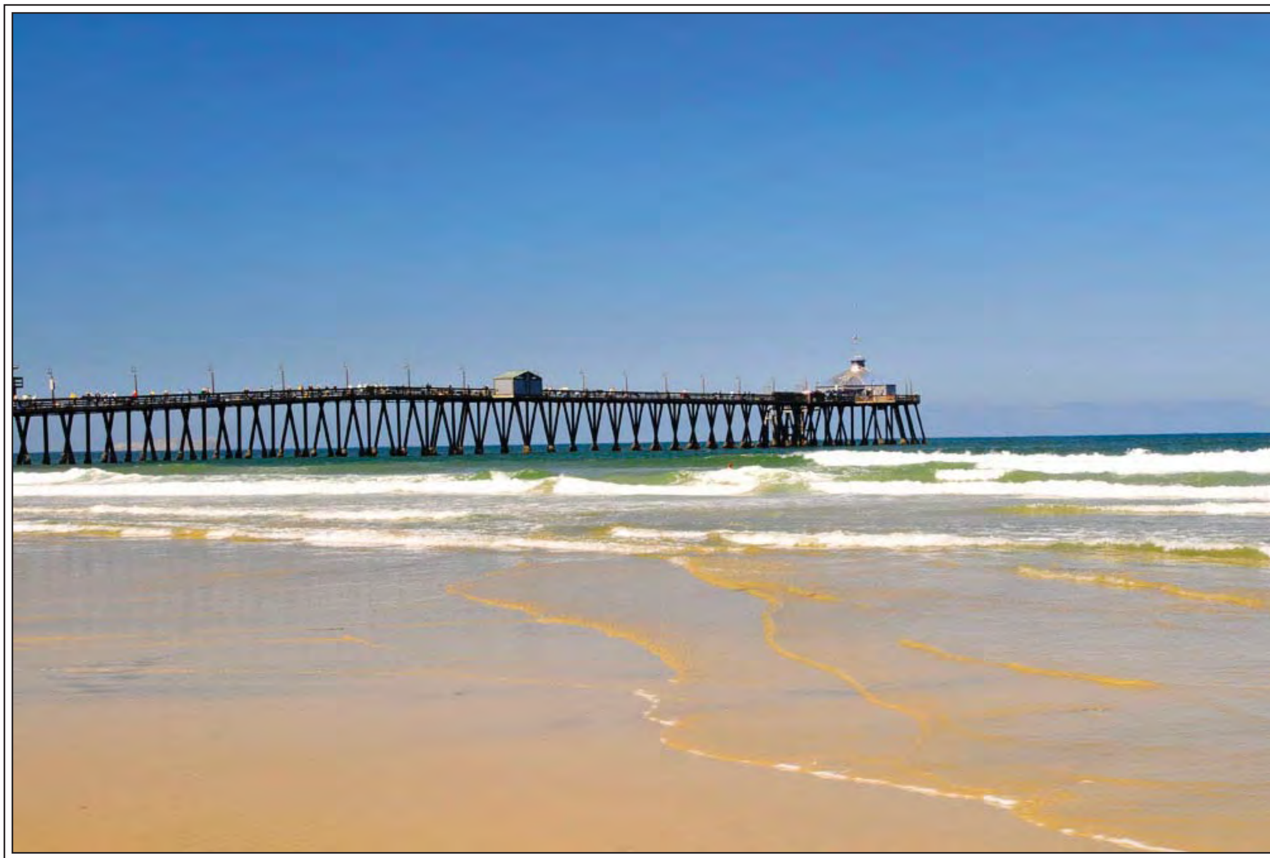
Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant) 2007



City of San Diego
Ocean Monitoring Program

Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

THE CITY OF SAN DIEGO
MAYOR JERRY SANDERS

June 30, 2008

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 2008 Annual Receiving Waters Monitoring Report for NPDES Permit No. CA0109045, Order No. 2006-067, 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

ACL/ag

Enclosure

cc: Department of Environmental Health, County of San Diego
U.S. Environmental Protection Agency, Region 9
Metropolitan Wastewater Department Library, City of San Diego

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Annual Receiving Waters Monitoring Report
for the
South Bay Ocean Outfall

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2007

Prepared by:

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

June 2008

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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 Permit 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 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 USA/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 2007 annual survey of randomly selected stations are presented herein (see Chapters 8 and 9).

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. Chapter 1 presents a general introduction and overview of the ocean monitoring program for the South Bay Ocean Outfall region. In Chapter 2 monitoring data regarding various physical and chemical oceanographic parameters are evaluated to characterize water mass transport potential in the region. Chapter 3 presents the results of water quality monitoring conducted along the shore and in offshore waters, which includes the measurement of bacteriological indicators to assess potential effects of both natural and anthropogenic inputs, and to determine compliance with 2001 California Ocean Plan (COP) water contact standards. The results of benthic sampling and analyses of soft-bottom sediments and their associated macrofaunal communities are presented in Chapters 4 and 5, respectively. Chapter 6 presents the results of trawling activities to assess the status of bottom dwelling (demersal) fish and megabenthic invertebrate communities. Bioaccumulation studies to determine whether contaminants are present in the tissues of local species supplement the monitoring of fish populations and are presented in Chapter 7. In addition to the above activities, the City and IBWC 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 2007. An overview and summary of the main findings for each of the major components of the monitoring program are included below.

OCEANOGRAPHIC CONDITIONS

Water temperatures, especially at bottom depths, were generally cooler during the spring and fall months of 2007 when compared to previous years.

