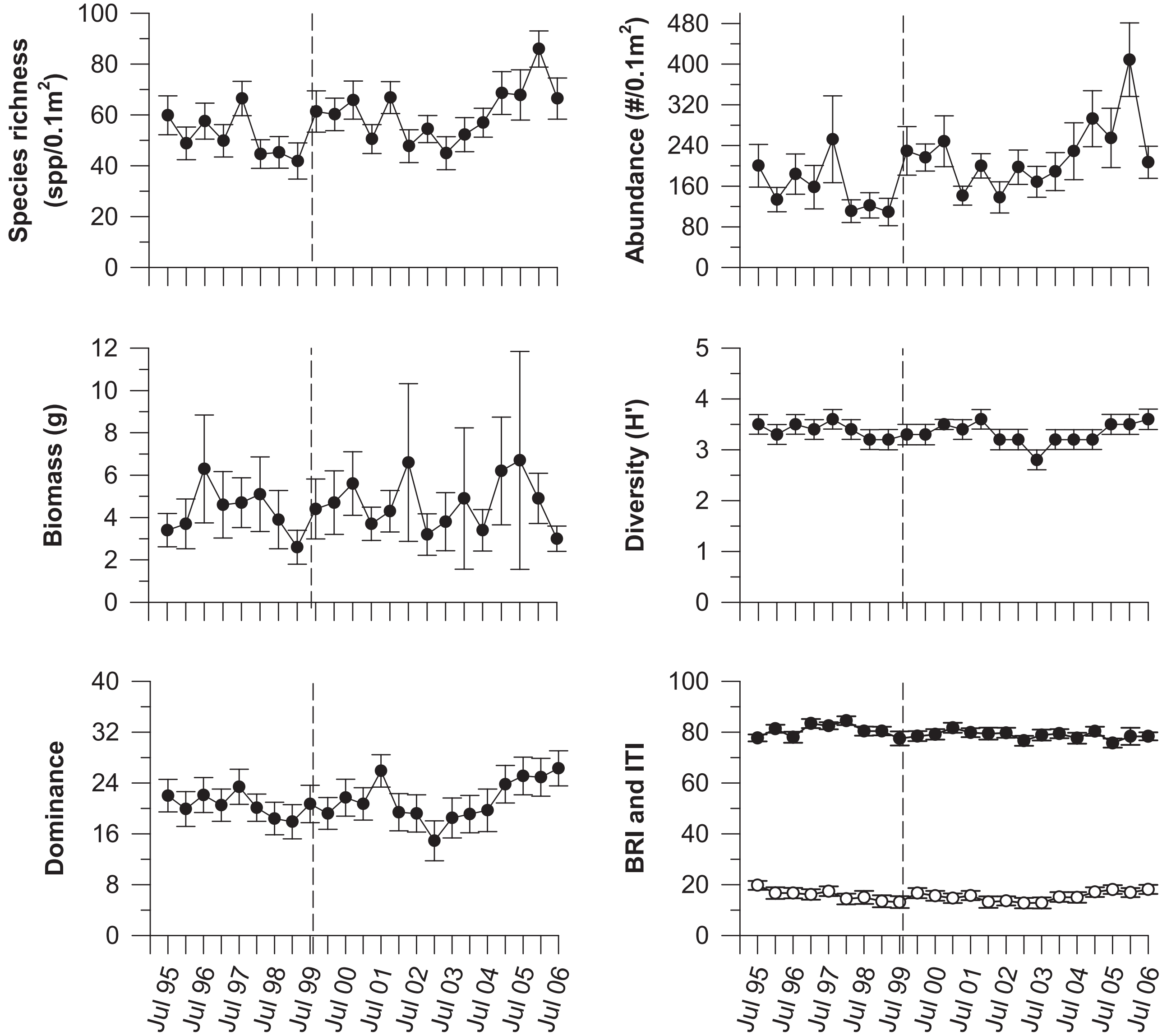



**Figure 5.2**
Summary of benthic community structure parameters surrounding the South Bay Ocean Outfall (1995–2006). Species richness; Abundance; Biomass; Diversity=Shannon diversity index (H'); Dominance=Swartz dominance index; BRI=Benthic response index (open circles); ITI=Infaunal trophic index (black circles). Data are expressed as means per 0.1 $m^2$ grab pooled over all stations for each survey (n=54). Error bars represent 95% confidence limits. Dashed line indicates onset of discharge from the SBOO.

relative to distance from the outfall, and index values at sites nearest the discharge do not suggest any deviation from reference conditions.

The infaunal trophic index (ITI) averaged from 49 to 88 at the various sites in 2006 (Table 5.1). There were no patterns with respect to the outfall, and all values at sites nearest the discharge were characteristic of undisturbed sediments (i.e., ITI>60). The only ITI value below 60 was from station I34, located nearest the mouth of the San Diego Bay. This value was inconsistent with the BRI value of 9 for that station, suggesting that differences in indicator species used by each index can sometimes produce conflicting results (see, Word 1980 and Smith et al. 2001 for a discussion of the species used to calculate each index). Average annual ITI among all sites has changed little since monitoring began (see Figure 5.2).

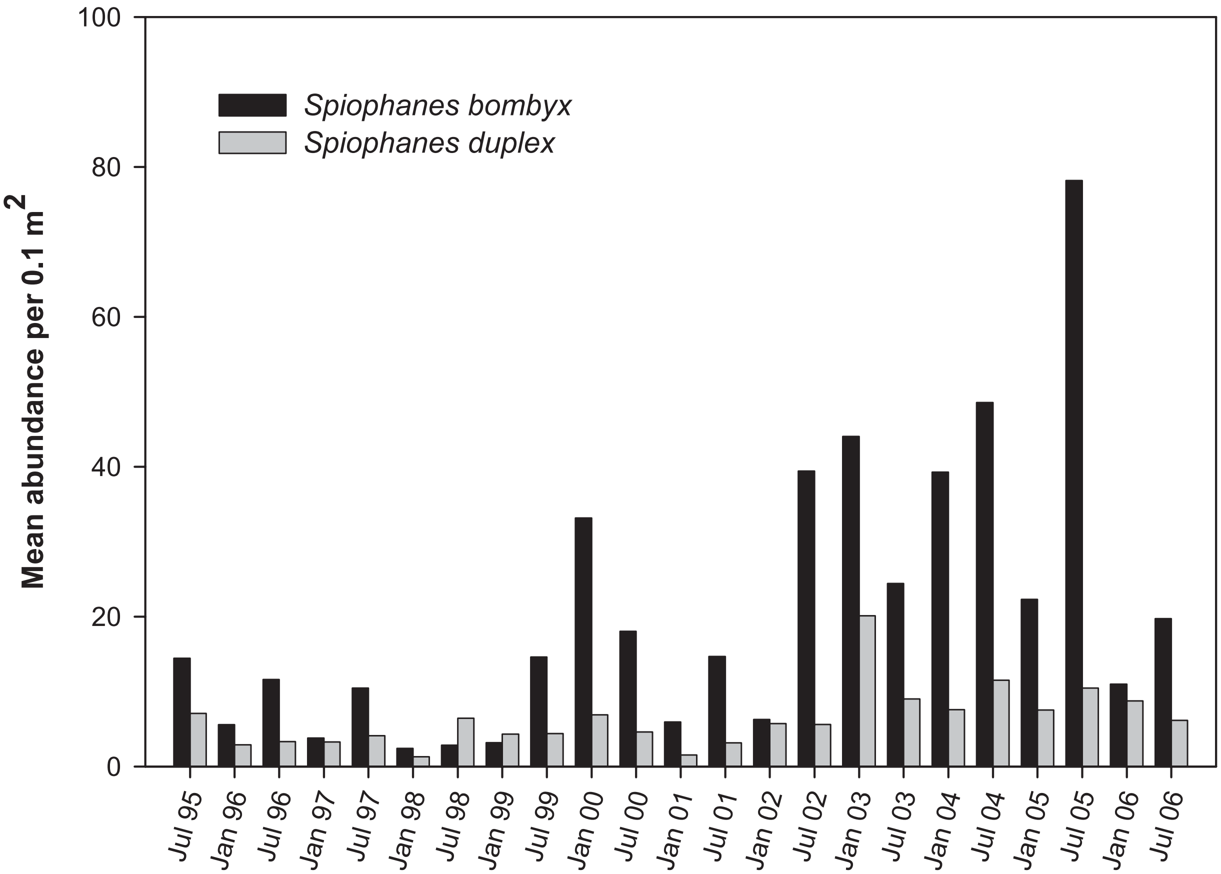



**Figure 5.3**
Mean abundance per 0.1 $m^2$ grab of the common polychaetes *Spiophanes bombyx* and *Spiophanes duplex*, for each survey at the SBOO benthic stations from July 1995 to July 2006.

### Dominant Species

Most assemblages in the SBOO region were dominated by polychaete worms. For example, the list of dominant fauna in **Table 5.2** includes 12 polychaetes, 4 crustaceans, one echinoderm, one sipunculid, and one cnidarian.

The most abundant species was the cirratulid polychaete *Monticellina siblina*, which averaged 32 animals per sample. The spionid polychaete *Spiophanes bombyx* was the most ubiquitous species and the second most numerous, occurring in 96% of the samples and averaging about 15 worms per sample. A closely related species, *S. duplex*, was third in total abundance. Together, these two spionid worms accounted for 8% of all individuals collected during 2006, which is much fewer than in the 2005 surveys (**Figure 5.3**). Polychaetes comprised 7 of the top 10 most abundant species per occurrence. The phyllodocid, *Hesionura coineaui difficilis,* was found in relatively high numbers at only a few stations. Few macrobenthic species were widely distributed, and of these only *S. bombyx*, *Glycinde armigera*, *Prionospio jubata*, *Euphilomedes carcharodonta*, and *Ampelisca cristata cristata* occurred in more than 80% of the samples. Five of the most frequently collected species were also among the top 10 taxa in terms of abundance (i.e., *S. bombyx*, *G. armigera*, *P. jubata*, *E. carcharodonta*, and *Moorenuphis* sp SD1).

### Multivariate Analyses

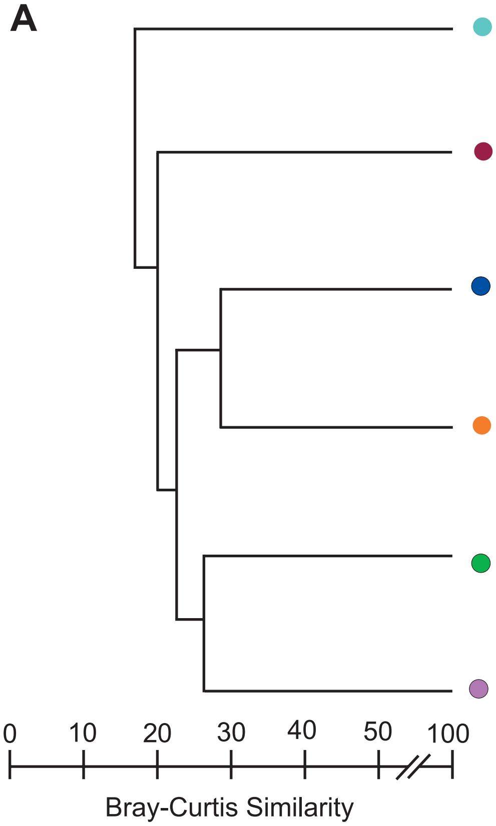
Classification analysis discriminated between 6 habitat-related benthic assemblages (cluster groups A–F) during 2006 (**Figure 5.4**). These assemblages differed in terms of their species composition, including the specific taxa present and their relative

## Table 5.2

Dominant macroinvertebrates at the SBOO benthic stations sampled during 2006. The most abundant species overall, the most abundant per occurrence, and the most frequently collected (or widely distributed) species are included. Abundance values are expressed as mean number of individuals per 0.1 $m^2$ grab sample.

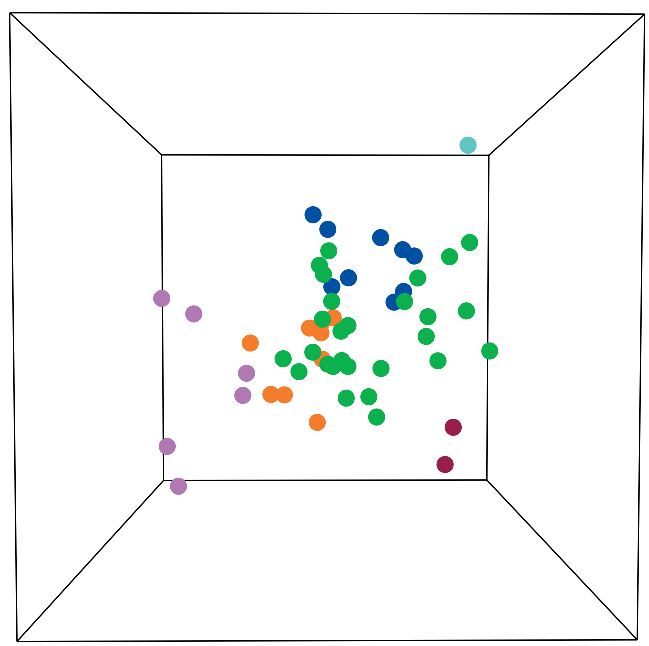
| Species | Higher taxa | Percent occurence | Abundance per sample | Abundance per occurence |
|---|---|---|---|---|
| Most frequently collected | | | | |
| *Spiophanes bombyx* | Polychaeta: Spionidae | 96 | 14.8 | 15.4 |
| *Glycinde armigera* | Polychaeta: Goniadidae | 91 | 3.9 | 4.3 |
| *Prionospio jubata* | Polychaeta: Spionidae | 89 | 4.6 | 5.2 |
| *Euphilomedes carcharodonta* | Crustacea: Ostracoda | 81 | 4.3 | 5.3 |
| *Ampelisca cristata cristata* | Crustacea: Amphipoda | 81 | 2.8 | 3.4 |
| *Mooreonuphis* sp SD1 | Polychaeta: Onuphidae | 76 | 2.3 | 3.0 |
| *Spiophanes berkeleyorum* | Polychaeta: Spionidae | 76 | 1.9 | 2.4 |
| Maldanidae | Polychaeta: Maldanidae | 76 | 1.8 | 2.3 |
| Amphiuridae | Echinodermata: Amphiuridae | 76 | 1.4 | 1.9 |
| *Foxiphalus obtusidens* | Crustacea: Amphipoda | 74 | 1.8 | 2.4 |
| Most abundant | | | | |
| *Monticellina siblina* | Polychaeta: Cirratulidae | 72 | 22.7 | 31.5 |
| *Spiophanes bombyx* | Polychaeta: Spionidae | 96 | 14.8 | 15.4 |
| *Spiophanes duplex* | Polychaeta: Spionidae | 70 | 5.2 | 7.4 |
| *Edwardsia* sp G | Cnidaria: Edwardsiidae | 54 | 4.7 | 8.8 |
| *Prionospio jubata* | Polychaeta: Spionidae | 89 | 4.6 | 5.2 |
| *Euphilomedes carcharodonta* | Crustacea: Ostracoda | 81 | 4.3 | 5.3 |
| *Glycinde armigera* | Polychaeta: Goniadidae | 91 | 3.9 | 4.3 |
| *Mooreonuphis* sp SD1 | Polychaeta: Onuphidae | 69 | 3.8 | 5.5 |
| *Hesionura coineaui difficilis* | Polychaeta: Phyllodocidae | 17 | 3.7 | 22.2 |
| *Axiothella* sp | Polychaeta: Capitellidae | 54 | 3.1 | 5.7 |
| Most abundant per occurrence | | | | |
| *Monticellina siblina* | Polychaeta: Cirratulidae | 72 | 22.7 | 31.5 |
| *Hesionura coineaui difficilis* | Polychaeta: Phyllodocidae | 17 | 3.7 | 22.2 |
| *Spiophanes bombyx* | Polychaeta: Spionidae | 96 | 14.8 | 15.4 |
| *Ampelisca agassizi* | Crustacea: Amphipoda | 17 | 1.9 | 11.2 |
| *Myriochele gracilis* | Polychaeta: Oweniidae | 7 | 0.7 | 9.3 |
| *Edwardsia* sp G | Cnidaria: Edwardsiidae | 54 | 4.7 | 8.8 |
| *Saccocirrus* sp | Polychaeta: Saccocirridae | 7 | 0.6 | 8.4 |
| *Mooreonuphis* sp SD1 | Polychaeta: Onuphidae | 24 | 2.0 | 8.2 |
| *Spiophanes duplex* | Polychaeta: Spionidae | 70 | 5.2 | 7.4 |
| *Apionsoma misakianum* | Sipuncula: Phascolosomatidae | 20 | 1.4 | 6.8 |

A




| CG | % Fines | TOC | SR | Abun | Top Taxa |
|---|---|---|---|---|---|
| A | 0 | 0.1 | 34 | 109 | *Carinoma mutabilis*<br>*Phoronopsis* sp<br>*Scoloplos armiger* |
| B | 4 | 4.2 | 59 | 332 | *Hesionura coineaui difficilis*<br>*Protodorvillea gracilis*<br>*Pisione* sp |
| C | 1 | 0.1 | 50 | 181 | *Spiophanes bombyx*<br>*Axiothella* sp<br>*Euphilomedes carcharodonta* |
| D | 4 | 0.1 | 61 | 175 | *Spiophanes bombyx*<br>*Moorenuphis* sp SD1<br>*Moorenuphis* sp |
| E | 13 | 0.3 | 75 | 245 | *Monticellina siblina*<br>*Spiophanes bombyx*<br>*Edwardsia* sp G |
| F | 25 | 0.4 | 118 | 386 | *Spiophanes duplex*<br>*Ampelisca agassizi*<br>*Pronospio jubata* |

B



**3D stress: 0.09**

## Figure 5.4

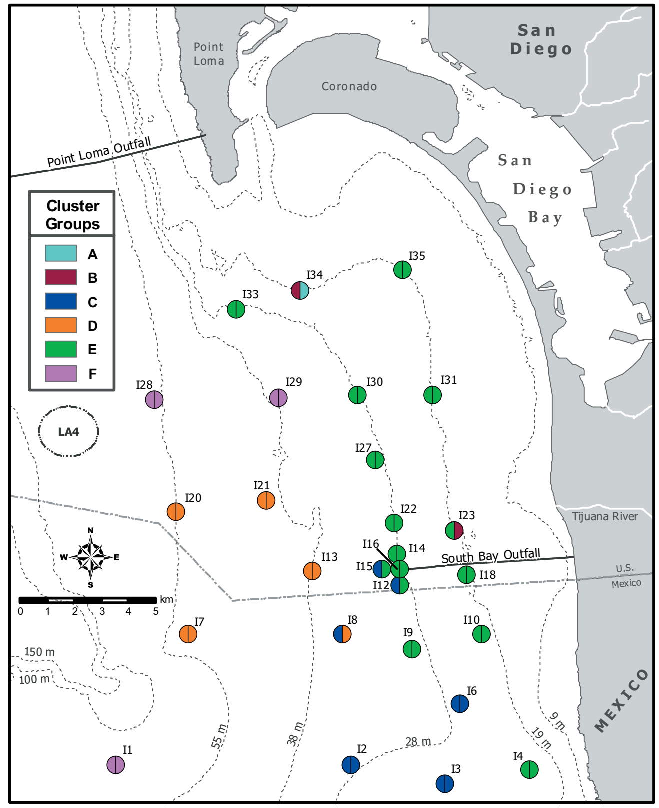
**(A)** Cluster results of the macrofaunal abundance data for the SBOO benthic stations sampled during January and July 2006. Data are expressed as mean values per 0.1 $m^2$ grab over all stations in each group. **(B)** MDS ordination based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between infaunal assemblages.

abundances. The dominant species composing each group are listed in **Table 5.3**. An MDS ordination of the station/survey entities confirmed the validity of cluster groups A–F (Figure 5.4). These analyses identified no significant patterns regarding proximity to the discharge site (**Figure 5.5**).

<u>Cluster group A</u> represented the July survey for station I34 along the 19-m contour. The sediment habitat for this assemblage was comprised almost entirely of sand with no fine particles. Group A contained the fewest number of taxa (34) and the lowest abundance (109) per grab among all the groups. The total organic carbon (TOC) concentration for the associated sediment sample from this site was 0.1%. *Carinoma mutabilis* was the most abundant species in the group, the only nemertean within all cluster groups that characterized an assemblage. The phoronid *Phoronopsis* sp and *Scoloplos armiger* (polychaete species complex) were also numerically dominant.

<u>Cluster group B</u> represented the July survey at station I23 and the January survey from station I34, both located on the 19-m depth contour. Sediments at these stations were characterized by a low percentage of fine particles and more than 3 times the coarse material (e.g., cobble, shell hash) than any other group. Species richness averaged 59 taxa and 332 individuals per $0.1m^2$. As in previous years this assemblage was somewhat unique for the region (City of San Diego 2004, 2006); it was dominated by nematode worms and several polychaete species commonly found in sediments with coarse particles and/or high organic content (e.g., *H. coineaui difficilis*, *Protodorvillea gracilis*, and *Pisione* sp). Average TOC values (4.2%) at the 2 stations comprising this cluster group were much higher than those at stations from any other group.

<u>Cluster group C</u> comprised sites that were located on or near the 28-m depth contour, mostly south of the SBOO. These sites had a low percentage of fines, with some stations containing relict red sands and shell hash. Relative to stations in other groups, TOC at group C was low (0.1%). The group C assemblage averaged 50 taxa and 181




## Figure 5.5

SBOO benthic stations sampled during January and July 2006, color-coded to represent affiliation with benthic cluster groups. Left half of circle represents cluster group affiliation for the January survey, right half represents the July survey.

individuals per grab. *Spiophanes bombyx* was numerically dominant in this group, followed by the polychaetes *Axiothella* sp and the ostracod crustacean *E. carcharodonta*.

<u>Cluster group D</u> comprised stations characterized by coarse particles and relict red sand sediments located along the 55-m and 38-m contour. TOC at this group averaged 0.1%. This group had 61 taxa and 175 individual organisms per grab. *Spiophanes bombyx*, *Moorenuphis* sp SD1, and *Edwardsia* sp G comprised the 3 most abundant taxa. Overall, polychaetes numerically dominated this group.

<u>Cluster group E</u> included sites primarily located along the 19 and 28-m depth contours, where sediments contained the second highest amount of fine particles. TOC at stations within this group averaged 0.25%. This assemblage averaged 75 taxa and 245 individuals per $0.1\ m^2$. The numerically

## Table 5.3

Summary of the most abundant taxa composing cluster groups A–F from the 2006 surveys of SBOO benthic stations. Data are expressed as mean abundance per sample (no./0.1 $m^2$) and represent the 10 most abundant taxa in each group. Values for the 3 most abundant species in each cluster group are bolded. (n)=number of station/survey entities per cluster group.

| | | Cluster group | | | | | |
|---|---|---|---|---|---|---|---|
| Species/Taxa | Taxa | A (1) | B (2) | C (9) | D (9) | E (27) | F (6) |
| *Ampelisca agassizi* | Crustacea | — | — | 0.1 | — | 0.5 | **14.6** |
| *Apionsoma misakianum* | Sipuncula | — | 1.0 | 0.1 | 6.4 | — | 2.3 |
| *Axiothella* sp | Polychaeta | — | — | **11.4** | 0.6 | 2.1 | 0.1 |
| *Carinoma mutabilis* | Nemertea | **20.0** | 0.8 | 2.6 | 0.4 | 1.9 | 0.3 |
| *Edwardsia* sp G | Cnidaria | — | 5.8 | 2.0 | 2.4 | **7.5** | 0.2 |
| *Euclymeninae* sp A | Polychaeta | — | 5.0 | 0.1 | 0.7 | 5.7 | 5.6 |
| *Euphilomedes carcharodonta* | Crustacea | 0.5 | 0.3 | **6.9** | 1.3 | 4.3 | 7.0 |
| *Glycera oxycephala* | Polychaeta | — | — | 6.4 | 1.8 | 0.8 | 0.2 |
| *Glycinde armigera* | Polychaeta | 1.5 | 1.5 | 1.8 | 0.7 | 6.3 | 2.2 |
| *Hesionura coineaui difficilis* | Polychaeta | — | **87.8** | 0.4 | 2.2 | — | — |
| *Lanassa venusta venusta* | Polychaeta | — | — | 0.1 | 5.5 | — | 0.1 |
| *Leptochelia dubia* | Crustacea | — | 0.5 | 1.1 | 1.4 | 1.6 | 10.5 |
| *Lumbrinerides platypygos* | Polychaeta | — | 1.8 | 5.7 | 2.4 | 0.5 | — |
| *Magelona sacculata* | Polychaeta | 8.5 | — | 0.4 | — | 0.3 | — |
| *Monticellina siblina* | Polychaeta | 5.0 | 2.8 | 0.4 | 0.6 | **43.7** | 4.7 |
| *Mooreonuphis* sp | Polychaeta | — | — | 0.9 | **8.9** | — | — |
| *Mooreonuphis* sp SD1 | Polychaeta | — | — | 2.4 | **9.3** | 0.1 | — |
| Nematoda | Nematoda | — | 21.8 | 0.4 | 2.8 | 1.3 | 2.1 |
| *Phoronopsis* sp | Phoronida | **19.5** | — | 0.6 | — | 0.3 | — |
| *Pisione* sp | Polychaeta | — | **22.3** | — | 0.8 | — | 0.1 |
| *Prionospio jubata* | Polychaeta | — | 0.5 | 1.3 | 2.7 | 5.2 | **11.7** |
| *Protodorvillea gracilis* | Polychaeta | — | **34.3** | 3.7 | 1.1 | 0.1 | 0.1 |
| *Saccocirrus* sp | Polychaeta | — | 16.3 | — | 0.1 | — | — |
| *Scoloplos armiger* (=spp complex) | Polychaeta | **9.0** | 3.0 | 5.3 | 0.5 | 0.6 | 2.0 |
| *Spiophanes bombyx* | Polychaeta | 3.0 | 1.0 | **34.6** | **17.5** | **9.8** | 10.1 |
| *Spiophanes duplex* | Polychaeta | — | 0.3 | 0.2 | 1.9 | 4.3 | **24.0** |

dominant species in this group were the polychaetes *Monticellina siblina* and *S. bombyx,* and the anthozoan *Edwardsia* sp G.

Cluster group F comprised 2 stations located along the 55-m depth contour and one at the 38-m contour. Sediments at these deepwater sites contained the highest average percentage of fine particles. TOC for this group averaged 0.4%. The group F assemblage was characterized by the highest species richness and abundance, averaging 118 taxa and 386 individuals per grab. The 3 most abundant species were the polychaetes, *S. duplex* and *P. jubata*, and the amphipod crustacean *Ampelisca agassizi*. The tanaid crustacean *Leptochelia dubia* was also characteristic of this assemblage, but relatively uncommon in other groups.

## SUMMARY AND CONCLUSIONS

Benthic macrofaunal assemblages surrounding the South Bay Ocean Outfall were similar in 2006 to those that occurred during previous years (City of San Diego 2004, 2005, 2006) including those that occurred before the initiation of wastewater discharge in 1999 (City of San Diego 1998). In addition, these assemblages were generally typical of those occurring in other sandy, shallow-water habitats throughout the

Southern California Bight (SCB) (e.g., Thompson et al. 1987, 1993b, City of San Diego 1999, Bergen et al. 2001). For example, assemblages found at the majority of stations (e.g., groups C and E) contained high numbers of the spionid polychaete *Spiophanes bombyx*, a species characteristic of shallow-water environments in the SCB (see Bergen et al. 2001, Mikel et al. 2007). These 2 groups represented sub-assemblages of the shallow SCB benthos that differed as a result of sediment structure, such as the presence of a fine component (i.e., group E), or coarser sands (i.e., group C).

Consistent with historical values, sediments in the shallow SBOO region generally were coarser south of the outfall relative to northern stations (see Chapter 4). In contrast, the group F assemblage occurs in mid-depth shelf habitats that probably represent a transition between the shallow sandy sediments common in the area and the finer mid-depth sediments characteristic of much of the SCB mainland shelf (see Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, Thompson et al. 1987, 1993a, b, EcoAnalysis et al. 1993, Zmarzly et al. 1994, Diener and Fuller 1995, Bergen et al. 2001, Mikel et al. 2007). A second deeper-water assemblage (group D) occurred where relict red sands were present. Polychaetes dominated group D, including the ubiquitous *S. bombyx*. The group B assemblage characteristic of station I23 during the July survey and I34 during the January survey was different from assemblages found at any other station. Nematode worms and several species of polychaetes (i.e., *Protodorvillea gracilis*, *Hesionura coineaui difficilis*, and *Pisione* sp) in these samples were not common elsewhere in the region. This assemblage is similar to that sampled previously at I23 during July 2003, 2004, and 2005.

Analysis of the sediment chemistry data provides some evidence to explain the occurrence of this assemblage (**Figure 5.6**): mean sediment grain sizes were the highest measured among all stations for 2006 (see chapter 4). Also, mean total organic carbon was an order of magnitude higher at group B relative to the other groups. High organic carbon content in sediments can be an indication of stress to

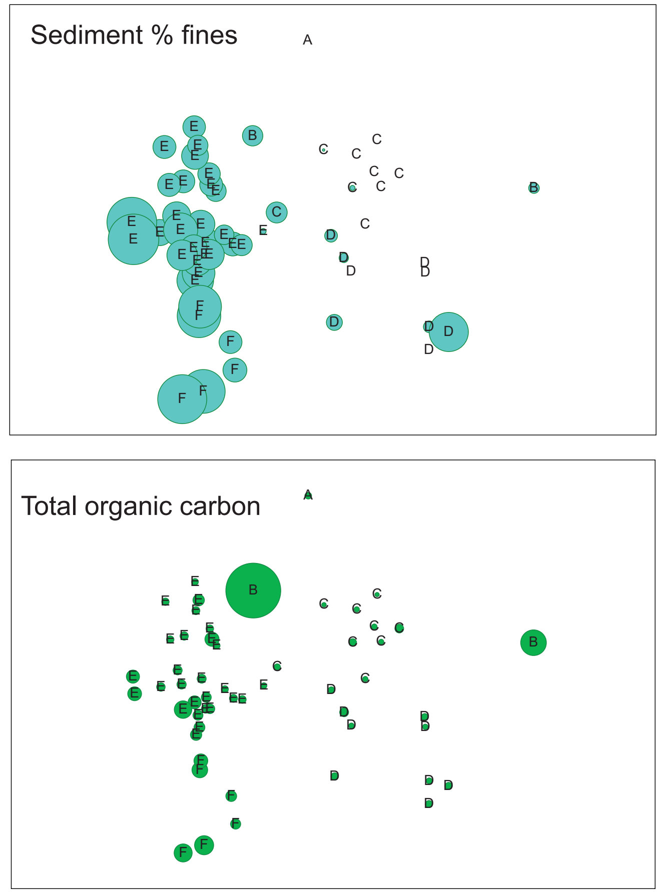



**Figure 5.6**
MDS ordination of SBOO benthic stations sampled during January and July 2006. Cluster groups A–F are superimposed on station/surveys. Percentages of fine particles and total organic carbon in the sediments are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of benthic assemblages with habitats that differ in sediment grain size. Stress=0.14.

the marine macrobenthos (Hyland et al. 2005). The presence of animals associated with coarse sediments and/or high organic content reflect the particular components of the sediments such as variation in microhabitats or types and amounts of shell hash or organic detritus.

Multivariate analyses revealed no clear spatial patterns relative to the outfall. Comparisons of the biotic data to the physico-chemical data indicated that macrofaunal distribution and abundance in the region varied primarily along gradients of sediment type and depth and to a lesser degree, organic carbon. Relatively lower numbers of S. *bombyx* and *S. duplex* were collected during 2006 as versus 2005.

However, temporal fluctuations in the populations of these taxa are similar in magnitude to those that occur elsewhere in the region and that often correspond to large-scale oceanographic conditions (see Zmarzly et al. 1994). Overall, temporal patterns suggest that the benthic community has not been significantly impacted by wastewater discharge via the SBOO. For example, the range of values for species richness and abundance during 2006 was similar to that seen in previous years (see City of San Diego 2000, 2004, 2005). In addition, environmental disturbance indices such as mean BRI and mean ITI generally were characteristic of assemblages from undisturbed sediments.

Anthropogenic impacts have spatial and temporal dimensions that can vary depending on a range of biological and physical factors. Such impacts can be difficult to detect, and specific effects of the SBOO discharge on the macrobenthos could not be identified during 2006. Furthermore, benthic invertebrate populations exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, b, Otway 1995). Although some changes likely have occurred near the SBOO, benthic assemblages in the area remain similar to those observed prior to discharge and to natural indigenous communities characteristic of similar habitats on 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 habitats, and assessment of their communities has become an important focus of ocean monitoring programs throughout the world. Such assemblages have been sampled extensively for more than 30 years on the mainland shelf of the Southern California Bight (SCB), primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of demersal fish inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998). For the region surrounding the South Bay Ocean Outfall (SBOO), the most common trawl-caught fishes include speckled sanddab, longfin sanddab, hornyhead turbot, California halibut, California lizardfish, and occasionally white croaker. Common trawl-caught invertebrates include relatively large taxa such as sea urchins and sand dollars.

The structure of these communities is inherently variable and 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 that may affect these communities 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 factors can impact the migration of adult fish or the recruitment of juveniles into an area (Murawski 1993). Population fluctuations that affect diversity and abundance may also be due to the mobile nature of many species (e.g., schools of fish or aggregations of urchins).

The City of San Diego has been conducting trawl surveys in the area surrounding the SBOO since 1995. These surveys are designed to monitor the effects of wastewater discharge on the local marine biota by assessing the structure and stability of the demersal fish and megabenthic invertebrate communities. This chapter presents analyses and interpretations of data collected during the 2006 trawl surveys.

## MATERIALS AND METHODS

### Field Sampling

Trawl surveys were conducted in January, April, July, and October 2006 at 7 fixed sites around the SBOO (**Figure 6.1**). These stations, SD15–SD21, are located along the 28-m isobath, and encompass an area south of Point Loma, California, USA to Punta Bandera, Baja California, Mexico. During

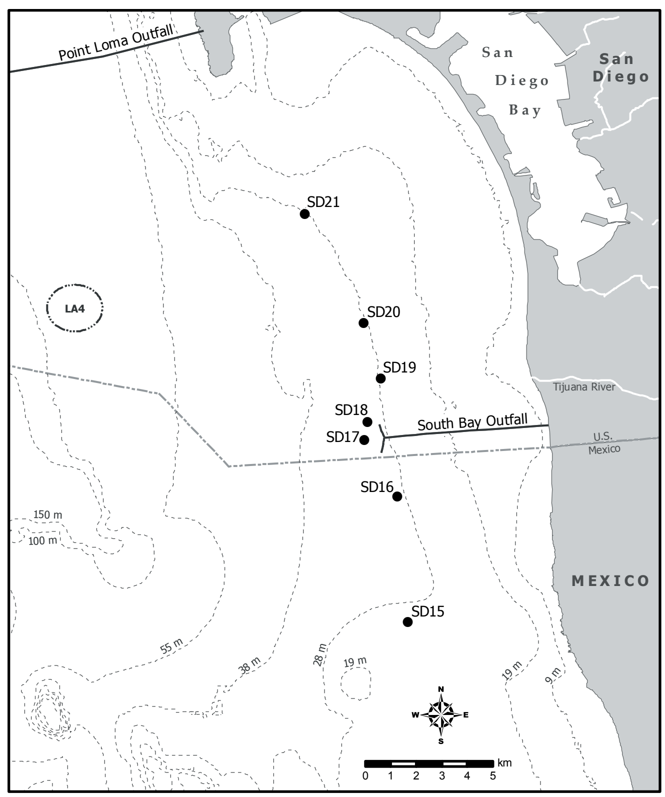



**Figure 6.1**
Otter trawl station locations, South Bay Ocean Outfall Monitoring Program (SD15–SD21).

each survey 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 bottom time at a speed of about 2.5 knots along a predetermined heading.

Trawl catches were brought on board for sorting and inspection. All organisms were identified to species or to the lowest taxon possible. If an animal could not be identified in the field, it was returned to the laboratory for further identification. For fishes, the total number of individuals and total biomass (wet weight, kg) were recorded for each species. Additionally, each individual fish was inspected for external parasites or physical anomalies (e.g., tumors, fin erosion, discoloration) and measured to the nearest centimeter size class (standard lengths). For invertebrates, the total number of individuals was recorded per species. Due to the small size of most organisms, invertebrate biomass was typically measured as a composite wet weight (kg) of all species combined; however, large or exceptionally abundant species were weighed separately.

### Data Analyses

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

Multivariate analyses were performed on 12 years of data from the July surveys of all 7 stations. PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software was used to examine spatio-temporal patterns in the overall similarity of fish 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). 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 AND DISCUSSION

### Fish Community

Thirty-six species of fish were collected in the area surrounding the SBOO during 2006 (**Table 6.1**). The total catch for the year was 4244 individuals, representing an average of about 152 fish per trawl. Speckled sanddabs and California lizardfish comprised 49% and 18% of the total catch, respectively. No other species contributed more than 5% of the total catch. Speckled sanddabs were present in every haul, while California lizardfish occurred in 96% of the hauls. Other frequently occurring fishes were yellowchin sculpin, longfin sanddab, hornyhead turbot, California tonguefish, roughback sculpin, and English sole. Most of these common fishes, as well as the majority of other species collected, tended to be relatively small (average length <20 cm, see **Appendix D.1**). The largest species were relatively rare, and consisted primarily of sharks, skates, and rays (e.g., brown smoothhound, shovelnose guitarfish, California skate, bat ray).

During 2006, species richness and diversity (H') were relatively low across the survey area (**Table 6.2**). Species richness ranged from 2 to 18 during the year, but 27 of the 28 samples had fewer than 15 species. On average, the lowest species richness occurred at station SD15 (6 spp), while the highest number of species (18 spp) occurred at station SD18. Diversity (H') values can range from 0 to 5; average diversity values from the SBOO

## Table 6.1

Demersal fish species collected in 28 trawls in the SBOO region during 2006. Data for each species are expressed as: percent abundance (PA); frequency of occurrence (FO); mean abundance per haul (MAH).

| Species | PA | FO | MAH | Species | PA | FO | MAH |
|---|---|---|---|---|---|---|---|
| Speckled sanddab | 49 | 100 | 74 | California halibut | <1 | 36 | 1 |
| California lizardfish | 18 | 96 | 28 | Calico rockfish | <1 | 29 | <1 |
| Yellowchin sculpin | 5 | 61 | 7 | Pygmy poacher | <1 | 21 | <1 |
| Longfin sanddab | 5 | 54 | 7 | Spotted turbot | <1 | 21 | <1 |
| White croaker | 5 | 32 | 7 | Basketweave cuskeel | <1 | 14 | <1 |
| Hornyhead turbot | 5 | 82 | 7 | Fantail sole | <1 | 18 | <1 |
| California tonguefish | 3 | 82 | 4 | Bigmouth sole | <1 | 18 | <1 |
| Roughback sculpin | 2 | 64 | 4 | California skate | <1 | 18 | <1 |
| Longspine combfish | 2 | 25 | 3 | Spotted cuskeel | <1 | 11 | <1 |
| English sole | 1 | 54 | 2 | California butterfly ray | <1 | 4 | <1 |
| Queenfish | 1 | 21 | 1 | Shovelnose guitarfish | <1 | 4 | <1 |
| Pacific pompano | 1 | 7 | 1 | Bat ray | <1 | 4 | <1 |
| California scorpionfish | <1 | 39 | 1 | Bluespotted poacher | <1 | 4 | <1 |
| Northern anchovy | <1 | 18 | 1 | Brown smoothhound | <1 | 4 | <1 |
| Plainfin midshipman | <1 | 39 | 1 | Curlfin sole | <1 | 4 | <1 |
| Pacific sanddab | <1 | 14 | 1 | Diamond turbot | <1 | 4 | <1 |
| Shiner perch | <1 | 25 | 1 | Kelp pipefish | <1 | 4 | <1 |
| Specklefin midshipman | <1 | 32 | 1 | Spotted ratfish | <1 | 4 | <1 |

## Table 6.2

Summary of demersal fish community parameters for SBOO stations sampled during 2006. Data are expressed as mean and standard deviation (SD) for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight); n=4.

| Station | Jan | Apr | Jul | Oct | Mean | SD | Station | Jan | Apr | Jul | Oct | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Species richness* | | | | | | | *Abundance* | | | | | | |
| SD15 | 2 | 10 | 4 | 7 | 6 | 4 | SD15 | 62 | 106 | 84 | 115 | 92 | 24 |
| SD16 | 9 | 11 | 7 | 12 | 10 | 2 | SD16 | 49 | 127 | 295 | 230 | 175 | 109 |
| SD17 | 13 | 14 | 9 | 11 | 12 | 2 | SD17 | 113 | 115 | 302 | 169 | 175 | 89 |
| SD18 | 18 | 12 | 14 | 10 | 14 | 3 | SD18 | 187 | 150 | 354 | 215 | 227 | 89 |
| SD19 | 6 | 12 | 13 | 10 | 10 | 3 | SD19 | 67 | 65 | 175 | 176 | 121 | 63 |
| SD20 | 9 | 14 | 14 | 11 | 12 | 2 | SD20 | 55 | 131 | 195 | 186 | 142 | 64 |
| SD21 | 9 | 14 | 11 | 12 | 12 | 2 | SD21 | 43 | 129 | 197 | 152 | 130 | 65 |
| Mean | 9 | 12 | 10 | 10 | | | Mean | 82 | 118 | 229 | 178 | | |
| SD | 5 | 2 | 4 | 2 | | | SD | 52 | 27 | 93 | 38 | | |
| *Diversity* | | | | | | | *Biomass* | | | | | | |
| SD15 | 0.08 | 0.94 | 0.63 | 1.21 | 0.72 | 0.49 | SD15 | 0.6 | 3.9 | 1.0 | 2.4 | 2.0 | 1.5 |
| SD16 | 1.21 | 1.75 | 0.78 | 1.11 | 1.21 | 0.40 | SD16 | 1.1 | 3.1 | 3.1 | 5.3 | 3.2 | 1.7 |
| SD17 | 1.73 | 2.00 | 1.04 | 1.79 | 1.64 | 0.42 | SD17 | 3.8 | 4.4 | 2.5 | 3.6 | 3.6 | 0.8 |
| SD18 | 1.51 | 1.79 | 1.48 | 1.28 | 1.52 | 0.21 | SD18 | 14.0 | 3.5 | 6.4 | 5.9 | 7.5 | 4.5 |
| SD19 | 1.28 | 1.77 | 1.51 | 0.91 | 1.37 | 0.36 | SD19 | 3.3 | 2.5 | 4.5 | 2.5 | 3.2 | 0.9 |
| SD20 | 1.49 | 1.63 | 1.02 | 1.09 | 1.31 | 0.30 | SD20 | 3.6 | 5.1 | 5.2 | 3.5 | 4.4 | 0.9 |
| SD21 | 1.81 | 1.97 | 1.75 | 1.62 | 1.79 | 0.15 | SD21 | 3.1 | 9.9 | 5.5 | 5.1 | 5.9 | 2.9 |
| Mean | 1.30 | 1.69 | 1.17 | 1.29 | | | Mean | 4.2 | 4.6 | 4.0 | 4.0 | | |
| SD | 0.58 | 0.36 | 0.41 | 0.31 | | | SD | 4.5 | 2.5 | 1.9 | 1.4 | | |

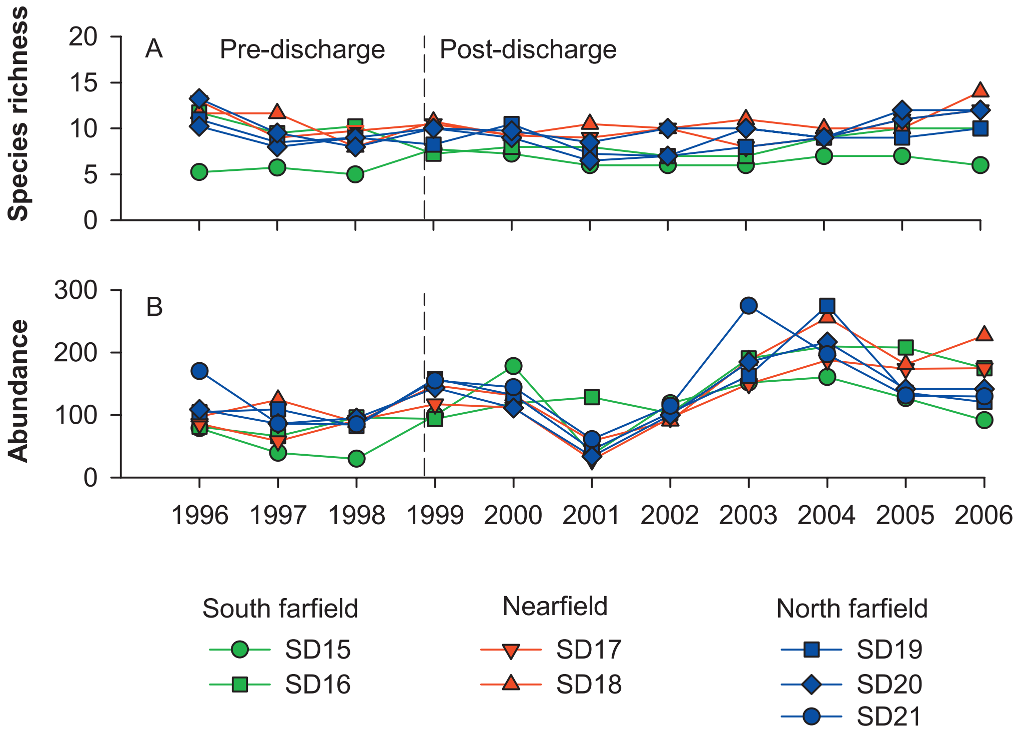



**Figure 6.2**
Annual mean species richness (number of species) and abundance (number of individuals) per SBOO station of demersal fish collected from 1996 through 2006.

region were ≤2.0 at all stations. These low values are typical of the southern region of the SCB, where median diversity was about 1.5 (Allen et al. 1998, Allen et al. 2002), and reflect the small number of species that comprise this community.

Abundance and biomass were highly variable across the survey area in 2006. The wide range in abundance (43–354 fish per haul) was due to population fluctuations of a few common species. For example, quarterly catches of California lizardfish and speckled sanddab ranged from 8 to 581 and 284 to 781, respectively. These fishes contributed to the highest abundance values at stations SD16–SD21 during July. The wide range of biomass values (0.6–14.0 kg per haul) reflect these population fluctuations and the size of individual fishes, such as the 2.5 kg bat ray collected at SD18 in January. The low species richness, diversity, abundance, and biomass values at station SD15 may be indicative of a different habitat at this location relative to the other stations (see Chapter 4).

Fish community structure in this region has varied in response to population fluctuations of a few dominant species since 1996 (**Figures 6.2, 6.3**). Although annual mean species richness has remained fairly consistent over the years (e.g., between 5 and 14 species per station), mean abundances have fluctuated between 28 and 275 individuals per station (Figure 6.2). Variability across stations primarily reflects changes in the populations of the dominant species. For example, the total catch for 2006 represents a decline of about 29% from the peak of 6010 individuals collected in 2004. This decline was due to a substantial drop in the total speckled sanddab catch at all stations from 2004 to 2006 (Figure 6.3). In contrast, inter-annual variability at individual stations is most often caused by large hauls of schooling species that occur infrequently. For example, large hauls of white croaker were responsible for the high abundance at SD21 in 1996, while a large haul of northern anchovy caused the relatively high abundance at SD16 in 2001. Overall, none of the observed changes appear to be associated with the South Bay outfall.

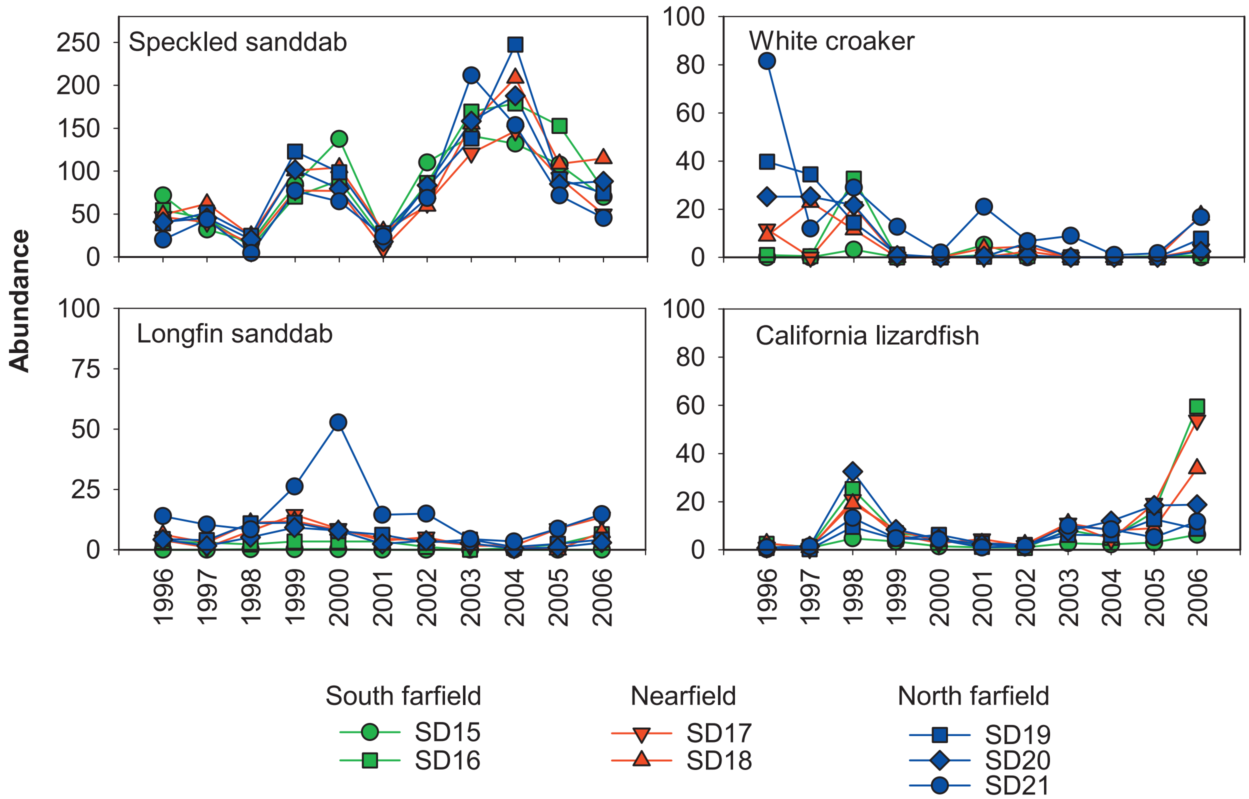



**Figure 6.3**
Annual mean abundance (number of individuals) per SBOO station for the four most abundant fish species collected from 1996 through 2006; n=4.

Ordination and classification analyses of fish data from July surveys between 1995 and 2006 resulted in 6 major cluster groups (station groups A–F) (see **Figure 6.4**). All of the assemblages were dominated by speckled sanddabs and were differentiated by relative abundances of this and other common species. No patterns of change in fish assemblages were associated with the SBOO. Instead, differences in the assemblages seem to be related to oceanographic events (e.g., El Niño conditions in 1998) or location (i.e., station). For example, station SD15 frequently grouped apart from the remaining stations. The composition of each station group and the species characteristic of each assemblage are described below (**Table 6.3**).

Station group A comprised the 2 northernmost stations (SD20–21) from 1995, and every station except SD15 during the 1998 El Niño. This assemblage had the second fewest individuals per haul, with an average of 9 species and 64 individuals. Station group A was characterized by the lowest abundance of speckled sanddabs, as well as relatively abundant longfin sanddabs and hornyhead turbot. The low number of speckled sanddabs separated this assemblage from those comprising groups C–F, while the relative number of longfin sanddabs separated group A from groups B and F.

Station group B comprised every station sampled during July 2001 except SD21, 3 southern and one northern station sampled in 1997, and station SD15 from 1998. The group had the fewest individuals per haul, averaging only 36 fishes representing 7 species. Like group A, station group B was also characterized by relatively low numbers of speckled sanddabs. The low number of speckled sanddabs separated this assemblage from all the others.

Station group C consisted of only 2 stations, SD16 and SD17, sampled in 2006. This assemblage was unique in that it contained large numbers of California

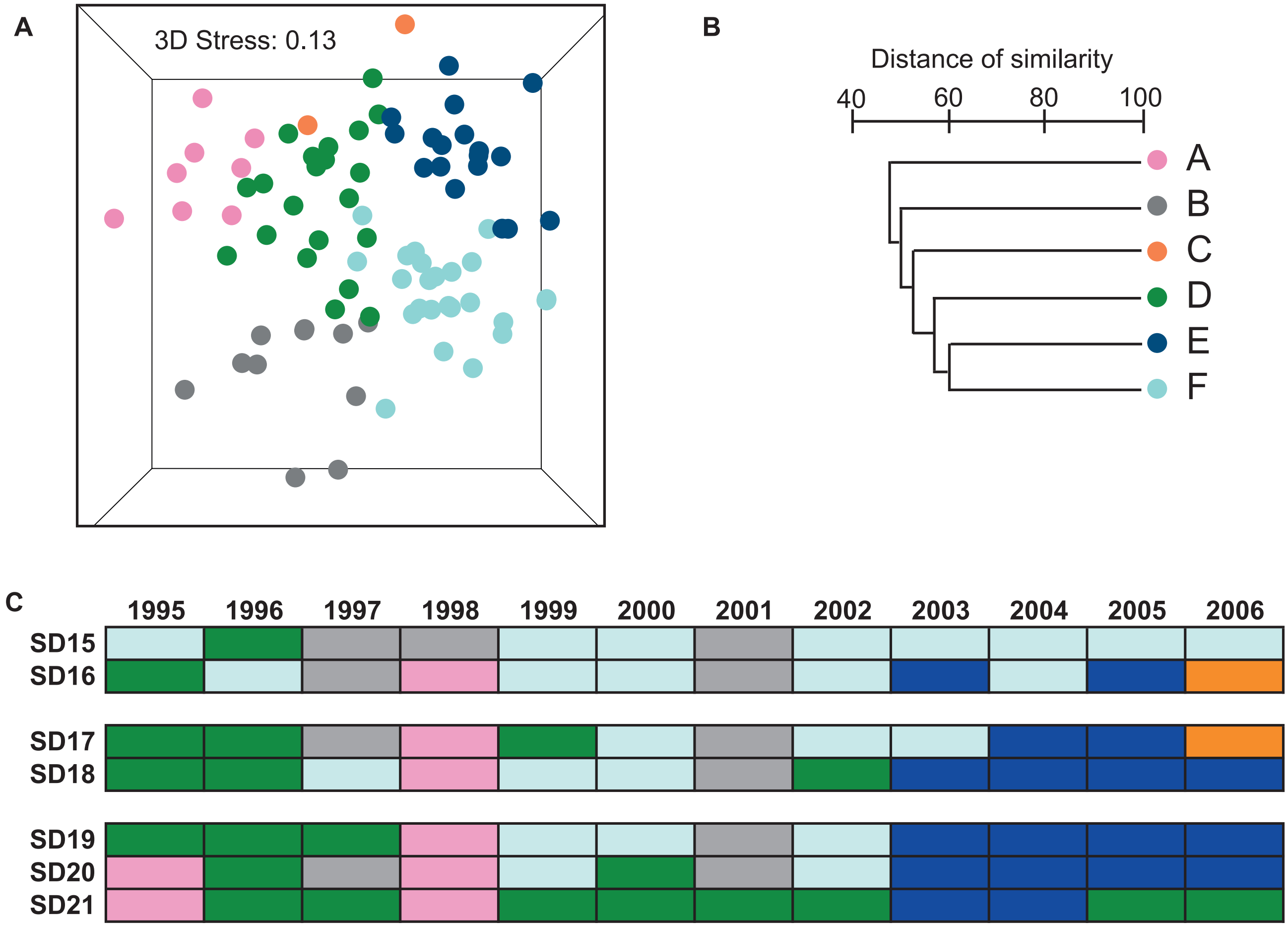



**Figure 6.4**
Results of classification analysis of demersal fish assemblages collected at SBOO stations SD15–SD21 between 1995 and 2006 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major station groups and (C) a matrix showing distribution over time.

lizardfish. Over 200 lizardfish were collected at each of these stations during July 2006, almost twice as many than any other haul included in these analyses.

Station group D encompassed 9 of the 12 surveys and included 10 of the 14 stations sampled in 1995 and 1996, 8 surveys at station SD21 (including 1996), and one trawl each from stations SD17—SD20 during various years from 1997 to 2002. Speckled sanddabs and hornyhead turbot were representative of this assemblage, although the numbers of English sole, California tonguefish, and longfin sanddabs distinguished it from the others.

Station group E comprised most stations sampled from 2003 to the present. This group averaged the highest number of species and the highest number of speckled sanddabs; it corresponds strongly to peak numbers of speckled sanddab numbers over the same years as depicted in Figure 6.3. The combination of relatively high numbers of speckled sanddabs and the presence of roughback sculpin distinguished this station group from all of the others.

Station group F comprised the largest number of trawls overall (n=24), and was represented in all but 2 surveys. This assemblage comprised most stations from 1999, 2000, and 2002, as well as several stations near the SBOO (SD17, SD18) and southward (SD15, SD16) during other years. The assemblage had the third highest overall abundance but the lowest species richness. It was dominated almost exclusively by speckled sanddabs and was unique in the absence of many species common to other

**Table 6.3**

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

| | Group A | Group B | Group C | Group D | Group E | Group F |
|---|---|---|---|---|---|---|
| Number of hauls | 8 | 11 | 2 | 21 | 18 | 24 |
| Average similarity | 64 | 58 | 78 | 64 | 70 | 70 |
| Mean species richness | 9 | 7 | 7 | 9 | 10 | 6 |
| Mean abundance | 64 | 36 | 298 | 115 | 226 | 124 |
| **Species** | | | **Mean abundance** | | | |
| Bigmouth sole | | | | 1 | | |
| California halibut | | 1 | | | | |
| California lizardfish | 24 | 2 | **212** | 3 | 17 | |
| California scorpionfish | | 2 | | | | |
| California tonguefish | 2 | | | 5 | | |
| English sole | 5 | | | 3 | 4 | |
| Hornyhead turbot | **3** | 3 | **4** | **6** | 5 | 4 |
| Longfin sanddab | **12** | | | 25 | 5 | |
| Roughback sculpin | | | | | 5 | |
| Speckled sanddab | **12** | **23** | **56** | **60** | **165** | **111** |
| Spotted turbot | | 2 | | | | 2 |
| Yellowchin sculpin | | | | | 18 | |

assemblages (e.g., California lizardfish, English sole, longfin sanddab, roughback sculpins).

### Physical Abnormalities and Parasitism

The overall absence of fin rot or other physical abnormalities among fishes collected for this survey suggest that fish populations in the area continue to appear healthy. No physical abnormalities and no external parasites were found attached to any fish collected during 2006. However, 2 known fish parasites, the ectoparasitic isopod *Elthusa vulgaris* and a leech (Annelida: Hirudinea), were observed in at least one trawl. Both types of parasites can become detached from their hosts during sorting, therefore it is unknown which fish were actually parasitized. Although *E. vulgaris* occurs on a wide variety of fish species in southern California, it is especially common on sanddabs and California lizardfish, where it may reach infestation rates of 3% and 80%, respectively (Brusca 1978, 1981).

### Invertebrate Community

A total of 829 megabenthic invertebrates (~30 per trawl), representing 53 taxa, were collected during 2006 (**Appendix D.2**). The sea star *Astropecten verrilli* was the most abundant and most frequently captured species. This sea star was captured in almost all of the trawls and accounted for 62% of the total invertebrate abundance (**Table 6.4**). Another sea star, *Pisaster brevispinus*, occurred in 46% of the trawls but accounted for only 2% of the total abundance. The remaining taxa occurred infrequently, with only 7 occurring in 25% or more of the hauls. All of the taxa collected, with the exception of *A. verrilli*, had an average abundance per haul of 2 or less.

As with fish, invertebrate community measures varied among stations and between surveys during the year (**Table 6.5**). Species richness ranged from 4 to 12 species per haul and abundance values ranged from 8 to 98 individuals per haul. The biggest hauls

## Table 6.4

Megabenthic invertebrate species collected in 28 trawls in the SBOO region during 2006. Data for each species are expressed as: percent abundance (PA); frequency of occurrence (FO); mean abundance per haul (MAH).

| Species | PA | FO | MAH | Species | PA | FO | MAH |
|---|---|---|---|---|---|---|---|
| *Astropecten verrilli* | 62 | 93 | 18 | *Luidia armata* | <1 | 7 | <1 |
| *Crangon nigromaculata* | 7 | 32 | 2 | Majidae | <1 | 7 | <1 |
| *Lytechinus pictus* | 6 | 29 | 2 | *Pleurobranchaea californica* | <1 | 7 | <1 |
| *Philine auriformis* | 3 | 11 | 1 | *Pteropurpura festiva* | <1 | 7 | <1 |
| *Cancer gracilis* | 2 | 32 | 1 | *Sicyonia ingentis* | <1 | 7 | <1 |
| *Kelletia kelletii* | 2 | 25 | 1 | *Aphrodita armifera* | <1 | 4 | <1 |
| *Pisaster brevispinus* | 2 | 46 | 1 | *Aphrodita* sp | <1 | 4 | <1 |
| *Heterocrypta occidentalis* | 2 | 29 | <1 | *Armina californica* | <1 | 4 | <1 |
| *Dendraster terminalis* | 1 | 11 | <1 | *Cancer jordani* | <1 | 4 | <1 |
| *Hemisquilla californiensis* | 1 | 18 | <1 | *Dendronotus frondosus* | <1 | 4 | <1 |
| *Ophiothrix spiculata* | 1 | 25 | <1 | *Dendronotus iris* | <1 | 4 | <1 |
| *Pagurus spilocarpus* | 1 | 29 | <1 | *Farfantepenaeus californiensis* | <1 | 4 | <1 |
| *Randallia ornata* | 1 | 18 | <1 | *Flabellina pricei* | <1 | 4 | <1 |
| *Platymera gaudichaudii* | 1 | 21 | <1 | *Florometra serratissima* | <1 | 4 | <1 |
| *Crangon alba* | 1 | 7 | <1 | *Heptacarpus stimpsoni* | <1 | 4 | <1 |
| *Octopus rubescens* | 1 | 11 | <1 | Hirudinea | <1 | 4 | <1 |
| *Pyromaia tuberculata* | 1 | 21 | <1 | *Lamellaria diegoensis* | <1 | 4 | <1 |
| *Loxorhynchus grandis* | 1 | 18 | <1 | *Loligo opalescens* | <1 | 4 | <1 |
| *Cancer anthonyi* | <1 | 4 | <1 | *Loxorhynchus* sp | <1 | 4 | <1 |
| *Crossata californica* | <1 | 14 | <1 | *Luidia foliolata* | <1 | 4 | <1 |
| *Crangon alaskensis* | <1 | 7 | <1 | *Megasurcula carpenteriana* | <1 | 4 | <1 |
| *Elthusa vulgaris* | <1 | 11 | <1 | *Paguristes bakeri* | <1 | 4 | <1 |
| *Flabellina iodinea* | <1 | 11 | <1 | *Paguristes turgidus* | <1 | 4 | <1 |
| *Megastraea undosa* | <1 | 7 | <1 | *Pagurus armatus* | <1 | 4 | <1 |
| *Cancer* sp | <1 | 7 | <1 | *Paracerceis cordata* | <1 | 4 | <1 |
| *Dendronotus* sp | <1 | 4 | <1 | *Sicyonia penicillata* | <1 | 4 | <1 |

included large numbers of *A. verrilli*, particularly during April when their abundances ranged from 4 to 92 per haul. Although biomass was also somewhat variable, high values generally corresponded to the collection of large species such as the sea star *P. brevispinus* and cancer or sheep crabs.

Variations in megabenthic invertebrate community structure in the South Bay area generally reflect changes in species abundance (**Figures 6.5, 6.6**). Although species richness has varied little over the years (e.g., 4–14 species per station), annual abundance values have averaged between 7 and 273 individuals per station. These wide ranging abundance values are generally due to fluctuations in the populations of several dominant species, especially the echinoderms *A. verrilli*, *Lytechinus pictus*, and *Dendraster terminalis,* as well as the shrimp *Crangon nigromaculata* (Figure 6.6). For example, the high abundances recorded at SD17 in 1996 and SD15 in 1996 and 1997 were due to large hauls of *A. verrilli* and *L. pictus*. In contrast, the general decline in overall abundance values since 2004 is a result of declining numbers of *D. terminalis* and *A. verrilli.* None of the observed variability in the invertebrate communities can be attributed to the South Bay outfall.

## SUMMARY AND CONCLUSIONS

As in previous years, speckled sanddabs continued to dominate fish assemblages surrounding the South Bay Ocean Outfall during 2006. Although the numbers of speckled sanddabs continued to decline markedly from their peak in 2004, this

## Table 6.5

Summary of megabenthic invertebrate community parameters for SBOO stations sampled during 2006. Data are expressed as mean and standard deviation (SD) for species richness (number of species), abundance (number of individuals), diversity (H') and biomass (kg, wet weight); n=4.

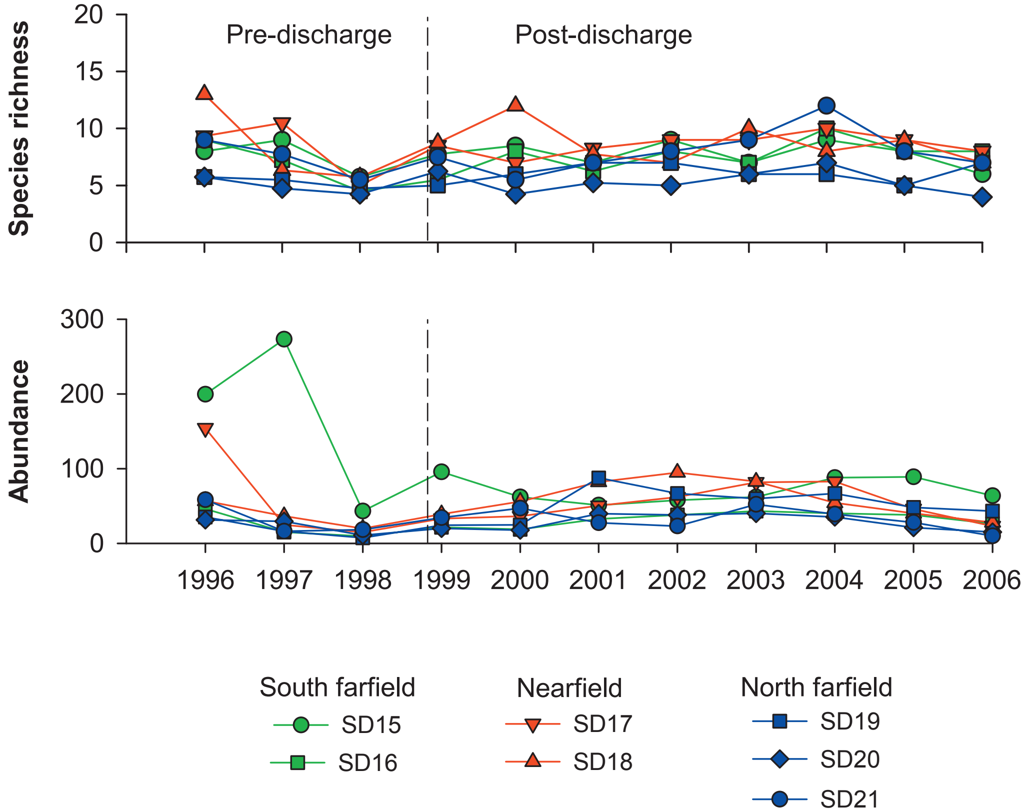
| Station | Jan | Apr | Jul | Oct | Mean | SD | Station | Jan | Apr | Jul | Oct | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Species richness* | | | | | | | *Abundance* | | | | | | |
| SD15 | 6 | 6 | 5 | 8 | 6 | 1 | SD15 | 26 | 98 | 54 | 77 | 64 | 31 |
| SD16 | 8 | 6 | 8 | 9 | 8 | 1 | SD16 | 29 | 34 | 25 | 14 | 26 | 9 |
| SD17 | 6 | 9 | 7 | 9 | 8 | 2 | SD17 | 22 | 34 | 13 | 21 | 23 | 9 |
| SD18 | 9 | 8 | 5 | 6 | 7 | 2 | SD18 | 27 | 62 | 15 | 8 | 28 | 24 |
| SD19 | 5 | 4 | 6 | 12 | 7 | 4 | SD19 | 8 | 96 | 43 | 23 | 43 | 38 |
| SD20 | 5 | 2 | 4 | 4 | 4 | 1 | SD20 | 9 | 19 | 20 | 11 | 15 | 6 |
| SD21 | 10 | 5 | 7 | 4 | 7 | 3 | SD21 | 10 | 8 | 13 | 10 | 10 | 2 |
| Mean | 7 | 6 | 6 | 7 | | | Mean | 19 | 50 | 26 | 23 | | |
| SD | 2 | 2 | 1 | 3 | | | SD | 9 | 36 | 16 | 24 | | |
| *Diversity* | | | | | | | *Biomass* | | | | | | |
| SD15 | 1.14 | 0.66 | 0.74 | 0.88 | 0.86 | 0.21 | SD15 | 0.1 | 0.3 | 0.3 | 2.9 | 0.9 | 1.3 |
| SD16 | 1.25 | 0.96 | 1.37 | 2.11 | 1.42 | 0.49 | SD16 | 1.8 | 0.5 | 0.7 | 1.3 | 1.1 | 0.6 |
| SD17 | 1.28 | 1.12 | 1.69 | 1.63 | 1.43 | 0.27 | SD17 | 0.7 | 0.2 | 0.3 | 0.2 | 0.4 | 0.2 |
| SD18 | 1.58 | 0.72 | 1.23 | 1.67 | 1.30 | 0.43 | SD18 | 1.7 | 0.7 | 0.4 | 0.3 | 0.8 | 0.6 |
| SD19 | 1.39 | 0.22 | 0.83 | 2.22 | 1.17 | 0.85 | SD19 | 1.2 | 0.1 | 0.3 | 0.3 | 0.5 | 0.5 |
| SD20 | 1.43 | 0.21 | 0.59 | 1.34 | 0.89 | 0.59 | SD20 | 1.0 | 0.1 | 0.5 | 0.8 | 0.6 | 0.4 |
| SD21 | 2.30 | 1.39 | 1.69 | 0.94 | 1.58 | 0.57 | SD21 | 2.6 | 0.1 | 1.0 | 0.1 | 1.0 | 1.2 |
| Mean | 1.48 | 0.75 | 1.16 | 1.54 | | | Mean | 1.3 | 0.3 | 0.5 | 0.8 | | |
| SD | 0.39 | 0.44 | 0.45 | 0.52 | | | SD | 0.8 | 0.2 | 0.3 | 1.0 | | |

species occurred at all stations and accounted for 49% of the total catch. Other characteristic, but less abundant species included the California lizardfish, yellowchin sculpin, longfin sanddab, hornyhead turbot, California tonguefish, roughback sculpin, and English sole. Most of these common fishes were relatively small, averaging less than 20 cm in length. Although the composition and structure of the fish assemblages varied among stations, these differences were mostly due to variations in speckled sanddab and California lizardfish populations.

Assemblages of relatively large (megabenthic) trawl-caught invertebrates were similarly dominated by one prominent species, the sea star *A. verrilli.* Although megabenthic community structure also varied between sites, these assemblages were generally characterized by low species richness, abundance, biomass, and diversity. As a result of declining numbers of *D. terminalis* and *A. verrilli,* there has been an overall decline in trawl-caught invertebrate abundance values since 2004.

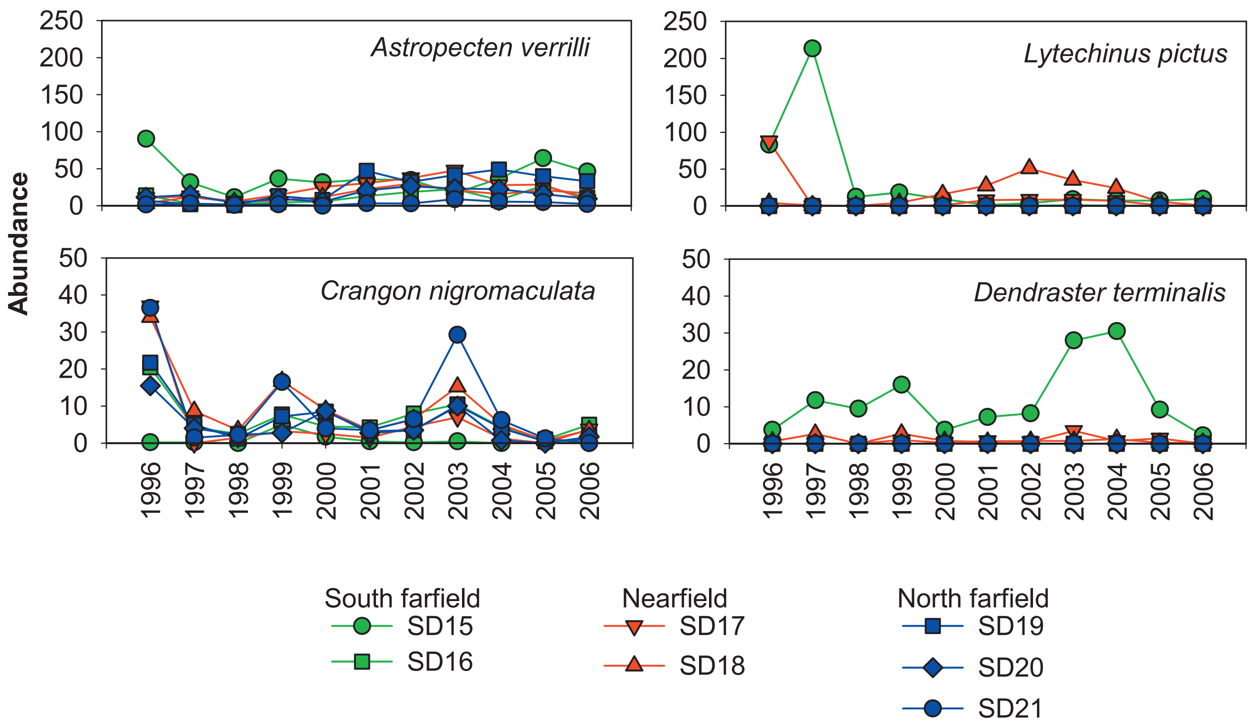
The relatively low numbers and low species richness of fish and invertebrates found in the SBOO surveys are consistent with the depth and type of habitat in which the SBOO stations are located (see Allen et al. 1998). In contrast, trawl surveys for the Point Loma Ocean Outfall region include stations located farther offshore on the mainland shelf containing finer sediments, and result in higher species richness and abundance in each trawl. The mean number of fish species collected per haul off Point Loma often reaches 23 species per station with mean abundances up to 1368 individuals per station (e.g., City of San Diego 2006).

Overall, results of the 2006 trawl surveys provide no evidence that the discharge of wastewater from the South Bay Ocean Outfall has affected either the fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of species were similar at stations located near the outfall and farther away, indicating a lack of anthropogenic influence. Changes in the communities appeared




## Figure 6.5

Annual mean species richness (number of species) and abundance (number of individuals) per SBOO station of megabenthic invertebrates collected from 1996 through 2006.




## Figure 6.6

Annual mean abundance (number of individuals) per SBOO station for the four most abundant megabenthic invertebrate species collected from 1996 through 2006; n=4.

to be more likely due to natural factors such as changes in water temperature associated with large scale oceanographic events (e.g., El Niño) and the mobile nature of many of the species collected. Finally, the absence of disease or other physical abnormalities in 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 South Bay Ocean Outfall (SBOO) 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 SBOO monitoring program consists of 2 components: (1) liver tissues are analyzed from trawl-caught fishes; (2) muscle tissues are analyzed from fishes collected by rig fishing. Fishes collected from trawls are considered representative of the demersal fish community, and certain species are targeted based on their ecological significance (i.e., prevalence in the community). Chemical analyses are performed using livers because this is the organ where contaminants typically concentrate. In contrast, fishes targeted for collection by rig fishing represent species from a typical sport fisher's catch, and are therefore of recreational and commercial importance. Muscle tissue is analyzed from these fish because it is the tissue most often consumed by humans, and therefore the results have human health implications.

All muscle and liver samples were analyzed for contaminants as specified in the NPDES discharge permits governing the SBOO 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 during 2006.

## MATERIALS AND METHODS

### Collection

Fishes were collected during the April and October surveys of 2006 at 7 trawl and 2 rig fishing stations (**Figure 7.1**). Trawl-caught fishes were collected, measured, and weighed following guidelines described in Chapter 6 of this report. Fishes targeted at the rig fishing sites were collected using rod and reel fishing tackle, and then measured and weighed.

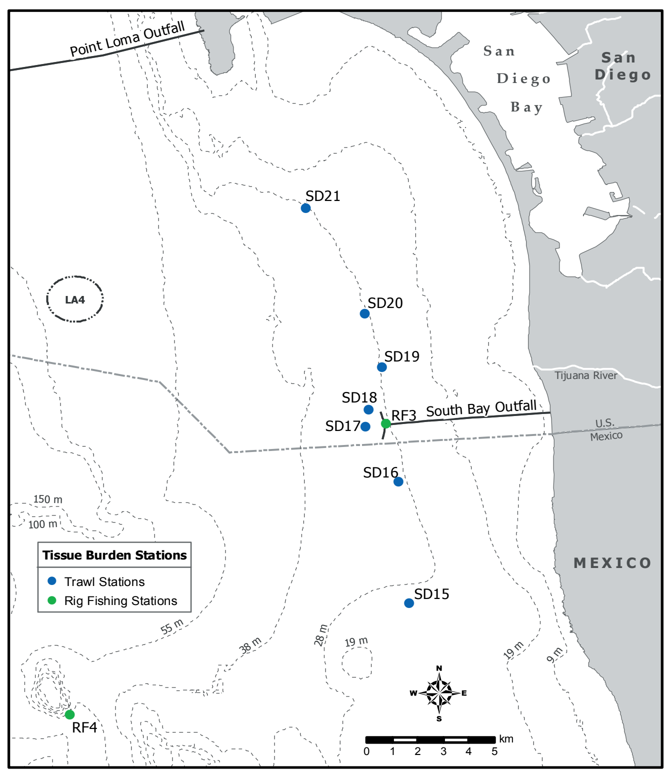



**Figure 7.1**
Otter trawl and rig fishing station locations for the South Bay Ocean Outfall Monitoring Program.

## Table 7.1

Species collected at each SBOO trawl and rig fishing station during April and October 2006.

| Station | Rep 1 | Rep 2 | Rep 3 |
|---|---|---|---|
| *April 2006* | | | |
| SD15 | Hornyhead turbot | (no sample) | (no sample) |
| SD16 | Hornyhead turbot | Longfin sanddab | English sole |
| SD17 | Hornyhead turbot | Longfin sanddab | English sole |
| SD18 | Hornyhead turbot | English sole | Longfin sanddab |
| SD19 | Hornyhead turbot | English sole | Longfin sanddab |
| SD20 | Hornyhead turbot | English sole | Longfin sanddab |
| SD21 | Longfin sanddab | Hornyhead turbot | English sole |
| RF3 | Brown rockfish | Brown rockfish | Brown rockfish |
| RF4 | California scorpionfish | California scorpionfish | California scorpionfish |
| *October 2006* | | | |
| SD15 | Hornyhead turbot | Pacific sanddab | Hornyhead turbot |
| SD16 | Longfin sanddab | Hornyhead turbot | Hornyhead turbot |
| SD17 | California scorpionfish | California scorpionfish | Hornyhead turbot |
| SD18 | California scorpionfish | Hornyhead turbot | Hornyhead turbot |
| SD19 | Hornyhead turbot | Hornyhead turbot | Longfin sanddab |
| SD20 | Longfin sanddab | Hornyhead turbot | Hornyhead turbot |
| SD21 | Longfin sanddab | Hornyhead turbot | Hornyhead turbot |
| RF3 | Mixed rockfish | Mixed rockfish | Brown rockfish |
| RF4 | Mixed rockfish | Honeycomb rockfish | Treefish |

The species that were analyzed from each station are summarized in **Table 7.1**. The effort to collect targeted fishes was limited to 5 10-minute trawls at each trawl station. Occasionally, insufficient numbers of target species were obtained despite this effort. Only fish >13 cm standard length were retained for tissue analyses. These fish were sorted into no more than 3 composite samples per station, each containing a minimum of 3 individuals. Composite samples are typically made up of a single species; the only exceptions are samples that consist of mixed rockfish species. Fishes were then wrapped in aluminum foil, labeled, sealed in Ziplock bags, placed on dry ice, transported to the City's 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 E.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 permits under which this sampling was performed. These chemical constituents include trace metals, chlorinated pesticides, polychlorinated biphynel compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs), as listed in **Appendix E.2**. Values for individual constituents of pollutants reported as totals (e.g., total DDT) are listed in **Appendix E.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 2007).