This was likely due to strong upwelling events that occurred during these times. In contrast, surface temperatures were extremely high in August, coincident with near record air temperatures. Thermal stratification of the water column followed typical patterns with maximum stratification in mid-summer and reduced stratification during the winter. Relatively low annual rainfall generated less stormwater runoff in 2007 than in previous years. DMSC aerial imagery detected the wastewater plume in sub-surface waters above the southern diffuser leg of the SBOO on several occasions between January–March and November–December when the water column was well mixed. In contrast, the plume was deeply submerged between June and October when the water column was stratified. A review of historical data did not reveal any major changes in water quality parameters that could be attributed to the beginning of outfall operations in January 1999. Instead, these data indicate that other factors such as stormwater runoff and large-scale oceanographic events (e.g., El Niño) explain most of the observed temporal and spatial variability in water quality parameters in the South Bay region.

MICROBIOLOGY

Densities of indicator bacteria (total and fecal coliforms, enterococcus) at shore and kelp stations sampled in the South Bay region were lower overall in 2007 than in previous years, which resulted in higher compliance with the various 2001 COP standards. Although elevated bacterial densities occurred occasionally along the shore and at some nearshore stations, these data did not indicate shoreward transport of the SBOO wastewater plume during the past year. Instead, bacteria data and satellite imagery indicate that turbidity flows originating from the Tijuana River and Los Buenos Creek, or associated with stormwater and surface runoff following storm events are more likely to impact water quality along and near the shore. For example, shore stations located near the Tijuana River and Los Buenos Creek have historically had higher fecal coliform concentrations than stations located further north. Historical analyses of various water quality parameters have also demonstrated that the general relationship between rainfall and elevated bacteria levels has remained consistent since sampling began in 1995.

Data from offshore monitoring sites in 2007 suggest that the wastewater plume from the SBOO was confined to sub-surface waters from April through October when the water column was stratified. In contrast, bacterial counts indicative of wastewater were evident in surface waters near the SBOO during January–March, November and December when the water column was well-mixed. There was no evidence that the wastewater plume impacted any of the kelp or shore stations.

SEDIMENT CHARACTERISTICS

The composition of sediments at the various benthic sites sampled in the South Bay region during 2007 varied from fine silts to very coarse sands (or other materials), which is similar to patterns seen in previous years. The large variation in sediment composition may be partially attributed to the multiple geological origins of red relict sands, shell hash, coarse sands, and other detrital sediments. In addition, deposition of sediments originating from the Tijuana River and to a lesser extent from San Diego Bay may contribute to higher silt content at some of the stations located near the outfall and to the north. There was no evident relationship between sediment composition and proximity to the outfall discharge site.

Contaminant concentrations in South Bay sediments, including organic loading indicators such as sulfides, total nitrogen (TN) and total organic carbon (TOC), trace metals, pesticides, PCBs and PAHs, were generally low compared to other areas of the southern California continental shelf. Concentrations of sulfides, TN and TOC, as well as several metals, tended to increase as sediments became finer. Further, levels of the organic loading indicators have not shown changes around the outfall or elsewhere coincident with the start of wastewater discharge in early 1999. Only two metals exceeded Effects Range Low (ERL) environmental threshold values during the year:

(1) the ERL for arsenic was exceeded in sediments from a single site located offshore of the SBOO; (2) the ERL for silver was exceeded in sediments from stations located throughout the monitoring area. Other contaminants were detected rarely (i.e., PCBs and pesticides) or in only low concentrations (i.e., PAHs) in SBOO sediments during 2007. Overall, there was no pattern in sediment contaminant concentrations relative to the SBOO discharge site.

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 2007 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). Numbers of *S. bombyx* collected during 2007 were the highest recorded since monitoring began in 1995.

The South Bay shallow water benthos was represented by several distinct sub-assemblages that occurred at sites differing in sediment structure (i.e., either more fines or more coarse materials), and to a lesser degree, TOC content. A different type of assemblage occurred at sites located in slightly deeper water where sediments contain finer particles, and which 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 *Spio maculata* and *Mooreonuphis* sp SD1, and the amphipod *Ampelisca cristata cristata*. Finally, sites with sediments composed of relict red sands or varied amounts of other coarse sands or shell hash were characterized by unique assemblages.

Species richness and total infaunal abundance values also varied with depth and sediment type, although there were no clear patterns relative to the outfall. Overall abundance and species richness were at their highest levels since monitoring began in the region. Patterns of region-wide abundance fluctuations over time appear to mirror historical patterns for *S. bombyx*. The range of values for most community parameters was similar in 2007 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 wastewater discharge has caused degradation of the marine benthos in the SBOO monitoring region.

DEMERSAL FISH AND MEGABENTHIC INVERTEBRATE COMMUNITIES

As in previous years, speckled sanddabs continued to dominate fish assemblages surrounding the SBOO during 2007. This species occurred at all stations and accounted for 68% of the total catch. Other characteristic, but less abundant species included the hornyhead turbot, roughback sculpin, California lizardfish, longfin sanddab, English sole, yellowchin sculpin, California tonguefish and California scorpionfish. Most of these common fishes were relatively small, averaging less than 20 cm in length. Although the composition and structure of fish assemblages varied among stations, these differences were mostly due to variations in speckled sanddab populations.

Assemblages of relatively large (megabenthic) trawl-caught invertebrates in the region were similarly dominated by one prominent species, the sea star *Astropectin verrilli*. Variations in megabenthic invertebrate community structure generally reflected changes in the abundance of this species, as well as other characteristic species such as the sea urchin *Lytechinus pictus*, the sand dollar *Dendraster terminalis*, and the shrimp *Crangon nigromaculata*. Two species which usually do not occur in South Bay trawls, the nereid polychaete *Platynereis bicanaliculata*, and the pea crab *Pinnixa franciscana* were captured during the year. These two species were apparently feeding on squid eggs that were also collected in one particular trawl.

Overall, results of the 2007 trawl surveys provide no evidence that the discharge of wastewater has affected either demersal fish or megabenthic invertebrate communities in the region. The relatively low numbers and low species richness of organisms found in the SBOO surveys are consistent with the depth and sandy habitat in which the trawl stations are located. Further, 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 these communities instead appear to be more likely due to natural factors such as changes in water temperatures associated with large-scale oceanographic events (e.g., El Niño) and the mobile nature of many species. Finally, the absence of any indicators of disease or other physical abnormalities in local fishes suggests that populations in the area remain healthy.

CONTAMINANTS IN FISH TISSUES

There was no clear evidence to suggest that tissue contaminant loads in fish captured at the SBOO monitoring sites were affected by the discharge of wastewater in 2007. Although several samples contained metal concentrations that exceeded pre-discharge maximum values, concentrations of most contaminants were not substantially different from pre-discharge data. In addition, the few samples that did exceed pre-discharge values were distributed widely among the stations and showed no pattern relative to wastewater discharge. Further, all contaminant values were within the range of those reported previously for SCB fishes

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 bioaccumulation and distribution of contaminants in local fishes include the different physiologies and life history traits of various species. Exposure to contaminants can vary greatly between species and even among individuals of the same species depending on migration habits. For example, 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 in the region that may contribute to contamination.

SAN DIEGO REGIONAL SURVEY

For the summer 2007 regional survey the City of San Diego revisited the same 40 randomly chosen sites that were initially selected for sampling in 1997 in order to compare benthic conditions 10 years later. Of these, a total of 39 sites ranging in depth from 13–216 m were successfully sampled during 2007.

The distribution of sediment particles at these regional stations was similar to that seen in previous years. Only seven of the sites showed any substantial change in mean particle size between 1997 and 2007. As in the past, there was a trend towards higher sand content in shallow nearshore areas compared to finer sands and silt at deeper offshore sites. For example, sediments from depths ≤30 m were composed of about 90% sands and 9% fines, whereas sediments at depths of 30–120 m were about 60% sands and 37% fines. Deeper sites occuring at depths of 120–200 m contained sediments that were about 52% sand and 47% fines. Exceptions to the general pattern occurred in mid-shelf sediments offshore of the SBOO, as well as along the Coronado Bank, a southern rocky ridge located soutwest of Point Loma at a depth of 150–170 m. Sediment composition at the stations from these areas tended to be coarser and have less fine materials than regional mid-shelf stations located off of Point Loma and further to the north. Overall, the sediments throughout the San Diego region reflect the diverse and patchy types of habitats that are common to the SCB.

Patterns in sediment chemistries at the regional sites generally followed the expected relationship of increasing concentrations with decreasing particle size. 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. The regional sediment survey data did not show any pattern of contamination relative to wastewater discharges.

The SCB benthos has long been considered a heterogeneous habitat, with the distribution of species and communities varying in space and time. The mainland shelf of this region consists largely of an *Amphiodia* (brittle star) mega-community with other sub-communities representing simple variations determined by differences in substrate type and microhabitat. Results of the 2007 and previous regional surveys off San Diego generally support this characterization. In addition, there were no substantial changes in community parameters between the 1997 and 2007 surveys. Therefore, results from 2007 support the conclusion that benthic assemblages in the vicinity of the South Bay and Point Loma outfalls, as well as dredge material disposal sites in the region have maintained a benthic community structure consistent with regional assemblages sampled in the past and throughout the entire SCB.

One third of the regional benthic sites sampled off San Diego in 2007 were characterized by an assemblage dominated by the ophiuroid *Amphiodia urtica*, a dominant species along the mainland shelf of southern California. Co-dominant species within this assemblage included other taxa common to the region such as the bivalve *Axinopsida serricata*. In contrast, the dominant species of other assemblages (or sub-assemblages) varied according to the sediment type or depth. For example, polychaete worms such as *Mediomastus* sp and *Monticellina siblina* were numerically dominant in mixed, sandy sediments. Another shallow shelf assemblage was characterized by coarser sediments, which were dominated by the spionid polychaete *Spiophanes bombyx*. The deepest stations (>130 m) had relatively high percentages of fine particles and organic carbon concentrations. These sites were characterized by relatively low species richness and abundance values, and were dominated by several different species of polychaetes (e.g., *Mediomastus* sp, *Paraprionospio pinnata*). Another deepwater assemblage with a lower percentage of fines and much higher TOC levels was characterized by high abundances of species found infrequently in other assemblages (e.g., *Aphelochaeta glandaria*, *Ceacum crebricinctum*).

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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 two separate sources, including the International Wastewater Treatment Plant (IWTP) operated by the City of San Diego's South Bay Water Reclamation Plant (SBWRP) and the International Boundary and Water Commission (IBWC). Wastewater discharge from the IWTP began on January 13, 1999 and is 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 is presently performed according to the provisions set forth in Order No. R9-2006-0067 for NPDES Permit No. CA0109045. The Monitoring and Reporting Programs (MRPs) included in the above permits and orders define the requirements for monitoring receiving waters in the region, including sampling design, compliance criteria, types of laboratory analyses, and data analysis 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 3½ years of pre-discharge monitoring 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 post-discharge data and conditions 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, 2007) 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 large-scale 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 or stormwater discharges, urban runoff, 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 produce 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 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. Results from the San Diego/Tijuana remote sensing program for calendar year 2007 are summarized in Svejkovsky (2008).