## RESULTS AND DISCUSSION

### Contaminants in Trawl-Caught Fishes

***Metals***

Ten metals, including arsenic, cadmium, chromium, iron, manganese, mercury, selenium, silver, tin, and zinc occurred in over 80% of the liver samples analyzed from fishes collected by trawl in 2006 (**Table 7.2**). Aluminum, antimony, barium, copper, lead, nickel, and thallium were also detected, but less frequently. Beryllium was not detected at all. Concentrations of most metals were <10 ppm. Exceptions occurred for arsenic, copper, iron, and zinc, which had concentrations above 15 ppm in at least one sample. Compared to all of the other metals, iron was relatively high in all 5 species of fish collected. In contrast, concentrations of zinc and copper were highest in California scorpionfish, and arsenic concentrations were highest in English sole and longfin sanddabs.

Intraspecific comparisons of the frequently detected metals between the 2 stations closest to the discharge (SD17, SD18) and those located farther away (SD15, SD16, SD19–SD21) suggest that there was no clear relationship between contaminant loads and proximity to the outfall (**Figure 7.2**). Contaminant concentrations were fairly similar across all stations and most were close to or below the maximum levels detected in the same species prior to discharge. Arsenic occurred at concentrations above the pre-discharge maximums in 15 of 40 samples. However, these samples were not concentrated near the outfall and occurred in multiple species.

***Pesticides***

Several chlorinated pesticides were detected during the 2006 surveys (**Table 7.3**). Individual components of total BHC, chlordane, and DDT are listed in Appendix E.2, while their detected values are included in Appendix E.3. DDT was found in all samples with total DDT concentrations ranging from about 46 to 1379 ppb. Other pesticides that were detected frequently included hexachlorobenzene (HCB) and chlordane. Maximum concentrations for these 2 contaminants were 3.5 and 215.8 ppb, respectively. As with metals, there was no clear relationship between concentrations of these pesticides and proximity to the outfall (**Figure 7.3**). In addition, most concentrations were close to or below the maximum levels detected in the same species prior to discharge. The only exceptions were 2 samples of California scorpionfish from outfall station SD17. California scorpionfish are known to migrate long distances (Hartmann 1987, Love et al. 1987), so it is unknown where these pesticides may have been acquired. These 2 samples also contained the only detectable concentrations of aldrin, alpha endosulphan, dieldrin, endrin, and BHC (lindane). Mirex was found in a single longfin sanddab sample from station SD16.

***PAHs and PCBs***

PAHs were not detected in fish liver samples during 2006. In contrast, PCBs occurred in every sample. All of the individual PAHs and PCB congeners that were analyzed are listed in Appendix E.2, while detected PCB congeners are summarized in Appendix E.3. Total PCB concentrations (i.e., the sum of all congeners detected in a sample, tPCB) were variable, ranging from about 18 to 1689 ppb (Table 7.3). There was no clear relationship between PCB concentrations and proximity to the outfall (Figure 7.3).

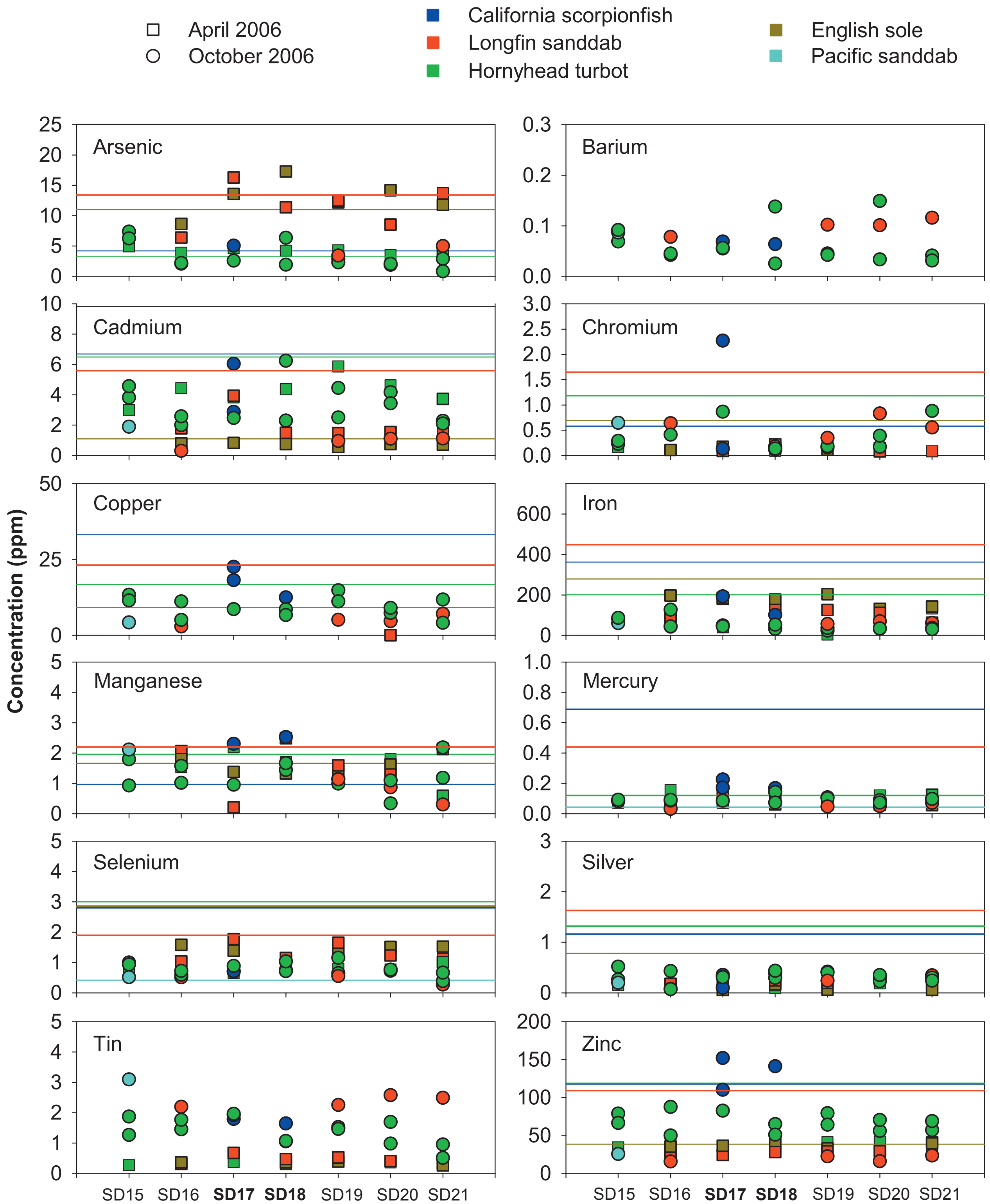
### Contaminants in Fishes Collected by Rig Fishing

Arsenic, cadmium, chromium, iron, manganese, mercury, selenium, tin, and zinc occurred in at least 75% of the muscle tissue samples from various rockfish collected at rig fishing stations in 2006 (**Table 7.4**). Aluminum, antimony, barium, copper, nickel, and thallium were also detected, but in 50% or fewer of the samples. The metals with the highest concentrations included aluminum, arsenic, iron, and zinc. Each exceeded 2 ppm for at least one species of fish sampled. Iron and zinc had the

## Table 7.2

Metals detected in liver tissues from fishes collected at SBOO trawl stations during 2006. Values are expressed as parts per million (ppm); n=number of detected values, nd=not detected.

| | Al | Sb | As | Ba | Cd | Cr | Cu | Fe | Pb | Mn | Hg | Ni | Se | Ag | Tl | Sn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| California scorpionfish | | | | | | | | | | | | | | | | | |
| N (out of 3) | 2 | nd | 1 | 3 | 3 | 3 | 3 | 3 | nd | 2 | 3 | 2 | 3 | 3 | nd | 3 | 3 |
| Min | 2.09 | — | 5.05 | 0.055 | 2.29 | 0.11 | 12.5 | 49.7 | — | 2.30 | 0.168 | 0.101 | 0.69 | 0.097 | — | 1.64 | 110.0 |
| Max | 2.62 | — | 5.05 | 0.069 | 6.04 | 2.27 | 22.6 | 193.0 | — | 2.52 | 0.225 | 0.463 | 0.75 | 0.388 | — | 1.92 | 152.0 |
| Mean | 2.36 | — | 5.05 | 0.063 | 3.74 | 0.84 | 17.8 | 114.6 | — | 2.41 | 0.188 | 0.282 | 0.72 | 0.279 | — | 1.78 | 134.3 |
| English sole | | | | | | | | | | | | | | | | | |
| N (out of 6) | nd | nd | 6 | nd | 6 | 5 | nd | 6 | 6 | 6 | 5 | 1 | 6 | 4 | 6 | 4 | 6 |
| Min | — | — | 8.66 | — | 0.57 | 0.11 | — | 132.0 | 0.52 | 1.33 | 0.056 | 0.117 | 1.10 | 0.057 | 1.46 | 0.26 | 29.2 |
| Max | — | — | 17.30 | — | 0.84 | 0.17 | — | 204.0 | 1.01 | 2.14 | 0.074 | 0.117 | 1.58 | 0.164 | 2.04 | 0.39 | 39.6 |
| Mean | — | — | 12.96 | — | 0.74 | 0.14 | — | 173.2 | 0.72 | 1.62 | 0.063 | 0.117 | 1.40 | 0.085 | 1.83 | 0.34 | 35.5 |
| Hornyhead turbot | | | | | | | | | | | | | | | | | |
| N (out of 20) | 7 | nd | 19 | 13 | 20 | 16 | 13 | 20 | 1 | 20 | 20 | 6 | 20 | 20 | 7 | 20 | 20 |
| Min | 1.13 | — | 0.83 | 0.026 | 2.00 | 0.10 | 4.1 | 5.0 | 0.32 | 0.34 | 0.073 | 0.098 | 0.39 | 0.071 | 1.58 | 0.27 | 34.1 |
| Max | 6.14 | — | 7.37 | 0.149 | 6.24 | 0.88 | 14.9 | 127.0 | 0.32 | 2.19 | 0.156 | 0.745 | 1.15 | 0.515 | 2.39 | 1.96 | 87.5 |
| Mean | 2.84 | — | 3.66 | 0.062 | 3.64 | 0.29 | 9.5 | 49.5 | 0.32 | 1.35 | 0.100 | 0.218 | 0.80 | 0.268 | 2.01 | 0.99 | 58.1 |
| Longfin sanddab | | | | | | | | | | | | | | | | | |
| N (out of 10) | 4 | 5 | 10 | 4 | 10 | 8 | 5 | 10 | 2 | 9 | 10 | 2 | 10 | 10 | 6 | 10 | 10 |
| Min | 2.01 | 0.26 | 1.90 | 0.078 | 0.30 | 0.08 | 0.1 | 42.8 | 0.35 | 0.21 | 0.031 | 0.096 | 0.27 | 0.076 | 2.35 | 0.30 | 15.6 |
| Max | 7.14 | 0.66 | 16.30 | 0.116 | 3.95 | 0.83 | 7.1 | 180.0 | 0.38 | 2.49 | 0.135 | 0.759 | 1.77 | 0.346 | 2.99 | 2.57 | 29.0 |
| Mean | 5.41 | 0.51 | 8.12 | 0.099 | 1.54 | 0.36 | 4.0 | 99.6 | 0.37 | 1.34 | 0.074 | 0.428 | 1.00 | 0.221 | 2.67 | 1.22 | 23.8 |
| Pacific sanddab | | | | | | | | | | | | | | | | | |
| N (out of 1) | nd | nd | nd | 1 | 1 | 1 | 1 | 1 | nd | 1 | 1 | nd | 1 | 1 | nd | 1 | 1 |
| Min | — | — | — | 0.087 | 1.90 | 0.65 | 4.3 | 60.8 | — | 2.11 | 0.081 | — | 0.51 | 0.198 | — | 3.09 | 25.4 |
| Max | — | — | — | 0.087 | 1.90 | 0.65 | 4.3 | 60.8 | — | 2.11 | 0.081 | — | 0.51 | 0.198 | — | 3.09 | 25.4 |
| Mean | — | — | — | 0.087 | 1.90 | 0.65 | 4.3 | 60.8 | — | 2.11 | 0.081 | — | 0.51 | 0.198 | — | 3.09 | 25.4 |
| ALL SPECIES | | | | | | | | | | | | | | | | | |
| % Detected | 33 | 13 | 90 | 53 | 100 | 83 | 55 | 100 | 23 | 95 | 98 | 28 | 100 | 95 | 48 | 95 | 100 |
| Max Value | 7.14 | 0.66 | 17.30 | 0.149 | 6.24 | 2.27 | 22.6 | 204.0 | 1.01 | 2.52 | 0.225 | 0.759 | 1.77 | 0.515 | 2.99 | 3.09 | 152.0 |




## Figure 7.2

Concentrations of frequently detected metals in liver tissues of fishes collected from each SBOO trawl station during 2006. Reference lines are maximum values detected during the pre-discharge period (1995–1998); tin and barium were not detected during this period because of substantially higher detection limits. Therefore no reference lines are present for these contaminants. Stations closest to the discharge site are labeled in bold.

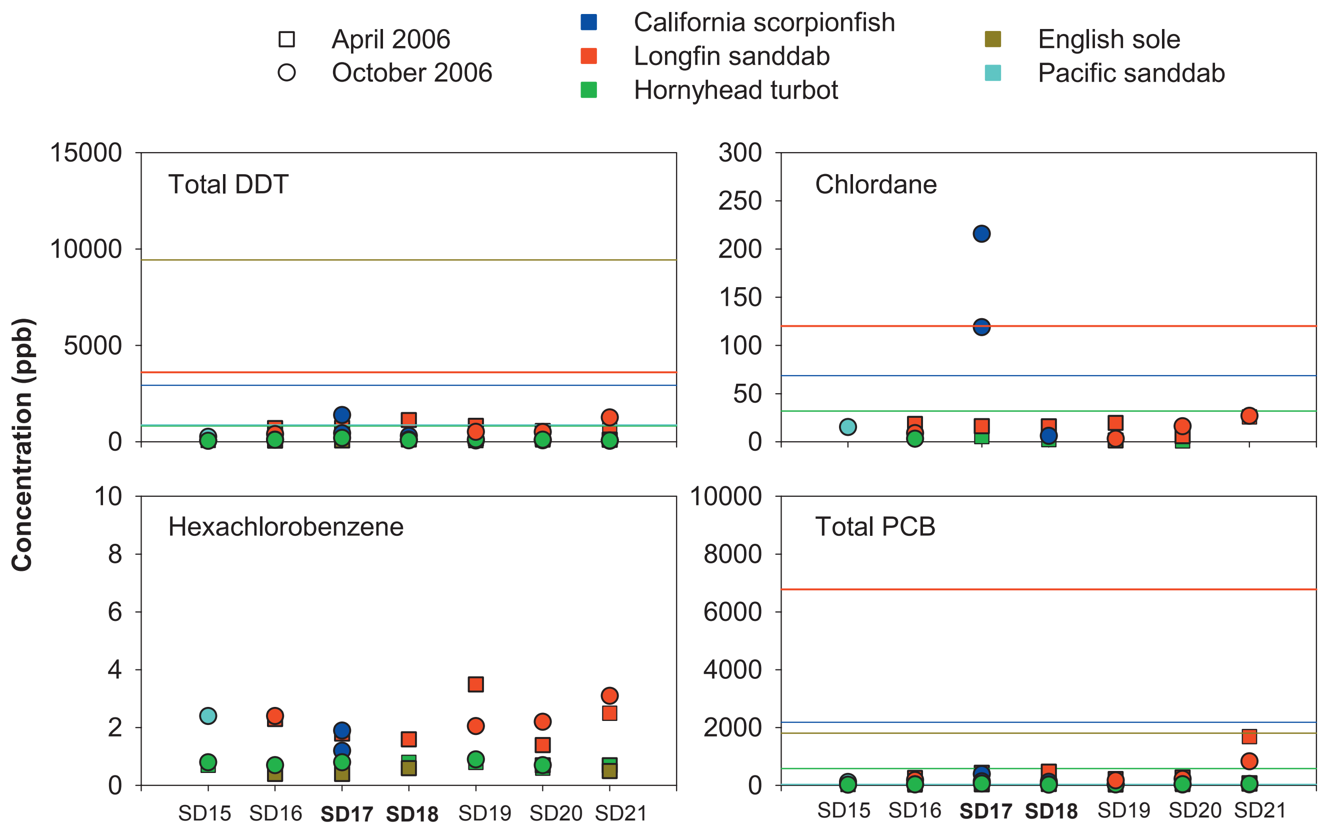
## Table 7.3

Chlorinated pesticides, total PCB, and lipids detected in liver tissues from fishes collected at SBOO trawl stations during 2006. Alpha enosulphan=(a)E; hexachlorobenzene=HCB; total BHC (lindane)=tBHC; total chlordane=tChlor, total DDT=tDDT; total PCB=tPCB. Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt), n=number of detected values, nd=not detected.

| | Pesticides | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aldrin | (a)E | Dieldrin | Endrin | HCB | Mirex | tBHC | tChlor | tDDT | tPCB | Lipids |
| California scorpionfish | | | | | | | | | | | |
| N (out of 3) | 2 | 2 | 2 | 2 | 2 | nd | 2 | 3 | 3 | 3 | 3 |
| Min | 5.1 | 8.3 | 14 | 44 | 1.2 | — | 97.0 | 6.1 | 308.1 | 124.3 | 16.4 |
| Max | 19.0 | 9.6 | 63 | 66 | 1.9 | — | 278.0 | 215.8 | 1379.0 | 387.7 | 32.2 |
| Mean | 12.1 | 9.0 | 38.5 | 55 | 1.6 | — | 187.5 | 113.6 | 706.1 | 218.6 | 23.6 |
| English sole | | | | | | | | | | | |
| N (out of 6) | nd | nd | nd | nd | 5 | nd | nd | 1 | 6 | 6 | 6 |
| Min | — | — | — | — | 0.4 | — | — | 1.4 | 65.4 | 41.8 | 2.4 |
| Max | — | — | — | — | 0.7 | — | — | 1.4 | 161.3 | 82.3 | 5.7 |
| Mean | — | — | — | — | 0.5 | — | — | 1.4 | 114.0 | 58.8 | 4.4 |
| Hornyhead turbot | | | | | | | | | | | |
| N (out of 20) | nd | nd | nd | nd | 11 | nd | 1 | 4 | 20 | 20 | 20 |
| Min | — | — | — | — | 0.4 | — | 5.9 | 0.8 | 45.5 | 18.0 | 2.7 |
| Max | — | — | — | — | 0.9 | — | 5.9 | 5.4 | 198.2 | 62.1 | 13.2 |
| Mean | — | — | — | — | 0.7 | — | 5.9 | 2.9 | 93.0 | 36.6 | 8.4 |
| Longfin sanddab | | | | | | | | | | | |
| N (out of 10) | nd | nd | nd | nd | 10 | 1 | nd | 10 | 10 | 10 | 10 |
| Min | — | — | — | — | 1.4 | 2.6 | — | 3.1 | 397.0 | 174.1 | 12.1 |
| Max | — | — | — | — | 3.5 | 2.6 | — | 26.8 | 1260.3 | 1689.0 | 62.4 |
| Mean | — | — | — | — | 2.3 | 2.6 | — | 15.7 | 749.9 | 478.9 | 31.7 |
| Pacific sanddab | | | | | | | | | | | |
| N (out of 1) | nd | nd | nd | nd | 1 | nd | nd | 1 | 1 | 1 | 1 |
| Min | — | — | — | — | 2.4 | — | — | 15.3 | 254.6 | 113.9 | 37.4 |
| Max | — | — | — | — | 2.4 | — | — | 15.3 | 254.6 | 113.9 | 37.4 |
| Mean | — | — | — | — | 2.4 | — | — | 15.3 | 254.6 | 113.9 | 37.4 |
| ALL SPECIES | | | | | | | | | | | |
| % Detected | 5 | 5 | 5 | 5 | 73 | 3 | 8 | 48 | 100 | 100 | 100 |
| Max Value | 19.0 | 9.6 | 63 | 66 | 3.5 | 2.6 | 278.0 | 215.8 | 1379.0 | 1689.0 | 62.4 |

highest values at 25.6 and 15.5 ppm, respectively. Both of these concentrations occurred in samples of Brown rockfish. DDT and PCB were detected in 100% of the muscle samples, while the pesticides HCB, aldrin, dieldrin, endrin, BHC (lindane), and chlordane were found much less frequently (**Table 7.5**). Each of these contaminants was detected in relatively low concentrations, from 0.1 ppb for HCB to 22.8 ppb for total DDT.

To address human health concerns, concentrations of constituents found in muscle tissue samples were compared to both national and international limits and standards (Table 7.4, Table 7.5). The United States Food and Drug Administration (FDA) has set limits on the amount of mercury, total DDT, and chlordane in seafood that is to be sold for human consumption and there are also international standards for acceptable concentrations of various metals (see Mearns et al. 1991). Of the compounds detected in the fish muscle tissues collected as part of the SBOO monitoring program, only arsenic, cadmium, and selenium had concentrations slightly higher than international standards.




## Figure 7.3

Concentrations of frequently detected chlorinated pesticides (total DDT, chlordane, hexachlorobenzene) and total PCBs in liver tissues of fishes collected from each SBOO trawl station during 2006. Reference lines are maximum values detected during the pre-discharge period (1995–1998); chlordane and hexachlorobenzene were not detected as frequently during this period because of substantially higher detection limits. Therefore reference lines for these 2 contaminants are absent for some or all of the species. Stations closest to the discharge site are labeled in bold.

In addition to addressing health concerns, spatial patterns were assessed for total DDT and total PCB, as well as all metals that occurred frequently in muscle tissue samples (**Figure 7.4**). Overall, concentrations of DDT, PCB, and metals were fairly similar in the muscle tissues from fishes at both rig fishing stations suggesting there was no evident relationship with proximity to the outfall.

Comparison of contaminant loads between RF3 and RF4 should be considered with caution however, because different species of fish were collected at the 2 sites. All specimens belong to the family Scorpaenidae and have similar life histories (i.e., bottom dwelling tertiary carnivores), and therefore have similar mechanisms of exposure (e.g., exposure from direct contact with the sediments and through possibly similar food sources). However, different species can have different physiologies and diet that could affect the accumulation of contaminants.

## SUMMARY AND CONCLUSIONS

Ten trace metals, DDT, and a combination of PCBs were each detected in over 75% of the liver samples from 5 species of fish collected around the South Bay Ocean Outfall (SBOO) in 2006. All contaminant values were within the range of those reported previously for the Southern California Bight (SCB) (see Mearns et al. 1991, City of San Diego 1996–2001, Allen et al. 1998). Although several individual samples contained concentrations of some trace metals that exceeded pre-discharge

## Table 7.4

Metals detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2006. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist. Bold values exceed these standards, n=number of detected values, nd=not detected.

| | Al | Sb | As | Ba | Cd | Cr | Cu | Fe | Mn | Hg | Ni | Se | Tl | Sn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brown rockfish | | | | | | | | | | | | | | | |
| N (out of 4) | 1 | 1 | 4 | 1 | 3 | 2 | 1 | 4 | 3 | 4 | 1 | 4 | 3 | 3 | 4 |
| Min | 5.40 | 0.74 | 0.60 | 0.034 | 0.03 | 0.13 | 0.334 | 2.13 | 0.10 | 0.12 | 0.10 | 0.20 | 1.09 | 0.29 | 2.81 |
| Max | 5.40 | 0.74 | **2.39** | 0.034 | **1.21** | 0.51 | 0.334 | 25.60 | 0.27 | 0.16 | 0.10 | 0.23 | 1.82 | 1.60 | 15.50 |
| Mean | 5.40 | 0.74 | 1.16 | 0.034 | 0.46 | 0.32 | 0.334 | 9.58 | 0.17 | 0.14 | 0.10 | 0.22 | 1.54 | 0.74 | 6.55 |
| California scorpionfish | | | | | | | | | | | | | | | |
| N (out of 3) | nd | nd | 3 | nd | 1 | 2 | | 3 | 1 | 3 | nd | 3 | 3 | 3 | 3 |
| Min | — | — | **2.85** | — | 0.03 | 0.10 | | 0.33 | 0.22 | 0.12 | — | **0.32** | 1.81 | 0.13 | 3.07 |
| Max | — | — | **5.77** | — | 0.03 | 0.20 | | 1.90 | 0.22 | 0.20 | — | **0.98** | 1.99 | 0.33 | 3.22 |
| Mean | — | — | **4.32** | — | 0.03 | 0.15 | | 1.22 | 0.22 | 0.15 | — | **0.70** | 1.90 | 0.26 | 3.15 |
| Honeycomb rockfish | | | | | | | | | | | | | | | |
| N (out of 1) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | nd | 1 | 1 |
| Min | 7.44 | 0.80 | **5.32** | 0.044 | 0.17 | 0.42 | 0.591 | 2.82 | 0.17 | 0.10 | 0.19 | **0.33** | — | 1.70 | 4.84 |
| Max | 7.44 | 0.80 | **5.32** | 0.044 | 0.17 | 0.42 | 0.591 | 2.82 | 0.17 | 0.10 | 0.19 | **0.33** | — | 1.70 | 4.84 |
| Mean | 7.44 | 0.80 | **5.32** | 0.044 | 0.17 | 0.42 | 0.591 | 2.82 | 0.17 | 0.10 | 0.19 | **0.33** | — | 1.70 | 4.84 |
| Mixed rockfish | | | | | | | | | | | | | | | |
| N (out of 3) | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | nd | 3 | 3 |
| Min | 2.18 | 0.85 | 1.30 | 0.033 | 0.13 | 0.38 | 0.474 | 2.01 | 0.09 | 0.05 | 0.15 | 0.29 | — | 1.54 | 4.10 |
| Max | 6.11 | 1.07 | **1.83** | 0.041 | 0.16 | 0.43 | 0.543 | 5.89 | 0.14 | 0.18 | 0.22 | **0.41** | — | 1.72 | 5.65 |
| Mean | 4.15 | 0.93 | **1.62** | 0.037 | 0.15 | 0.41 | 0.509 | 3.85 | 0.12 | 0.10 | 0.18 | **0.35** | — | 1.64 | 4.79 |
| Treefish | | | | | | | | | | | | | | | |
| N (out of 1) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | nd | 1 | 1 |
| Min | 4.37 | 0.83 | **1.43** | 0.038 | 0.13 | 0.38 | 0.473 | 4.19 | 0.08 | 0.23 | 0.17 | **0.41** | — | 1.80 | 5.20 |
| Max | 4.37 | 0.83 | **1.43** | 0.038 | 0.13 | 0.38 | 0.473 | 4.19 | 0.08 | 0.23 | 0.17 | **0.41** | — | 1.80 | 5.20 |
| Mean | 4.37 | 0.83 | **1.43** | 0.038 | 0.13 | 0.38 | 0.473 | 4.19 | 0.08 | 0.23 | 0.17 | **0.41** | — | 1.80 | 5.20 |
| ALL SPECIES | | | | | | | | | | | | | | | |
| % Detected | 42 | 50 | 100 | 50 | 75 | 75 | 50 | 100 | 75 | 100 | 50 | 100 | 50 | 92 | 100 |
| Max Value | 7.44 | 1.07 | 5.77 | 0.044 | 1.21 | 0.51 | 0.591 | 25.60 | 0.27 | 0.23 | 0.22 | 0.98 | 1.99 | 1.80 | 15.50 |
| US FDA Action Limit* | | | | | | | | | | 1.00 | | | | | |
| Median IS* | | | 1.4 | | 1.0 | 1.0 | 20 | | | 0.5 | | 0.3 | | 175 | 70 |

* From Mearns et al. 1991. FDA 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.

## Table 7.5

Total PCB, chlorinated pesticides, and lipids detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2006. Hexachlorobenzene=HCB; total BHC (lindane)=tBHC; total chlordane=tChlor, total DDT=tDDT; total PCB=tPCB Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt); n=number of detected values, nd=not detected. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist.

| | Pesticides | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | HCB | Aldrin | Dieldrin | Endrin | tBHC | tChlor | tDDT | tPCB | Lipids |
| Brown rockfish | | | | | | | | | |
| N (out of 4) | 1 | nd | nd | nd | nd | nd | 4 | 4 | 4 |
| Min | 0.1 | — | — | — | — | — | 2.4 | 0.9 | 0.1 |
| Max | 0.1 | — | — | — | — | — | 4.8 | 4.8 | 0.5 |
| Mean | 0.1 | — | — | — | — | — | 3.3 | 2.1 | 0.3 |
| California scorpionfish | | | | | | | | | |
| N (out of 3) | nd | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 |
| Min | — | 1.3 | 2.8 | 2.9 | 19.0 | 14.9 | 3.6 | 0.6 | 0.4 |
| Max | — | 1.3 | 2.8 | 2.9 | 19.0 | 14.9 | 9.2 | 1.1 | 1.4 |
| Mean | — | 1.3 | 2.8 | 2.9 | 19.0 | 14.9 | 5.7 | 0.9 | 0.8 |
| Honeycomb rockfish | | | | | | | | | |
| N (out of 1) | 1 | nd | nd | nd | nd | nd | 1 | 1 | 1 |
| Min | 0.1 | — | — | — | — | — | 7.8 | 2.1 | 0.8 |
| Max | 0.1 | — | — | — | — | — | 7.8 | 2.1 | 0.8 |
| Mean | 0.1 | — | — | — | — | — | 7.8 | 2.1 | 0.8 |
| Mixed rockfish | | | | | | | | | |
| N (out of 3) | 1 | nd | nd | nd | nd | 2 | 3 | 3 | 3 |
| Min | 0.1 | — | — | — | — | 0.2 | 2.0 | 0.6 | 0.5 |
| Max | 0.1 | — | — | — | — | 0.3 | 13.4 | 3.0 | 3.0 |
| Mean | 0.1 | — | — | — | — | 0.3 | 7.1 | 2.0 | 1.5 |
| Treefish | | | | | | | | | |
| N (out of 1) | nd | nd | nd | nd | nd | 1 | 1 | 1 | 1 |
| Min | — | — | — | — | — | 0.6 | 22.8 | 4.9 | 1.3 |
| Max | — | — | — | — | — | 0.6 | 22.8 | 4.9 | 1.3 |
| Mean | — | — | — | — | — | 0.6 | 22.8 | 4.9 | 1.3 |
| ALL SPECIES | | | | | | | | | |
| % Detected | 25 | 8 | 8 | 8 | 8 | 33 | 100 | 100 | 100 |
| Max Value | 0.1 | 1.3 | 2.8 | 2.9 | 19.0 | 14.9 | 22.8 | 4.9 | 3.0 |
| US FDA Action Limit* | | | | | | 300 | 5000 | | |
| Median IS* | | | | | | 100 | 5000 | | |

* From Mearns et al. 1991. FDA action limits for total DDT and chlordane are for fish muscle tissue 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.

maximum values, the concentrations of most contaminants were not substantially different from pre-discharge data (City of San Diego 2000b). In addition, the few samples that did exceed these pre-discharge values were distributed widely among the sampled stations and showed no pattern relative to wastewater discharge.

The frequent occurrence of metals and chlorinated hydrocarbons in SBOO fish tissues may be due to many factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB. In fact, many metals occur naturally in the environment (see chapters 4 and 8), although little

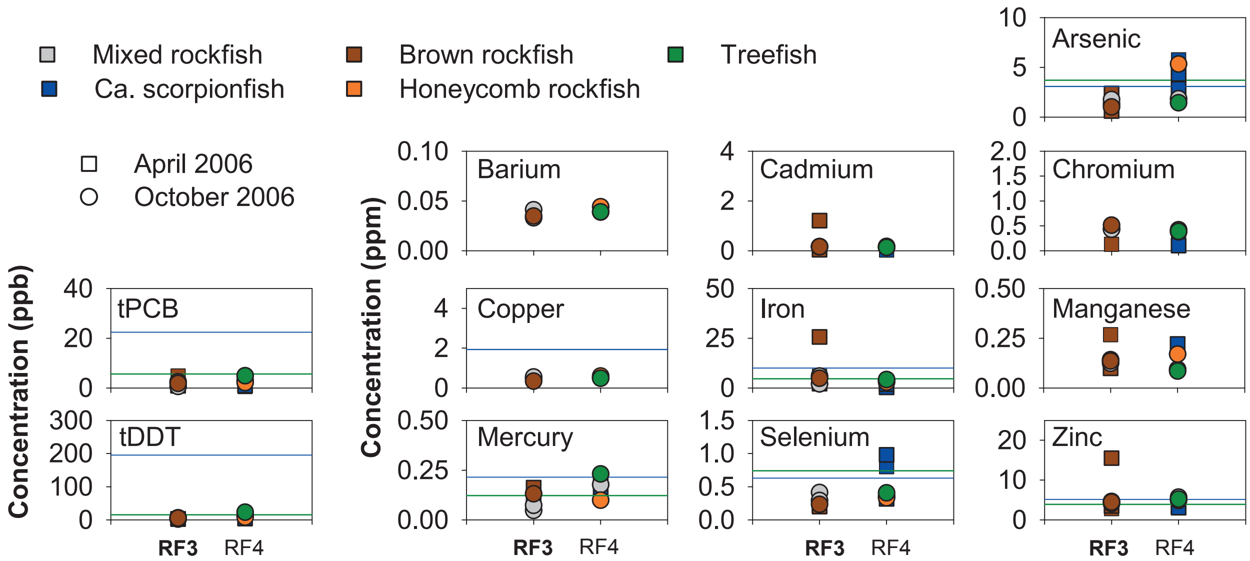



**Figure 7.4**
Concentrations of frequently detected metals, total DDT, and total PCB in muscle tissues of fishes collected from each SBOO rig fishing station during 2006. Missing data represent concentrations below detection limits. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for California scorpionfish and mixed rockfish. Honeycomb rockfish, treefish, and brown rockfish were not collected during that period. Station RF3 is the station closest to the discharge site.

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). The lack of contaminant-free reference areas in the SCB clearly pertains to the South Bay region, as demonstrated by the presence of many contaminants in fish tissues prior to wastewater discharge (City of San Diego 2000b).

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 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 is of particular concern for fishes collected in the vicinity of the SBOO, as there are many point and non-point sources that may contribute to contamination in the region (see Chapters 2–4). For example, some monitoring stations are located near the Tijuana River, San Diego Bay, and dredged materials disposal sites, and input from these sources may affect fish in surrounding areas.

Overall, there was no evidence that fishes collected in 2006 were contaminated by the discharge of wastewater from the SBOO. While some muscle tissue samples from sport fish collected in the area had concentrations of arsenic, cadmium, and selenium above the median international standard for shellfish, concentrations of mercury and DDT were below FDA human consumption limits. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot or other physical anomalies (see Chapter 6).

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# *Chapter 8. San Diego Regional Survey Sediment Characteristics*

## INTRODUCTION

The City of San Diego has conducted summer regional surveys of sediment conditions on the mainland shelf off San Diego since 1994 in order to evaluate physical and chemical patterns and trends over a large geographic area. Such region-wide monitoring is designed to assess the quality and characteristics of sediments, as well as provide additional information that may help to differentiate reference areas from sites impacted by wastewater and stormwater discharge. These annual surveys are based on an array of stations randomly selected each year by the United States Environmental Protection Agency (USEPA) using the USEPA probability-based EMAP design. The 1994, 1998, and 2003 surveys were conducted as part of the Southern California Bight 1994 Pilot Project (SCBPP), and the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight′98 and Bight′03, respectively). These large-scale surveys included other major southern California dischargers, and included sampling sites representing the entire Southern California Bight (i.e., Cabo Colnett, Mexico to Point Conception). The same randomized sampling design was used for the random sampling surveys limited to the San Diego region (1995–1997, 1999–2002, 2005). In the summer of 2006, the City revisited the 1996 survey sites in order to compare conditions 10 years later.

This chapter presents analyses of sediment particle size and chemistry data collected during the San Diego regional survey of 2006. Descriptions and comparisons of the sediment conditions present in 2006 are included with analyses of levels and patterns of contamination relative to known and presumed sources. Results from the 2006 survey are considered relative to those of the 1996 survey.

## MATERIALS AND METHODS

The summer 2006 survey of randomly selected sites off San Diego covered an area from Del Mar south to the United States/Mexico border (**Figure 8.1**). This survey revisited the sites selected for the 1996 regional survey, which was based on the USEPA probability-based EMAP sampling design. Site selection involved a hexagonal grid that was randomly placed over a map of the region. One sample site was then randomly selected from within each grid cell. This randomization helps to ensure an unbiased estimate of ecological condition. The area sampled included the section of the mainland shelf from nearshore to shallow slope

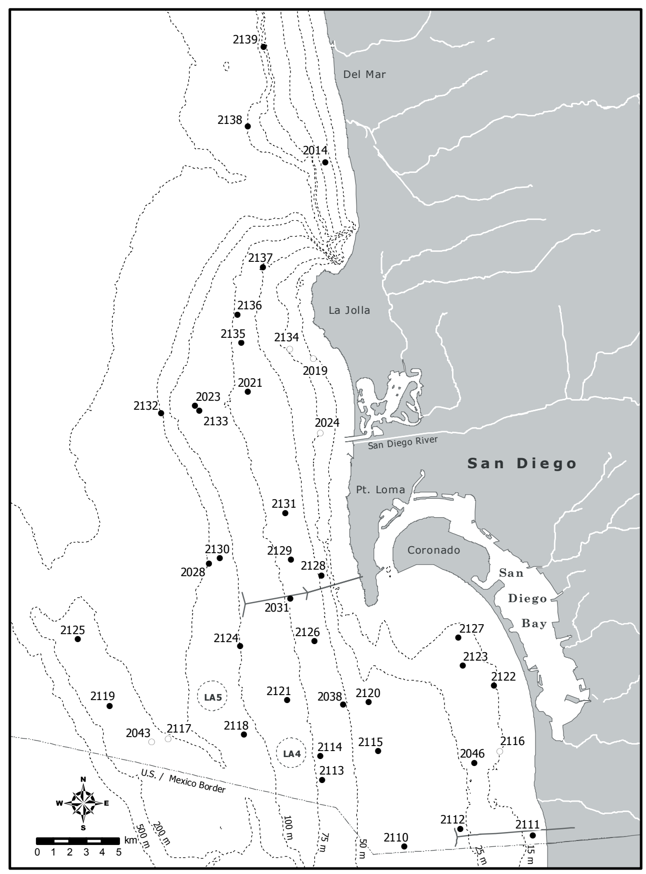


**Figure 8.1**
Randomly selected regional sediment quality stations sampled off San Diego, CA (August, 2006). Open circles represent abandoned stations (see text).

## Table 8.1

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: $D(phi) = -3.3219\log_{10}D(mm)$

depths (12–202 m). Although 40 sites were initially selected for the 1996 and 2006 surveys, sampling at 7 sites in 1996 and 6 sites in 2006 was unsuccessful due to the presence of a rocky reefs. In addition, 7 sites (2014, 2021, 2023, 2028, 2031, 2038, 2046) were sampled in 1995, 1996, 1997, 2005, and 2006.