This report presents the results of all receiving waters monitoring conducted as part of the South Bay monitoring program in 2007. Included are sampling at both regular fixed stations surrounding the SBOO and at a set of randomly selected sites monitored for the annual benthic survey of the entire San Diego coastal 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 other anthropogenic 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 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 two diffuser legs extending an additional 0.6 km to the north and south. The outfall was originally designed to discharge effluent via a total of 165 diffuser risers, which included one riser located at the center of the "Y" and 82 other risers 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, wastewater discharge has 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 1994 Southern California Bight Pilot Project (SCBPP), and the

Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight′98 and Bight′03, respectively). Results of these three bight-wide 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 2007 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 1997 (see City of San Diego 1999). Although 40 sites were targeted each year, 39 were successfully sampled in 2007 compared to 37 originally in 1997. Unsuccessful sampling was typically due to the presence of rocky substrates or reefs that made it impossible to collect benthic grab samples.

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Chapter 2. Oceanographic Conditions

INTRODUCTION

The City of San Diego monitors oceanographic conditions in the region surrounding the South Bay Ocean Outfall (SBOO) to assist in evaluating possible impacts of the outfall on the marine environment. Treated wastewater is currently discharged to the Pacific Ocean via the SBOO at a depth of ~27 m and at a distance of approximately 5.6 km west of Imperial Beach. During 2007, average daily flow through the outfall was 25 mgd. Changes in current patterns, water temperatures, salinity, and density can affect the fate of the wastewater plume. These types of changes can also affect the distribution of turbidity (or contaminant) plumes that originate from various non-point sources. In the South Bay region these include tidal exchange from San Diego Bay, storm water discharge, surface water runoff from local watersheds, and outflows from the Tijuana River and Los Buenos Creek (Mexico). For example, flows from San Diego Bay and the Tijuana River are fed by 1075 km^2 and 4483 km^2 of watershed, respectively, and can contribute significantly to nearshore turbidity, sedimentation, and bacterial contamination (see Largier et al. 2004). These factors can affect water quality within the region either individually or synergistically.

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 that determine water column mixing potential, such as water temperature, salinity, and density are important components of ocean monitoring programs (Bowden 1975). Analysis of the spatial and temporal variability of these parameters in addition to transmissivity, dissolved oxygen, pH, and chlorophyll can elucidate patterns of water mass movement. Analysis of all of these parameters together for the receiving waters surrounding the SBOO can help (1) describe deviations from expected patterns, (2) assess the impact of the wastewater plume relative to other input sources, (3) determine the extent to which water mass movement or mixing affects the dispersion/dilution potential for discharged materials, and (4) demonstrate the influence of natural events such as storms or El Niño/La Niña oscillations.

Remote sensing observations from aerial and satellite imagery, and evaluation of bacterial distribution patterns may provide the best indication of the horizontal transport of discharge waters in the absence of information on deepwater currents (Pickard and Emory 1990; Svejkovsky 2006, 2007a, b; also see Chapter 3 of this report). Thus, the City of San Diego combines measurements of physical oceanographic parameters with assessments of indicator bacteria concentrations and remote sensing data to provide further insight into the transport potential in coastal waters surrounding the SBOO discharge site.

This chapter describes the oceanographic conditions that occurred in the South Bay region during 2007, and is referred to in subsequent chapters to explain patterns of bacteriological occurrence (see Chapter 3) or other changes in the local marine environment (see Chapters 4–7).

Materials and Methods

Field Sampling

Oceanographic measurements were collected at least once per month at 40 fixed monitoring stations (**Figure 2.1**). These stations are located between 3.4–14.6 km offshore along the 9, 19, 28, 38, 55 and 60-m depth contours, and form a grid encompassing an area of ~450 km^2 surrounding the outfall. Three of these stations (I25, I26, I39) are considered kelp bed stations and are subject to the 2001 California Ocean Plan water contact standards (see Chapter 3);

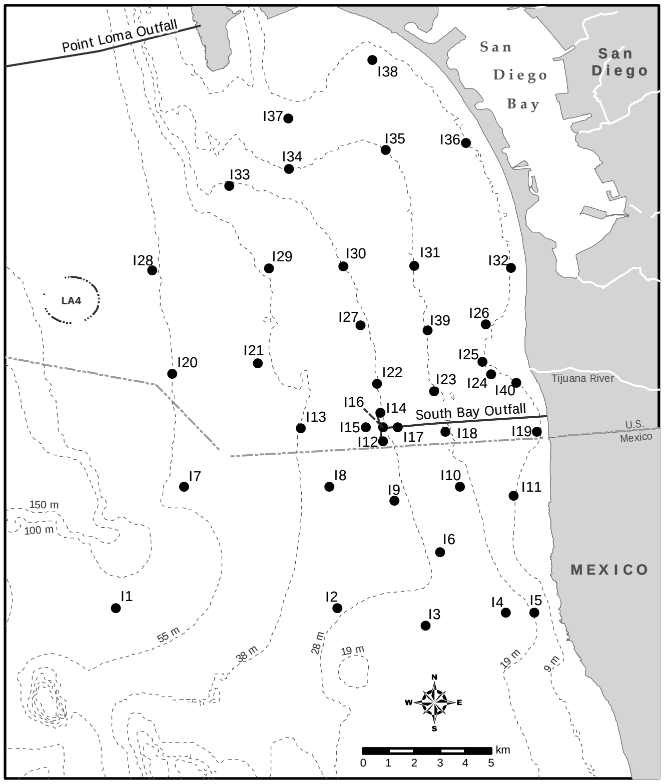

Figure 2.1
Water quality monitoring stations where CTD casts are taken, South Bay Ocean Outfall Monitoring Program.

each of these stations was sampled an additional four times per month.