Each sample was collected from one-half of a chain-rigged 0.1 $m^2$ double Van Veen grab; the other grab sample was used for macrofaunal community analysis (see Chapter 9). Sub-samples were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (USEPA 1987). All sediment analyses were performed at the City of San Diego Wastewater Chemistry Laboratory. Particle size analyses were performed using a Horiba LA-920 laser analyzer, which measures particles ranging in size from 0.00049–2.0 mm (i.e., -1 to 11 phi ). Coarse sediments (e.g., gravel, pebble, shell hash) were removed from each sample prior to analysis by screening the samples through a 2.0 mm mesh sieve. The retained material was weighed and expressed as the percent coarse of the total sample sieved. Sand was defined as particles ranging from ≥0.0625 to 2.0 mm, silt as particles from <0.0625 to 0.0039 mm, and clay as particles <0.0039 mm (**Table 8.1**). All of these data were standardized to obtain a distribution of coarse, sand, silt, and clay totaling 100%. The clay and silt fractions were then combined to yield the percent fines. Sediment particle size parameters were summarized according to calculations based on a normal probability scale with the sieved coarse fraction included with the >2 mm fraction (see Folk 1968). The calculated parameters include median and mean particle size in millimeters and phi, sorting coefficient (standard deviation), skewness, kurtosis and percent sediment type (i.e., coarse particles, 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

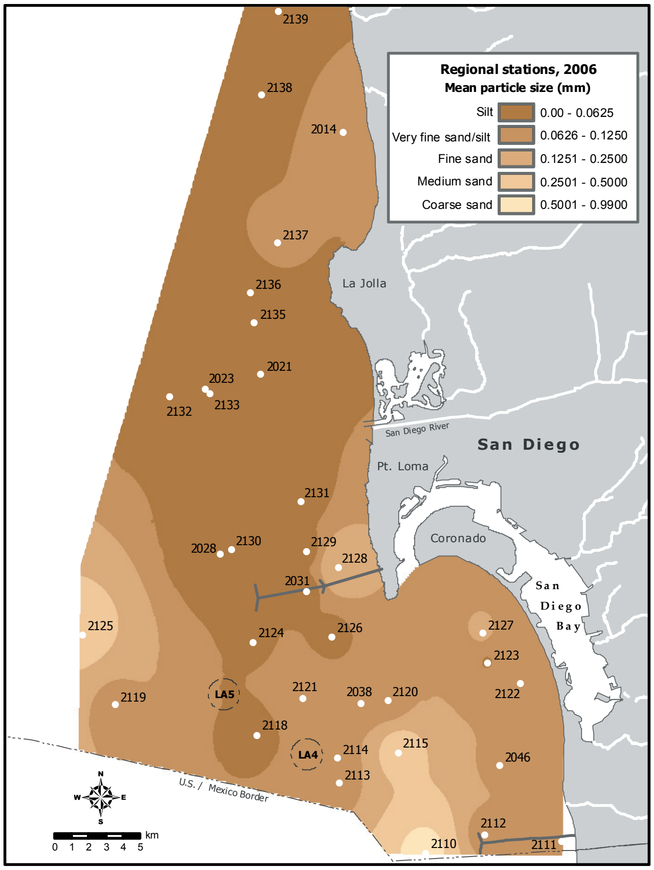


**Figure 8.2**
Mean particle size distribution for regional sediment quality stations sampled off San Diego, CA (August, 2006).

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 in the sample 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. The data are summarized by depth strata used in the Bight’98 and Bight’03 regional surveys of the entire Southern California Bight (SCB) including shallow shelf (5–30 m), mid-shelf (30–120 m), and deep shelf (120–200 m).

Cumulative distribution functions (CDFs) for TOC, TN, trace metals, and pesticides (i.e., DDT) were established previously for the SCB using data from the SCBPP (see Schiff and Gossett 1998). These reference values are presented as the median (50%) CDF in the tables included herein, allowing for comparison of the San Diego region relative to the entire SCB. Levels of contamination were also evaluated relative to several previously established sediment quality guidelines. These guidelines include the Effects Range-Low (ERL) and Effects Range-Medium (ERM) sensu Long et al. (1995), and the Threshold Effects Level (TEL) and Probable Effects Level (PEL) sensu MacDonald (1994).

## RESULTS AND DISCUSSION

### Particle Size Analysis

With few exceptions, the overall composition of sediments off San Diego in 2006 consisted of fine sands and silts (**Figure 8.2, Table 8.2**). The general distribution of sediment particles was similar to that of the previous years: higher sand content in shallow nearshore areas, decreasing to a mixture of mostly coarse silt and very fine sand at the mid-shelf region and deeper offshore sites (see City of San Diego 1998, 2000–2003, 2006a, b). Overall, the sediments reflect the diverse and patchy habitats common to the Southern California Bight (SCB). Stations of the mid-shelf strata (30–120 m) represented most of the shelf region off San Diego (n=21). These sites were composed primarily of fine sands with mean particle size of 0.105 mm composed of about 63% sands and 36% fines. By comparison, only 6 sites occurred within the shallow shelf strata at depths ≤30 m, which were slightly more coarse than the mid-shelf strata. Mean particle size at these sites was approximately 0.101 mm, and averaged around 81% sands and 19% fines. Seven deep water sites (120–200 m) contained sediments of 0.090 mm average particle size, including about 57% sand and 41% fines. Coarse sediments (mean >0.5 mm) occurred in shallow waters offshore of the SBOO (station 2110), and included relict sediments typical of the area offshore of the Tijuana River (see **Appendix F.1**). Station 2125 along the Coronado Bank, a southern rocky ridge located offshore of Point Loma at a depth of 150–170 m, was composed of more coarse particles (mean ≥0.3 mm) relative to surrounding sites. Additionally, several areas along the mid-

## Table 8.2

Summary of particle size and sediment chemistry parameters for the 2006 regional survey stations. CDF=median cumulative distribution functions (see text); nd=not detected. Bolded values exceed the median CDF. Means=mean of detected values. Area Mean=mean across all stations.

| Station | Depth | Mean | Fines | Sand | Sulfides | TN | TOC | HCB | tDDT | tPCB | tPAH | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (m) | (mm) | (%) | (%) | (ppm) | (%) | (%) | (ppb) | (ppb) | (ppb) | (ppt) | No. |
| *Shallow shelf* | | | | | | | | | | | | |
| 2111 | 12 | 0.093 | 23.4 | 76.6 | 33.80 | 0.027 | 0.273 | nd | nd | 440 | 74.7 | 6 |
| 2122 | 16 | 0.096 | 18.0 | 81.9 | 26.20 | 0.023 | 0.196 | nd | nd | nd | 43.4 | 3 |
| 2127 | 16 | 0.130 | 8.4 | 91.6 | 22.20 | 0.023 | 0.266 | nd | nd | nd | 70.6 | 5 |
| 2123 | 19 | 0.062 | 40.8 | 59.2 | 10.20 | 0.041 | 0.395 | nd | 310 | nd | 65.2 | 4 |
| 2046 | 22 | 0.118 | 8.4 | 91.5 | 0.35 | 0.018 | 0.152 | nd | nd | nd | 30.3 | 3 |
| 2112 | 26 | 0.107 | 12.8 | 87.2 | 0.81 | 0.022 | 0.200 | nd | nd | nd | 57.2 | 5 |
| **Mean** | 19 | 0.101 | 18.6 | 81.3 | 15.59 | 0.026 | 0.247 | — | 310 | 440 | 56.9 | 4 |
| *Mid-shelf* | | | | | | | | | | | | |
| 2128 | 37 | 0.203 | 12.1 | 87.9 | 19.50 | 0.026 | 0.580 | nd | nd | nd | 162.1 | 8 |
| 2014 | 38 | 0.083 | 26.4 | 73.6 | 2.58 | 0.047 | 0.460 | nd | 560 | nd | 169.8 | 9 |
| 2120 | 39 | 0.081 | 26.2 | 73.8 | 1.54 | 0.045 | 0.715 | 550 | nd | nd | 64.9 | 5 |
| 2110 | 40 | 0.546 | 0.0 | 92.7 | 0.00 | 0.000 | 0.054 | nd | nd | nd | 49.6 | 4 |
| 2115 | 42 | 0.301 | 4.9 | 94.9 | 0.00 | 0.014 | 0.120 | 140 | nd | nd | 40.0 | 4 |
| 2137 | 48 | 0.068 | 35.0 | 65.0 | 0.24 | **0.057** | **3.150** | nd | nd | nd | 144.8 | 8 |
| 2038 | 52 | 0.064 | 33.5 | 66.4 | 0.86 | **0.055** | 0.630 | nd | 720 | nd | 39.1 | 3 |
| 2126 | 62 | 0.053 | 42.9 | 57.1 | 10.60 | **0.073** | **0.853** | nd | 690 | 1990 | 183.2 | 11 |
| 2131 | 63 | 0.046 | 50.3 | 49.7 | 0.57 | **0.075** | **0.838** | nd | nd | nd | 273.1 | 13 |
| 2135 | 66 | 0.043 | 54.3 | 45.7 | 1.08 | **0.087** | **1.040** | nd | 550 | **8440** | 170.3 | 10 |
| 2021 | 67 | 0.049 | 46.2 | 53.8 | 0.81 | **0.068** | **0.838** | nd | nd | nd | 208.2 | 12 |
| 2129 | 67 | 0.047 | 48.5 | 51.5 | 1.42 | **0.070** | **0.755** | nd | 580 | nd | 198.1 | 12 |
| 2114 | 68 | 0.089 | 25.0 | 75.0 | 2.12 | 0.048 | 0.636 | nd | 490 | nd | 91.6 | 7 |
| 2113 | 69 | 0.109 | 18.9 | 81.1 | 1.26 | 0.033 | 0.361 | nd | nd | nd | 98.7 | 8 |
| 2136 | 69 | 0.047 | 48.1 | 51.9 | 0.62 | **0.074** | **0.855** | nd | 350 | nd | 169.3 | 7 |
| 2031 | 74 | 0.048 | 49.0 | 51.0 | 2.75 | **0.082** | **0.909** | nd | 760 | nd | 233.9 | 11 |
| 2139 | 77 | 0.054 | 41.4 | 58.6 | 0.93 | 0.044 | 0.531 | 390 | 440 | nd | 110.2 | 7 |
| 2121 | 83 | 0.114 | 64.2 | 27.6 | 6.92 | **0.070** | **0.973** | nd | 750 | 1300 | 221.8 | 12 |
| 2133 | 89 | 0.048 | 48.1 | 51.9 | 0.53 | **0.074** | **1.690** | nd | 550 | nd | 227.0 | 13 |
| 2023 | 90 | 0.053 | 44.4 | 54.1 | 0.17 | **0.068** | **1.600** | nd | nd | nd | 153.4 | 10 |
| 2124 | 100 | 0.058 | 37.0 | 63.0 | 0.83 | **0.052** | **1.060** | 540 | nd | nd | 115.7 | 7 |
| **Mean** | 64 | 0.105 | 36.0 | 63.2 | 2.63 | 0.055 | 0.888 | 405 | 585 | 3910 | 148.8 | 9 |
| *Deep shelf* | | | | | | | | | | | | |
| 2118 | 123 | 0.048 | 44.0 | 56.0 | 2.47 | **0.071** | **0.967** | 220 | nd | 1240 | 344.3 | 15 |
| 2119 | 145 | 0.116 | 20.6 | 79.4 | 1.19 | **0.072** | **4.840** | nd | nd | nd | 162.8 | 12 |
| 2130 | 147 | 0.042 | 51.1 | 48.9 | 1.12 | **0.088** | **1.080** | nd | nd | nd | 217.2 | 12 |
| 2125 | 157 | 0.300 | 14.6 | 72.5 | 0.27 | **0.053** | **4.320** | nd | nd | nd | 119.4 | 9 |
| 2138 | 190 | 0.038 | 56.2 | 43.8 | 1.91 | **0.125** | **1.720** | nd | 550 | nd | 219.3 | 9 |
| 2028 | 190 | 0.036 | 63.2 | 36.8 | 3.55 | **0.090** | **1.180** | nd | 690 | nd | 195.4 | 9 |
| 2132 | 197 | 0.053 | 40.1 | 59.9 | 1.06 | **0.086** | **2.230** | nd | 490 | nd | 131.7 | 8 |
| **Mean** | 164 | 0.090 | 41.4 | 56.8 | 1.65 | 0.084 | 2.334 | 220 | 577 | 1240 | 198.6 | 11 |
| **Area Mean** | 76 | 0.101 | 34.1 | 65.0 | 4.72 | 0.056 | 1.073 | 368 | 565 | 2685 | 142.8 | 8 |
| **50% CDF** | | | | | na | 0.051 | 0.748 | na | 1200 | 2600 | na | na |

and deep-shelf strata included gravel or coarse black sands. These include one site east of the LA-5 dredge spoils disposal site (station 2121); one site between LA-5 and the PLOO (2124), several sites north of Point Loma (stations 2023, 2132, 2133, 2135, 2139); and 2 sites along the Coronado Bank (2119, 2125). The patchy nature of sediments in these areas has been well documented during previous surveys (see San Diego 1998, 2000–2003, 2006b).

Sediment composition at the shallow water sites in this survey was generally similar to that observed at the 19 and 28-m stations included in the regular semi-annual grid sampling surrounding the SBOO (see Chapter 4). In contrast, deeper grid stations (38 and 55-m) had sediments composed of more sand and less fine materials than comparable mid-shelf samples. This difference may relate to the greater number of grid stations located off-shore and in the southern portion of the South Bay surrounding the U.S.-Mexico border where relict sands are more common.

Generally, sediment particle size composition along the San Diego shelf in 2006 was little different than at the same sites sampled in 1996 (**Appendix F.2**). Only 5 of the 34 stations sampled in 2006 were different by more than 0.05 mm (mean particle size) from the 1996 samples. The mean particle size increased at 2 sites (2110, 2121), while 3 others (2115, 2119, 2137) decreased. Generally, however, sediment composition at the replicate stations sampled over time was remarkably consistent (**Table 8.3**).

### Organic Indicators

Concentrations of TOC and TN tended to increase with depth and with increased amounts of fines (Table 8.2). For example, mean TOC values were 0.25% at the shallow water stations, but increased to 0.89% at the mid-shelf stations, and 2.33% at the deep shelf sites. The highest values were collected at sites along the Coronado Bank and northward. Sediments at stations 2119 and 2125 along the Coronodo Bank had concentrations of TOC above 4%, while other stations with high TOC concentrations (>1%) occurred from just south of the PLOO (i.e., station 2124) and from Point Loma northward (i.e., stations 2023, 2028, 2130, 2132, 2133, 2135, 2137, 2138). Stations along the Coronado Bank have consistently had high concentrations of organics despite the coarse sediments and low percentages of fines relative to the other deep shelf stations (see City of San Diego 2006b). In contrast, the highest average for sulfides, and the lowest averages for TN and TOC occurred among the shallow-shelf strata stations. Additionally, the shallowest station among the mid-shelf strata (2128) had a high sulfide concentration and relatively lower TN and TOC values.

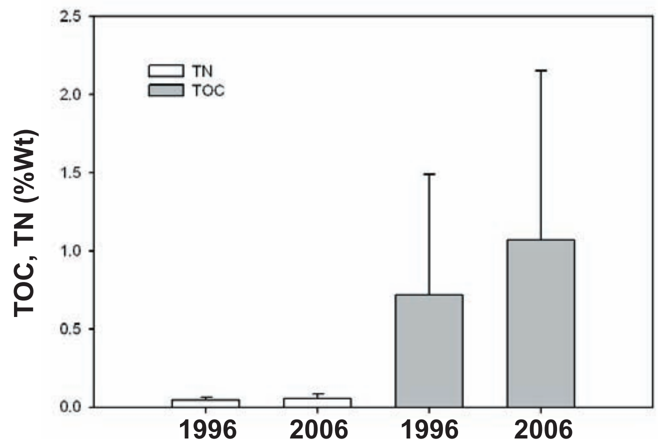


**Figure 8.3**
Mean concentrations of TOC and TN for the regional sediment quality stations sampled in 1996 vs 2006.

In general, average concentrations of TOC and TN in sediment samples collected during 2006 appeared slightly higher than in 1996 (**Figure 8.3**). For example, in 2006 approximately 56% of the stations had TOC values that exceeded median CDF levels, compared to 33% in 1996. Similarly, 59% of the TN samples exceeded the median in 2006 relative to 39% in 1996. This change seems to be region-wide and persistent, as most of the 7 repeat stations have increased in TOC and TN concentrations through time (Table 8.3). Episodic events such as storm runoff containing terrestrial detritus and plankton blooms have been considered the primary contributors to increased organic

## Table 8.3

Summary of mean particle size (PS=mm) and organic indicators for repeat regional sediment quality stations. TN and TOC=total nitrogen and total organic carbon, expressed as percent weight (wt %); Sulfides=ppm; STD=standard deviation. Bolded values exceed the median CDF (see Table 8.2).

| Station | Year | PS | Fines | Sulfides | TN | TOC |
|---|---|---|---|---|---|---|
| 2046 | 1995 | 0.109 | 10.8 | 1.5 | 0.000 | 0.092 |
| (22 m) | 1996 | 0.117 | 8.7 | 2.3 | 0.016 | 0.109 |
| | 1997 | 0.134 | 6.6 | 4.5 | 0.015 | 0.128 |
| | 2005 | 0.122 | 9.8 | 0.2 | 0.012 | 0.142 |
| | 2006 | 0.118 | 8.4 | 0.3 | 0.018 | 0.152 |
| | Mean | 0.120 | 8.9 | 1.8 | 0.012 | 0.125 |
| | STD | 0.009 | 1.6 | 1.8 | 0.007 | 0.024 |
| 2014 | 1995 | 0.088 | 23.0 | 2.1 | 0.015 | 0.328 |
| (38 m) | 1996 | 0.095 | 20.8 | 26.2 | 0.037 | 0.336 |
| | 1997 | 0.082 | 13.5 | 80.5 | 0.040 | 0.365 |
| | 2005 | 0.079 | 28.8 | 2.0 | 0.046 | 0.494 |
| | 2006 | 0.083 | 26.4 | 2.6 | 0.047 | 0.460 |
| | Mean | 0.085 | 22.5 | 22.7 | 0.037 | 0.397 |
| | STD | 0.006 | 5.9 | 34.0 | 0.013 | 0.076 |
| 2038 | 1995 | 0.051 | 43.1 | 3.1 | 0.042 | 0.601 |
| (52 m) | 1996 | 0.051 | 45.0 | 2.4 | **0.064** | 0.532 |
| | 1997 | 0.058 | 39.0 | 5.8 | **0.055** | 0.583 |
| | 2005 | 0.055 | 40.0 | 0.7 | **0.056** | 0.617 |
| | 2006 | 0.064 | 33.5 | 0.9 | **0.055** | 0.630 |
| | Mean | 0.056 | 40.1 | 2.6 | 0.054 | 0.593 |
| | STD | 0.005 | 4.4 | 2.1 | 0.008 | 0.038 |
| 2021 | 1995 | 0.041 | 52.4 | 2.6 | 0.045 | 0.640 |
| (67 m) | 1996 | 0.044 | 50.4 | 1.3 | **0.057** | 0.642 |
| | 1997 | 0.047 | 46.8 | 12.1 | **0.076** | 0.716 |
| | 2005 | 0.051 | 44.9 | 2.8 | **0.072** | **1.050** |
| | 2006 | 0.049 | 46.2 | 0.8 | **0.068** | **0.838** |
| | Mean | 0.046 | 48.1 | 3.9 | 0.064 | 0.777 |
| | STD | 0.004 | 3.1 | 4.6 | 0.013 | 0.172 |
| 2031 | 1995 | 0.102 | 35.5 | 3.5 | 0.048 | 0.665 |
| (74 m) | 1996 | 0.044 | 50.4 | 3.3 | **0.065** | **0.749** |
| | 1997 | 0.047 | 49.9 | 2.7 | **0.073** | 0.697 |
| | 2005 | 0.048 | 49.0 | 6.4 | **0.079** | **0.850** |
| | 2006 | 0.048 | 49.0 | 2.8 | **0.082** | **0.909** |
| | Mean | 0.058 | 46.8 | 3.7 | 0.069 | 0.774 |
| | STD | 0.025 | 6.3 | 1.5 | 0.014 | 0.103 |
| 2023 | 1995 | 0.038 | 54.7 | 1.3 | 0.031 | 0.660 |
| (90 m) | 1996 | 0.063 | 43.0 | 1.7 | **0.051** | **1.000** |
| | 1997 | 0.044 | 51.3 | 7.7 | **0.076** | 0.691 |
| | 2005 | 0.210 | 33.7 | 1.0 | **0.081** | **1.250** |
| | 2006 | 0.053 | 44.4 | 0.2 | **0.068** | **1.600** |
| | Mean | 0.082 | 45.4 | 2.4 | 0.061 | 1.040 |
| | STD | 0.072 | 8.1 | 3.0 | 0.020 | 0.395 |
| 2028 | 1995 | 0.029 | 69.8 | 4.3 | **0.055** | **1.070** |
| (190 m) | 1996 | 0.031 | 67.1 | 3.4 | **0.086** | **1.200** |
| | 1997 | 0.033 | 65.5 | 7.9 | **0.122** | **1.170** |
| | 2005 | 0.037 | 61.4 | 8.1 | **0.121** | **1.660** |
| | 2006 | 0.036 | 63.2 | 1.9 | **0.125** | **1.720** |
| | Mean | 0.033 | 65.4 | 5.1 | 0.102 | 1.364 |
| | STD | 0.003 | 3.3 | 2.8 | 0.031 | 0.302 |

content along the shelf (see City of San Diego 2006a, b). Periodic increases in sulfides seem to be restricted to nearshore waters where anoxic conditions following burial of organic materials from storm runoff such as plant debris and decaying plankton are likely factors (Gray 1981). Finally, comparisons between the semi-annual grid and regional stations were inconsistent in terms of concentrations of the various organic indicators (see Chapter 4). The 2006 regional shallow-shelf samples were higher than the 19- and 28-m grid stations for sulfides and TN (15.6 vs. 4.9 ppm, 0.03 vs. 0.02%, respectively), but lower for TOC (0.25 vs. 0.40%). In contrast, sulfides concentrations were similar between the regional mid-shelf strata and the 38- and 55-m grid stations (2.2 vs 2.6 ppm), but much higher for TOC (0.88 vs. 0.26%) and TN (0.05 vs. 0.02%).

## Trace Metals

Fourteen trace metals (i.e., aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc) were detected in sediments from at least 70% of the 34 survey stations in 2006 (**Table 8.4**). Three metals (silver, selenium, thallium) were detected at 20% or fewer stations. Beryllium was not detected at all. Concentrations of several metals (aluminum, copper, iron, manganese, mercury, nickel, zinc) generally correlated with increasing percentage of fines ($R^2>0.6$, $p<0.05$) or appeared to be associated with nearby sources of anthropogenic inputs (e.g., ocean outfalls and dredge spoils disposal sites). Average concentrations for 11 metals in deep shelf sediments were higher than in either the shallow or mid-shelf strata. Sediments containing relatively higher concentrations of several metals such as aluminum, iron and manganese occurred primarily at mid-shelf and deep water sites: 2023, 2028, 2031, 2118, 2121, 2126, 2129, 2131, 2132, 2133, 2135, 2136, 2138. Station 2121, located inshore of the LA-5 disposal site, had the highest concentrations of 4 metals (i.e., antimony, lead, tin, and zinc), with the lead concentration of 331 ppm being well above the ERL (46.7 ppm). Overall, this is similar to the general distribution pattern of metals described previously for the SCB (Schiff and Gossett 1998) and other San Diego regional surveys (sees City of San Diego 1998, 2000–2003, 2006b).

Unlike organics, concentrations of trace metals in sediments were relatively similar between 1996 and 2006 (**Table 8.5**). Although there was little difference in sediment concentrations between these 2 years, the sediments at 13 stations sampled in 2006 had 3 or more metals whose concentrations exceeded the median CDF values, whereas only 6 did so in 1996. Aluminum and antimony were the most common trace metals exceeding median CDF values in 2006 with concentrations of each exceeding the median value at 20 stations. However, antimony was not detected in 1996; a result likely related to differences in instrumentation and method detection limits in use at the time. Mean concentrations of most metals were either equivalent or higher in the regional shallow- and mid-shelf strata when compared to the SBOO equivalents. For example, mean concentrations of 10 shallow-shelf and 12 mid-shelf strata metals were higher than the SBOO equivalent by 50% or more.

## Other Contaminants: Pesticides, PCBs and PAHs

PAHs occurred at every station in low concentrations during 2006, while pesticides and PCBs were rarely detected (Table 8.2). For example, the pesticides hexachlorobenzene (HCB) and total DDT (the sum of several metabolites) were detected at 5 and 15 sites, respectively. These occurrences were limited to the mid- and deep shelf stations, except for one instance of DDT at shallow-shelf station 2123. Neither substance had concentrations above 800 ppb, and DDT levels were well below the median CDF of 1200 ppb. PCBs were detected at 5 sites. Sediments at station 2135, a northern site located offshore of La Jolla, exceeded the median CDF for PCBs (2600 ppb) with 14 different PCB congeners present and a total concentration of 8440 ppb. Stations 2126, 2121, and 2118 are located towards the south between Point Loma and the LA-5 disposal site and contained from 3–5 PCB congeners each, although total PCB concentrations were below the CDF. PAHs were widely distributed, but at generally low concentrations (<350 ppt). Station 2118, located between the LA-4 and LA-5 dredge spoils disposal areas, had the highest number of PAH compounds (15) and highest total PAH concentration (344 ppt). Overall, pesticide, PCB and PAH contamination was most common and in highest concentrations among sites where the percentage of fines was over 20%. There appears to be some relationship between these contaminants and dredge waste disposal. Large plumes of sediment have been observed spreading across the Point Loma and South Bay regions during the disposal of dredged sediments (see Chapter 2). Consequently, the wide distribution of contaminants via sediment plumes makes it difficult to distinguish other potential sources such as the PLOO, SBOO, or river discharges.

## Table 8.4

Concentrations of trace metals (ppm) from regional sediment stations, August 2006. CDF=cumulative distribution function. ERL=effects range low threshold value. nd=not detected. na=not available. See Appendix A.1 for names and periodic table symbols.

| Station | Al | Sb | As | Ba | Cd | Cr | Cu | Fe | Pb |
|---|---|---|---|---|---|---|---|---|---|
| *Shallow shelf* | | | | | | | | | |
| 2111 | 11100 | 0.3 | 2.29 | 69.5 | 0.09 | 17.8 | 5.3 | 14300 | 24.4 |
| 2122 | 6430 | 0.2 | 1.63 | 27.1 | 0.09 | 10.5 | 2.2 | 6330 | 4.5 |
| 2127 | 5050 | nd | 2.23 | 17.2 | 0.05 | 7.8 | 1.4 | 5640 | 4.5 |
| 2123 | 11200 | nd | 2.20 | 48.8 | 0.13 | 16.0 | 5.6 | 11600 | 8.4 |
| 2046 | 5380 | 0.1 | 0.86 | 21.9 | 0.06 | 9.0 | 0.8 | 5750 | 4.1 |
| 2112 | 5870 | nd | 1.27 | 35.5 | 0.04 | 9.8 | 0.0 | 6140 | 3.9 |
| **Mean** | 7505 | 0.2 | 1.75 | 36.7 | 0.07 | 11.8 | 2.6 | 8293 | 8.3 |
| *Mid-shelf* | | | | | | | | | |
| 2128 | 3190 | 0.1 | 1.42 | 13.7 | 0.05 | 12.7 | 0.6 | 9940 | 4.2 |
| 2014 | 11500 | nd | 3.81 | 68.1 | 0.10 | 18.4 | 6.1 | 14600 | 9.0 |
| 2120 | 7700 | nd | 2.74 | 31.2 | 0.10 | 13.5 | 4.2 | 9880 | 7.6 |
| 2110 | 1400 | 0.1 | 7.10 | 2.6 | 0.06 | 10.7 | nd | 7020 | 2.6 |
| 2115 | 1990 | nd | 2.53 | 6.3 | 0.05 | 7.1 | nd | 4600 | 2.5 |
| 2137 | 7110 | nd | 3.41 | 35.6 | 0.12 | 17.6 | 3.5 | 15900 | 8.3 |
| 2038 | 9950 | 0.2 | 2.74 | 41.1 | 0.15 | 15.6 | 6.1 | 11100 | 9.2 |
| 2126 | 13300 | 0.4 | 3.30 | 61.6 | 0.21 | 20.8 | 9.1 | 15200 | 12.9 |
| 2131 | 13900 | 0.4 | 3.82 | 62.0 | 0.18 | 22.6 | 9.5 | 16300 | 13.6 |
| 2135 | 16000 | 0.4 | 3.22 | 68.2 | 0.16 | 25.6 | 9.8 | 19000 | 14.6 |
| 2021 | 11000 | nd | 3.62 | 46.2 | 0.11 | 19.0 | 7.1 | 11700 | 10.7 |
| 2129 | 15000 | 0.2 | 4.48 | 66.1 | 0.20 | 23.5 | 10.7 | 16900 | 14.4 |
| 2114 | 6160 | 0.1 | 2.02 | 19.8 | 0.10 | 10.6 | 3.5 | 7250 | 5.6 |
| 2113 | 4490 | nd | 1.42 | 13.1 | 0.05 | 8.3 | 1.8 | 5280 | 4.3 |
| 2136 | 13200 | 0.2 | 3.01 | 62.5 | 0.13 | 22.9 | 7.7 | 17100 | 12.4 |
| 2031 | 1500 | 0.4 | 3.81 | 68.6 | 0.19 | 23.5 | 10.8 | 17200 | 12.7 |
| 2139 | 10700 | 0.2 | 3.23 | 79.5 | 0.07 | 19.4 | 5.0 | 16500 | 9.1 |
| 2121 | 12500 | 0.7 | 3.42 | 52.4 | 0.20 | 20.2 | 12.4 | 14800 | 331.0 |
| 2133 | 12400 | 0.3 | 3.77 | 50.2 | 0.12 | 23.8 | 8.0 | 18800 | 11.7 |
| 2023 | 11300 | 0.3 | 4.61 | 74.2 | 0.09 | 26.5 | 6.3 | 22200 | 11.1 |
| 2124 | 10400 | 0.2 | 2.50 | 36.6 | 0.12 | 17.6 | 6.9 | 12800 | 10.7 |
| **Mean** | 9271 | 0.3 | 3.33 | 45.7 | 0.12 | 18.1 | 6.8 | 13527 | 24.7 |
| *Deep shelf* | | | | | | | | | |
| 2118 | 12100 | 0.3 | 3.84 | 44.4 | 0.12 | 20.1 | 14.3 | 14400 | 13.3 |
| 2119 | 6130 | 0.2 | 4.31 | 22.3 | 0.16 | 24.5 | 4.5 | 14600 | 6.2 |
| 2130 | 12200 | 0.2 | 3.61 | 46.7 | 0.19 | 22.2 | 9.4 | 15300 | 11.6 |
| 2125 | 5900 | 0.4 | 5.12 | 51.0 | 0.15 | 29.0 | 3.3 | 15600 | 5.3 |
| 2138 | 15800 | 0.3 | 3.45 | 63.9 | 0.50 | 26.7 | 10.3 | 18300 | 13.9 |
| 2028 | 17000 | 0.5 | 3.32 | 65.1 | 0.25 | 28.6 | 13.7 | 18600 | 15.3 |
| 2132 | 10700 | 0.4 | 3.52 | 34.4 | 0.45 | 29.9 | 7.6 | 20300 | 9.7 |
| **Mean** | 11404 | 0.3 | 3.88 | 46.8 | 0.26 | 25.9 | 9.0 | 16729 | 10.7 |
| **Area Mean** | 9399 | 0.3 | 3.17 | 44.3 | 0.14 | 18.6 | 6.5 | 13263 | 18.9 |
| **CDF** | 9400 | 0.2 | 4.80 | na | 0.29 | 34.0 | 12.0 | 16800 | na |
| **ERL** | na | na | 8.2 | na | 1.2 | 81.0 | 34 | na | 46.7 |

**Table 8.4** *continued.*

| Station | Mn | Hg | Ni | Se | Ag | Tl | Sn | Zn |
|---|---|---|---|---|---|---|---|---|
| *Shallow shelf* | | | | | | | | |
| 2111 | 129 | nd | 6.8 | nd | nd | nd | 1.13 | 25.0 |
| 2122 | 70 | nd | 3.4 | nd | nd | nd | 0.83 | 12.5 |
| 2127 | 60 | nd | 2.3 | nd | nd | nd | — | 11.1 |
| 2123 | 112 | 0.014 | 6.3 | nd | nd | nd | 1.24 | 23.8 |
| 2046 | 73 | nd | 2.2 | nd | nd | 0.24 | 0.46 | 5.7 |
| 2112 | 57 | nd | 3.3 | nd | nd | nd | 0.85 | 11.4 |
| **Mean** | 83 | 0.014 | 4.0 | — | — | 0.24 | 0.90 | 14.9 |
| *Mid-shelf* | | | | | | | | |
| 2128 | 69 | nd | 2.2 | 0.36 | nd | nd | 0.51 | 7.5 |
| 2014 | 144 | nd | 6.7 | nd | nd | 0.35 | 0.47 | 22.9 |
| 2120 | 85 | 0.013 | 4.8 | nd | nd | nd | 1.22 | 17.9 |
| 2110 | 20 | nd | 0.9 | nd | nd | nd | 0.69 | 5.7 |
| 2115 | 19 | nd | 1.5 | nd | nd | nd | 1.24 | 5.8 |
| 2137 | 90 | 0.003 | 5.2 | nd | nd | nd | 0.78 | 16.9 |
| 2038 | 94 | 0.02 | 7.0 | nd | nd | nd | 1.36 | 20.6 |
| 2126 | 147 | 0.031 | 9.6 | 0.66 | nd | nd | 1.20 | 26.2 |
| 2131 | 142 | 0.05 | 10.0 | nd | nd | 0.19 | 1.12 | 25.2 |
| 2135 | 164 | 0.038 | 10.5 | nd | nd | nd | 1.06 | 26.5 |
| 2021 | 114 | 0.024 | 7.9 | nd | nd | nd | 1.02 | 18.6 |
| 2129 | 149 | 0.048 | 10.8 | nd | nd | nd | 1.40 | 28.9 |
| 2114 | 60 | 0.008 | 5.2 | nd | nd | nd | 1.15 | 12.8 |
| 2113 | 48 | nd | 3.5 | nd | 0.02 | 0.24 | 1.12 | 9.0 |
| 2136 | 139 | 0.02 | 8.9 | nd | nd | nd | 0.95 | 21.5 |
| 2031 | 151 | 0.05 | 10.8 | nd | nd | nd | 1.71 | 33.1 |
| 2139 | 119 | 0.008 | 6.7 | nd | nd | nd | 0.10 | 21.0 |
| 2121 | 116 | 0.05 | 9.0 | nd | nd | nd | 8.99 | 40.6 |
| 2133 | 126 | 0.022 | 9.9 | nd | nd | nd | 0.99 | 21.5 |
| 2023 | 135 | 0.018 | 9.0 | nd | nd | nd | 0.68 | 24.0 |
| 2124 | 95 | 0.022 | 7.5 | nd | nd | nd | 0.77 | 20.2 |
| **Mean** | 106 | 0.027 | 7.0 | 0.51 | 0.024 | 0.26 | 1.36 | 20.3 |
| *Deep shelf* | | | | | | | | |
| 2118 | 111 | 0.074 | 9.8 | 0.32 | nd | nd | 1.22 | 25.9 |
| 2119 | 42 | 0.006 | 7.3 | 0.29 | nd | nd | 0.32 | 14.3 |
| 2130 | 115 | 0.035 | 11.3 | nd | nd | nd | 0.79 | 21.9 |
| 2125 | 33 | 0.004 | 6.3 | nd | nd | nd | 0.18 | 14.7 |
| 2138 | 145 | 0.031 | 12.0 | 0.32 | nd | nd | 0.91 | 24.2 |
| 2028 | 150 | 0.047 | 16.0 | 0.36 | nd | nd | 0.48 | 29.5 |
| 2132 | 92 | 0.021 | 10.0 | 0.29 | nd | nd | 0.80 | 22.8 |
| **Mean** | 98 | 0.031 | 10.4 | 0.31 | — | — | 0.67 | 21.9 |
| **Area Mean** | 100 | 0.027 | 7.2 | 0.37 | 0.02 | 0.25 | 1.14 | 19.7 |
| **CDF** | na | 0.040 | na | 0.29 | 0.17 | na | na | 56.0 |
| **ERL** | na | 0.15 | 20.9 | na | 1.0 | na | na | 150 |

## Table 8.5

Summary of mean trace metals concentrations (ppm) for 7 repeat regional survey stations. See Appendix A.1 for names and periodic table symbols.

| Station | Year | Al | Sb | As | Be | Cr | Cu | Fe | Pb | Mn | Hg | Ni | Se | Sn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2046 | 1995 | 6050 | 0.0 | 1.65 | 0.00 | 9.7 | 0.0 | 6460 | 0.00 | — | 0.000 | 0.00 | 0.00 | — | 12.90 |
| (22 m) | 1996 | 4480 | 0.0 | 1.75 | 0.00 | 8.2 | 2.5 | 5040 | 0.00 | 49 | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1997 | 5220 | 0.0 | 1.58 | 0.00 | 9.6 | 2.1 | 4910 | 0.00 | 54 | 0.000 | 0.00 | 0.00 | 0.00 | 10.80 |
| | 2005 | 10000 | 0.0 | 1.48 | 0.00 | 14.9 | 2.4 | 13300 | 0.00 | 350 | 0.000 | 3.37 | 0.00 | 0.00 | 25.50 |
| | 2006 | 5380 | 0.1 | 0.86 | 0.00 | 9.0 | 0.8 | 5750 | 4.13 | 73 | 0.000 | 2.18 | 0.00 | 0.46 | 5.65 |
| | Mean | 6226 | 0.0 | 1.46 | 0.00 | 10.3 | 1.6 | 7092 | 0.83 | 131 | 0.000 | 1.11 | 0.00 | 0.11 | 10.97 |
| | Std | 2182 | 0.1 | 0.35 | 0.00 | 2.7 | 1.1 | 3525 | 1.85 | 146 | 0.000 | 1.58 | 0.00 | 0.23 | 9.53 |
| 2014 | 1995 | 10600 | 0.0 | 3.38 | 0.22 | 14.3 | 7.5 | 14800 | 0.00 | — | 0.000 | 7.30 | 0.00 | — | 32.80 |
| (38 m) | 1996 | 7630 | 0.0 | 3.29 | 0.00 | 13.5 | 5.5 | 9820 | 0.00 | 96 | 0.000 | 6.20 | 0.00 | 0.00 | 27.10 |
| | 1997 | 10900 | 0.0 | 4.48 | 2.75 | 16.9 | 8.0 | 11500 | 0.00 | 118 | 0.000 | 9.60 | 0.00 | 0.00 | 33.30 |
| | 2005 | 19200 | 0.0 | 3.94 | 0.36 | 24.7 | 8.0 | 19400 | 6.93 | 313 | 0.000 | 7.91 | 0.00 | 0.00 | 46.30 |
| | 2006 | 11500 | 0.0 | 3.81 | 0.00 | 18.4 | 6.1 | 14600 | 9.02 | 144 | 0.000 | 6.72 | 0.00 | 0.47 | 22.90 |
| | Mean | 11966 | 0.0 | 3.78 | 0.67 | 17.6 | 7.0 | 14024 | 3.19 | 168 | 0.000 | 7.55 | 0.00 | 0.12 | 32.48 |
| | Std | 4246 | 0.0 | 0.43 | 1.15 | 4.1 | 1.1 | 3645 | 4.07 | 86 | 0.000 | 1.31 | 0.00 | 0.20 | 8.84 |
| 2038 | 1995 | 10700 | 0.0 | 3.31 | 0.20 | 20.1 | 8.9 | 13700 | 6.40 | — | 0.000 | 10.30 | 0.00 | — | 29.80 |
| (52 m) | 1996 | 9960 | 0.0 | 4.19 | 0.23 | 16.6 | 8.3 | 11700 | 0.00 | 92 | 0.095 | 8.50 | 0.00 | 0.00 | 29.50 |
| | 1997 | 10900 | 0.0 | 2.38 | 0.25 | 16.3 | 8.0 | 11000 | 0.00 | 89 | 0.000 | 11.10 | 0.35 | 0.00 | 29.00 |
| | 2005 | 17400 | 0.0 | 3.59 | 0.30 | 22.3 | 8.9 | 18400 | 7.03 | 263 | 0.000 | 9.41 | 0.00 | 0.00 | 39.30 |
| | 2006 | 9950 | 0.2 | 2.74 | 0.00 | 15.6 | 6.1 | 11100 | 9.20 | 94 | 0.020 | 6.98 | 0.00 | 1.36 | 20.60 |
| | Mean | 11782 | 0.0 | 3.24 | 0.20 | 18.2 | 8.0 | 13180 | 4.53 | 134 | 0.023 | 9.26 | 0.07 | 0.34 | 29.64 |
| | Std | 3170 | 0.1 | 0.71 | 0.12 | 2.9 | 1.1 | 3114 | 4.26 | 86 | 0.041 | 1.60 | 0.15 | 0.68 | 6.62 |

## SUMMARY AND CONCLUSIONS

Although the presence of canyons, peninsulas, bays, and alluvial fans from rivers contribute to the complexity of sediment composition and origin along the San Diego shelf (see Emery 1960), the distribution of sediment particles off San Diego in 2006 was similar to that of previous years and to the Southern California Bight (SCB) in general. There was a trend towards higher sand content in shallow nearshore areas and increased fine sand and silt at the deeper offshore sites. Exceptions to the general pattern occurred in shallow waters offshore of the SBOO, and along the Coronado Bank, a southern rocky ridge located offshore of Point Loma at a depth of 150–170 m. Additionally, several mid-shelf areas contained coarse sediments (black sands or gravel) relative to most mid-shelf stations. These included an area near the EPA-designated disposal sites (LA-4 and LA-5), an area surrounding the Point Loma Ocean Outfall (PLOO) discharge site, and patches of coarse sediments northward of the San Diego River and towards La Jolla Canyon. The patchy nature of sediments in these areas has been well documented during previous surveys (see City of San Diego 1998, 2000–2003, 2006a, b).

There has been little change in sediment composition or average particle size since 1996 when these sites were first sampled. Only 5 of the 34 sites changed in mean particle size between the 1996 and 2006 surveys. Moreover, the 7 repeat stations sampled in 1995–1997 and 2005–2006 maintained remarkably consistent sediment composition.

Patterns in sediment chemistries followed the expected relationship of increasing concentrations with decreasing particle size (see Emery 1960,

**Table 8.5** *continued*

| Station | Year | Al | Sb | As | Be | Cr | Cu | Fe | Pb | Mn | Hg | Ni | Se | Sn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | 1995 | 12600 | 0.0 | 4.87 | 0.25 | 16.8 | 7.1 | 15900 | 0.00 | — | 0.000 | 9.70 | 0.24 | — | 32.90 |
| (67 m) | 1996 | 10200 | 0.0 | 4.73 | 0.22 | 19.8 | 8.9 | 13600 | 0.00 | 106 | 0.074 | 9.10 | 0.26 | 13.00 | 30.50 |
| | 1997 | 14300 | 0.0 | 4.76 | 0.28 | 21.8 | 10.9 | 14100 | 0.00 | 113 | 0.000 | 10.60 | 0.28 | 0.00 | 34.20 |
| | 2005 | 18000 | 0.0 | 3.38 | 0.35 | 24.5 | 9.2 | 19500 | 8.12 | 290 | 0.000 | 9.32 | 0.00 | 0.00 | 44.90 |
| | 2006 | 11000 | 0.0 | 3.62 | 0.00 | 19.0 | 7.1 | 11700 | 10.70 | 114 | 0.024 | 7.85 | 0.00 | 1.02 | 18.60 |
| | Mean | 13220 | 0.0 | 4.27 | 0.22 | 20.4 | 8.6 | 14960 | 3.76 | 156 | 0.020 | 9.31 | 0.16 | 3.51 | 32.22 |
| | Std | 3082 | 0.0 | 0.63 | 0.13 | 2.2 | 1.4 | 2901 | 4.81 | 78 | 0.030 | 0.98 | 0.14 | 5.50 | 9.40 |
| 2031 | 1995 | 15100 | 0.0 | 4.03 | 0.00 | 24.6 | 13.3 | 18800 | 7.80 | — | 0.000 | 11.00 | 0.00 | — | 43.10 |
| (74 m) | 1996 | 12900 | 0.0 | 5.64 | 0.00 | 20.2 | 9.8 | 14400 | 5.70 | 123 | 0.096 | 11.00 | 0.00 | 0.00 | 40.20 |
| | 1997 | 18900 | 0.0 | 4.80 | 1.54 | 26.3 | 12.7 | 16300 | 0.00 | 149 | 0.000 | 14.20 | 0.26 | 0.00 | 44.00 |
| | 2005 | 24300 | 0.0 | 4.23 | 0.40 | 30.5 | 11.9 | 22700 | 11.60 | 336 | 0.048 | 12.40 | 0.00 | 0.00 | 54.20 |
| | 2006 | 1500 | 0.4 | 3.81 | 0.00 | 23.5 | 10.8 | 17200 | 12.70 | 151 | 0.050 | 10.80 | 0.00 | 1.71 | 33.10 |
| | Mean | 14540 | 0.1 | 4.50 | 0.39 | 25.0 | 11.7 | 17880 | 7.56 | 190 | 0.039 | 11.88 | 0.05 | 0.43 | 42.92 |
| | Std | 8475 | 0.2 | 0.73 | 0.67 | 3.8 | 1.4 | 3128 | 5.08 | 98 | 0.040 | 1.45 | 0.12 | 0.86 | 7.62 |
| 2023 | 1995 | 15800 | 0.0 | 6.73 | 0.47 | 35.5 | 11.4 | 32200 | 0.00 | — | 0.000 | 11.00 | 0.29 | — | 45.30 |
| (90 m) | 1996 | 10400 | 15.2 | 3.99 | 0.33 | 28.6 | 8.8 | 23600 | 0.00 | 126 | 0.065 | 10.60 | 0.26 | 15.00 | 38.70 |
| | 1997 | 14600 | 0.0 | 5.53 | 0.32 | 30.3 | 11.0 | 22500 | 0.00 | 130 | 0.000 | 10.10 | 0.34 | 0.00 | 45.10 |
| | 2005 | 20900 | 0.0 | 7.69 | 0.69 | 39.4 | 10.9 | 37700 | 9.66 | 258 | 0.000 | 12.20 | 0.00 | 0.00 | 61.30 |
| | 2006 | 11300 | 0.3 | 4.61 | 0.00 | 26.5 | 6.3 | 22200 | 11.10 | 135 | 0.018 | 9.00 | 0.00 | 0.68 | 24.00 |
| | Mean | 14600 | 3.1 | 5.71 | 0.36 | 32.1 | 9.7 | 27640 | 4.15 | 162 | 0.017 | 10.58 | 0.18 | 3.92 | 42.88 |
| | Std | 4121 | 6.6 | 1.41 | 0.25 | 4.9 | 1.9 | 6507 | 5.24 | 55 | 0.027 | 1.15 | 0.15 | 6.40 | 13.39 |
| 2028 | 1995 | 18000 | 6.0 | 3.04 | 0.27 | 28.3 | 15.1 | 19200 | 7.10 | — | 0.000 | 14.00 | 0.58 | — | 42.20 |
| (190 m) | 1996 | 16900 | 0.0 | 2.98 | 0.33 | 28.9 | 14.1 | 17200 | 0.00 | 138 | 0.073 | 15.80 | 0.54 | 0.00 | 40.30 |
| | 1997 | 19300 | 9.7 | 2.84 | 0.29 | 28.7 | 15.3 | 16100 | 6.20 | 124 | 0.000 | 16.60 | 0.57 | 0.00 | 44.90 |
| | 2005 | 25500 | 0.0 | 3.06 | 0.46 | 35.5 | 15.4 | 23600 | 9.28 | 310 | 0.057 | 16.90 | 0.37 | 0.00 | 57.80 |
| | 2006 | 17000 | 0.5 | 3.32 | 0.00 | 28.6 | 13.7 | 18600 | 15.30 | 150 | 0.047 | 16.00 | 0.36 | 0.48 | 29.50 |
| | Mean | 19340 | 3.2 | 3.05 | 0.27 | 30.0 | 14.7 | 18940 | 7.58 | 181 | 0.035 | 15.86 | 0.49 | 0.12 | 42.94 |
| | Std | 3577 | 4.4 | 0.17 | 0.17 | 3.1 | 0.8 | 2872 | 5.52 | 87 | 0.034 | 1.13 | 0.11 | 0.24 | 10.16 |

Anderson et al. 1993, Schiff and Gossett 1998). Concentrations of organic indicators, metals, and other contaminants were higher along the mid-shelf and deep water strata where the percentage of fines was typically greatest. As in prior years, some of the highest contaminant loads occurred near the LA-4 and LA-5 dredge disposal sites. However, there was a marked decrease in concentrations of various constituents, particularly TOC, TN, and trace metals, relative to 2005 when concentrations were substantially higher as a result of heavy rains and non-point source discharges. In contrast, sulfide concentrations increased significantly in shallow-shelf sites in 2006 relative to 2005. This increase is likely a residual affect of the large organic load and plankton blooms experienced in 2005. Results from the repeat stations showed an incremental, but consistent increase in TOC and TN over the past 10 years, while concentrations of sulfides and trace metals were variable over time.

Although pesticides, PCB, and PAH concentrations were generally low in 2006, the pattern of detection was similar to that seen previously. Values were highest across the mid-shelf and deep water strata where the percentage of fines was greatest. PCBs were detected at only 5 sites with the highest concentration occurring north of La Jolla. Chlorinated pesticides were detected in sediments at over 50% of the sites, while PAHs were more widespread, but more concentrated near the EPA-designated disposal sites as in past surveys. Finally, the regional survey data did not show any pattern of contamination relative to wastewater discharge from the SBOO.

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# Chapter 9. San Diego Regional Survey Macrobenthic Communities

## INTRODUCTION

The City of San Diego has conducted regional benthic monitoring surveys off the coast of San Diego since 1994 (see Chapter 1). The main objectives of these surveys are: (1) to characterize benthic conditions of the large and diverse coastal region off San Diego; (2) to characterize the ecological health of the marine benthos in the area; (3) to gain a better understanding of regional conditions in order to distinguish between areas impacted by anthropogenic versus natural events.

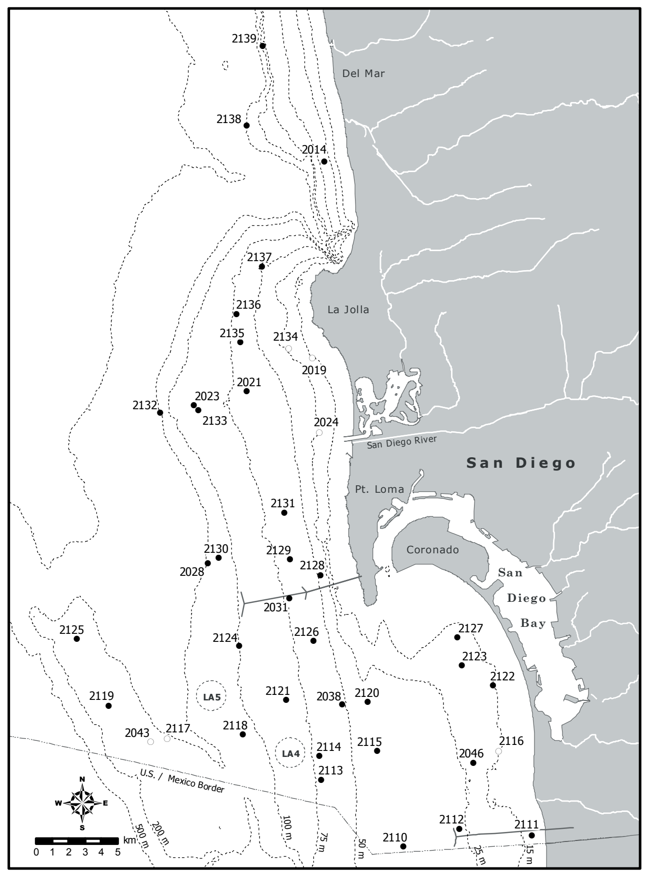
These annual surveys were based on an array of stations randomly selected each year by the United States Environmental Protection Agency (USEPA) using the USEPA probability-based EMAP design. The 1994, 1998, and 2003 surveys off San Diego were conducted as part of the Southern California Bight 1994 Pilot Project (SCBPP) and the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight'98, Bight'03; see Bight'98 Steering Committee 1998, Ranasinghe et al. 2003). These large-scale surveys included other major southern California dischargers, and included sampling sites representing the entire Southern California Bight (i.e., Cabo Colnett, Mexico to Point Conception, USA). The same randomized sampling design was used in surveys limited to the San Diego region in 1995–1997, 1999–2002, and 2005. In 2006, the City revisited the 1996 randomized survey sites to allow for comparisons of conditions after 10 years.

This chapter presents an analysis and interpretation of the benthic macrofaunal data collected during the San Diego 2006 regional survey. Included are descriptions and comparisons of the region's soft-bottom macrobenthic assemblages, and analyses of benthic community structure.

## MATERIALS AND METHODS

### Collection and Processing of Benthic Samples

The July 2006 survey covered an area off San Diego, CA from Del Mar south to the United States/Mexico border (**Figure 9.1**). Site selection was based on the USEPA probability-based EMAP sampling design used in 1996 (City of San Diego 1997). The area sampled included the section of the mainland shelf from nearshore to shallow slope depths (12–202 m). Although 40 sites were initially selected for the 1996 and 2006 surveys, sampling at 7 sites in 1996




## Figure 9.1
Randomly selected regional macrobenthic stations sampled off San Diego, CA (August, 2006). Open circles represent abandoned stations (see text).

and 6 sites in 2006 was unsuccessful due to the presence of rocky reefs. In addition, 7 sites (2014, 2021, 2023, 2028, 2031, 2038, 2046) were sampled in 1995, 1996, 1997, 2005, and 2006.

Samples for benthic community analyses were collected from one 0.1 $m^2$ van Veen grab at each station. 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 and seawater solution and then fixed with 10% buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All organisms were sorted from the debris into groups by a subcontractor and identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

### Data Analyses

The following community structure parameters were calculated for each station: species richness (number of species per 0.1 $m^2$ grab), abundance (number of individuals per grab), Shannon diversity index (H' per grab), Pielou's evenness index (J' per grab), Swartz dominance (minimum number of species accounting for 75% of the total abundance in each grab), Infaunal Trophic Index (ITI per grab, see Word 1980), and Benthic Response Index (mean BRI per grab, see Smith et al. 2001). These data are summarized according to depth strata used in the Bight'98 and Bight'03 surveys: shallow water (5–30 m), mid-depth (31–120 m), and deep (121–200 m).

Multivariate analyses were performed using PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software to examine spatiotemporal 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). The macrofaunal abundance data were square root transformed and the Bray-Curtis measure of similarity was used as the basis for both classification and ordination. SIMPER (similarity percentage) analysis was used to identify individual species that typified each cluster group. Patterns in the distribution of macrofaunal assemblages were compared to environmental variables by overlaying the physicochemical data onto MDS plots based on the biotic data (see Field et al. 1982).

## RESULTS AND DISCUSSION

### Community Parameters

***Number of species***

A total of 654 macrobenthic taxa were identified during 2006. Of these, 34% represented rare or unidentifiable taxa that were recorded only once. The number of taxa per station ranged from 40 to 133 (**Table 9.1a**). This variation in species richness generally is consistent with recent years but lower than values in 1996 when the average number of taxa per 0.1 $m^2$ ranged from 47 to 266 (see **Table 9.1b**). Polychaete worms made up the greatest proportion of species, accounting for 49% of the taxa per site during 2006. Crustaceans represented 23% of the taxa, molluscs 16%, echinoderms 5%, and all other taxa combined about 8%. These percentages are generally similar to those observed during previous years (e.g., City of San Diego 2006).

***Macrofaunal abundance***

Macrofaunal abundance averaged 136–639 individuals per 0.1 $m^2$ in 2006 versus 45–1219 individuals per 0.1 $m^2$ in 1996 (Table 9.1a, b). The greatest number of animals in 2006 occurred at stations 2137 and 2128, both of which averaged over 600 individuals per 0.1 $m^2$. Five other stations had abundance values greater than 400 individuals per 0.1 $m^2$, while most sites had values between 200–400 individuals per 0.1 $m^2$. Region wide, only 5% fewer individuals were collected in 2006 than in 1996.

Polychaetes were the most abundant animals in the region, accounting for about 48% of the different assemblages during 2006. Crustaceans averaged

## Table 9.1a

Benthic community parameters at regional stations sampled during 2006: Species richness (SR), no. species/0.1 $m^2$ ; abundance (Abun), no. individuals/0.1 $m^2$ ; Shannon diversity index (H'); evenness (J'); Swartz dominance (Dom), no. species comprising 75% of a community by abundance; benthic response index (BRI); infaunal trophic index (ITI).

| Station | Depth (m) | SR | Abun | H' | J' | Dom | BRI | ITI |
|---|---|---|---|---|---|---|---|---|
| *Inner shelf* | | | | | | | | |
| 2111 | 12 | 40 | 219 | 2.9 | 0.78 | 10 | 22 | 72 |
| 2122 | 16 | 58 | 140 | 3.6 | 0.90 | 23 | 27 | 81 |
| 2127 | 16 | 50 | 175 | 3.3 | 0.85 | 19 | 26 | 76 |
| 2123 | 19 | 85 | 365 | 3.4 | 0.76 | 23 | 31 | 74 |
| 2046 | 22 | 72 | 242 | 3.6 | 0.85 | 24 | 22 | 87 |
| 2112 | 26 | 95 | 385 | 3.8 | 0.82 | 31 | 25 | 82 |
| **Mean** | | 67 | 254 | 3.4 | 0.83 | 22 | 26 | 79 |
| *Mid shelf* | | | | | | | | |
| 2128 | 37 | 119 | 609 | 3.9 | 0.82 | 30 | 24 | 76 |
| 2014 | 38 | 124 | 405 | 4.2 | 0.87 | 42 | 20 | 77 |
| 2120 | 39 | 130 | 452 | 4.4 | 0.90 | 47 | 21 | 80 |
| 2110 | 40 | 77 | 240 | 3.8 | 0.87 | 28 | 11 | 83 |
| 2115 | 42 | 66 | 236 | 3.4 | 0.82 | 22 | 20 | 77 |
| 2137 | 48 | 125 | 639 | 4.1 | 0.85 | 39 | 8 | 83 |
| 2038 | 52 | 128 | 419 | 4.3 | 0.88 | 47 | 17 | 85 |
| 2126 | 62 | 76 | 323 | 3.2 | 0.74 | 19 | 9 | 93 |
| 2131 | 63 | 101 | 334 | 3.7 | 0.80 | 30 | 8 | 87 |
| 2135 | 66 | 76 | 323 | 3.4 | 0.78 | 24 | 6 | 89 |
| 2129 | 67 | 79 | 306 | 3.6 | 0.82 | 24 | 11 | 88 |
| 2021 | 67 | 103 | 299 | 3.8 | 0.83 | 37 | 8 | 88 |
| 2114 | 68 | 112 | 356 | 4.1 | 0.87 | 40 | 15 | 74 |
| 2113 | 69 | 73 | 246 | 3.8 | 0.88 | 27 | 17 | 75 |
| 2136 | 69 | 115 | 440 | 4.0 | 0.84 | 37 | 3 | 82 |
| 2031 | 74 | 72 | 377 | 3.0 | 0.71 | 16 | 13 | 89 |
| 2139 | 77 | 108 | 345 | 4.1 | 0.88 | 43 | 5 | 83 |
| 2121 | 83 | 133 | 401 | 4.1 | 0.83 | 47 | 7 | 87 |
| 2133 | 89 | 106 | 263 | 4.0 | 0.86 | 41 | 6 | 84 |
| 2023 | 90 | 73 | 252 | 3.5 | 0.81 | 23 | 7 | 85 |
| 2124 | 100 | 92 | 258 | 4.0 | 0.88 | 37 | 6 | 77 |
| **Mean** | | 99 | 358 | 3.8 | 0.84 | 33 | 12 | 83 |
| *Outer shelf* | | | | | | | | |
| 2118 | 123 | 85 | 213 | 4.1 | 0.92 | 40 | 6 | 79 |
| 2119 | 145 | 81 | 212 | 3.9 | 0.89 | 34 | -2 | 75 |
| 2130 | 147 | 86 | 298 | 3.7 | 0.83 | 27 | 13 | 78 |
| 2125 | 157 | 110 | 311 | 4.1 | 0.88 | 40 | 0 | 78 |
| 2138 | 190 | 74 | 273 | 3.6 | 0.84 | 25 | 22 | 80 |
| 2028 | 190 | 62 | 147 | 3.6 | 0.88 | 27 | 13 | 82 |
| 2132 | 197 | 63 | 136 | 3.9 | 0.93 | 30 | 13 | 83 |
| **Mean** | | 80 | 227 | 3.8 | 0.88 | 32 | 9 | 79 |
| *All stations* | | | | | | | | |
| **Mean** | | 90 | 313 | 3.8 | 0.84 | 31 | 14 | 81 |
| **Min** | | 40 | 136 | 2.9 | 0.71 | 10 | -2 | 72 |
| **Max** | | 133 | 639 | 4.4 | 0.93 | 47 | 31 | 93 |

## Table 9.1b

Benthic community parameters at regional stations sampled during 1996: Species richness (SR), no. species/0.1 $m^2$ ; abundance (Abun), no. individuals/0.1 $m^2$ ; Shannon diversity index (H'); evenness (J'); Swartz dominance (Dom), no. species comprising 75% of a community by abundance; benthic response index (BRI); infaunal trophic index (ITI).

| Station | Depth (m) | SR | Abun | H' | J' | Dom | BRI | ITI |
|---|---|---|---|---|---|---|---|---|
| *Inner shelf* | | | | | | | | |
| 2111 | 12 | 33 | 83 | 2.1 | 0.60 | 6 | 22 | 66 |
| 2122 | 16 | 58 | 45 | 3.2 | 0.80 | 18 | 21 | 70 |
| 2127 | 16 | 47 | 63 | 3.1 | 0.81 | 18 | 19 | 75 |
| 2123 | 19 | 85 | 155 | 3.7 | 0.83 | 28 | 23 | 77 |
| 2046 | 22 | 56 | 53 | 2.9 | 0.72 | 20 | 25 | 79 |
| 2112 | 26 | 63 | 76 | 3.4 | 0.82 | 23 | 25 | 77 |
| **Mean** | | 57 | 79 | 3.1 | 0.76 | 19 | 23 | 74 |
| *Mid shelf* | | | | | | | | |
| 2128 | 37 | 147 | 347 | 4.0 | 0.80 | 42 | 21 | 77 |
| 2014 | 38 | 155 | 386 | 4.3 | 0.85 | 43 | 19 | 83 |
| 2120 | 39 | 146 | 285 | 4.2 | 0.83 | 44 | 19 | 83 |
| 2110 | 40 | 73 | 268 | 3.4 | 0.79 | 12 | 11 | 86 |
| 2115 | 42 | 155 | 146 | 4.2 | 0.83 | 25 | 26 | 75 |
| 2137 | 48 | 266 | 1219 | 4.6 | 0.83 | 42 | 10 | 86 |
| 2038 | 52 | 167 | 454 | 4.1 | 0.80 | 42 | 10 | 86 |
| 2126 | 62 | 113 | 417 | 3.8 | 0.80 | 18 | 21 | 91 |
| 2131 | 63 | 110 | 522 | 3.8 | 0.81 | 8 | 11 | 93 |
| 2135 | 66 | 134 | 713 | 4.0 | 0.81 | 9 | 8 | 84 |
| 2129 | 67 | 122 | 395 | 3.9 | 0.81 | 17 | 13 | 92 |
| 2021 | 67 | 165 | 838 | 4.3 | 0.84 | 34 | 8 | 79 |
| 2114 | 68 | 163 | 346 | 4.1 | 0.80 | 45 | 11 | 81 |
| 2113 | 69 | 125 | 212 | 4.2 | 0.86 | 38 | 10 | 84 |
| 2136 | 69 | 130 | 519 | 3.9 | 0.80 | 15 | 4 | 88 |
| 2031 | 74 | 91 | 432 | 3.6 | 0.80 | 7 | 10 | 95 |
| 2139 | 77 | 162 | 370 | 4.2 | 0.82 | 47 | 7 | 84 |
| 2121 | 83 | 120 | 427 | 3.7 | 0.77 | 17 | 9 | 89 |
| 2133 | 89 | 122 | 263 | 3.8 | 0.79 | 21 | 3 | 89 |
| 2023 | 90 | 119 | 226 | 3.9 | 0.83 | 31 | 6 | 82 |
| 2124 | 100 | 128 | 342 | 3.9 | 0.80 | 29 | 3 | 84 |
| **Mean** | | 139 | 435 | 4.0 | 0.81 | 28 | 12 | 85 |
| *Outer shelf* | | | | | | | | |
| 2118 | 123 | 128 | 288 | 4.1 | 0.85 | 34 | 6 | 84 |
| 2119 | 145 | 125 | 300 | 3.8 | 0.79 | 32 | -5 | 82 |
| 2130 | 147 | 114 | 265 | 3.8 | 0.80 | 30 | 10 | 87 |
| 2043 | 157 | 59 | 80 | 3.2 | 0.77 | 16 | 2 | 75 |
| 2138 | 190 | 97 | 180 | 3.6 | 0.79 | 27 | 8 | 88 |
| 2028 | 190 | 62 | 120 | 3.2 | 0.77 | 22 | 11 | 87 |
| **Mean** | | 98 | 206 | 3.6 | 0.80 | 27 | 5 | 84 |
| *All stations* | | | | | | | | |
| **Mean** | | 116 | 328 | 3.8 | 0.80 | 26 | 12 | 83 |
| **Min** | | 47 | 45 | 2.9 | 0.72 | 7 | -5 | 70 |
| **Max** | | 266 | 1219 | 4.6 | 0.86 | 47 | 26 | 95 |

20% of the animals at a station, molluscs about 13%, echinoderms 14%, and all remaining taxa combined 5%. These values were similar to those observed in previous years (see City of San Diego 2006).

***Species diversity and dominance***

Species diversity (H') varied among stations, and ranged from 2.9 to 4.4 (Table 9.1a). Although most of the stations had values between 3.0 and 4.0, stations with the highest diversity (i.e., ≥4.0, n=12) were found predominantly along the mid shelf. The lowest value occurred at station 2111, a shallow water station located near the US/Mexico border. Diversity values were similar to averages at 1996 stations which ranged from 2.9 to 4.4 (Table 9.1b).

Species dominance was measured as the minimum number of species whose combined abundance accounts for 75% of the individuals in a sample (Swartz et al. 1986, Ferraro et al. 1994). Consequently, dominance as discussed herein is inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species. These values varied widely throughout the region, averaging from 10 to 47 species per station in 2006. The pattern of dominance across depth strata was similar to that of diversity. The 3 stations with dominance values <20 also had the lowest H' values. Dominance at stations in 1996 averaged from 7 to 47 species per station, similar to 2006 (Table 9.1b).

***Environmental disturbance indices: ITI and BRI***

Average Infaunal Trophic Index (ITI) values were slightly higher than in 2005, but generally similar to those of recent years and ranged from 72 to 93 throughout the San Diego region (Table 9.1a). The lowest value occurred at station 2111 (ITI=72). ITI values >60 are generally considered characteristic of normal benthic conditions (Bascom et al. 1979, Word 1980). ITI values in 1996 were very similar to those in 2006, averaging from 70 to 95.

Similarly, Benthic Response Index (BRI) values at most stations were indicative of undisturbed communities or "reference conditions." Index values below 25 suggest undisturbed communities or "reference conditions," and those in the range of 25–33 represent "a minor deviation from reference condition," (Smith et al. 2001). Values greater than 44 indicate a loss of community function. BRI values throughout the San Diego Region were generally indicative of reference conditions in 2006 (see Table 9.1a). For example, all of the mid and outer shelf stations (depth>30 m) had BRI values <25. Index values ≥25 were restricted to 4 stations located in shallower depths where the BRI is less reliable. Three stations had BRI values ≥25 in 1996: 2046, 2112, 2115 (Table 9.1b).

## Dominant Species

Most assemblages in the San Diego region were dominated by polychaete worms and brittle stars. For example, the list of dominant fauna in **Table 9.2** includes 12 polychaetes, 4 echinoderms, 3 molluscs, and 2 crustaceans. The ophiuroid *Amphiodia urtica* was the most numerous species, averaging 25 individuals per sample. However, since juvenile ophiuroids usually cannot be identified to species and are recorded at the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae, respectively), this number underestimates actual populations of *A. urtica*. The only other species of *Amphiodia* that occurred in this assemblage in 2006 were *A. digitata* and *A. psara*, which accounted for 20 individuals. If the values for *A. urtica* abundance are adjusted to include juveniles, then the estimated density becomes about 35 animals per 0.1 $m^2$. The second most abundant species was the cirratulid polychaete *Monticellina siblina*. The spionid polychaete, *Prionospio jubata,* was third in total abundance. Polychaetes comprised 8 of the 10 most frequently collected species per occurrence. Several polychaete species were found in high numbers at only a few stations (e.g., *Notoproctus pacificus*).

## Classification of Assemblages and Dominant Macrofauna

Classification analysis discriminated between 7 habitat-related benthic assemblages (cluster groups A–G) during 2006 (**Figures 9.2, 9.3**). These assemblages differed in terms of their species

**Table 9.2**
Dominant macroinvertebrates at regional benthic stations sampled during 2006. Included are the most abundant species overall, the most abundant per occurrence, and the most frequently collected (or widely distributed) species. Abundance values are expressed as mean number of individuals per 0.1 $m^2$ grab sample.

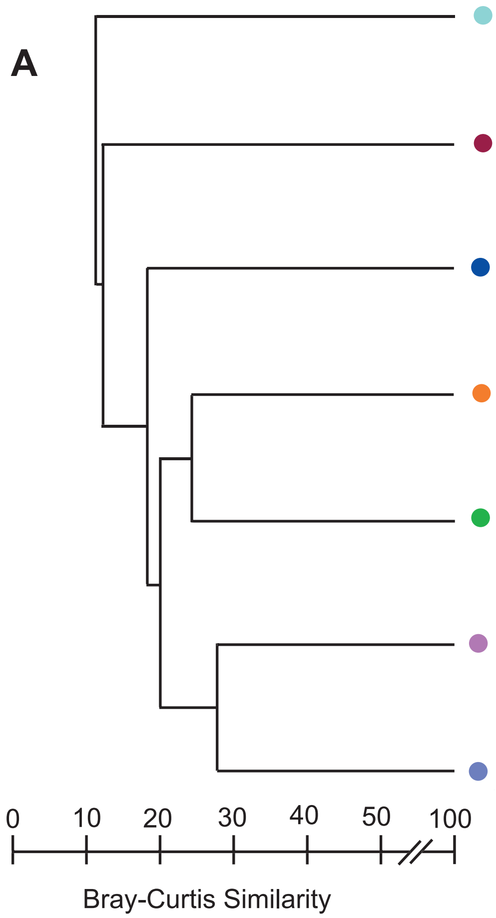
| Species | Higher taxa | Percent occurence | Abundance per sample | Abundance per occurence |
|---|---|---|---|---|
| *Paraprionospio pinnata* | Polychaeta: Spionidae | 97 | 3.6 | 3.7 |
| *Prionospio jubata* | Polychaeta: Spionidae | 88 | 7.3 | 8.3 |
| *Spiophanes duplex* | Polychaeta: Spionidae | 82 | 6.9 | 8.4 |
| Euclymeninae sp *A* | Polychaeta: Maldanidae | 82 | 3.9 | 4.8 |
| Amphiuridae | Echinodermata: Ophiuroidea | 74 | 7.1 | 9.6 |
| *Mediomastus* sp | Polychaeta: Capitellidae | 74 | 4.0 | 5.4 |
| Maldanidae | Polychaeta: Maldanidae | 71 | 3.0 | 4.2 |
| *Glycera nana* | Polychaeta: Glyceridae | 71 | 2.6 | 3.8 |
| *Spiophanes berkeleyorum* | Polychaeta: Spionidae | 68 | 2.4 | 3.5 |
| *Ampelisca pugetica* | Crustacea: Amphipoda | 65 | 2.3 | 3.5 |
| *Leptochelia dubia* | Crustacea: Tanaidacea | 62 | 4.5 | 7.3 |
| *Amphiodia* sp | Echinodermata: Ophiuroidea | 59 | 9.6 | 16.4 |
| *Amphiodia urtica* | Echinodermata: Ophiuroidea | 56 | 24.8 | 44.4 |
| *Monticellina siblina* | Polychaeta: Cirratulidae | 53 | 11.1 | 20.9 |
| *Axinopsida serricata* | Mollusca: Bivalvia | 50 | 5.6 | 11.2 |
| *Spiophanes kimballi* | Polychaeta: Spionidae | 35 | 4.7 | 13.4 |
| *Spiophanes bombyx* | Polychaeta: Spionidae | 35 | 4.7 | 13.3 |
| *Caecum crebricinctum* | Mollusca: Gastropoda | 9 | 1.1 | 12.0 |
| *Notoproctus pacificus* | Polychaeta: Maldanidae | 3 | 2.4 | 83.0 |
| Mactridae | Mollusca: Bivalvia | 3 | 0.8 | 28.0 |
| *Dougaloplus* sp SD1 | Echinodermata: Ophiuroidea | 3 | 0.4 | 14.0 |

composition, including the specific taxa present and their relative abundances. The dominant species composing each group are listed in **Table 9.3**. An MDS ordination of the station/survey entities confirmed the validity of cluster groups A–G. Similar to previous random sample surveys of the region, depth, sediment grain size, and organic composition were the primary factors affecting the distribution of assemblages (Bergen et al. 1998; see **Figure 9.4**).

Cluster group A consisted of one station (2110, 40 m) with coarse sediments (0% fine particles) and contained 77 taxa and 240 individuals per 0.1 $m^2$. Total organic carbon (TOC) concentration at this station was less than 0.1%. Unidentified onuphid polychaetes (Onuphidae, *Moorenuphis* sp) were the most abundant animals characterizing this group, followed by the spionid *Spiophanes bombyx* and the crustacean *Foxiphalus obtusidens*.

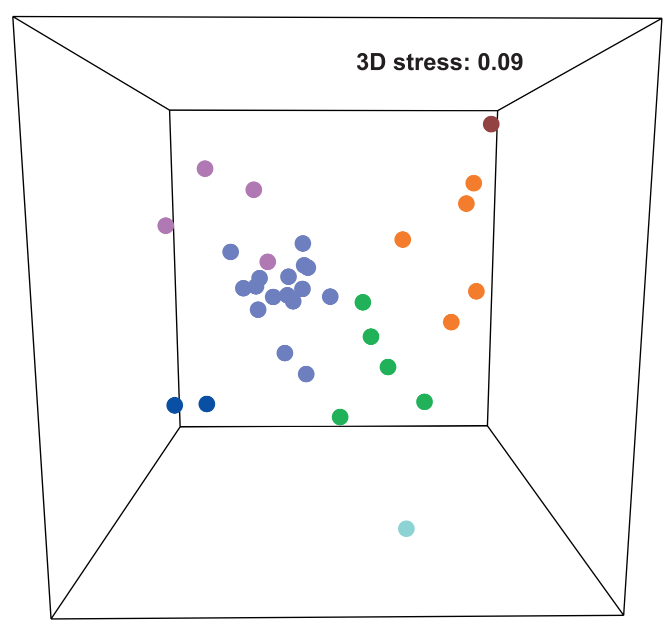
Cluster group B comprised the shallowest station 2111 (12 m). The sediments at this site were generally mixed (23% fines) and TOC concentration was 0.3%. Group B contained the fewest taxa (40) and the second lowest abundance (219 individuals per 0.1 $m^2$) among all the groups. Dominate species included the polychaete *Scoletoma* sp, unidentified molluscs of the family Mactridae, and the bivalve *Tellina modesta*. Other characteristic taxa in this assemblage included the sabellid polychaete *Chone* sp SD1 and the gastropod *Nassarius* sp.

A




| CG | % Fines | TOC | SR | Abun | Top taxa |
|---|---|---|---|---|---|
| A | 0 | 0.1 | 77 | 240 | Onuphidae<br>*Moorenuphis* sp<br>*Spiophanes bombyx* |
| B | 23 | 0.3 | 40 | 219 | *Scoletoma* sp<br>Mactridae<br>*Tellina modesta* |
| C | 18 | 4.6 | 96 | 262 | *Aphelochaeta glandaria*<br>*Pronospio jubata*<br>*Leptochelia dubia* |
| D | 18 | 0.2 | 72 | 261 | *Monticellina siblina*<br>*Spiophanes bombyx*<br>*Ampelisca brevisimulata* |
| E | 21 | 1.0 | 113 | 468 | *Monticellina siblina*<br>*Pronospio jubata*<br>*Spiophanes bombyx* |
| F | 53 | 1.6 | 71 | 213 | *Spiophanes kimballi*<br>*Paradiopatra parva*<br>*Compressidens stearnsii* |
| G | 43 | 0.9 | 96 | 322 | *Amphiodia urtica*<br>*Amphiodia* sp<br>Amphiuridae |

B




## Figure 9.2

**(A)** Cluster results of the macrofaunal abundance data for the regional benthic stations sampled during July 2006. Data are expressed as mean values per 0.1 m$^2$ grab over all stations in each group. **(B)** MDS ordination based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between faunal assemblages.

Cluster group C consisted of 2 stations along the Coronado bank (145–157 m). Sediments at this group were relatively coarse and contained pea gravel, rock, and shell hash. These sites averaged 18% fines and had the highest organic load (e.g., TOC = 4.6%). Species richness for this assemblage averaged 95 taxa and abundance averaged 262 individuals per 0.1 $m^2$. The dominant species included 2 polychaetes, *Aphelochaeta glandaria* and *Prionospio jubata*, as well as the crustacean *Leptochelia dubia*.

Cluster group D consisted of 5 nearshore stations located in the South Bay area that ranged in depth from 16 to 26 m. Sediments at stations within this group averaged 18% fines. Overall, the benthic assemblage at these stations was typical of the shallow water sites in the region (e.g., see Chapter 5). Group D averaged 72 taxa and 261 individuals per 0.1 $m^2$. The dominant species included the polychaetes *Monticellina siblina* and *Scoletoma* sp, as well as the amphipod *Ampelisca brevisimulata*.

Cluster group E included sites primarily located along the 19 and 28 m depth contours, where sediments contained 23% fine particles. TOC at stations within this group averaged 1.0%. This assemblage averaged the highest species richness (113 taxa) and abundance (468 individuals per 0.1 $m^2$). Three polychaetes, *Prionospio jubata*, *M. siblina,* and *S. bombyx* were the numerically dominant species in this group.

Cluster group F represented 4 of the 7 outer shelf stations, including 3 of the deepest sites (mean depth=181 m). This group contained 53% fine sediments and averaged the second highest concentration of TOC (1.6%). The number of taxa at group F averaged 71 taxa and 213 individuals per 0.1 $m^2$. The most abundant species were the polychaetes *Spiophanes kimballi* and *Paradiopatra parva*, and the mollusc *Compressidens stearnsii*.

Cluster group G comprised most of the mid-shelf sites ranging in depth from 52 to 123 m. This cluster group, characterized by mixed sediments averaging 43% fines (range=19–64%), had the second highest average species richness (96), and the second highest values for abundance (322). This assemblage is typical of the ophiuroid dominated community that occurs along the mainland shelf off southern California (City of San Diego 2006). The most abundant species representing this mid-shelf group were the ophiuroid *Amphiodia urtica,* the polychaete *Spiophanes duplex,* and the bivalve *Axinopsida serricata*.