Data for various water column parameters were collected using a SeaBird conductivity, temperature, and depth (CTD) instrument. The CTD was lowered through the water column at each station to collect continuous measurements of water temperature (°C), salinity (parts per thousand = ppt), density (δ/θ), pH, water clarity (% transmissivity), chlorophyll *a* (μg/L), and dissolved oxygen (mg/L). Profiles of each parameter were then constructed for each station by averaging the data values recorded over 1-m depth intervals. This ensured that physical measurements used in subsequent data analyses could correspond to discrete sampling depths for indicator bacteria (see Chapter 3). Visual observations of weather and water conditions were recorded just prior to each CTD cast.

Remote Sensing – Aerial and Satellite Imagery

Monitoring of the SBOO monitoring area also included aerial and satellite imagery generated and analyzed by Ocean Imaging (OI) of Solana Beach, CA (see Svejkovsky 2008). All usable images captured during 2007 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 four channels were configured to a specific wavelength (color) combination which maximizes the detection of the SBOO wastewater plume's turbidity signature by differentiating between the plume and coastal turbidity. The depth penetration of the sensor varies between 8–15 m, depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 m. Fifteen overflights were conducted in 2007, which consisted of two overflights per month during the winter when the outfall plume had the greatest surfacing potential, and one overflight per month during spring and summer.

Data Treatment

The water column parameters measured in 2007 were summarized for each month by depth zone; profile data from the three kelp stations were summarized for surface depths (≤2 m) and bottom depths (10–20 m), whereas profile data from the other offshore stations were summarized for surface depths (≤2 m), mid-depths (10–20 m), and bottom depths (≥ 27 m).

Mean temperature and salinity profile data from 2007 were compared with profile plots for 1995–2006 that consisted of means ±1 standard deviation (SD) at 5-m depth increments. Data for these comparisons were limited to four stations located along the 28-m depth contour, including station I12 located near the end of the southern diffuser leg, station I9 located south of the outfall, and stations I22 and I27 located north of the outfall. In addition, a time series of anomalies for each water column parameter was created to evaluate significant oceanographic events in the SBOO region.

Anomalies were calculated by subtracting the monthly means for each year (1995–2007) from the mean of all 13 years combined. Means were calculated using the same four stations described above, all depths combined.

Results and Discussion

Climate Factors and Ocean Conditions

Southern California weather can generally be classified into wet (winter) and dry (spring–fall) seasons (NOAA/NWS 2008a), and differences between these seasons affect certain oceanographic conditions (e.g., water column stratification, current patterns and direction). Understanding patterns of change in such conditions is important in that they can affect the transport and distribution of wastewater, storm water, or other types of turbidity plumes that may arise from various point or non-point sources (e.g., ocean outfalls, storm drains, outflows from rivers and bays, surface runoff from coastal watersheds). Winter conditions typically prevail in southern California from December through February during which time higher wind, rain and wave activity often contribute to the formation of a well-mixed or relatively homogenous (non-stratified) water column. The chance that the wastewater plume from the SBOO may surface is highest during such times when there is little, if any, stratification of the water column. These conditions often extend into March as the frequency of winter storms decreases and the seasons begin to transition from wet to dry. In late March or April the increasing elevation of the sun and lengthening days begin to warm surface waters, mixing conditions diminish with decreasing storm activity, and seasonal thermoclines and pycnoclines become re-established. Once the water column becomes stratified again by late spring, minimal mixing conditions typically remain throughout the summer and early fall months. In October or November, cooler temperatures associated with seasonal changes in isotherms, reduced solar input, along with increases in stormy weather, begin to cause the return of well-mixed or non-stratified water column conditions.

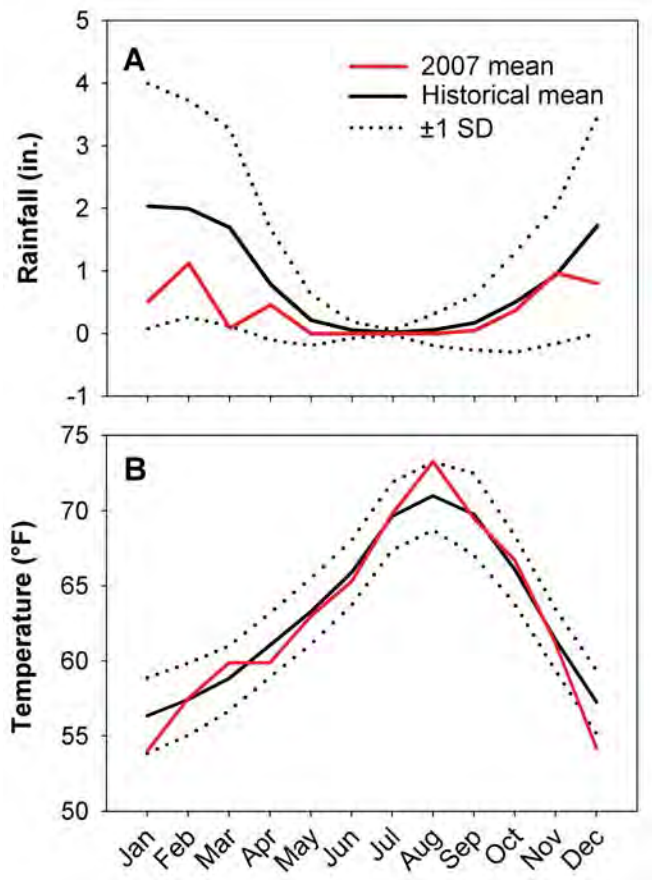

Figure 2.2
Total monthly rainfall (A) and monthly mean air temperature (B) at Lindbergh Field (San Diego, CA) for 2007 compared to monthly mean rainfall and air temperature (±1 SD) for the historical period 1914–2006.