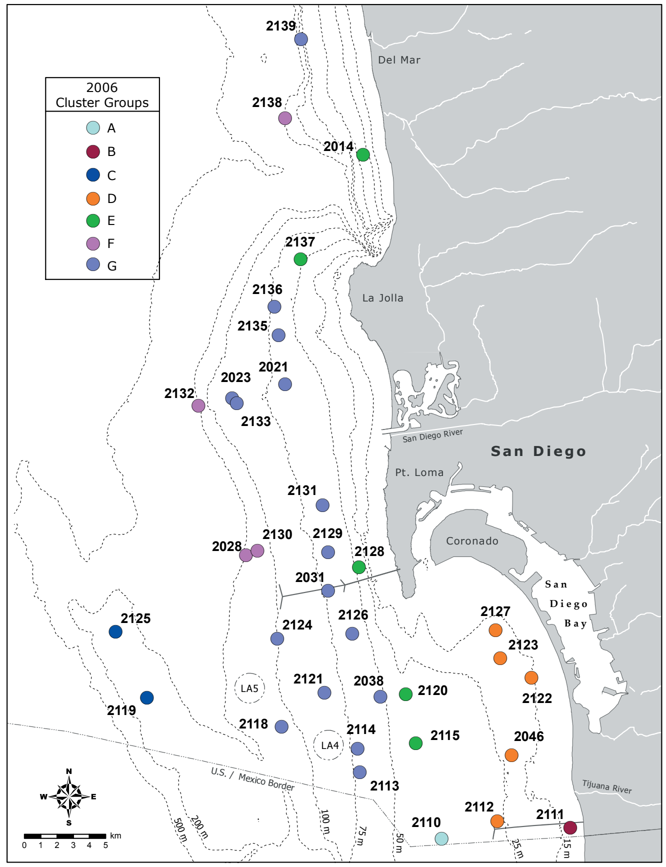



**Figure 9.3**
Regional benthic stations sampled during July 2006, color-coded to represent affiliation with benthic cluster groups.

## SUMMARY AND CONCLUSIONS

The Southern California Bight (SCB) benthos has long been considered a patchy habitat, with the distribution of species and communities varying in space and time. Barnard and Ziesenhenne (1961) described the SCB shelf as consisting of an *Amphiodia* mega-community with other sub-communities representing simple variations

## Table 9.3

Summary of the most abundant taxa composing cluster groups A–G from the 2006 regional benthic station survey. Data are expressed as mean abundance per cluster group and represent the 10 most abundant taxa in each group. Values for the 3 most abundant species in each cluster group are bolded. n=number of station/survey entities per cluster group

| | | Cluster group | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G |
| Species/Taxa | Taxa | (n=1) | (n=1) | (n=2) | (n=5) | (n=5) | (n=4) | (n=22) |
| *Ampelisca brachycladus* | Crustacea | — | — | — | 6.2 | — | — | — |
| *Ampelisca brevisimulata* | Crustacea | — | — | — | **10.4** | 7.0 | 1.0 | 2.0 |
| *Ampelisca cristata cristata* | Crustacea | 11.0 | — | — | 5.0 | — | — | 0.3 |
| *Amphiodia* sp | Echinodermata | — | — | 1.0 | — | 1.4 | 0.3 | **19.9** |
| *Amphiodia urtica* | Echinodermata | 2.0 | — | — | — | 0.4 | 0.5 | **52.3** |
| Amphiuridae | Echinodermata | — | 1.0 | — | 0.4 | 3.2 | 1.8 | **13.4** |
| *Aphelochaeta glandaria* | Polychaeta | — | — | **25.5** | 0.4 | 1.6 | 1.8 | 0.6 |
| *Axinopsida serricata* | Mollusca | — | — | — | — | 0.6 | 0.5 | 11.6 |
| *Compressidens stearnsii* | Mollusca | — | — | 1.5 | — | — | **7.0** | 0.1 |
| *Foxiphalus obtusidens* | Crustacea | **15.0** | — | 1.0 | 1.4 | 8.6 | — | 0.3 |
| *Huxleyia munita* | Mollusca | — | — | 8.5 | — | — | — | — |
| *Leptochelia dubia* | Crustacea | 6.0 | — | **12.0** | 1.2 | 6.8 | 0.3 | 5.1 |
| Mactridae | Mollusca | — | **28.0** | — | — | — | — | — |
| *Mediomastus* sp | Polychaeta | — | 4.0 | 1.0 | 8.6 | 5.8 | 4.0 | 2.6 |
| *Monticellina siblina* | Polychaeta | — | — | 7.5 | **44.4** | **24.6** | 1.5 | 0.6 |
| *Mooreonuphis exigua* | Polychaeta | — | — | 8.0 | — | — | — | — |
| *Mooreonuphis* sp | Polychaeta | **19.0** | — | 3.0 | — | 1.8 | — | 0.3 |
| *Nassarius* sp | Mollusca | — | 19.0 | — | 0.4 | 0.2 | — | — |
| *Notoproctus pacificus* | Polychaeta | — | — | — | — | 16.6 | — | — |
| Onuphidae | Polychaeta | **23.0** | 2.0 | 2.0 | — | 0.2 | — | 0.1 |
| *Onuphis* sp A | Polychaeta | — | 12.0 | — | 3.0 | 3.0 | — | 0.3 |
| *Paradiopatra parva* | Polychaeta | — | — | 2.0 | — | 0.2 | **14.8** | 1.9 |
| *Paraprionospio pinnata* | Polychaeta | — | 1.0 | 2.0 | 3.6 | 4.0 | 5.8 | 3.4 |
| *Phyllochaetopterus limicolus* | Polychaeta | — | — | — | — | — | 6.0 | 0.1 |
| *Prionospio jubata* | Polychaeta | — | — | **13.0** | 0.8 | **24.8** | 2.8 | 5.2 |
| *Scoletoma* sp | Polychaeta | — | **51.0** | — | **10.4** | — | 3.0 | 1.1 |
| *Spiophanes bombyx* | Polychaeta | **15.0** | 1.0 | — | 2.6 | **24.2** | — | 0.6 |
| *Spiophanes duplex* | Polychaeta | — | 5.0 | 0.5 | 5.6 | 13.6 | 2.3 | 7.8 |
| *Spiophanes kimballi* | Polychaeta | — | — | 0.5 | — | — | **34.3** | 1.4 |
| *Syllis heterochaeta* | Polychaeta | — | — | — | 0.2 | 14.6 | 0.5 | 0.9 |
| *Tellina modesta* | Mollusca | — | **21.0** | — | 2.6 | 1.2 | — | — |

determined by differences in substrate type and microhabitat. Results of the 2006 and previous regional surveys off San Diego generally support this characterization. The 2006 benthic assemblages segregated mostly by habitat characteristics (e.g., depth, sediment grain size, and TOC) and were similar to those sampled in the past.

Almost half of the benthos off San Diego was characterized by an assemblage dominated by the ophiuroid *Amphiodia urtica* (Station group G). *Amphiodia urtica*, a dominant species along the mainland shelf of southern California, averaged 25 animals per 0.1 $m^2$ (Table 9.2). The co-dominant species within this assemblage included other taxa common to the region such as the polychaete *Spiophanes duplex*.

Nearshore assemblages in the region varied depending upon the sediment type and depth where they were collected, but were generally similar to other shallow, sandy sediment communities in the SCB (see Barnard 1963, Jones 1969, Thompson et al. 1987, 1992, ES Engineering-Science 1988, Mikel et al. 2007). At groups D and E, polychaete species such as *Monticellina siblina* were numerically dominant in mixed, sandy sediments. However, the single site (2110) that constituted group A was characterized by unique, coarse sediments composed of relict red or black sands that are typically associated with distinct benthic assemblages. This assemblage was dominated by the polychaetes *Moorenuphis* sp and *Spiophanes bombyx*, and the crustacean *Foxiphalus obtusidens*, the latter species being rare at most other assemblages. Another shallow water assemblage, group B, occurred at a depth of 12 m, and contained taxa associated with shallow habitats exposed to water motion like Mactrid bivalves, the polychaete *Chone* sp SD1, and the gastropod *Nassarius* sp.

The deepest sites (group F, >180 m) had the highest percentage of fine particles and second highest TOC concentrations. These sites had a relatively lower species richness and abundance and were dominated by polychaetes, including *Spiophanes kimballi, Paradiopatra parva*, and *Paraprionospio pinnata*.


## Figure 9.4

MDS ordination of regional benthic stations sampled in July 2006. Cluster groups A–G are superimposed on stations. Percentage of fine particles in the sediments, station depth, and total organic carbon (TOC) are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of macrobenthic assemblages with habitats that differ in sediment grain size and depth. Stress=0.14.

The results of the 2006 regional survey off San Diego indicated that benthic assemblages in the vicinity of the Point Loma Ocean Outfall, the South Bay Ocean Outfall, and the dredge spoils disposal sites have maintained a benthic community structure consistent with regional assemblages sampled in the past (e.g., City of San Diego 2005, 2006) and the SCB as a whole (e.g., Mikel et al. 2007). While assemblages varied based on depth, sediment composition, and TOC concentrations, no patterns of disturbance relative to point sources were evident. Abundances of soft-bottom invertebrates exhibit substantial spatial and temporal variability that may mask the effects of natural or anthropogenic disturbances (Morrisey et al. 1992a, 1992b, Otway 1995). However, region-wide surveys are valuable tools that provide context for localized monitoring and help to establish the baseline conditions necessary to identify any natural or anthropogenic disturbances.

There were no substantial changes in community parameters between the 1996 random and 2006 surveys. Over the 10 year period, changes in taxonomic resolution created some disparity in nomenclature among select species. For example, certain species complexes (e.g., *Americhelidium*, *Chaetozone*) have been further resolved into individual species. These types of changes can account for some of the differences in species richness and the associated diversity indexes. However, the similarities between macrofaunal community parameters from 1996 and 2006 suggest that benthic assemblages have not changed substantially in recent years.

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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 SBOO Stations

# Ocean Conditions

## Appendix A.1a

Mean data at all surface depths (≤2 m) for 2006 is compared to mean data and standard deviations (±1 SD) for 1995–2005 at stations I9, I12, I22, and I27, and difference (Δ) between 2006 and 1995–2005 mean data. Data includes temperature (°C), salinity (ppt), density ( δ/θ dissolved oxygen (mg/L), pH, transmissivity (%), and chlorophyll *a* (µg/L).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Temperature* | | | | | | | | | | | | |
| 2006 | 14.5 | 13.8 | 13.2 | 14.3 | 16.1 | 18.5 | 20.1 | 18.7 | 18.7 | 17.3 | 17.5 | 15.7 |
| 1995–2005 | 14.7 | 14.1 | 14.6 | 15.2 | 17.2 | 18.9 | 18.2 | 18.6 | 20.1 | 18.6 | 17.1 | 15.6 |
| SD | 1.0 | 1.1 | 1.0 | 1.0 | 1.9 | 1.7 | 1.4 | 1.4 | 2.2 | 1.5 | 1.1 | 1.2 |
| Δ | -0.2 | -0.3 | -1.4 | -0.9 | -1.2 | -0.4 | 1.9 | 0.1 | -1.4 | -1.3 | 0.4 | 0.1 |
| *Salinity* | | | | | | | | | | | | |
| 2006 | 33.35 | 33.40 | 33.43 | 33.44 | 33.57 | 33.56 | 33.56 | 33.45 | 33.43 | 33.41 | 33.43 | 33.50 |
| 1995–2005 | 33.44 | 33.45 | 33.44 | 33.54 | 33.58 | 33.64 | 33.62 | 33.54 | 33.54 | 33.48 | 33.46 | 33.47 |
| SD | 0.23 | 0.12 | 0.21 | 0.14 | 0.10 | 0.12 | 0.18 | 0.12 | 0.14 | 0.12 | 0.15 | 0.13 |
| Δ | -0.08 | -0.05 | -0.01 | -0.10 | -0.01 | -0.09 | -0.06 | -0.09 | -0.11 | -0.07 | -0.02 | 0.03 |
| *Density* | | | | | | | | | | | | |
| 2006 | 24.80 | 24.99 | 25.13 | 24.92 | 24.64 | 24.04 | 23.63 | 23.90 | 23.89 | 24.22 | 24.19 | 24.66 |
| 1995–2005 | 24.82 | 24.95 | 24.85 | 24.80 | 24.35 | 23.99 | 24.07 | 23.99 | 23.68 | 24.00 | 24.27 | 24.70 |
| SD | 0.23 | 0.22 | 0.31 | 0.27 | 0.45 | 0.40 | 0.39 | 0.37 | 0.60 | 0.37 | 0.27 | 0.26 |
| Δ | -0.02 | 0.04 | 0.28 | 0.12 | 0.29 | 0.05 | -0.44 | -0.09 | 0.21 | 0.22 | -0.08 | -0.04 |
| *Dissolved oxygen* | | | | | | | | | | | | |
| 2006 | 8.3 | 9.5 | 9.2 | 8.7 | 9.5 | 9.8 | 8.2 | 8.0 | 8.2 | 7.9 | 7.6 | 7.7 |
| 1995–2005 | 7.9 | 7.9 | 8.7 | 8.5 | 8.3 | 8.4 | 8.4 | 8.4 | 7.8 | 8.1 | 7.9 | 7.8 |
| SD | 0.5 | 1.0 | 0.9 | 1.0 | 1.2 | 0.7 | 0.9 | 1.3 | 1.1 | 1.0 | 0.9 | 0.8 |
| Δ | 0.4 | 1.6 | 0.5 | 0.2 | 1.2 | 1.4 | -0.2 | -0.4 | 0.4 | -0.2 | -0.3 | -0.1 |
| *pH* | | | | | | | | | | | | |
| 2006 | 8.1 | 8.2 | 8.2 | 8.2 | 8.3 | 8.4 | 8.2 | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 |
| 1995–2005 | 8.1 | 8.1 | 8.1 | 8.1 | 8.2 | 8.1 | 8.1 | 8.1 | 8.1 | 8.2 | 8.1 | 8.1 |
| Std_Dev | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Δ | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 | -0.0 | 0.0 | 0.0 |
| *Transmissivity* | | | | | | | | | | | | |
| 2006 | 80 | 77 | 70 | 73 | 79 | 75 | 78 | 83 | 82 | 87 | 83 | 76 |
| 1995–2005 | 84 | 83 | 79 | 79 | 82 | 82 | 81 | 81 | 84 | 84 | 85 | 84 |
| SD | 6 | 6 | 7 | 8 | 5 | 7 | 6 | 6 | 7 | 9 | 3 | 10 |
| Δ | -4 | -6 | -9 | -6 | -3 | -7 | -3 | 2 | -2 | 3 | -2 | -8 |
| *Chlorophyll a* | | | | | | | | | | | | |
| 2006 | 2.8 | 7.5 | 9.4 | 4.6 | 6.8 | 12.1 | 3.0 | 2.4 | 2.7 | 2.1 | 1.8 | 2.2 |
| 1995–2005 | 4.1 | 4.1 | 4.3 | 7.3 | 4.5 | 4.2 | 3.2 | 3.3 | 4.1 | 4.7 | 3.0 | 4.5 |
| SD | 2.0 | 1.9 | 2.1 | 5.9 | 2.4 | 2.7 | 1.4 | 1.8 | 3.2 | 7.6 | 2.3 | 3.0 |
| Δ | -1.3 | 3.4 | 5.1 | -2.7 | 2.3 | 7.9 | -0.2 | -0.9 | -1.4 | -2.6 | -1.2 | -2.3 |

# Appendix A.1b

Mean data at mid-depths (≥10 and ≤27) m for 2006 is compared to mean historical data and standard deviations (±1 SD) for 1995–2005 at stations I9, I12, I22, and I27, and difference (Δ) between 2006 and 1995–2005 mean data.. Data includes temperature (°C), salinity (ppt), density ( δ/θ) dissolved oxygen (mg/L), pH, transmissivity (%), and chlorophyll *a* (µg/L).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Temperature* | | | | | | | | | | | | |
| 2006 | 14.3 | 13.3 | 11.7 | 10.9 | 11.4 | 15.2 | 13.8 | 13.6 | 14.8 | 15.2 | 16.4 | 15.3 |
| 1995–2005 | 14.4 | 13.5 | 13.3 | 12.9 | 13.0 | 13.3 | 13.2 | 13.1 | 14.8 | 15.0 | 15.3 | 14.9 |
| SD | 1.2 | 1.2 | 1.3 | 1.4 | 2.3 | 2.0 | 1.8 | 1.5 | 2.5 | 2.2 | 1.6 | 1.2 |
| Δ | -0.1 | -0.2 | -1.6 | -2.0 | -1.6 | 1.9 | 0.6 | 0.5 | -0.0 | 0.2 | 1.1 | 0.4 |
| *Salinity* | | | | | | | | | | | | |
| 2006 | 33.36 | 33.42 | 33.54 | 33.68 | 33.62 | 33.63 | 33.52 | 33.42 | 33.45 | 33.39 | 33.40 | 33.49 |
| 1995–2005 | 33.49 | 33.51 | 33.50 | 33.61 | 33.63 | 33.66 | 33.60 | 33.53 | 33.48 | 33.41 | 33.41 | 33.45 |
| SD | 0.20 | 0.18 | 0.19 | 0.13 | 0.11 | 0.12 | 0.14 | 0.14 | 0.11 | 0.11 | 0.15 | 0.15 |
| Δ | -0.13 | -0.09 | 0.04 | 0.07 | -0.01 | -0.03 | -0.08 | -0.11 | -0.03 | -0.02 | -0.01 | 0.04 |
| *Density* | | | | | | | | | | | | |
| 2006 | 24.85 | 25.10 | 25.51 | 25.76 | 25.63 | 24.86 | 25.08 | 25.05 | 24.81 | 24.67 | 24.41 | 24.74 |
| 1995–2005 | 24.92 | 25.14 | 25.17 | 25.33 | 25.31 | 25.28 | 25.19 | 25.20 | 24.83 | 24.75 | 24.63 | 24.80 |
| SD | 0.27 | 0.26 | 0.35 | 0.34 | 0.51 | 0.41 | 0.44 | 0.34 | 0.60 | 0.47 | 0.39 | 0.31 |
| Δ | -0.07 | -0.04 | 0.34 | 0.43 | 0.32 | -0.42 | -0.11 | -0.15 | -0.02 | -0.08 | -0.22 | -0.06 |
| *Dissolved Oxygen* | | | | | | | | | | | | |
| 2006 | 8.1 | 8.5 | 6.5 | 5.2 | 5.4 | 8.2 | 7.6 | 7.3 | 7.9 | 8.0 | 7.7 | 7.3 |
| 1995–2005 | 7.8 | 7.7 | 7.6 | 7.4 | 7.2 | 8.0 | 8.5 | 8.5 | 8.3 | 8.6 | 7.8 | 8.0 |
| SD | 0.6 | 0.9 | 1.1 | 1.4 | 1.7 | 1.5 | 1.2 | 1.4 | 1.4 | 1.5 | 0.7 | 0.5 |
| Δ | 0.3 | 0.8 | -1.1 | -2.2 | -1.8 | 0.2 | -0.9 | -1.2 | -0.4 | -0.6 | -0.1 | -0.7 |
| *pH* | | | | | | | | | | | | |
| 2006 | 8.1 | 8.2 | 8.0 | 7.9 | 7.9 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 |
| 1995–2005 | 8.0 | 8.0 | 8.0 | 7.9 | 8.0 | 8.0 | 8.0 | 8.0 | 8.1 | 8.1 | 8.1 | 8.1 |
| SD | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Δ | 0.1 | 0.2 | 0.0 | -0.0 | -0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Transmissivity* | | | | | | | | | | | | |
| 2006 | 81 | 80 | 81 | 85 | 86 | 79 | 84 | 88 | 86 | 87 | 86 | 80 |
| 1995–2005 | 85 | 83 | 85 | 82 | 84 | 82 | 85 | 85 | 86 | 87 | 86 | 86 |
| SD | 5 | 7 | 6 | 6 | 5 | 6 | 5 | 5 | 3 | 4 | 3 | 3 |
| Δ | -4 | -3 | -4 | 3 | 2 | -3 | -1 | 3 | 0 | 0 | 0 | -6 |
| *Chlorophyll a* | | | | | | | | | | | | |
| 2006 | 5.2 | 10.3 | 10.2 | 3.6 | 6.1 | 11.7 | 5.7 | 3.9 | 5.1 | 3.7 | 2.8 | 3.2 |
| 1995–2005 | 5.1 | 6.9 | 5.1 | 8.5 | 7.2 | 8.5 | 4.6 | 6.5 | 5.7 | 4.0 | 5.0 | 6.1 |
| SD | 2.1 | 6.0 | 1.9 | 6.9 | 4.4 | 5.8 | 3.5 | 4.9 | 4.2 | 2.3 | 3.1 | 3.4 |
| Δ | 0.1 | 3.4 | 5.1 | -4.9 | -1.1 | 3.2 | 1.0 | -2.6 | -0.6 | -0.3 | -2.2 | -2.9 |

## Appendix A.1c

Mean data at bottom depths (≥27 m) for 2006 is compared to mean historical data and standard deviations (±1 SD) for 1995–2005 at stations I9, I12, I22, and I27, and difference (Δ) between 2006 and 1995–2005 mean data.. Data includes temperature (°C), salinity (ppt), density ( δ/θ) dissolved oxygen (mg/L), pH, transmissivity (%), and chlorophyll *a* (µg/L).

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Temperature* | | | | | | | | | | | | |
| 2006 | 12.4 | 12.1 | 10.3 | 10.2 | 10.5 | 11.6 | 11.8 | 12.1 | 12.6 | 13.3 | 14.5 | 14.8 |
| 1995–2005 | 13.9 | 12.5 | 12.4 | 11.4 | 11.5 | 11.4 | 11.9 | 12.2 | 13.5 | 13.9 | 14.6 | 14.4 |
| SD | 1.3 | 1.1 | 1.0 | 0.7 | 1.0 | 0.5 | 1.5 | 1.3 | 2.0 | 1.8 | 1.5 | 1.3 |
| Δ | -1.5 | -0.4 | -2.1 | -1.2 | -1.0 | 0.2 | -0.1 | -0.1 | -0.9 | -0.4 | -0.1 | 0.4 |
| *Salinity* | | | | | | | | | | | | |
| 2006 | 33.40 | 33.49 | 33.78 | 33.82 | 33.73 | 33.66 | 33.54 | 33.48 | 33.48 | 33.38 | 33.40 | 33.48 |
| 1995–2005 | 33.48 | 33.56 | 33.58 | 33.67 | 33.66 | 33.66 | 33.61 | 33.56 | 33.48 | 33.44 | 33.42 | 33.43 |
| SD | 0.18 | 0.15 | 0.18 | 0.12 | 0.10 | 0.10 | 0.15 | 0.12 | 0.11 | 0.10 | 0.13 | 0.19 |
| Δ | -0.08 | -0.07 | 0.20 | 0.15 | 0.07 | -0.00 | -0.07 | -0.08 | 0.00 | -0.06 | -0.02 | 0.05 |
| Density | | | | | | | | | | | | |
| 2006 | 25.26 | 25.40 | 25.95 | 26.00 | 25.88 | 25.63 | 25.49 | 25.38 | 25.29 | 25.07 | 24.84 | 24.85 |
| 1995–2005 | 25.02 | 25.36 | 25.39 | 25.67 | 25.64 | 25.66 | 25.49 | 25.39 | 25.08 | 24.98 | 24.79 | 24.89 |
| SD | 0.28 | 0.24 | 0.31 | 0.17 | 0.22 | 0.14 | 0.40 | 0.28 | 0.49 | 0.44 | 0.34 | 0.34 |
| Δ | 0.24 | 0.04 | 0.56 | 0.33 | 0.24 | -0.03 | -0.00 | -0.01 | 0.21 | 0.09 | 0.05 | -0.04 |
| *Dissolved Oxygen* | | | | | | | | | | | | |
| 2006 | 6.5 | 5.9 | 4.0 | 3.7 | 4.0 | 4.3 | 5.2 | 6.0 | 6.1 | 7.3 | 7.2 | 6.7 |
| 1995–2005 | 7.3 | 6.5 | 6.3 | 5.2 | 5.4 | 5.7 | 6.3 | 7.2 | 7.6 | 7.8 | 7.3 | 7.4 |
| SD | 0.8 | 0.7 | 1.3 | 0.9 | 1.4 | 1.5 | 1.2 | 1.1 | 1.7 | 2.0 | 0.9 | 0.8 |
| Δ | -0.8 | -0.6 | -2.3 | -1.5 | -1.4 | -1.4 | -1.1 | -1.2 | -1.5 | -0.5 | -0.1 | -0.7 |
| *pH* | | | | | | | | | | | | |
| 2006 | 8.0 | 8.0 | 7.8 | 7.8 | 7.8 | 7.8 | 7.9 | 8.0 | 7.9 | 8.1 | 8.1 | 8.0 |
| 1995–2005 | 8.0 | 7.9 | 7.9 | 7.8 | 7.8 | 7.8 | 7.9 | 7.9 | 8.0 | 8.0 | 8.0 | 8.0 |
| Std_Dev | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Δ | -0.0 | 0.1 | -0.1 | 0.0 | -0.0 | 0.0 | 0.0 | 0.1 | -0.1 | 0.1 | 0.0 | 0.0 |
| *Transmissivity* | | | | | | | | | | | | |
| 2006 | 85 | 85 | 88 | 88 | 91 | 88 | 89 | 90 | 90 | 89 | 89 | 82 |
| 1995–2005 | 74 | 67 | 72 | 76 | 83 | 82 | 85 | 84 | 84 | 81 | 82 | 79 |
| SD | 12 | 20 | 19 | 10 | 5 | 7 | 4 | 6 | 5 | 9 | 7 | 10 |
| Δ | 10 | 18 | 16 | 12 | 8 | 6 | 4 | 6 | 6 | 8 | 7 | 3 |
| *Chlorophyll a* | | | | | | | | | | | | |
| 2006 | 2.9 | 2.7 | 0.8 | 1.2 | 1.3 | 2.9 | 3.5 | 2.4 | 2.2 | 4.5 | 2.4 | 1.9 |
| 1995–2005 | 4.3 | 4.7 | 4.7 | 6.1 | 4.8 | 6.1 | 5.8 | 4.9 | 4.1 | 4.9 | 3.8 | 4.7 |
| SD | 2.1 | 2.5 | 2.9 | 3.1 | 3.0 | 4.7 | 4.9 | 2.5 | 2.0 | 2.8 | 2.6 | 2.8 |
| Δ | -1.4 | -2.0 | -3.9 | -4.9 | -3.5 | -3.2 | -2.3 | -2.5 | -1.9 | -0.4 | -1.4 | -2.7 |

## Appendix A.2

Differences between the surface (≤2 m) and bottom (≥27 m) waters for mean values of temperature (Temp, °C), salinity (ppt), density (δ/θ), dissolved oxygen (DO, mg/L), pH, transmissivity (XMS, %), and chlorophyll *a* (µg/L) at SBOO kelp stations during 2006.

| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temp** | *Surface* | 13.7 | 14.1 | 13.4 | 15.1 | 17.1 | 19.2 | 22.0 | 17.9 | 18.3 | 17.4 | 17.3 | 15.6 |
| | *Bottom* | 12.9 | 12.8 | 11.4 | 11.2 | 13.0 | 13.0 | 15.7 | 13.6 | 15.1 | 16.1 | 16.3 | 15.1 |
| | Δ | 0.8 | 1.3 | 2.0 | 3.9 | 4.1 | 6.2 | 6.3 | 4.3 | 3.2 | 1.3 | 1.0 | 0.5 |
| **Density** | *Surface* | 24.97 | 24.95 | 25.13 | 24.83 | 24.39 | 23.89 | 23.08 | 24.10 | 23.99 | 24.19 | 24.23 | 24.69 |
| | *Bottom* | 25.20 | 25.24 | 25.61 | 25.76 | 25.35 | 25.32 | 24.61 | 25.06 | 24.72 | 24.47 | 24.46 | 24.79 |
| | Δ | -0.23 | -0.29 | -0.48 | -0.93 | -0.96 | -1.43 | -1.53 | -0.96 | -0.74 | -0.28 | -0.23 | -0.10 |
| **Salinity** | *Surface* | 33.34 | 33.43 | 33.47 | 33.57 | 33.58 | 33.58 | 33.52 | 33.45 | 33.42 | 33.42 | 33.44 | 33.51 |
| | *Bottom* | 33.44 | 33.46 | 33.60 | 33.76 | 33.65 | 33.64 | 33.44 | 33.43 | 33.43 | 33.39 | 33.42 | 33.49 |
| | Δ | -0.10 | -0.03 | -0.13 | -0.19 | -0.07 | -0.06 | 0.08 | 0.02 | -0.01 | 0.03 | 0.02 | 0.02 |
| **DO** | *Surface* | 8.0 | 8.9 | 9.5 | 10.2 | 9.6 | 8.1 | 8.0 | 8.6 | 8.7 | 7.9 | 8.0 | 7.7 |
| | *Bottom* | 6.9 | 7.0 | 6.0 | 3.2 | 5.5 | 5.4 | 8.1 | 7.8 | 8.1 | 7.9 | 7.9 | 7.5 |
| | Δ | 1.1 | 1.9 | 3.5 | 7.0 | 4.0 | 2.7 | -0.1 | 0.8 | 0.6 | -0.0 | 0.1 | 0.2 |
| **pH** | *Surface* | 8.2 | 8.2 | 8.3 | 8.3 | 8.4 | 8.3 | 8.2 | 8.2 | 8.2 | 8.1 | 8.1 | 8.1 |
| | *Bottom* | 8.1 | 8.1 | 8.0 | 7.7 | 7.9 | 7.9 | 8.2 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 |
| | Δ | 0.1 | 0.1 | 0.3 | 0.6 | 0.5 | 0.4 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| **XMS** | *Surface* | 67 | 74 | 71 | 66 | 71 | 71 | 80 | 80 | 80 | 85 | 79 | 80 |
| | *Bottom* | 77 | 81 | 77 | 73 | 79 | 79 | 85 | 79 | 81 | 85 | 80 | 81 |
| | Δ | -10 | -7 | -6 | -7 | -8 | -8 | -5 | 1 | -1 | -0 | -1 | -1 |
| **Chl a** | *Surface* | 4.2 | 9.5 | 4.9 | 17.6 | 6.3 | 7.1 | 2.4 | 3.0 | 2.3 | 2.6 | 2.3 | 2.5 |
| | *Bottom* | 6.2 | 10.5 | 12.8 | 9.2 | 12.0 | 8.9 | 2.8 | 12.4 | 5.1 | 3.6 | 5.0 | 3.7 |
| | Δ | -2.0 | -0.9 | -7.9 | 8.4 | -5.7 | -1.8 | -0.5 | -9.4 | -2.8 | -1.0 | -2.7 | -1.2 |

# Appendix B

# Supporting Data

# 2006 SBOO Stations

# Microbiology

## Appendix B.1

Bacteriological densities for SBOO biweekly kelp station water quality samples with total coliform concentrations ≥1000 CFU/100 mL collected during 2006. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Fecal to total coliform ratio=F:T. Sample depth is in meters. Monthly kelp station samples are included in Appendices A.2 and A.3.

| Station | Month | Sample depth | Total | Fecal | Entero | F:T |
|---|---|---|---|---|---|---|
| I39 | Jan | 12 | 1400 | 320 | 30 | 0.23 |
| I39 | Feb | 12 | 2000 | 130 | 22 | 0.07 |
| I25 | Mar | 2 | 1400 | 120 | 2 | 0.09 |
| I25 | | 6 | 5400 | 200 | 2 | 0.04 |
| I26 | Apr | 2 | 7800 | 620 | 28 | 0.08 |
| I25 | Jun | 6 | 1100 | 56 | 20 | 0.05 |
| I26 | | 6 | 1800 | 10 | 30 | 0.01 |
| I39 | Dec | 2 | 1100 | 16 | 2 | 0.01 |
| I39 | | 12 | 1400 | 28 | 4 | 0.02 |

## Appendix B.2

Bacteriological densities for monthly water quality samples with total coliform concentrations ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥0.1 collected from SBOO offshore stations during 2006. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Individual values for corresponding total suspended solids (TSS) and 2 m oil and grease (O&G) samples are listed. The minimum levels of detection are 1.4 mg/L. (O&G) and 1.6 mg/L (TSS). Sample depth is in meters.

| | Station | Month | Sample depth | Total | Fecal | Entero | F:T | O&G | TSS |
|---|---|---|---|---|---|---|---|---|---|
| *9 to 19-m Contours* | | | | | | | | | |
| | I10 | Jan | 12 | 1000 | 160 | 6 | 0.16 | | 5.1 |
| | I37 | Feb | 6 | 1300 | 320 | 10 | 0.25 | | 3.9 |
| | I18 | Mar | 12 | 1300 | 320 | 2 | 0.25 | | 7.3 |
| | I23 | | 18 | 1900 | 400 | 26 | 0.21 | | 3.3 |
| | I32 | | 6 | 1800 | 320 | 300 | 0.18 | | 7.2 |
| | I40 | | 2 | 16000 | 2200 | 52 | 0.14 | <1.4 | 15.5 |
| | I19 | Apr | 2 | 16000 | 1600 | 440 | 0.10 | <1.4 | 7.5 |
| | I23 | | 12 | 6800 | 2000 | 46 | 0.29 | | 3.3 |
| | I39 | | 12 | 1000 | 200 | 16 | 0.20 | | 10.2 |
| | I40 | | 2 | 16000 | 11000 | 1800 | 0.69 | <1.4 | 19.3 |
| | I40 | | 9 | 16000 | 2400 | 1300 | 0.15 | | 27.2 |
| | I10 | May | 12 | 16000 | 1600 | 100 | 0.10 | | 2.3 |
| | I11 | | 6 | 4800 | 2000 | 160 | 0.42 | | 8.4 |
| | I5 | Jun | 2 | 16000 | 1600 | 240 | 0.10 | <1.4 | 5.6 |
| | I11 | | 2 | 16000 | 1800 | 140 | 0.11 | <1.4 | 5.3 |
| | I39 | Sep | 18 | 1000 | 170 | 68 | 0.17 | | 4.4 |
| | I5 | Oct | 2 | 16000 | 1600 | 980 | 0.10 | <1.4 | 2.5 |
| *28 and 38-m Contours* | | | | | | | | | |
| | I9 | Jan | 18 | 12000 | 1600 | 340 | 0.13 | | 3.0 |
| | I9 | | 27 | 16000 | 3800 | 420 | 0.24 | | 4.0 |
| | I21 | Apr | 37 | 1000 | 300 | 26 | 0.30 | | 4.1 |
| | I30 | Jul | 18 | 3400 | 380 | 460 | 0.11 | | 6.6 |
| *55-m Contour* | | | | | | | | | |
| | I3 | Jan | 18 | 1500 | 620 | 36 | 0.41 | | 3.8 |
| | I20 | Apr | 55 | 1300 | 180 | 40 | 0.14 | | 4.2 |
| *Outfall* | | | | | | | | | |
| | I12 | Jan | 2 | 16000 | 12000 | 5800 | 0.75 | <1.4 | 3.3 |
| | I12 | | 18 | 7600 | 1000 | 86 | 0.13 | | 2.4 |
| | I16 | | 18 | 16000 | 12000 | 1600 | 0.75 | | 2.4 |
| | I16 | | 27 | 9000 | 1200 | 160 | 0.13 | | 2.4 |
| | I14 | Mar | 27 | 4200 | 460 | 18 | 0.11 | | 3.3 |
| | I16 | | 18 | 2600 | 500 | 38 | 0.19 | | 2.6 |
| | I16 | | 27 | 1000 | 140 | 2 | 0.14 | | 2.7 |
| | I12 | May | 27 | 1100 | 240 | 24 | 0.22 | | 1.9 |
| | I12 | Jul | 18 | 16000 | 13000 | 4200 | 0.81 | | 8.9 |
| | I16 | | 18 | 15000 | 2000 | 280 | 0.13 | | 8.7 |
| | I12 | Aug | 18 | 5400 | 1200 | 360 | 0.22 | | 4.8 |
| | I16 | | 18 | 4600 | 1100 | 220 | 0.24 | | 3.0 |
| | I12 | Sep | 27 | 9800 | 3600 | 680 | 0.37 | | 4.9 |
| | I12 | Oct | 18 | 16000 | 4600 | 900 | 0.29 | | 2.7 |
| | I12 | | 27 | 1600 | 480 | 60 | 0.30 | | 4.9 |

## Appendix B.3

Bacteriological densities for monthly water quality samples with total coliform concentrations ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) <0.1 collected from SBOO offshore stations during 2006. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Individual values for corresponding total suspended solids (TSS) and 2 m oil and grease (O&G) samples are listed. The minimum levels of detection are 1.4 mg/L. (O&G) and 1.6 mg/L (TSS). Sample depth is in meters.

| Station | Month | Sample depth | Total | Fecal | Entero | F:T | O&G | TSS |
|---|---|---|---|---|---|---|---|---|
| *9 to 19-m Contours* | | | | | | | | |
| I19 | Feb | 2 | 2400 | 82 | 12 | 0.03 | <1.4 | 18.8 |
| I19 | | 6 | 1600 | 120 | 20 | 0.08 | | 12.1 |
| I19 | | 11 | 1800 | 100 | 14 | 0.06 | | 20.6 |
| I24 | | 11 | 1200 | 86 | 6 | 0.07 | | 8.9 |
| I26 | | 6 | 1100 | 78 | 12 | 0.07 | | 9.0 |
| I26 | | 9 | 1100 | 72 | 8 | 0.07 | | 10.4 |
| I40 | | 2 | 1100 | 54 | 2 | 0.05 | <1.4 | 5.5 |
| I40 | | 6 | 1100 | 80 | 12 | 0.07 | | 6.0 |
| I40 | | 9 | 1100 | 74 | 12 | 0.07 | | 7.2 |
| I5 | Mar | 6 | 2000 | 100 | 4 | 0.05 | | 6.5 |
| I19 | | 2 | 1600 | 66 | 2 | 0.04 | <1.4 | 13.9 |
| I19 | | 6 | 1700 | 48 | 2 | 0.03 | | 12.4 |
| I19 | | 11 | 2000 | 68 | 2 | 0.03 | | 12.4 |
| I40 | | 6 | 16000 | 1200 | 40 | 0.08 | | 16.1 |
| I40 | | 9 | 3400 | 140 | 4 | 0.04 | | 13.7 |
| I32 | | 2 | 8000 | 440 | 340 | 0.06 | <1.4 | 7.8 |
| I32 | | 9 | 2400 | 180 | 160 | 0.08 | | 10.0 |
| I19 | Apr | 6 | 16000 | 1200 | 580 | 0.08 | | 7.7 |
| I19 | | 11 | 16000 | 1200 | 1000 | 0.08 | | 26.8 |
| I24 | | 2 | 16000 | 1100 | 150 | 0.07 | <1.4 | 6.0 |
| I24 | | 6 | 4000 | 110 | 36 | 0.03 | | 7.7 |
| I24 | | 11 | 16000 | 260 | 76 | 0.02 | | 74.3 |
| I39 | | 2 | 2600 | 74 | 26 | 0.03 | <1.4 | 10.7 |
| I40 | | 6 | 16000 | 840 | 260 | 0.05 | | 18 |
| I5 | Jun | 6 | 10000 | 420 | 30 | 0.04 | | 3.5 |
| I10 | | 12 | 3000 | 220 | 50 | 0.07 | | 3.2 |
| I11 | | 6 | 3400 | 180 | 40 | 0.05 | | 4.8 |
| I5 | Sep | 11 | 2600 | 62 | 10 | 0.02 | | 8.9 |
| I5 | Oct | 6 | 16000 | 640 | 220 | 0.04 | | 3.8 |
| I5 | | 11 | 7400 | 100 | 38 | 0.01 | | 5.8 |
| I10 | | 12 | 1200 | 100 | 80 | 0.08 | | 4.0 |
| I5 | Dec | 6 | 1800 | 48 | 2 | 0.03 | | 10.8 |
| I5 | | 11 | 1300 | 86 | 8 | 0.07 | | 7.6 |
| *28-m Contour* | | | | | | | | |
| I9 | Nov | 18 | 1600 | 8 | 2 | 0.01 | | 5.9 |
| I9 | | 18 | 1400 | 4 | 2 | 0.00 | | 5.4 |
| *Outfall* | | | | | | | | |
| I12 | Mar | 18 | 9000 | 700 | 72 | 0.08 | | 2.5 |
| I12 | Apr | 18 | 7400 | 8 | 2 | 0.00 | | 2.9 |
| I12 | May | 18 | 6400 | 56 | 110 | 0.01 | | 2.0 |
| I12 | Nov | 18 | 16000 | 22 | 4 | 0.00 | | 6.9 |
| I14 | | 18 | 2000 | 110 | 8 | 0.06 | | 6.5 |
| I16 | | 18 | 16000 | 340 | 54 | 0.02 | | 6.2 |
| I12 | Dec | 18 | 15000 | 260 | 2 | 0.02 | | 5.5 |
| I12 | | 27 | 1600 | 30 | 2 | 0.02 | | 5.9 |

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# Appendix C

# Supporting Data

# 2006 SBOO Stations

# Sediment Characteristics

## Appendix C.1

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

| Parameter | Units | MDL January | MDL 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 | MDL 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 C.1 *continued*.