Total rainfall was only a little over 4 inches in the San Diego region during 2007, which was well below the historical average of more than 10 inches/year (NOAA/NWS 2008b). Although below normal, rainfall followed expected seasonal patterns, with the greatest and most frequent rains occurring during February (**Figure 2.2A**). In contrast, air temperatures were generally similar during the year to historical averages, although exceptions occurred in January, August and December (Figure 2.2B). The above normal air temperatures present during the summer months coincided with higher than normal surface water temperatures and salinity values that were observed in the SBOO region (see below). Aerial imagery indicated that current flow was predominantly southward in 2007, although with occasional northward flows occurred following storm events (Svejkovsky 2008). For example, increased outflows from the Tijuana

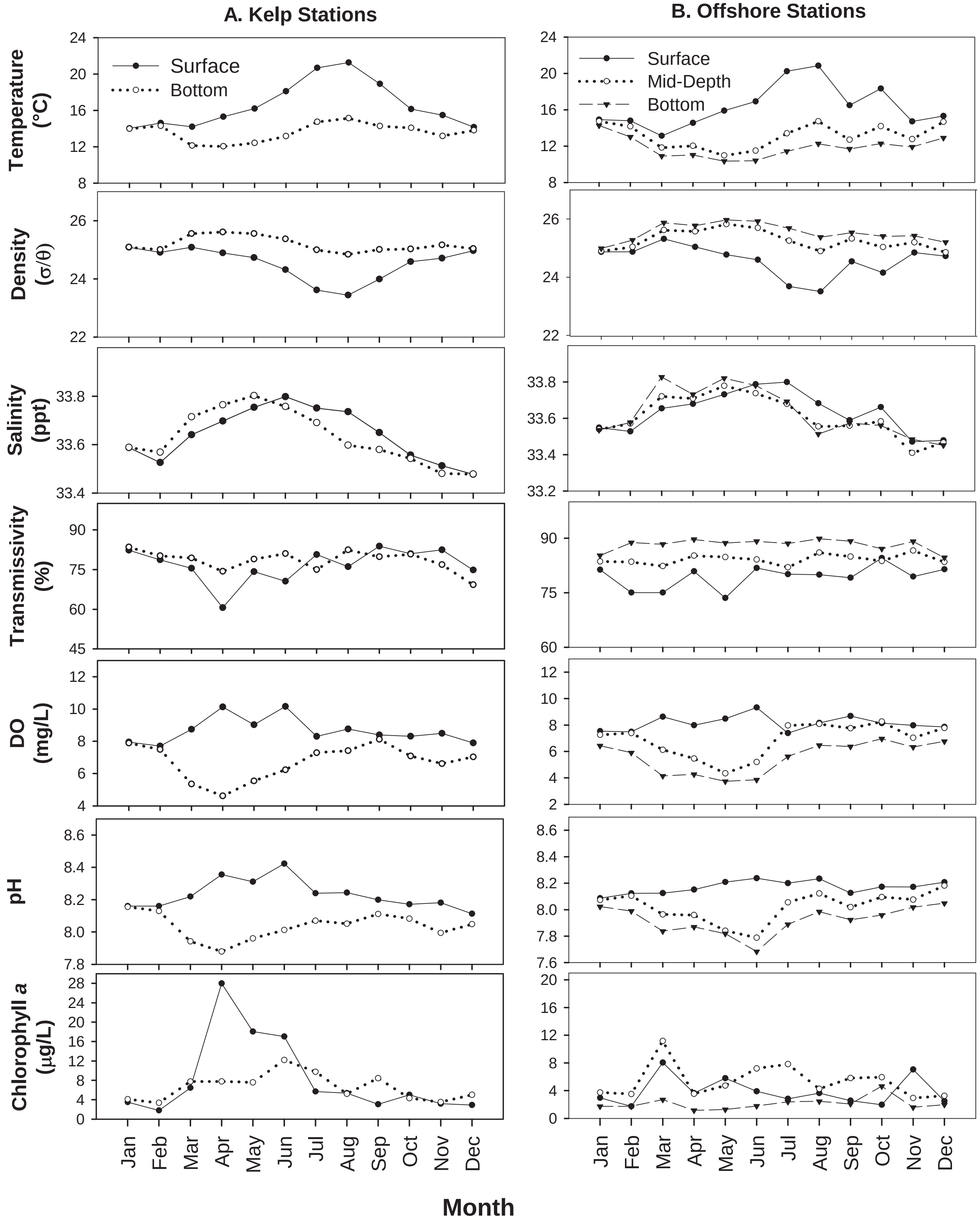

Figure 2.3

Monthly mean temperature, density, salinity, transmissivity, dissolved oxygen (DO), pH, and chlorophyll *a* values for (A) surface (≤2m) and bottom (10-20 m) waters at the kelp stations and (B) surface (≤2m), mid-depth (10–20 m) and bottom (≥27m) waters at SBOO stations during 2007.