| Parameter | Units | MDL January | MDL 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 |

| Parameter | Units | MDL January | MDL 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 C.2

SBOO sediment statistics January 2006.

| Station | Mean (mm) | Mean (phi) | SD (phi) | Median (phi) | Skewness (phi) | Kurtosis (phi) | Coarse (%) | Sand (%) | Silt (%) | Clay (%) | Sediment observations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *19 m stations* | | | | | | | | | | | |
| I35 | 0.065 | 4.0 | 1.4 | 3.7 | 0.3 | 1.2 | 0.0 | 60.2 | 37.4 | 2.4 | Fine sand, silt, tube debris |
| I34 | 0.702 | 0.5 | 1.3 | 0.7 | -0.1 | 0.7 | 35.2 | 62.9 | 1.8 | 0.0 | Shell hash, cobble, coarse red relict sand, coarse sand |
| I31 | 0.131 | 2.9 | 0.7 | 3.0 | -0.2 | 2.0 | 0.3 | 93.1 | 6.6 | 0.0 | Fine sand |
| I23 | 0.112 | 3.2 | 0.7 | 3.1 | 0.2 | 5.7 | 0.3 | 91.1 | 8.5 | 0.1 | Shell hash, fine sand, silt |
| I18 | 0.111 | 3.2 | 0.6 | 3.0 | 0.3 | 3.3 | 0.3 | 91.5 | 8.2 | 0.0 | Fine sand |
| I10 | 0.116 | 3.1 | 0.7 | 3.0 | 0.2 | 4.3 | 0.3 | 91.5 | 8.1 | 0.0 | Shell hash, fine sand, silt |
| I4 | 0.132 | 2.9 | 0.9 | 3.0 | -0.1 | 1.4 | 0.3 | 92.7 | 7.0 | 0.0 | Fine sand, silt |
| *28 m stations* | | | | | | | | | | | |
| I33 | 0.128 | 3.0 | 1.0 | 3.0 | 0.1 | 28.8 | 0.8 | 88.1 | 10.5 | 0.7 | Shell hash, fine sand, silt |
| I30 | 0.110 | 3.2 | 1.0 | 3.2 | -0.2 | 1.6 | 0.8 | 86.4 | 12.5 | 0.2 | Fine sand, silt |
| I27 | 0.116 | 3.1 | 0.8 | 3.1 | 0.0 | 1.5 | 0.3 | 88.7 | 11.0 | 0.0 | Fine sand, silt |
| I22 | 0.201 | 2.3 | 1.1 | 2.5 | -0.2 | 1.1 | 0.9 | 92.9 | 6.2 | 0.0 | Fine sand, silt |
| I16 | 0.144 | 2.8 | 1.1 | 2.8 | 0.1 | 1.5 | 0.3 | 90.4 | 9.0 | 0.2 | Shell hash, fine sand, organic debris |
| I15 | 0.215 | 2.2 | 1.2 | 2.3 | -0.1 | 1.0 | 1.9 | 91.0 | 7.1 | 0.0 | Fine sand |
| I14 | 0.116 | 3.1 | 1.2 | 3.1 | 0.0 | 1.8 | 0.3 | 85.5 | 13.5 | 0.8 | Fine sand, silt |
| I12 | 0.386 | 1.4 | 0.8 | 1.4 | 0.0 | 0.9 | 4.8 | 95.1 | 0.1 | 0.0 | Shell hash, sand, fine sand |
| I9 | 0.089 | 3.5 | 1.1 | 3.2 | 0.5 | 2.4 | 0.3 | 78.1 | 20.2 | 1.4 | Fine sand, silt, tube debris |
| I6 | 0.484 | 1.0 | 0.8 | 1.0 | 0.2 | 1.0 | 7.4 | 92.6 | 0.0 | 0.0 | Shell hash, red relict sand |
| I3 | 0.412 | 1.3 | 0.8 | 1.3 | 0.0 | 0.9 | 5.7 | 94.3 | 0.0 | 0.0 | Fine sand |
| I2 | 0.343 | 1.5 | 0.8 | 1.6 | -0.2 | 0.9 | 4.3 | 95.6 | 0.0 | 0.0 | Fine sand |
| *38 m stations* | | | | | | | | | | | |
| I29 | 0.078 | 3.7 | 1.2 | 3.5 | 0.3 | 1.7 | 0.2 | 69.3 | 28.9 | 1.6 | Fine sand, silt, organic debris |
| I21 | 0.606 | 0.7 | 0.6 | 0.7 | 0.2 | 1.1 | 11.1 | 88.9 | 0.0 | 0.0 | Shell hash, fine and coarse red relict sand |
| I13 | 0.606 | 0.7 | 0.6 | 0.7 | 0.2 | 1.1 | 10.7 | 89.3 | 0.0 | 0.0 | Shell hash, coarse and fine red relict sand |
| I8 | 0.441 | 1.2 | 0.8 | 1.2 | 0.1 | 0.9 | 6.1 | 93.9 | 0.0 | 0.0 | Fine sand |
| *55 m stations* | | | | | | | | | | | |
| I28 | 0.110 | 3.2 | 2.4 | 3.2 | 0.1 | 1.2 | 5.5 | 63.7 | 27.8 | 3.0 | Coarse black sand, silt |
| I20 | 0.179 | 2.5 | 2.6 | 1.4 | 0.6 | 0.8 | 8.4 | 67.0 | 22.6 | 2.1 | Shell hash, coarse red relict sand |
| I7 | 0.561 | 0.8 | 0.7 | 0.8 | 0.2 | 1.1 | 9.4 | 90.5 | 0.0 | 0.0 | Red relict sand |
| I1 | 0.132 | 2.9 | 0.9 | 2.9 | 0.1 | 2.5 | 0.0 | 91.7 | 8.1 | 0.3 | Shell hash, fine sand |

## Appendix C.2 *continued*

SBOO sediment statistics July 2006.

| Station | Mean (mm) | Mean (phi) | SD (phi) | Median (phi) | Skewness (phi) | Kurtosis (phi) | Coarse (%) | Sand (%) | Silt (%) | Clay (%) | Sediment observations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *19 m stations* | | | | | | | | | | | |
| I35 | 0.062 | 4.0 | 1.5 | 3.7 | 0.4 | 1.1 | 0.0 | 58.8 | 38.4 | 2.8 | Fine sand, silt, organic debris |
| I34 | 0.319 | 1.7 | 0.9 | 1.7 | -0.2 | 0.9 | 4.4 | 95.6 | 0.0 | 0.0 | Sand, shell hash |
| I31 | 0.117 | 3.1 | 0.5 | 3.0 | 0.3 | 2.0 | 0.0 | 91.6 | 8.4 | 0.1 | Fine sand, silt |
| I23 | 0.801 | 0.3 | 1.5 | 0.4 | 0.1 | 1.1 | 37.7 | 55.6 | 6.7 | 0.0 | Coarse sand, shell hash, fine sand, silt |
| I18 | 0.111 | 3.2 | 0.7 | 3.1 | 0.3 | 1.8 | 0.0 | 88.4 | 11.4 | 0.2 | Fine sand, silt |
| I10 | 0.119 | 3.1 | 0.6 | 3.0 | 0.3 | 2.1 | 0.0 | 91.4 | 8.5 | 0.0 | Fine sand, silt |
| I4 | 0.137 | 2.9 | 0.8 | 2.9 | 0.0 | 1.8 | 0.0 | 91.7 | 8.3 | 0.1 | Sand, fine sand, silt |
| *28 m stations* | | | | | | | | | | | |
| I33 | 0.119 | 3.1 | 1.1 | 2.9 | 0.4 | 1.7 | 0.0 | 85.0 | 13.9 | 1.1 | Fine sand, silt, organic debris |
| I30 | 0.093 | 3.4 | 1.0 | 3.4 | 0.3 | 1.7 | 0.0 | 81.2 | 17.7 | 1.1 | Fine sand, silt |
| I27 | 0.102 | 3.3 | 0.7 | 3.2 | 0.3 | 1.3 | 0.0 | 87.3 | 12.5 | 0.2 | Fine sand, silt |
| I22 | 0.111 | 3.2 | 1.0 | 3.1 | 0.3 | 2.0 | 0.0 | 85.3 | 14.2 | 0.5 | Fine sand, silt |
| I16 | 0.176 | 2.5 | 0.9 | 2.6 | 0.0 | 1.6 | 0.0 | 92.8 | 7.1 | 0.1 | Sand, fine sand, silt |
| I15 | 0.431 | 1.2 | 0.8 | 1.2 | 0.0 | 0.9 | 5.5 | 94.0 | 0.5 | 0.0 | Sand, fine sand, silt |
| I14 | 0.106 | 3.2 | 0.8 | 3.1 | 0.4 | 2.0 | 0.0 | 85.9 | 13.5 | 0.5 | Fine sand, silt |
| I12 | 0.137 | 2.9 | 0.8 | 2.9 | 0.1 | 2.1 | 0.0 | 91.0 | 8.9 | 0.2 | Fine sand, silt, organic debris |
| I9 | 0.097 | 3.4 | 0.9 | 3.3 | 0.3 | 1.7 | 0.0 | 82.9 | 16.6 | 0.6 | Fine sand, silt, organic debris |
| I6 | 0.553 | 0.9 | 0.7 | 0.8 | 0.2 | 1.1 | 9.7 | 89.9 | 0.4 | 0.0 | Shell hash, fine red relict sand |
| I3 | 0.387 | 1.4 | 0.8 | 1.4 | -0.1 | 0.9 | 5.4 | 94.6 | 0.0 | 0.0 | Sand |
| I2 | 0.342 | 1.5 | 0.8 | 1.6 | -0.1 | 0.9 | 4.2 | 95.8 | 0.0 | 0.0 | Sand |
| *38 m stations* | | | | | | | | | | | |
| I29 | 0.082 | 3.6 | 1.1 | 3.5 | 0.3 | 1.5 | 0.0 | 70.6 | 27.8 | 1.6 | Coarse and fine sand, silt, organic debris |
| I21 | 0.611 | 0.7 | 0.6 | 0.6 | 0.2 | 1.1 | 10.5 | 89.5 | 0.0 | 0.0 | Relict red sand |
| I13 | 0.450 | 1.2 | 0.9 | 1.1 | 0.2 | 1.2 | 5.8 | 92.8 | 1.4 | 0.0 | Cobble, red relict sand, shell hash |
| I8 | 0.515 | 1.0 | 0.8 | 0.8 | 0.3 | 0.7 | 8.6 | 88.7 | 2.6 | 0.0 | Sand |
| *55 m stations* | | | | | | | | | | | |
| I28 | 0.058 | 4.1 | 1.7 | 3.7 | 0.4 | 1.1 | 2.2 | 59.2 | 35.5 | 3.2 | Coarse black sand, silt |
| I20 | 0.424 | 1.2 | 1.0 | 1.2 | 0.2 | 1.0 | 6.3 | 89.6 | 4.1 | 0.0 | Red relict sand, coarse sand, fine sand, silt |
| I7 | 0.539 | 0.9 | 0.9 | 0.8 | 0.3 | 1.2 | 11.3 | 86.5 | 2.2 | 0.0 | Relict red sand |
| I1 | 0.129 | 3.0 | 0.9 | 2.9 | 0.2 | 2.6 | 0.0 | 90.7 | 8.9 | 0.3 | Fine sand, silt |

# Appendix D

## Supporting Data

## 2006 SBOO Stations

## Demersal Fishes and Megabenthic Invertebrates

# Appendix D.1

Summary of demersal fish species captured during 2006 at SBOO 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** |
| CHRACHARHINIFORMES | | | | | | |
| Triakidae | | | | | | |
| *Mustelus henlei* | brown smoothhound | 1 | 0.7 | 61 | 61 | 61 |
| RAJIFORMES | | | | | | |
| Rhinobatidae | | | | | | |
| *Rhinobatos productus* | shovelnose guitarfish | 2 | 0.6 | 30 | 46 | 38 |
| Rajidae | | | | | | |
| *Raja inornata* | California skate | 6 | 3.5 | 26 | 56 | 43 |
| Gymnuridae | | | | | | |
| *Gymnura marmorata* | California butterfly ray | 2 | 2 | 31 | 31 | 31 |
| Myliobatitidae | | | | | | |
| *Myliobatis californica* | bat ray | 1 | 2.5 | 80 | 80 | 80 |
| CHIMAERIFORMIS | | | | | | |
| Chimaeridae | | | | | | |
| *Hydrolagus colliei* | spotted ratfish | 1 | 0.4 | 40 | 40 | 40 |
| CLUPEIFORMES | | | | | | |
| Engraulidae | | | | | | |
| *Engraulis mordax* | northern anchovy | 18 | 0.6 | 11 | 15 | 13 |
| AULOPIFORMES | | | | | | |
| Synodontidae | | | | | | |
| *Synodus lucioceps* | California lizardfish | 770 | 10.6 | 7 | 29 | 14 |
| OPHIDIIFORMES | | | | | | |
| Ophidiidae | | | | | | |
| *Chilara taylori* | spotted cusk-eel | 3 | 0.3 | 10 | 22 | 14 |
| *Ophidion scrippsae* | basketweave cusk-eel | 8 | 0.4 | 13 | 21 | 16 |
| BATRACHOIDIFORMES | | | | | | |
| Batrachoididae | | | | | | |
| *Porichthys myriaster* | specklefin midshipman | 15 | 1.3 | 8 | 26 | 15 |
| *Porichthys notatus* | plainfin midshipman | 17 | 1.2 | 5 | 26 | 12 |
| SYNGNATHIFORMIES | | | | | | |
| Syngnathidae | | | | | | |
| *Syngnathus californiensis* | kelp pipefish | 1 | 0.1 | 17 | 17 | 17 |
| SCORPAENIFORMES | | | | | | |
| Scorpaenidae | | | | | | |
| *Scorpaena guttata* | California scorpionfish | 21 | 8.6 | 14 | 30 | 22 |
| *Sebastes dallii* | calico rockfish | 13 | 0.8 | 5 | 7 | 6 |
| Hexagrammidae | | | | | | |
| *Zaniolepis latipinnis* | longspine combfish | 83 | 2.4 | 12 | 16 | 14 |
| Cottidae | | | | | | |
| *Chitonotus pugetensis* | roughback sculpin | 101 | 1.9 | 4 | 11 | 8 |
| *Icelinus quadriseriatus* | yellowchin sculpin | 208 | 1.7 | 3 | 8 | 6 |

## Appendix D.1 *continued*

| Taxon/Species | Common Name | N | BM | LENGTH Min | Max | Mean |
|---|---|---|---|---|---|---|
| Agonidae | | | | | | |
| *Odontopyxis trispinosa* | pygmy poacher | 10 | 0.6 | 5 | 9 | 7 |
| *Xeneretmus triacanthus* | bluespotted poacher | 1 | 0.1 | 7 | 7 | 7 |
| PERCIFORMES | | | | | | |
| Sciaenidae | | | | | | |
| *Genyonemus lineatus* | white croaker | 195 | 17.2 | 11 | 24 | 17 |
| *Seriphus politus* | queenfish | 28 | 1.3 | 11 | 16 | 14 |
| Embiotocidae | | | | | | |
| *Cymatogaster aggregata* | shiner perch | 16 | 0.7 | 9 | 13 | 10 |
| Stromateidae | | | | | | |
| *Peprilus simillimus* | Pacific pompano | 22 | 0.7 | 9 | 13 | 11 |
| PLEURONECTIFORMES | | | | | | |
| Paralichthyidae | | | | | | |
| *Citharichthys sordidus* | Pacific sanddab | 16 | 0.7 | 12 | 18 | 15 |
| *Citharichthys stigmaeus* | speckled sanddab | 2084 | 17.9 | 4 | 13 | 8 |
| *Citharichthys xanthostigma* | longfin sanddab | 197 | 5.5 | 4 | 20 | 11 |
| *Hippoglossina stomata* | bigmouth sole | 6 | 0.7 | 7 | 22 | 17 |
| *Paralichthys californicus* | California halibut | 14 | 7.9 | 23 | 44 | 31 |
| *Xystreurys liolepis* | fantail sole | 7 | 1.4 | 5 | 28 | 18 |
| Pleuronectidae | | | | | | |
| *Parophrys vetulus* | English sole | 54 | 6.2 | 10 | 26 | 18 |
| *Pleuronichthys decurrens* | curlfin sole | 1 | 0.1 | 6 | 6 | 6 |
| *Pleuronichthys guttulatus* | diamond turbot | 1 | 0.4 | 23 | 23 | 23 |
| *Pleuronichthys ritteri* | spotted turbot | 9 | 1.2 | 16 | 19 | 18 |
| *Pleuronichthys verticalis* | hornyhead turbot | 193 | 13.7 | 3 | 21 | 13 |
| Cynoglossidae | | | | | | |
| *Symphurus atricauda* | California tonguefish | 119 | 2.5 | 6 | 17 | 11 |

* Eschmeyer, W. N. and E.S. Herald. (1998). A Field Guide to Pacific Coast Fishes of North America. Houghton and Mifflin Company, New York. 336 p. Allen, M.J. 2005. The check list of trawl-caught fishes for Southern California from depths of 2–265 m. Southern California Research Project, Westminister, CA.

## Appendix D.2

List of megabenthic invertebrate taxa collected at SBOO stations SD15–SD21 during 2006 surveys. (N) = total number of individuals collected. Taxonomic arrangement from SCAMIT 2001.*

| Taxon/ Species | N |
|---|---|
| **MOLLUSCA** | |
| POLYPLACOPHORA | |
| NEOLORICATA | |
| Ischnochitonidae | |
| *Lepidozona scrobiculata* | 2 |
| GASTROPODA | |
| VETIGASTROPODA | |
| Turbinidae | |
| *Megastraea undosa* | 3 |
| NEOTAENIOGLOSSA | |
| Lamellariidae | |
| *Lamellaria diegoensis* | 1 |
| Bursidae | |
| *Crossata californica* | 4 |
| NEOGASTROPODA | |
| Muricidae | |
| *Pteropurpura festiva* | 2 |
| Buccinidae | |
| *Kelletia kelletii* | 14 |
| Turridae | |
| *Megasurcula carpenteriana* | 1 |
| CEPHALASPIDEA | |
| Philinidae | |
| *Philine auriformis* | 21 |
| NOTASPIDEA | |
| Pleurobranchaeidae | |
| *Pleurobranchaea californica* | 2 |
| NUDIBRANCHIA | |
| Dendronotidae | |
| *Dendronotus frondosus* | 1 |
| *Dendronotus* sp | 2 |
| *Dendronotus iris* | 1 |
| Arminidae | |
| *Armina califronica* | 1 |
| Flabellinidae | |
| *Flabellina iodinea* | 3 |
| *Flabellina pricei* | 1 |
| CEPHALOPODA | |
| TEUTHIDA | |
| Loliginidae | |
| *Loligo opalescens* | 1 |
| OCTOPODA | |
| Octopodidae | |
| *Octopus rubescens* | 6 |

## Appendix D.2 *continued*

| Taxon/ Species | N |
|---|---|
| **ANNELIDA** | |
| POLYCHAETA | |
| Phyllodocida | |
| Aphroditidae | |
| *Aphrodita armifera* | 1 |
| *Aphrodita* sp | 1 |
| HIRUDINEA | 1 |
| **ARTHROPODA** | |
| MALACOSTRACA | |
| STOMATOPODA | |
| Hemisquillidae | |
| *Hemisquilla californiensis* | 10 |
| ISOPODA | |
| Cymothoidae | |
| *Elthusa vulgaris* | 3 |
| Sphaeromatidae | |
| *Paracerceis cordata* | 1 |
| DECAPODA | |
| Penaeidae | |
| *Farfanteptenaeus californiensis* | 1 |
| Sicyoniidae | |
| *Sicyonia ingentis* | 2 |
| *Sicyonia penicicillata* | 1 |
| Hippolytidae | |
| *Heptacarpus stimpsoni* | 1 |
| Crangonidae | |
| *Crangon alaskensis* | 3 |
| *Crangon alba* | 6 |
| *Crangon nigromaculata* | 60 |
| Diogenidae | |
| *Paguristes bakeri* | 1 |
| *Paguristes turgidus* | 1 |
| Paguridae | |
| *Pagurus armatus* | 1 |
| *Pagurus spilocarpus* | 1 |
| Calappidae | |
| *Platymera gaudichaudii* | 7 |
| Leucosiidae | |
| *Randallia ornata* | 8 |

# Appendix D.2 *continued*

| Taxon/ Species | N |
|---|---|
| Majidae | 2 |
| Loxorhynchus grandis | 5 |
| *Loxorhynchus* sp | 1 |
| *Pyromaia tuberculata* | 6 |
| Parthenopidae | |
| *Heterocrypta occidentalis* | 13 |
| Cancridae | |
| *Cancer anthonyi* | 4 |
| *Cancer gracilis* | 17 |
| *Cancer jordani* | 1 |
| *Cancer* sp | 2 |
| **ECHINODERMATA** | |
| CRINOIDEA | |
| COMATULIDA | |
| Antedonidae | |
| *Florometra serratissima* | 1 |
| ASTEROIDEA | |
| PAXILLOSIDA | |
| Luidiidae | |
| *Luidia armata* | 2 |
| *Luidia foliolata* | 1 |
| Astropectinidae | |
| *Astropecten verrilli* | 511 |
| FORCIPULATIDA | |
| Asteriidae | |
| *Pisaster brevispinus* | 14 |
| OPHIUROIDEA | |
| OPHIURIDA | |
| Ophiotricidae | |
| *Ophiothrix spiculata* | 9 |
| ECHINOIDEA | |
| TEMNOPLEUROIDA | |
| Toxopneustidae | |
| *Lytechinus pictus* | 46 |
| CLYPEASTEROIDA | |
| Dendrasteridae | |
| *Dendraster terminalis* | 10 |

*[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 E

## Supporting Data

## 2006 SBOO Stations

## Bioaccumulation of Contaminants in Fish Tissues

## Appendix E.1

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

| Station | Rep | Species | N | min L | max L | avg L | min WT | max WT | avg WT |
|---|---|---|---|---|---|---|---|---|---|
| **April 2006** | | | | | | | | | |
| RF3 | 1 | Brown rockfish | 3 | 17 | 25 | 22 | 158 | 413 | 316 |
| RF3 | 2 | Brown rockfish | 3 | 18 | 26 | 22 | 158 | 600 | 329 |
| RF3 | 3 | Brown rockfish | 3 | 22 | 24 | 23 | 34 | 395 | 256 |
| RF4 | 1 | California scorpionfish | 3 | 23 | 26 | 24 | 422 | 548 | 466 |
| RF4 | 2 | California scorpionfish | 3 | 23 | 26 | 24 | 34 | 700 | 429 |
| RF4 | 3 | California scorpionfish | 3 | 25 | 28 | 26 | 526 | 700 | 599 |
| SD15 | 1 | Hornyhead turbot | 8 | 14 | 18 | 16 | 63 | 138 | 98 |
| SD16 | 1 | Hornyhead turbot | 8 | 12 | 19 | 15 | 50 | 217 | 99 |
| SD16 | 2 | Longfin sanddab | 15 | 12 | 16 | 14 | 35 | 70 | 48 |
| SD16 | 3 | English sole | 5 | 15 | 23 | 19 | 53 | 157 | 110 |
| SD17 | 1 | Hornyhead turbot | 6 | 17 | 19 | 18 | 123 | 189 | 157 |
| SD17 | 2 | Longfin sanddab | 8 | 13 | 18 | 17 | 46 | 114 | 92 |
| SD17 | 3 | English sole | 5 | 16 | 28 | 22 | 62 | 292 | 154 |
| SD18 | 1 | Hornyhead turbot | 7 | 16 | 19 | 17 | 105 | 194 | 136 |
| SD18 | 2 | English sole | 5 | 22 | 25 | 23 | 170 | 227 | 189 |
| SD18 | 3 | Longfin sanddab | 9 | 14 | 18 | 15 | 56 | 114 | 71 |
| SD19 | 1 | Hornyhead turbot | 8 | 14 | 22 | 17 | 74 | 247 | 127 |
| SD19 | 2 | English sole | 5 | 17 | 24 | 22 | 65 | 209 | 162 |
| SD19 | 3 | Longfin sanddab | 5 | 16 | 19 | 17 | 82 | 148 | 100 |
| SD20 | 1 | Hornyhead turbot | 7 | 14 | 22 | 18 | 74 | 245 | 139 |
| SD20 | 2 | English sole | 7 | 15 | 26 | 20 | 52 | 232 | 122 |
| SD20 | 3 | Longfin sanddab | 10 | 13 | 16 | 14 | 39 | 85 | 58 |
| SD21 | 1 | Longfin sanddab | 7 | 14 | 17 | 16 | 60 | 97 | 80 |
| SD21 | 2 | Hornyhead turbot | 13 | 13 | 18 | 15 | 65 | 128 | 94 |
| SD21 | 3 | English sole | 8 | 17 | 24 | 20 | 69 | 170 | 115 |
| **October 2006** | | | | | | | | | |
| RF3 | 1 | Mixed rockfish | 3 | 13 | 28 | 21 | 63 | 553 | 314 |
| RF3 | 2 | Mixed rockfish | 3 | 17 | 21 | 20 | 110 | 240 | 170 |
| RF3 | 3 | Brown rockfish | 3 | 17 | 28 | 21 | 151 | 585 | 299 |
| RF4 | 1 | Mixed rockfish | 3 | 20 | 22 | 21 | 223 | 315 | 265 |
| RF4 | 2 | Honeycomb rockfish | 3 | 14 | 18 | 17 | 138 | 173 | 157 |
| RF4 | 3 | Treefish | 3 | 25 | 28 | 27 | 478 | 650 | 540 |
| SD15 | 1 | Hornyhead turbot | 9 | 13 | 19 | 15 | 53 | 174 | 97 |
| SD15 | 2 | Pacific sanddab | 3 | 19 | 21 | 20 | 114 | 186 | 142 |
| SD15 | 3 | Hornyhead turbot | 7 | 16 | 20 | 18 | 93 | 182 | 139 |
| SD16 | 1 | Longfin sanddab | 7 | 12 | 15 | 14 | 35 | 80 | 57 |
| SD16 | 2 | Hornyhead turbot | 7 | 15 | 18 | 16 | 81 | 147 | 114 |
| SD16 | 3 | Hornyhead turbot | 6 | 15 | 21 | 17 | 97 | 230 | 136 |
| SD17 | 1 | California scorpionfish | 3 | 22 | 25 | 24 | 320 | 466 | 407 |
| SD17 | 2 | California scorpionfish | 3 | 18 | 24 | 21 | 174 | 413 | 321 |
| SD17 | 3 | Hornyhead turbot | 8 | 16 | 18 | 17 | 116 | 150 | 132 |
| SD18 | 1 | California scorpionfish | 3 | 21 | 24 | 22 | 312 | 420 | 358 |
| SD18 | 2 | Hornyhead turbot | 5 | 17 | 20 | 19 | 130 | 214 | 174 |
| SD18 | 3 | Hornyhead turbot | 8 | 15 | 19 | 17 | 97 | 180 | 124 |
| SD19 | 1 | Hornyhead turbot | 4 | 16 | 21 | 18 | 91 | 251 | 182 |
| SD19 | 2 | Hornyhead turbot | 12 | 14 | 16 | 15 | 69 | 114 | 88 |
| SD19 | 3 | Longfin sanddab | 4 | 16 | 17 | 17 | 82 | 125 | 102 |
| SD20 | 1 | Longfin sanddab | 6 | 14 | 17 | 15 | 49 | 95 | 70 |
| SD20 | 2 | Hornyhead turbot | 7 | 14 | 19 | 16 | 74 | 178 | 120 |
| SD20 | 3 | Hornyhead turbot | 7 | 14 | 18 | 16 | 64 | 159 | 115 |
| SD21 | 1 | Longfin sanddab | 5 | 13 | 18 | 15 | 51 | 131 | 84 |
| SD21 | 2 | Hornyhead turbot | 4 | 14 | 20 | 18 | 77 | 220 | 157 |
| SD21 | 3 | Hornyhead turbot | 6 | 14 | 18 | 16 | 73 | 166 | 109 |

## Appendix E.2

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

| Parameter | Units | Method Detection Limits | |
|---|---|---|---|
| | | Liver | Muscle |
| Lipids | %wt | 0.005 | 0.005 |
| Total Solids | %wt | 0.4 | 0.4 |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | |
| 1-methylnaphthalene | ug/kg | 100 | 30 |
| 1-methylphenanthrene | ug/kg | 100 | 30 |
| 2,3,5-trimethylnaphthalene | ug/kg | 100 | 30 |
| 2,6-dimethylnaphthalene | ug/kg | 100 | 30 |
| 2-methylnaphthalene | ug/kg | 100 | 30 |
| 3,4-benzo(B)fluoranthene | ug/kg | 100 | 30 |
| Acenaphthene | ug/kg | 100 | 30 |
| Acenaphthylene | ug/kg | 100 | 30 |
| Anthracene | ug/kg | 100 | 30 |
| Benzo[A]anthracene | ug/kg | 100 | 30 |
| Benzo[A]pyrene | ug/kg | 100 | 30 |
| Benzo[e]pyrene | ug/kg | 100 | 30 |
| Benzo[G,H,I]perylene | ug/kg | 100 | 30 |
| Benzo[K]fluoranthene | ug/kg | 100 | 30 |
| Biphenyl | ug/kg | 100 | 30 |
| Chrysene | ug/kg | 100 | 30 |
| Dibenzo(A,H)anthracene | ug/kg | 100 | 30 |
| Fluoranthene | ug/kg | 100 | 30 |
| Fluorene | ug/kg | 100 | 30 |
| Indeno(1,2,3-CD)pyrene | ug/kg | 100 | 30 |
| Naphthalene | ug/kg | 100 | 30 |
| Perylene | ug/kg | 100 | 30 |
| Phenanthrene | ug/kg | 100 | 30 |
| Pyrene | ug/kg | 100 | 30 |
| ***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 |

## Appendix E.2 *continued*

| Parameter | Units | Method Detection Limits | |
|---|---|---|---|
| | | Liver | Muscle |
| 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 |
| ***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 | 1.33, 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 |

## Appendix E.2 *continued*

| Parameter | Units | Method Detection Limits: Liver | Muscle |
|---|---|---|---|
| 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 E.3

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

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | p,p-DDE | 2.4 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 105 | 0.1 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 118 | 0.2 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 126 | 0.1 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 128 | 0.2 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 138 | 0.4 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 153/168 | 0.5 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 156 | 0.2 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 157 | 0.2 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 158 | 0.1 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 167 | 0.2 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 170 | 0.3 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 177 | 0.2 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 180 | 0.3 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 183 | 0.2 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 187 | 0.3 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 189 | 0.3 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 194 | 0.4 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 201 | 0.3 | ug/kg |
| 2006-2 | RF3 | 1 | Brown rockfish | Muscle | PCB 206 | 0.3 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | p,p-DDD | 0.3 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | p,p-DDE | 2.6 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | p,p-DDT | 0.3 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | PCB 118 | 0.1 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | PCB 138 | 0.2 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | PCB 153/168 | 0.4 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | PCB 180 | 0.2 | ug/kg |
| 2006-2 | RF3 | 2 | Brown rockfish | Muscle | PCB 187 | 0.1 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | p,p-DDD | 0.1 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | p,p-DDE | 2.5 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | PCB 118 | 0.1 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | PCB 138 | 0.2 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | PCB 149 | 0.1 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | PCB 153/168 | 0.3 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | PCB 180 | 0.1 | ug/kg |
| 2006-2 | RF3 | 3 | Brown rockfish | Muscle | PCB 187 | 0.1 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | Alpha (cis) Chlordane | 3.1 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | BHC, Alpha isomer | 2.4 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | BHC, Beta isomer | 9.7 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | BHC, Delta isomer | 3.9 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | BHC, Gamma isomer | 3 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | Gamma (trans) Chlordane | 4.1 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | Heptachlor | 1.3 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | Heptachlor epoxide | 6.4 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | p,p-DDD | 2.6 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | p,p-DDE | 5.6 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | p,p-DDT | 1 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | PCB 118 | 0.1 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | PCB 138 | 0.1 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | PCB 153/168 | 0.2 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | PCB 180 | 0.1 | ug/kg |
| 2006-2 | RF4 | 1 | California scorpionfish | Muscle | PCB 187 | 0.1 | ug/kg |
| 2006-2 | RF4 | 2 | California scorpionfish | Muscle | p,p-DDE | 3.55 | ug/kg |
| 2006-2 | RF4 | 2 | California scorpionfish | Muscle | PCB 118 | 0.2 | ug/kg |
| 2006-2 | RF4 | 2 | California scorpionfish | Muscle | PCB 138 | 0.2 | ug/kg |
| 2006-2 | RF4 | 2 | California scorpionfish | Muscle | PCB 153/168 | 0.35 | ug/kg |
| 2006-2 | RF4 | 2 | California scorpionfish | Muscle | PCB 180 | 0.2 | ug/kg |
| 2006-2 | RF4 | 2 | California scorpionfish | Muscle | PCB 187 | 0.1 | ug/kg |
| 2006-2 | RF4 | 3 | California scorpionfish | Muscle | p,p-DDE | 4.2 | ug/kg |
| 2006-2 | RF4 | 3 | California scorpionfish | Muscle | PCB 118 | 0.1 | ug/kg |
| 2006-2 | RF4 | 3 | California scorpionfish | Muscle | PCB 138 | 0.2 | ug/kg |
| 2006-2 | RF4 | 3 | California scorpionfish | Muscle | PCB 153/168 | 0.3 | ug/kg |
| 2006-2 | RF4 | 3 | California scorpionfish | Muscle | PCB 180 | 0.2 | ug/kg |
| 2006-2 | RF4 | 3 | California scorpionfish | Muscle | PCB 187 | 0.2 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | o,p-DDE | 1.5 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | p,p-DDD | 2.4 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | p,p-DDE | 73 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 2.6 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | p,p-DDT | 1.5 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 101 | 2.2 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 105 | 0.7 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 118 | 3.1 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 138 | 4 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 149 | 1.5 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 7 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 170 | 1.3 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 180 | 4.4 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 183 | 1 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 187 | 3.5 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 201 | 1.7 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 28 | 0.3 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 52 | 0.7 | ug/kg |
| 2006-2 | SD15 | 1 | Hornyhead turbot | Liver | PCB 99 | 2.3 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | p,p-DDD | 1.3 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | p,p-DDE | 58 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 3.7 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 101 | 1 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 118 | 1.5 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 138 | 2.5 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 149 | 0.9 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 3.7 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 170 | 1 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 180 | 2.3 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 183 | 0.8 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 187 | 2 | ug/kg |
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 201 | 0.9 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD16 | 1 | Hornyhead turbot | Liver | PCB 99 | 1.4 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 4.8 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | Cis Nonachlor | 4.1 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | Gamma (trans) Chlordane | 1.3 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | o,p-DDD | 1.5 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | o,p-DDE | 8.4 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | o,p-DDT | 1.6 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | p,p-DDD | 7.8 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | p,p-DDE | 680 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | p,-p-DDMU | 18 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | p,p-DDT | 11 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 101 | 5.9 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 105 | 4.6 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 110 | 3.4 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 118 | 19 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 123 | 2.2 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 128 | 5.7 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 138 | 35 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 149 | 5.9 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 151 | 5.8 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 153/168 | 55 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 156 | 4.3 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 157 | 1 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 158 | 2.5 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 167 | 2.1 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 170 | 11 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 177 | 5.7 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 180 | 26 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 183 | 7.3 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 187 | 26 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 201 | 8.1 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 206 | 2.8 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 28 | 0.7 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 49 | 0.7 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 66 | 2.3 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 70 | 1 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 74 | 1.7 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 87 | 1 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | PCB 99 | 13 | ug/kg |
| 2006-2 | SD16 | 2 | Longfin sanddab | Liver | Trans Nonachlor | 8.5 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | o,p-DDE | 1.7 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | p,p-DDD | 1.7 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | p,p-DDE | 62 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | p,-p-DDMU | 2.1 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 101 | 4 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 105 | 0.7 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 110 | 2.5 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 118 | 3.6 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 123 | 0.5 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 138 | 5.1 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 149 | 4 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 151 | 1.5 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 153/168 | 9.7 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 158 | 0.5 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 170 | 2.2 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 177 | 1.7 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 180 | 5.3 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 183 | 1.3 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 187 | 5.9 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 194 | 2.3 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 201 | 3 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 206 | 1.2 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 66 | 0.6 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 70 | 0.6 | ug/kg |
| 2006-2 | SD16 | 3 | English sole | Liver | PCB 99 | 2.8 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | Alpha (cis) Chlordane | 2.3 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | o,p-DDE | 3.2 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | p,p-DDD | 2.6 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | p,p-DDE | 110 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 5.6 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 101 | 2.5 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 105 | 1.1 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 110 | 1 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 118 | 3.4 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 123 | 0.5 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 128 | 0.7 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 138 | 5 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 149 | 1.7 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 8.4 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 170 | 1.9 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 177 | 0.7 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 180 | 4.6 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 183 | 1.2 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 187 | 3.4 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 194 | 1.4 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 201 | 1.2 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 206 | 0.8 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 28 | 0.4 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 49 | 0.8 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 52 | 0.8 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 66 | 1.1 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 74 | 0.6 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | PCB 99 | 2.5 | ug/kg |
| 2006-2 | SD17 | 1 | Hornyhead turbot | Liver | Trans Nonachlor | 3.1 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 5.7 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | Cis Nonachlor | 3.3 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | o,p-DDD | 1.5 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | o,p-DDE | 11 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | o,p-DDT | 1.4 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | p,p-DDD | 10 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | p,p-DDE | 700 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | p,-p-DDMU | 22 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | p,p-DDT | 7.8 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 101 | 18 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 105 | 8.6 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 110 | 15 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 118 | 33 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 119 | 1 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 123 | 3.9 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 128 | 10 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 138 | 51 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 149 | 15 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 151 | 9.9 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 153/168 | 78 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 156 | 5.6 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 157 | 1.6 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 158 | 4.5 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 167 | 3.6 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 170 | 17 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 177 | 8.3 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 180 | 39 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 183 | 11 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 187 | 34 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 194 | 12 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 201 | 11 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 206 | 5 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 28 | 1.4 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 49 | 3.1 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 52 | 5.2 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 66 | 4.3 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 70 | 2.8 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 74 | 2.5 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 87 | 4.1 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | PCB 99 | 25 | ug/kg |
| 2006-2 | SD17 | 2 | Longfin sanddab | Liver | Trans Nonachlor | 7.2 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | o,p-DDE | 2.5 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | p,p-DDE | 75 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | p,-p-DDMU | 2.3 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 101 | 2.2 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 105 | 0.7 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 110 | 1.3 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 118 | 2.6 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 138 | 4.5 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 149 | 2.2 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 151 | 1.2 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 153/168 | 7.9 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 158 | 0.4 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 170 | 2 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 177 | 1.7 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 180 | 4.4 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 183 | 1.3 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 187 | 4.5 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 194 | 1.9 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 201 | 1.7 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 206 | 0.7 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 49 | 0.5 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 52 | 0.6 | ug/kg |
| 2006-2 | SD17 | 3 | English sole | Liver | PCB 99 | 1.7 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | o,p-DDE | 1.95 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | p,p-DDD | 3.6 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | p,p-DDE | 160 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 5.65 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | p,p-DDT | 1.9 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 101 | 2.2 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 105 | 1 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 110 | 0.7 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 118 | 3.3 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 128 | 1 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 138 | 6.25 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 149 | 1.55 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 151 | 0.9 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 9.9 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 158 | 0.65 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 170 | 2.15 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 177 | 0.75 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 180 | 6.35 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 183 | 1.85 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 187 | 4.55 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 194 | 2.15 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 201 | 1.55 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 206 | 0.95 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 49 | 0.5 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 52 | 0.55 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 66 | 0.65 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 74 | 0.4 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | PCB 99 | 2.7 | ug/kg |
| 2006-2 | SD18 | 1 | Hornyhead turbot | Liver | Trans Nonachlor | 2.2 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | o,p-DDE | 5.1 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | p,p-DDD | 1.8 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | p,p-DDE | 120 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | p,-p-DDMU | 5.7 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 101 | 3.3 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 105 | 1.1 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 110 | 2.3 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 118 | 3.8 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 128 | 0.9 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 138 | 4.7 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 149 | 2.6 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 151 | 1.2 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 153/168 | 7.9 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 158 | 0.4 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 167 | 0.4 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 170 | 1.6 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 177 | 1 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 180 | 3.1 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 183 | 1 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 187 | 3.8 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 194 | 1.1 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 201 | 1.1 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 206 | 0.6 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 28 | 0.5 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 49 | 0.9 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 52 | 0.6 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 66 | 1.3 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 70 | 0.9 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 74 | 0.6 | ug/kg |
| 2006-2 | SD18 | 2 | English sole | Liver | PCB 99 | 2.8 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 4.1 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | Cis Nonachlor | 3.9 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | o,p-DDD | 2 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | o,p-DDE | 9 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | p,p-DDD | 9.2 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | p,p-DDE | 1100 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | p,-p-DDMU | 18 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | p,p-DDT | 8.6 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 101 | 18 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 105 | 12 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 110 | 15 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 118 | 42 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 119 | 1.1 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 123 | 3.6 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 128 | 10 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 138 | 59 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 149 | 12 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 151 | 11 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 153/168 | 94 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 156 | 7.2 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 157 | 1.6 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 158 | 6.6 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 167 | 3.4 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 170 | 17 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 177 | 7.9 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 180 | 41 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 183 | 11 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 187 | 35 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 194 | 11 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 201 | 11 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 206 | 3.9 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 28 | 1.1 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 49 | 1.7 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 52 | 4.8 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 66 | 4 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 70 | 1.7 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 74 | 3.1 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 87 | 4.2 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | PCB 99 | 26 | ug/kg |
| 2006-2 | SD18 | 3 | Longfin sanddab | Liver | Trans Nonachlor | 8 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | p,p-DDD | 1.95 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | p,p-DDE | 64 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 2.9 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 101 | 1.35 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 110 | 0.5 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 118 | 1.7 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 138 | 2.65 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 149 | 1 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 4.05 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 180 | 2.2 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 183 | 0.6 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 187 | 2.15 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 49 | 0.4 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 52 | 0.55 | ug/kg |
| 2006-2 | SD19 | 1 | Hornyhead turbot | Liver | PCB 99 | 1.5 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | Heptachlor | 1.4 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | o,p-DDD | 0.8 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | o,p-DDE | 6.1 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | p,p-DDD | 4.4 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | p,p-DDE | 150 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | p,-p-DDMU | 9.5 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 101 | 2.8 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 105 | 1.1 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 110 | 1.7 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 118 | 3.3 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 128 | 0.6 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 138 | 4.6 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 149 | 3.1 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 153/168 | 6.9 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 158 | 0.3 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 167 | 0.3 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 170 | 1.2 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 177 | 1.1 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 180 | 2.7 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 183 | 1 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 187 | 3.6 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 201 | 1.3 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 49 | 0.7 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 52 | 0.7 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 66 | 1 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 70 | 0.7 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 74 | 0.6 | ug/kg |
| 2006-2 | SD19 | 2 | English sole | Liver | PCB 99 | 2.5 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 7.1 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | Cis Nonachlor | 4.7 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | o,p-DDD | 4.2 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | o,p-DDE | 19 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | o,p-DDT | 2.1 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | p,p-DDD | 18 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | p,p-DDE | 780 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | p,-p-DDMU | 30 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | p,p-DDT | 7.8 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 101 | 13 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 105 | 5 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 110 | 8.9 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 118 | 19 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 119 | 0.6 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 123 | 2.4 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 128 | 4.8 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 138 | 24 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 149 | 9 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 151 | 5.2 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 153/168 | 39 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 156 | 2.2 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 158 | 1.8 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 167 | 1.6 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 170 | 6.5 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 177 | 3.6 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 180 | 15 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 183 | 4.1 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 187 | 15 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 201 | 5.9 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 206 | 2.1 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 28 | 1.5 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 49 | 2.6 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 52 | 4.5 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 66 | 3.6 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 70 | 2.5 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 74 | 2.1 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 87 | 2.9 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | PCB 99 | 13 | ug/kg |
| 2006-2 | SD19 | 3 | Longfin sanddab | Liver | Trans Nonachlor | 7.9 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | Heptachlor | 0.8 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | o,p-DDE | 1.5 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | p,p-DDD | 2.1 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | p,p-DDE | 88 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 5.6 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 101 | 2.1 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 105 | 0.7 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 110 | 0.7 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 118 | 3.6 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 128 | 0.6 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 138 | 3.7 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 149 | 1.3 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 151 | 0.7 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 6.8 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 158 | 0.5 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 167 | 0.5 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 170 | 1.4 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 180 | 3.2 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 183 | 1 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 187 | 2.5 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 201 | 1.1 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 66 | 0.6 | ug/kg |
| 2006-2 | SD20 | 1 | Hornyhead turbot | Liver | PCB 99 | 2.8 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | o,p-DDD | 0.9 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | o,p-DDE | 3.1 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | p,p-DDD | 2.6 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | p,p-DDE | 140 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | p,-p-DDMU | 3.7 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | p,p-DDT | 1.3 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 101 | 5.1 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 105 | 1.6 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 110 | 2.5 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 118 | 5.6 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 123 | 0.5 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 128 | 1.4 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 138 | 8.6 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 149 | 4 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 151 | 1.5 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 153/168 | 13 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 156 | 1.2 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 158 | 0.7 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 170 | 2.6 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 177 | 1.7 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 180 | 5.9 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 183 | 1.6 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 187 | 6.2 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 194 | 2.3 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 201 | 1.7 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 206 | 0.9 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 49 | 0.9 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 52 | 0.6 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 66 | 1.1 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 70 | 0.8 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 74 | 0.5 | ug/kg |
| 2006-2 | SD20 | 2 | English sole | Liver | PCB 99 | 3.4 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 2.9 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | o,p-DDE | 8.3 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | p,p-DDD | 6.4 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | p,p-DDE | 540 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | p,-p-DDMU | 18 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | p,p-DDT | 4.6 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 101 | 7.6 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 105 | 5.4 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 110 | 5.5 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 118 | 20 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 123 | 2.6 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 128 | 6.9 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 138 | 35 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 149 | 7 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 151 | 6.4 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 153/168 | 58 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 156 | 3.9 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 157 | 1.2 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 158 | 2.7 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 167 | 2.6 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 170 | 11 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 177 | 6 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 180 | 26 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 183 | 7.7 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 187 | 27 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 201 | 9.5 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 206 | 3.6 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 28 | 0.8 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 49 | 1 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 52 | 2 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 66 | 2.8 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 70 | 1.2 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 74 | 1.6 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 87 | 2.1 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | PCB 99 | 17 | ug/kg |
| 2006-2 | SD20 | 3 | Longfin sanddab | Liver | Trans Nonachlor | 3 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 6.6 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | Cis Nonachlor | 7.3 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | o,p-DDD | 2.2 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | o,p-DDE | 13 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | p,p-DDD | 9.9 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | p,p-DDE | 830 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | p,-p-DDMU | 17 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | p,p-DDT | 8.2 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 101 | 54 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 105 | 55 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 110 | 66 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 114 | 4.2 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 118 | 240 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 123 | 15 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 128 | 47 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 138 | 220 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 149 | 18 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 151 | 25 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 153/168 | 310 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 156 | 31 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 157 | 6.4 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 158 | 28 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 167 | 15 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 170 | 46 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 177 | 17 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 180 | 91 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 183 | 25 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 187 | 72 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 189 | 2.6 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 194 | 25 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 201 | 24 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 206 | 7.8 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 28 | 2.6 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 49 | 5.8 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 52 | 27 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 66 | 19 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 70 | 2.6 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 74 | 13 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 87 | 14 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | PCB 99 | 160 | ug/kg |
| 2006-2 | SD21 | 1 | Longfin sanddab | Liver | Trans Nonachlor | 12 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | p,p-DDD | 2.3 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | p,p-DDE | 110 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | p,-p-DDMU | 3.3 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | p,p-DDT | 1.5 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 101 | 2.1 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 105 | 1.1 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 110 | 1.5 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 118 | 4.2 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 128 | 1.3 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 138 | 7.3 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 149 | 2 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 151 | 0.8 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 153/168 | 13 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 158 | 1 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 170 | 2.1 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 180 | 6.4 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 183 | 2.1 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 187 | 6.1 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 194 | 2.8 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 201 | 2.2 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 206 | 1.3 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 52 | 0.9 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 66 | 0.8 | ug/kg |
| 2006-2 | SD21 | 2 | Hornyhead turbot | Liver | PCB 99 | 3.1 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | o,p-DDE | 4 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | p,p-DDD | 2.1 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | p,p-DDE | 99 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | p,-p-DDMU | 4.2 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 101 | 5.6 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 105 | 1.4 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 110 | 3.9 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 118 | 5.8 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 123 | 0.7 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 128 | 0.8 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 138 | 7.5 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 149 | 5.2 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 151 | 1.5 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 153/168 | 13 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 158 | 1 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 167 | 0.7 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 170 | 2.8 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 177 | 1.9 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 180 | 5.5 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 183 | 1.6 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 187 | 5.2 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 194 | 2.3 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 201 | 2.3 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 206 | 1.2 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 28 | 0.7 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 49 | 1 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 52 | 1.2 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 66 | 1.8 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 70 | 1.1 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 74 | 0.9 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 87 | 1.1 | ug/kg |
| 2006-2 | SD21 | 3 | English sole | Liver | PCB 99 | 4.6 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | o,p-DDE | 0.1 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | p,p-DDD | 0.2 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | p,p-DDE | 5.7 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | p,-p-DDMU | 0.4 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 101 | 0.2 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 118 | 0.2 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 138 | 0.2 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 149 | 0.2 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 153/168 | 0.5 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 158 | 0.1 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 170 | 0.1 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 180 | 0.2 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 187 | 0.2 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 49 | 0.1 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 52 | 0.1 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 66 | 0.1 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | PCB 99 | 0.2 | ug/kg |
| 2006-4 | RF3 | 1 | Mixed rockfish | Muscle | Trans Nonachlor | 0.2 | ug/kg |
| 2006-4 | RF3 | 2 | Mixed rockfish | Muscle | p,p-DDE | 2 | ug/kg |
| 2006-4 | RF3 | 2 | Mixed rockfish | Muscle | PCB 118 | 0.1 | ug/kg |
| 2006-4 | RF3 | 2 | Mixed rockfish | Muscle | PCB 138 | 0.1 | ug/kg |
| 2006-4 | RF3 | 2 | Mixed rockfish | Muscle | PCB 153/168 | 0.2 | ug/kg |
| 2006-4 | RF3 | 2 | Mixed rockfish | Muscle | PCB 180 | 0.1 | ug/kg |
| 2006-4 | RF3 | 2 | Mixed rockfish | Muscle | PCB 187 | 0.1 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | p,p-DDD | 0.1 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | p,p-DDE | 4.7 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 101 | 0.1 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 118 | 0.2 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 138 | 0.3 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 149 | 0.1 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 153/168 | 0.5 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 170 | 0.1 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 180 | 0.2 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 187 | 0.2 | ug/kg |
| 2006-4 | RF3 | 3 | Brown rockfish | Muscle | PCB 99 | 0.1 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | Alpha (cis) Chlordane | 0.1 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | o,p-DDE | 0.05 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | p,p-DDD | 0.15 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | p,p-DDE | 13 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | p,-p-DDMU | 0.15 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | p,p-DDT | 0.2 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 101 | 0.15 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 105 | 0.1 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 110 | 0.1 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 118 | 0.4 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 128 | 0.05 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 138 | 0.35 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 149 | 0.2 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 153/168 | 0.8 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 170 | 0.1 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 180 | 0.2 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 183 | 0.05 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 187 | 0.2 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 66 | 0.05 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 74 | 0.05 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | PCB 99 | 0.15 | ug/kg |
| 2006-4 | RF4 | 1 | Mixed rockfish | Muscle | Trans Nonachlor | 0.2 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | p,p-DDE | 7.8 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 101 | 0.2 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 105 | 0.1 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 118 | 0.3 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 138 | 0.3 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 149 | 0.1 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 153/168 | 0.5 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 170 | 0.1 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 180 | 0.2 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 187 | 0.1 | ug/kg |
| 2006-4 | RF4 | 2 | Honeycomb rockfish | Muscle | PCB 99 | 0.2 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | Alpha (cis) Chlordane | 0.2 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | o,p-DDE | 0.1 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | p,p-DDD | 0.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | p,p-DDE | 22 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | p,-p-DDMU | 0.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | p,p-DDT | 0.4 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 101 | 0.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 105 | 0.2 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 110 | 0.2 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 118 | 0.6 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 128 | 0.1 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 138 | 0.5 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 149 | 0.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 153/168 | 1.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 170 | 0.2 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 180 | 0.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 183 | 0.1 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 187 | 0.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 66 | 0.1 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 74 | 0.1 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | PCB 99 | 0.3 | ug/kg |
| 2006-4 | RF4 | 3 | Treefish | Muscle | Trans Nonachlor | 0.4 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | p,p-DDD | 1.6 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | p,p-DDE | 53 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 2.1 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 101 | 1.4 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 118 | 2.9 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 138 | 4.3 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 149 | 2.1 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 7.8 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 170 | 1.5 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 180 | 3.6 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 183 | 1.2 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 187 | 3.9 | ug/kg |
| 2006-4 | SD15 | 1 | Hornyhead turbot | Liver | PCB 99 | 1.6 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | Alpha (cis) Chlordane | 5.2 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | Cis Nonachlor | 3.1 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | p,p-DDD | 2.6 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | p,p-DDE | 250 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | p,-p-DDMU | 5.1 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | p,p-DDT | 2 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 101 | 5.1 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 105 | 2.3 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 110 | 3.8 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 118 | 10 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 138 | 12 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 149 | 5.4 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 151 | 2.4 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 153/168 | 28 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 158 | 0.9 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 170 | 3.1 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 177 | 2.2 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 180 | 9 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 183 | 2.5 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 187 | 8.5 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 194 | 2.1 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 201 | 2.7 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 206 | 0.9 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 28 | 0.7 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 49 | 1.3 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 52 | 2.3 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 66 | 1 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 70 | 1.8 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 74 | 0.9 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | PCB 99 | 5 | ug/kg |
| 2006-4 | SD15 | 2 | Pacific sanddab | Liver | Trans Nonachlor | 7 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | p,p-DDD | 1.5 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | p,p-DDE | 44 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | p,-p-DDMU | 2.4 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 101 | 1.3 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 118 | 2.8 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 138 | 4 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 149 | 1.5 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 153/168 | 6.5 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 180 | 2.5 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 187 | 3 | ug/kg |
| 2006-4 | SD15 | 3 | Hornyhead turbot | Liver | PCB 99 | 1.1 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 4 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | o,p-DDD | 1.2 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | o,p-DDE | 5.4 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | p,p-DDD | 5.9 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | p,p-DDE | 380 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | p,-p-DDMU | 14 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | p,p-DDT | 4.5 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 101 | 4.2 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 105 | 3.8 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 110 | 2.9 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 118 | 14 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 128 | 4.6 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 138 | 23 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 149 | 6.8 | ug/kg |

**Appendix E.3** *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 151 | 3.7 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 153/168 | 39 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 156 | 2.4 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 158 | 1.3 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 170 | 7 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 177 | 4.1 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 180 | 15 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 183 | 4.2 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 187 | 17 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 194 | 4.6 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 201 | 5.4 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 206 | 2.1 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 28 | 1.6 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 49 | 1.6 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 66 | 2.3 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 70 | 1 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 74 | 1.2 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | PCB 99 | 7.5 | ug/kg |
| 2006-4 | SD16 | 1 | Longfin sanddab | Liver | Trans Nonachlor | 4.9 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | p,p-DDD | 2.2 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | p,p-DDE | 100 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | p,-p-DDMU | 4.8 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 101 | 1.1 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 118 | 3.4 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 138 | 5.4 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 149 | 1.6 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 153/168 | 9.7 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 170 | 2.2 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 180 | 4.5 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 183 | 1.5 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 187 | 4.2 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 194 | 1.8 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 201 | 1.7 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 66 | 0.7 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | PCB 99 | 2 | ug/kg |
| 2006-4 | SD16 | 2 | Hornyhead turbot | Liver | Trans Nonachlor | 3 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | p,p-DDD | 2.6 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | p,p-DDE | 95 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | p,-p-DDMU | 3.7 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 101 | 1.3 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 105 | 0.9 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 118 | 3.3 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 138 | 5 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 149 | 1.3 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 153/168 | 9.6 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 170 | 2.1 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 180 | 4.3 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 183 | 1.2 | ug/kg |
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 187 | 4.1 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD16 | 3 | Hornyhead turbot | Liver | PCB 99 | 1.7 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | Alpha (cis) Chlordane | 58 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | BHC, Alpha isomer | 15 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | BHC, Beta isomer | 55 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | BHC, Delta isomer | 27 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | Cis Nonachlor | 6.5 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | Gamma (trans) Chlordane | 9.7 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | Heptachlor | 1.8 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | Heptachlor epoxide | 30 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | o,p-DDE | 7 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | p,p-DDD | 45 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | p,p-DDE | 1300 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | p,-p-DDMU | 38 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | p,p-DDT | 27 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 101 | 17 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 105 | 9.9 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 110 | 12 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 118 | 35 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 119 | 1.7 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 123 | 4.1 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 128 | 7.4 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 138 | 41 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 149 | 14 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 151 | 8.1 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 153/168 | 69 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 156 | 4.5 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 157 | 1.4 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 158 | 3.2 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 170 | 11 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 177 | 7.4 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 180 | 26 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 183 | 7.4 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 187 | 26 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 194 | 7.7 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 201 | 9.1 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 206 | 3.6 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 28 | 1.9 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 44 | 1.9 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 49 | 4.2 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 52 | 5.2 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 66 | 7.1 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 70 | 15 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 74 | 3.4 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 87 | 5.5 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | PCB 99 | 17 | ug/kg |
| 2006-4 | SD17 | 1 | California scorpionfish | Liver | Trans Nonachlor | 13 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | Alpha (cis) Chlordane | 56 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | BHC, Alpha isomer | 120 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | BHC, Beta isomer | 120 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | BHC, Delta isomer | 38 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | Gamma (trans) Chlordane | 66 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | Heptachlor | 4.9 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | Heptachlor epoxide | 83 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | o,p-DDE | 2.3 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | p,p-DDD | 28 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | p,p-DDE | 390 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | p,-p-DDMU | 7.7 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | p,p-DDT | 11 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 101 | 5.3 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 105 | 3.9 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 110 | 3.8 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 118 | 13 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 123 | 1.3 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 138 | 9 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 149 | 5.3 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 151 | 3.4 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 153/168 | 33 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 156 | 1.8 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 158 | 1.5 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 170 | 5.4 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 177 | 3 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 180 | 14 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 183 | 3.9 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 187 | 14 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 194 | 3.8 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 201 | 4.7 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 206 | 2 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 28 | 0.7 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 49 | 1.1 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 66 | 2.1 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 70 | 1 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 74 | 1.1 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | PCB 99 | 5.6 | ug/kg |
| 2006-4 | SD17 | 2 | California scorpionfish | Liver | Trans Nonachlor | 5.9 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | o,p-DDE | 1.6 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | p,p-DDD | 4.9 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | p,p-DDE | 190 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | p,-p-DDMU | 6.2 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | p,p-DDT | 1.7 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 101 | 2.1 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 105 | 1.4 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 110 | 1.5 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 118 | 5.3 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 138 | 8.1 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 149 | 2.7 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 153/168 | 14 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 158 | 0.9 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 170 | 2.9 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 180 | 7 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 183 | 2.3 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 187 | 6.1 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 194 | 2.3 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 206 | 1.4 | ug/kg |
| 2006-4 | SD17 | 3 | Hornyhead turbot | Liver | PCB 99 | 2.5 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | p,p-DDD | 6 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | p,p-DDE | 300 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | p,-p-DDMU | 6.4 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | p,p-DDT | 2.1 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 101 | 5.1 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 105 | 2.9 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 110 | 3.2 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 118 | 9.5 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 123 | 1.4 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 138 | 14 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 149 | 4.4 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 151 | 2.5 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 153/168 | 27 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 156 | 1.5 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 158 | 1.3 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 170 | 4.4 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 177 | 3 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 180 | 11 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 183 | 2.8 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 187 | 11 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 194 | 3.5 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 201 | 4 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 206 | 1.6 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 49 | 1.4 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 66 | 1.9 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 70 | 1 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 74 | 1 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | PCB 99 | 4.9 | ug/kg |
| 2006-4 | SD18 | 1 | California scorpionfish | Liver | Trans Nonachlor | 6.1 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | p,p-DDD | 1.9 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | p,p-DDE | 110 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | p,-p-DDMU | 4.9 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 101 | 1.3 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 105 | 1.2 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 118 | 3.4 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 138 | 5.9 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 149 | 1.6 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 153/168 | 9.6 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 180 | 5 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 183 | 1.4 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 187 | 3.6 | ug/kg |
| 2006-4 | SD18 | 2 | Hornyhead turbot | Liver | PCB 99 | 1.8 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | p,p-DDD | 1.85 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | p,p-DDE | 70.5 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | p,-p-DDMU | 3.15 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 118 | 2.45 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 138 | 4.25 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 149 | 1.3 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 153/168 | 7.25 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 180 | 3.35 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 183 | 1 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 187 | 3.25 | ug/kg |
| 2006-4 | SD18 | 3 | Hornyhead turbot | Liver | PCB 99 | 1.55 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | p,p-DDD | 1.9 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | p,p-DDE | 66 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | p,-p-DDMU | 2.4 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 101 | 2 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 118 | 2.8 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 138 | 4.9 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 149 | 2 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 153/168 | 7.7 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 170 | 1.7 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 180 | 3.2 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 183 | 0.8 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 187 | 3.7 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 201 | 1.4 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 28 | 0.9 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 49 | 0.7 | ug/kg |
| 2006-4 | SD19 | 1 | Hornyhead turbot | Liver | PCB 99 | 1.9 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | p,p-DDD | 3.5 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | p,p-DDE | 120 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | p,-p-DDMU | 5.1 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 101 | 1.6 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 105 | 0.9 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 118 | 3.3 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 138 | 5 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 149 | 1.3 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 153/168 | 8.5 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 170 | 1.5 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 180 | 4.1 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 187 | 3.5 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 194 | 1.6 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 201 | 1.3 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 206 | 1 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 49 | 0.6 | ug/kg |
| 2006-4 | SD19 | 2 | Hornyhead turbot | Liver | PCB 99 | 2.3 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | o,p-DDD | 1.5 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | o,p-DDE | 6.25 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | p,p-DDD | 8.55 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | p,p-DDE | 490 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | p,-p-DDMU | 22 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | p,p-DDT | 3.85 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 101 | 5.9 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 105 | 3.9 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 110 | 3.8 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 118 | 13.5 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 123 | 1.75 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 128 | 3.8 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 138 | 21 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 149 | 6.1 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 151 | 3.15 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 153/168 | 35.5 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 156 | 2.2 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 158 | 1.45 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 170 | 5.9 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 177 | 3.5 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 180 | 13 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 183 | 3.65 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 187 | 15 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 194 | 4.5 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 201 | 4.65 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 206 | 2 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 28 | 1.65 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 49 | 1.5 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 52 | 2.2 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 66 | 2.85 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 70 | 1.25 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 74 | 1.55 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | PCB 99 | 8.85 | ug/kg |
| 2006-4 | SD19 | 3 | Longfin sanddab | Liver | Trans Nonachlor | 3.1 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 4.7 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | Cis Nonachlor | 2.4 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | Gamma (trans) Chlordane | 4.4 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | o,p-DDD | 1.4 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | o,p-DDE | 5.8 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | p,p-DDD | 18 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | p,p-DDE | 470 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | p,-p-DDMU | 18 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | p,p-DDT | 12 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 101 | 5.6 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 105 | 4.9 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 110 | 3.7 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 118 | 17 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 123 | 1.8 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 128 | 4.7 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 138 | 28 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 149 | 7.1 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 151 | 4.3 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 153/168 | 48 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 156 | 2.7 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 157 | 0.8 | ug/kg |

# Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 158 | 1.7 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 170 | 8.4 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 177 | 4.7 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 180 | 17 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 183 | 4.9 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 187 | 19 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 194 | 5.3 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 201 | 6.3 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 206 | 2.5 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 28 | 1.8 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 49 | 1.6 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 52 | 2.4 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 66 | 3 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 70 | 1.1 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 74 | 1.6 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | PCB 99 | 11 | ug/kg |
| 2006-4 | SD20 | 1 | Longfin sanddab | Liver | Trans Nonachlor | 4.6 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | BHC, Alpha isomer | 5.9 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | p,p-DDD | 2.2 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | p,p-DDE | 70 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | p,-p-DDMU | 3.8 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 101 | 1.1 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 118 | 2.3 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 138 | 4.4 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 153/168 | 7.2 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 170 | 1.2 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 180 | 3.2 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 183 | 0.9 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 187 | 3.2 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 201 | 1.2 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 206 | 0.7 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 66 | 0.6 | ug/kg |
| 2006-4 | SD20 | 2 | Hornyhead turbot | Liver | PCB 99 | 1.6 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | o,p-DDE | 1.4 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | p,p-DDD | 2.6 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | p,p-DDE | 99 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | p,-p-DDMU | 5.5 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 101 | 1.7 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 105 | 1.2 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 118 | 3.7 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 138 | 5.7 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 153/168 | 9.8 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 170 | 1.8 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 180 | 4.5 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 183 | 1.3 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 187 | 3.5 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 194 | 1.5 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 201 | 1.4 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 206 | 0.9 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 66 | 0.9 | ug/kg |
| 2006-4 | SD20 | 3 | Hornyhead turbot | Liver | PCB 99 | 2.3 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | Alpha (cis) Chlordane | 6.5 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | Cis Nonachlor | 6.3 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | o,p-DDD | 2.8 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | o,p-DDE | 13 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | o,p-DDT | 2.5 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | p,p-DDD | 18 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | p,p-DDE | 1200 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | p,-p-DDMU | 37 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | p,p-DDT | 24 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 101 | 17 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 105 | 16 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 110 | 12 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 118 | 67 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 123 | 7 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 128 | 19 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 138 | 120 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 149 | 16 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 151 | 12 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 153/168 | 190 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 156 | 9.7 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 157 | 2.7 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 158 | 7.8 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 170 | 31 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 177 | 15 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 180 | 69 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 183 | 20 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 187 | 80 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 194 | 20 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 201 | 22 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 206 | 8.9 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 28 | 3.8 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 44 | 1 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 49 | 4 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 52 | 6.5 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 66 | 7.7 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 70 | 1.7 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 74 | 4.5 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 87 | 3 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | PCB 99 | 40 | ug/kg |
| 2006-4 | SD21 | 1 | Longfin sanddab | Liver | Trans Nonachlor | 14 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | p,p-DDD | 1.5 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | p,p-DDE | 48 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | p,-p-DDMU | 2.1 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 101 | 1.5 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 118 | 2.9 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 138 | 5 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 149 | 1.5 | ug/kg |

## Appendix E.3 *continued*

| YR-QTR | Station | Rep | Species | Tissue | Parameter | Value | Units |
|---|---|---|---|---|---|---|---|
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 153/168 | 8.5 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 170 | 1.3 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 180 | 3.3 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 183 | 1.2 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 187 | 4.3 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 201 | 1.2 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 206 | 1 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 49 | 0.8 | ug/kg |
| 2006-4 | SD21 | 2 | Hornyhead turbot | Liver | PCB 99 | 2.2 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | o,p-DDE | 1.3 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | p,p-DDD | 1.9 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | p,p-DDE | 66 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | p,-p-DDMU | 3.1 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 101 | 1.9 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 105 | 1 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 118 | 4 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 138 | 7.1 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 149 | 1.9 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 153/168 | 11 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 170 | 1.8 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 180 | 4.4 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 183 | 1.6 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 187 | 4.7 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 194 | 1.8 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 201 | 1.4 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 206 | 1.2 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 66 | 0.9 | ug/kg |
| 2006-4 | SD21 | 3 | Hornyhead turbot | Liver | PCB 99 | 2.8 | ug/kg |

# Appendix F

# Supporting Data

# SBOO Stations

# San Diego Regional Survey
# Sediment Characteristics

## Appendix F.1

Randomly selected regional sediment quality statistics, August 2006.

| Station | Depth (m) | Mean (mm) | Mean (phi) | SD (phi) | Median (phi) | Skewness (phi) | Kurtosis (phi) | Coarse (%) | Sand (%) | Silt (%) | Clay (%) | Sediment observations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2111 | 12 | 0.093 | 3.4 | 1.1 | 3.2 | 0.5 | 1.4 | 0.0 | 76.6 | 22.7 | 0.7 | Some organic debris |
| 2122 | 16 | 0.096 | 3.4 | 1.0 | 3.3 | 0.3 | 1.6 | 0.0 | 81.9 | 17.5 | 0.5 | Some organic debris |
| 2127 | 16 | 0.130 | 2.9 | 0.8 | 2.9 | 0.3 | 4.0 | 0.0 | 91.6 | 8.2 | 0.2 | Some shell hash, organic debris |
| 2123 | 19 | 0.062 | 4.0 | 1.3 | 3.8 | 0.3 | 1.2 | 0.0 | 59.2 | 38.9 | 1.9 | Some organic debris |
| 2046 | 22 | 0.118 | 3.1 | 0.7 | 3.0 | 0.2 | 1.3 | 0.0 | 91.5 | 8.2 | 0.2 | Some organic debris |
| 2112 | 26 | 0.107 | 3.2 | 0.8 | 3.2 | 0.2 | 1.4 | 0.0 | 87.2 | 12.4 | 0.4 | Some organic debris |
| 2128 | 37 | 0.203 | 2.3 | 1.3 | 2.2 | 0.3 | 2.0 | 0.0 | 87.9 | 11.5 | 0.7 | Coarse sand, shell hash, organic debris |
| 2014 | 38 | 0.083 | 3.6 | 1.2 | 3.3 | 0.5 | 1.5 | 0.0 | 73.6 | 24.8 | 1.7 | Some organic debris |
| 2120 | 39 | 0.081 | 3.6 | 1.3 | 3.2 | 0.6 | 1.5 | 0.0 | 73.8 | 24.6 | 1.6 | Some coarse sand, shell hash |
| 2110 | 40 | 0.546 | 0.9 | 0.6 | 0.8 | 0.2 | 1.0 | 7.2 | 92.7 | 0.0 | 0.0 | Coarse relict red sand, shell hash |
| 2115 | 42 | 0.301 | 1.7 | 0.8 | 1.8 | 0.1 | 1.7 | 0.2 | 94.9 | 4.9 | 0.0 | Some organic debris |
| 2137 | 48 | 0.068 | 3.9 | 1.9 | 3.0 | 0.6 | 0.7 | 0.0 | 65.0 | 32.2 | 2.8 | Coarse sand, shell hash |
| 2038 | 52 | 0.064 | 4.0 | 1.4 | 3.6 | 0.4 | 1.2 | 0.0 | 66.4 | 31.1 | 2.4 | Some coarse sand, shell hash |
| 2126 | 62 | 0.053 | 4.2 | 1.5 | 3.8 | 0.4 | 1.1 | 0.0 | 57.1 | 40.0 | 2.9 | Some shell hash, organic debris |
| 2131 | 63 | 0.046 | 4.5 | 1.6 | 4.0 | 0.4 | 1.0 | 0.0 | 49.7 | 46.8 | 3.5 | Some organic debris |
| 2135 | 66 | 0.043 | 4.6 | 1.6 | 4.1 | 0.4 | 0.9 | 0.0 | 45.7 | 50.4 | 3.9 | Coarse sand, shell hash, gravel, organic debris |
| 2021 | 67 | 0.049 | 4.3 | 1.6 | 3.8 | 0.4 | 0.9 | 0.0 | 53.8 | 42.9 | 3.3 | Some shell hash |
| 2129 | 67 | 0.047 | 4.4 | 1.5 | 4.0 | 0.4 | 1.0 | 0.0 | 51.5 | 45.3 | 3.2 | Some organic debris |
| 2114 | 68 | 0.089 | 3.5 | 1.7 | 2.8 | 0.6 | 1.4 | 0.0 | 75.0 | 22.6 | 2.4 | Some organic debris |
| 2113 | 69 | 0.109 | 3.2 | 1.3 | 2.8 | 0.6 | 1.7 | 0.0 | 81.1 | 17.6 | 1.3 | Some organic debris |
| 2136 | 69 | 0.047 | 4.4 | 1.6 | 4.0 | 0.4 | 1.0 | 0.0 | 51.9 | 44.5 | 3.6 | Some shell hash |
| 2031 | 74 | 0.048 | 4.4 | 1.5 | 4.0 | 0.4 | 1.0 | 0.0 | 51.0 | 45.7 | 3.3 | Some organic debris |
| 2139 | 77 | 0.054 | 4.2 | 1.7 | 3.6 | 0.5 | 0.9 | 0.0 | 58.6 | 37.9 | 3.5 | Coarse black sand, shell debris |
| 2121 | 83 | 0.114 | 3.1 | 1.6 | 4.1 | -0.9 | 1.0 | 8.2 | 27.6 | 64.2 | 0.0 | Lots coarse sand, shell hash, gravel |
| 2133 | 89 | 0.048 | 4.4 | 1.7 | 3.9 | 0.4 | 0.8 | 0.0 | 51.9 | 44.5 | 3.6 | Shell hash, gravel |
| 2023 | 90 | 0.053 | 4.2 | 1.7 | 3.8 | 0.4 | 0.9 | 1.5 | 54.1 | 41.1 | 3.3 | Coarse black sand, shell hash, gravel, rock |
| 2124 | 100 | 0.058 | 4.1 | 1.5 | 3.7 | 0.5 | 1.1 | 0.0 | 63.0 | 34.3 | 2.8 | Some coarse black sand, shell debris |
| 2118 | 123 | 0.048 | 4.4 | 1.7 | 3.7 | 0.5 | 0.8 | 0.0 | 56.0 | 39.9 | 4.1 | Some organic debris |
| 2119 | 145 | 0.116 | 3.1 | 1.8 | 2.4 | 0.5 | 1.8 | 0.0 | 79.4 | 18.7 | 1.9 | Sand, shell hash, gravel, rock |
| 2130 | 147 | 0.042 | 4.6 | 1.7 | 4.0 | 0.4 | 0.8 | 0.0 | 48.9 | 46.8 | 4.4 | Some organic debris, Chaetopteridae tubes |
| 2125 | 157 | 0.300 | 1.7 | 1.4 | 1.9 | -0.2 | 1.4 | 13.0 | 72.5 | 14.6 | 0.0 | Coarse black sand, gravel, rock |
| 2138 | 190 | 0.038 | 4.7 | 1.6 | 4.3 | 0.4 | 0.8 | 0.0 | 43.8 | 51.6 | 4.6 | Some organic debris, Phyllochaetopterus tubes |
| 2028 | 190 | 0.036 | 4.8 | 1.6 | 4.5 | 0.3 | 0.8 | 0.0 | 36.8 | 58.7 | 4.5 | Some gravel, Chaetopteridae tubes |
| 2132 | 197 | 0.053 | 4.2 | 1.8 | 3.5 | 0.6 | 0.8 | 0.0 | 59.9 | 36.1 | 3.9 | Shell hash, gravel |

## Appendix F.2

Randomly selected regional sediment quality statistics, July 1996.

| Station | Depth (m) | Mean (mm) | Mean (phi) | SD (phi) | Median (phi) | Coarse (%) | Sand (%) | Silt (%) | Clay (%) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 2111 | 13 | 0.109 | 3.2 | 0.8 | 3.1 | 0.0 | 85.9 | 13.4 | 0.7 | |
| 2122 | 16 | 0.102 | 3.3 | 1.1 | 3.2 | 0.0 | 83.3 | 12.4 | 4.3 | |
| 2127 | 17 | 0.134 | 2.9 | 0.8 | 3.0 | 0.0 | 93.3 | 6.2 | 0.5 | |
| 2123 | 19 | 0.063 | 4.0 | 1.2 | 3.8 | 0.0 | 57.5 | 40.6 | 1.9 | |
| 2046 | 20 | 0.117 | 3.1 | 0.6 | 3.1 | 0.0 | 91.2 | 8.1 | 0.6 | |
| 2112 | 26 | 0.109 | 3.2 | 0.8 | 3.2 | 0.0 | 86.7 | 12.5 | 0.8 | |
| 2128 | 37 | 0.250 | 2.0 | 0.6 | 2.0 | 0.0 | 97.2 | 2.1 | 0.1 | |
| 2014 | 38 | 0.095 | 3.4 | 1.2 | 3.1 | 0.0 | 79.2 | 18.9 | 1.9 | |
| 2120 | 39 | 0.077 | 3.7 | 1.5 | 3.3 | 0.0 | 71.4 | 24.7 | 3.9 | |
| 2110 | 40 | 0.406 | 1.3 | 0.5 | 1.3 | 0.4 | 99.5 | 0.0 | 0.0 | |
| 2115 | 43 | 0.467 | 1.1 | 0.8 | 0.8 | 0.4 | 96.1 | 3.3 | 0.1 | |
| 2137 | 48 | 0.189 | 2.4 | 2.1 | 2.0 | 7.7 | 73.7 | 15.2 | 3.3 | |
| 2038 | 52 | 0.051 | 4.3 | 1.6 | 3.8 | 0.0 | 55.0 | 40.9 | 4.1 | |
| 2126 | 62 | 0.051 | 4.3 | 1.6 | 3.8 | 0.3 | 53.8 | 42.2 | 3.8 | |
| 2131 | 63 | 0.047 | 4.4 | 1.4 | 4.0 | 0.0 | 51.1 | 45.2 | 3.7 | |
| 2135 | 66 | 0.047 | 4.4 | 1.8 | 4.0 | 0.6 | 50.3 | 44.5 | 4.5 | |
| 2021 | 67 | 0.044 | 4.5 | 1.6 | 4.0 | 0.0 | 49.6 | 45.9 | 4.5 | |
| 2129 | 67 | 0.047 | 4.4 | 1.5 | 4.0 | 0.0 | 50.6 | 45.6 | 3.8 | |
| 2114 | 68 | 0.109 | 3.2 | 2.0 | 2.7 | 0.9 | 74.6 | 21.4 | 3.1 | |
| 2113 | 70 | 0.144 | 2.8 | 1.4 | 2.7 | 0.1 | 84.3 | 13.3 | 2.2 | |
| 2136 | 70 | 0.047 | 4.4 | 1.5 | 4.0 | 0.0 | 51.2 | 44.9 | 3.9 | |
| 2031 | 72 | 0.044 | 4.5 | 1.5 | 4.0 | 0.0 | 49.6 | 46.4 | 4.0 | |
| 2139 | 77 | 0.082 | 3.6 | 2.2 | 3.3 | 2.6 | 63.1 | 30.3 | 4.0 | |
| 2121 | 84 | 0.054 | 4.2 | 1.8 | 3.8 | 0.5 | 55.0 | 40.8 | 3.8 | |
| 2133 | 90 | 0.054 | 4.2 | 1.9 | 3.8 | 1.0 | 55.7 | 38.9 | 4.4 | |
| 2023 | 90 | 0.063 | 4.0 | 2.1 | 3.7 | 2.4 | 54.6 | 38.5 | 4.5 | |
| 2124 | 100 | 0.058 | 4.1 | 1.9 | 3.6 | 1.2 | 58.0 | 36.9 | 3.9 | |
| 2118 | 124 | 0.047 | 4.4 | 1.7 | 3.8 | 0.0 | 55.4 | 39.6 | 4.9 | |
| 2119 | 145 | 0.218 | 2.2 | 1.7 | 1.9 | 2.1 | 83.4 | 12.0 | 2.5 | |
| 2130 | 147 | 0.044 | 4.5 | 1.6 | 4.0 | 0.0 | 49.2 | 45.5 | 5.1 | |
| 2125 | — | — | — | — | — | — | — | — | — | Not sampled in 1996 |
| 2043 | 165 | 0.287 | 1.8 | 0.8 | 1.7 | 0.3 | 94.6 | 3.2 | 0.4 | Not sampled in 2006 |
| 2138 | 191 | 0.036 | 4.8 | 1.7 | 4.3 | 0.0 | 41.1 | 53.6 | 5.2 | |
| 2028 | 189 | 0.031 | 5.0 | 1.7 | 4.6 | 0.0 | 32.9 | 61.1 | 6.0 | |
| 2132 | — | — | — | — | — | — | — | — | — | Not sampled in 1996 |