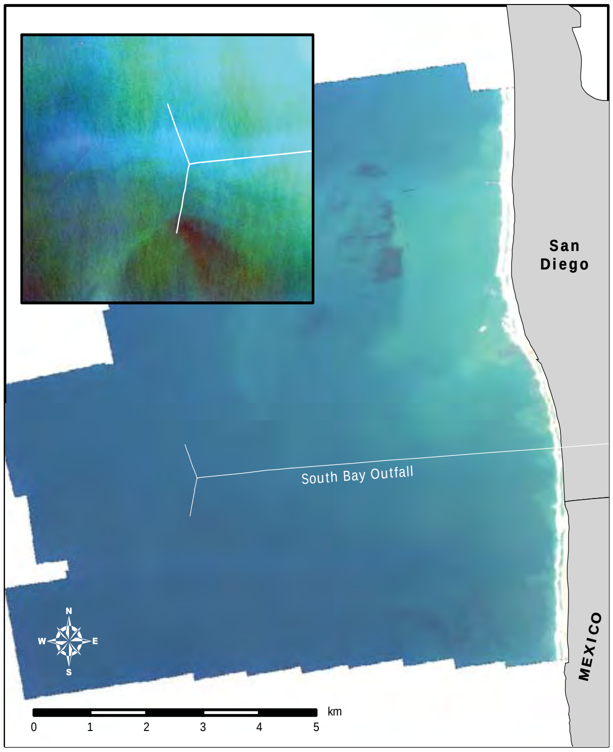

Figure 2.4
DMSC image composite of the SBOO outfall and coastal region acquired on January 3, 2007. Effluent from the south diffuser leg is seen as red plume in the inset and indicates a southerly flow.

River and Los Buenos Creek during the wet season resulted in large northward-flowing turbidity plumes along the coast. These plumes were often associated with increases in bacterial contamination along the shoreline or in nearshore waters (see Chapter 3).

Oceanographic Conditions in 2007

Water Temperature

Water temperature is the main factor affecting water density and stratification of southern California ocean waters (Dailey et al. 1993, Largier et al. 2004), and differences in surface and bottom temperatures can provide the best indication of the surfacing potential of wastewater plumes This is particularly true for the South Bay outfall region where waters are relatively shallow and salinity is relatively constant. In 2007, surface temperatures at the kelp stations ranged from 14.0°C in January to 21.3°C in August, whereas bottom temperatures ranged from 12.0°C in April to 15.1°C in August (**Appendix A.1**). Temperatures at the other offshore stations ranged from 13.1°C in March to 20.9°C in August in surface waters, and from 10.4°C in May/June to 14.3°C in January in bottom waters (**Appendix A.2**). Thermal stratification of the water column generally followed normal seasonal patterns, with the least stratification occurring during the winter (January–March, December), and the greatest stratification occurred during July and August in the summer (**Figure 2.3**).

Remote sensing results generally confirmed water column stratification patterns that were apparent in CTD data (Svejkovsky 2008). For example, DMSC aerial imagery detected the near-surface signature of the wastewater plume on several occasions above the location of the SBOO southern terminus when the water column was well mixed (i.e., not stratified). This included the period from January–March (see **Figure 2.4**), and during November and December. Subsequent aerial imagery suggested that the plume, as usual, remained deeply submerged from June–October when the water column was stratified.

Salinity

Salinity profiles were relatively uniform in 2007. Salinities at the kelp stations ranged from 33.48 ppt in December to 33.80 ppt in June in surface waters, and from 33.48 ppt in November and December to 33.80 ppt in May at bottom depths (Appendix A.1). Surface salinities at the other offshore stations ranged from 33.47 ppt in November to 33.80 ppt in July, while bottom salinities ranged from 33.45 ppt in December to 33.83 ppt in March (Appendix A.2). Salinity values at all stations followed normal seasonal patterns with values increasing at all depths from March through July, followed by a steady decline thereafter (Figure 2.3).

Density

Density, a product of temperature, salinity, and pressure, is influenced primarily by temperature differences in the South Bay region where depths are shallow and salinity profiles are relatively uniform. Therefore, changes in density typically mirror changes in water temperature. This relationship was true for 2007, as indicated by water column data collected at the kelp and other offshore water quality stations (Appendix A.1, A.2). The differences between surface and bottom water densities resulted in a pycnocline from April through October with maximum stratification occurring in August (Figure 2.3).

Chlorophyll *a*

Mean chlorophyll *a* concentrations in surface waters ranged from 1.8 µg/L in February to 28.0 µg/L in April at the kelp stations, and from 1.7 µg/L in February to 8.1 µg/L in March at the other offshore stations (Appendix A.1, A.2). The high chlorophyll values reported for surface waters beginning in March corresponded to plankton blooms observed in MODIS satellite imagery (Svejkovsky 2008). The spring plankton blooms are likely the result of upwelling events that typically occur during this time of the year (Jackson 1986, Svejkovsky 2008). Elevated chlorophyll concentrations persisted at the kelp stations from March until June, but declined gradually from 28.0 µg/L to 17.0 µg/L. Chlorophyll levels were also elevated at offshore mid-depths and kelp station bottom depths during June, July and September, which was most likely due to decaying plankton sinking towards the bottom. Increases in plankton density, as estimated using chlorophyll *a*, likely influenced some of the declines in transmissivity and increases in dissolved oxygen and pH that occurred during these periods (Figure 2.3).

Historical Assessment of Oceanographic Conditions

Water temperatures at stations I9, I12, I22, and I27 exceeded historical ranges during most of 2007 (**Figure 2.5**). Average temperatures for March–June and September–November of 2007 were much lower than the historical average due to strong upwelling that occurred during the year. In contrast, temperatures in the upper 15 m of the water column during August were well above the historical average. The relatively high temperatures recorded in surface waters in August may have been influenced by the above average air temperatures for this month (NOAA/NWS 2008b).

Salinity values were also well above historical averages (**Figure 2.6**), another indication that stronger than normal upwelling may have occurred during these periods. Previous studies of the South Bay region have concluded that topographic features such as the Point Loma headland create a divergence of the prevailing southerly flow as it encounters shallower isobaths, creating a vorticity that transports deeper water to the surface (i.e., upwelling) where it is subsequently swept southward within the South Bay (see **Figure 2.7**; Roughan et al. 2005; City of San Diego 2007). This is supported by MODIS imagery and CODAR plots, which indicated the presence of strong southward currents during March, April, September, October and November of 2007 (Svejkovsky 2008). Furthermore, large plankton and turbidity plumes were observed moving offshore and across South Bay during these months. In addition, maximum wind speed for 2007 occurred in March (32 mph NW) and may have contributed to the upwelling event in early spring (Appendix A.3).

A review of oceanographic data between 1995 and 2007, using the same four SBOO stations (I9, I12, I22, I27), does not reveal any measurable impact that can be attributed to the beginning of wastewater discharge via the SBOO in 1999 (**Figure 2.8**). Instead, these data are notably consistent with changes in large scale patterns observed for the region by CalCOFI (Peterson et al. 2006; Goericke et al. 2007). Four significant events have affected the California Current System (CCS) 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; (4) the intrusion of subarctic surface waters that resulted in lower than normal salinities in southern California during 2002–2003. Temperature and salinity data for the South Bay region are consistent with the first, second,

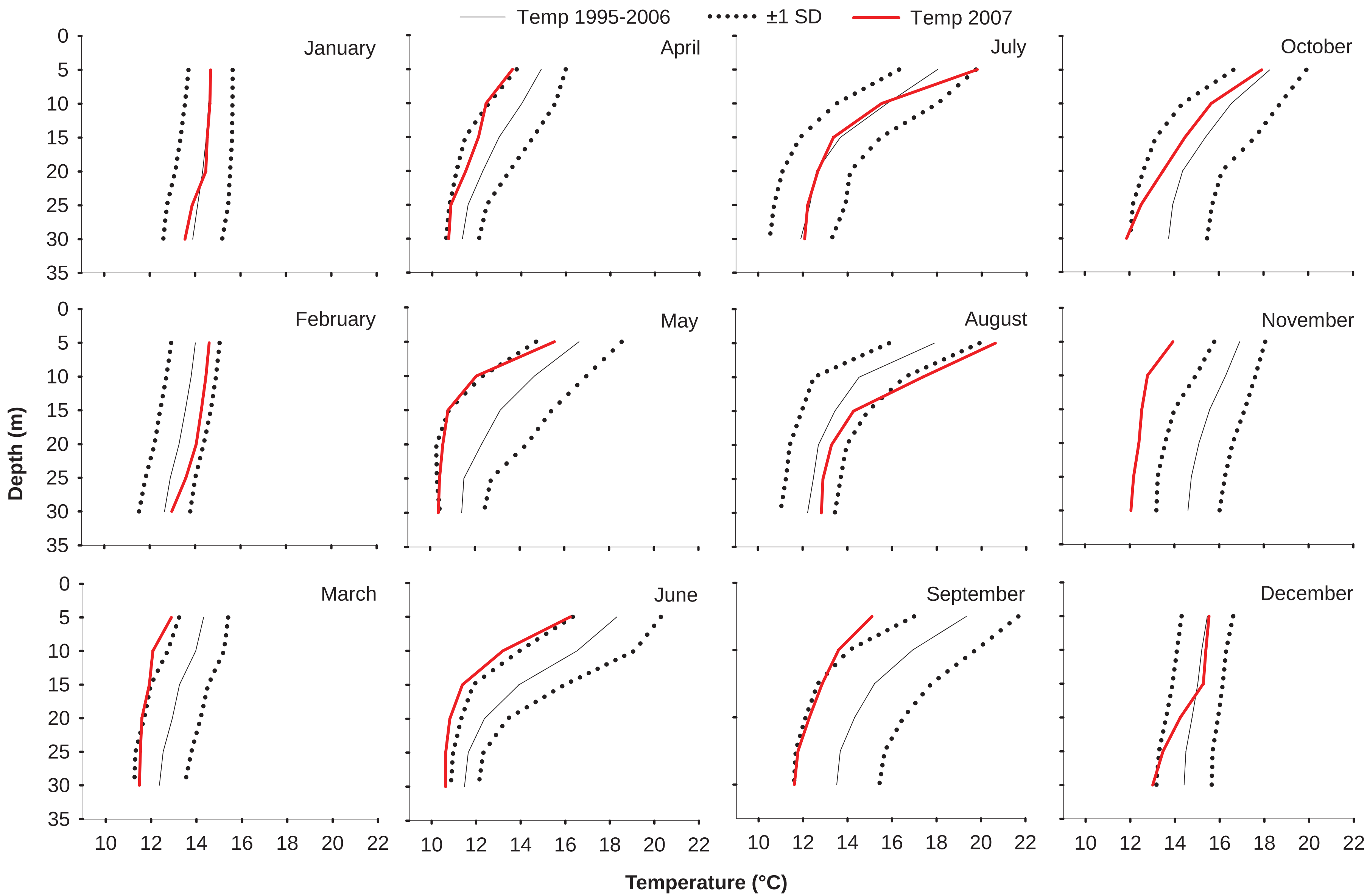

Figure 2.5
Mean temperature CTD profile data for January–December 2007 compared to mean temperature (±1 SD) profiles for the historical period 1995 through 2006 at stations I9, I12, I22, and I27.

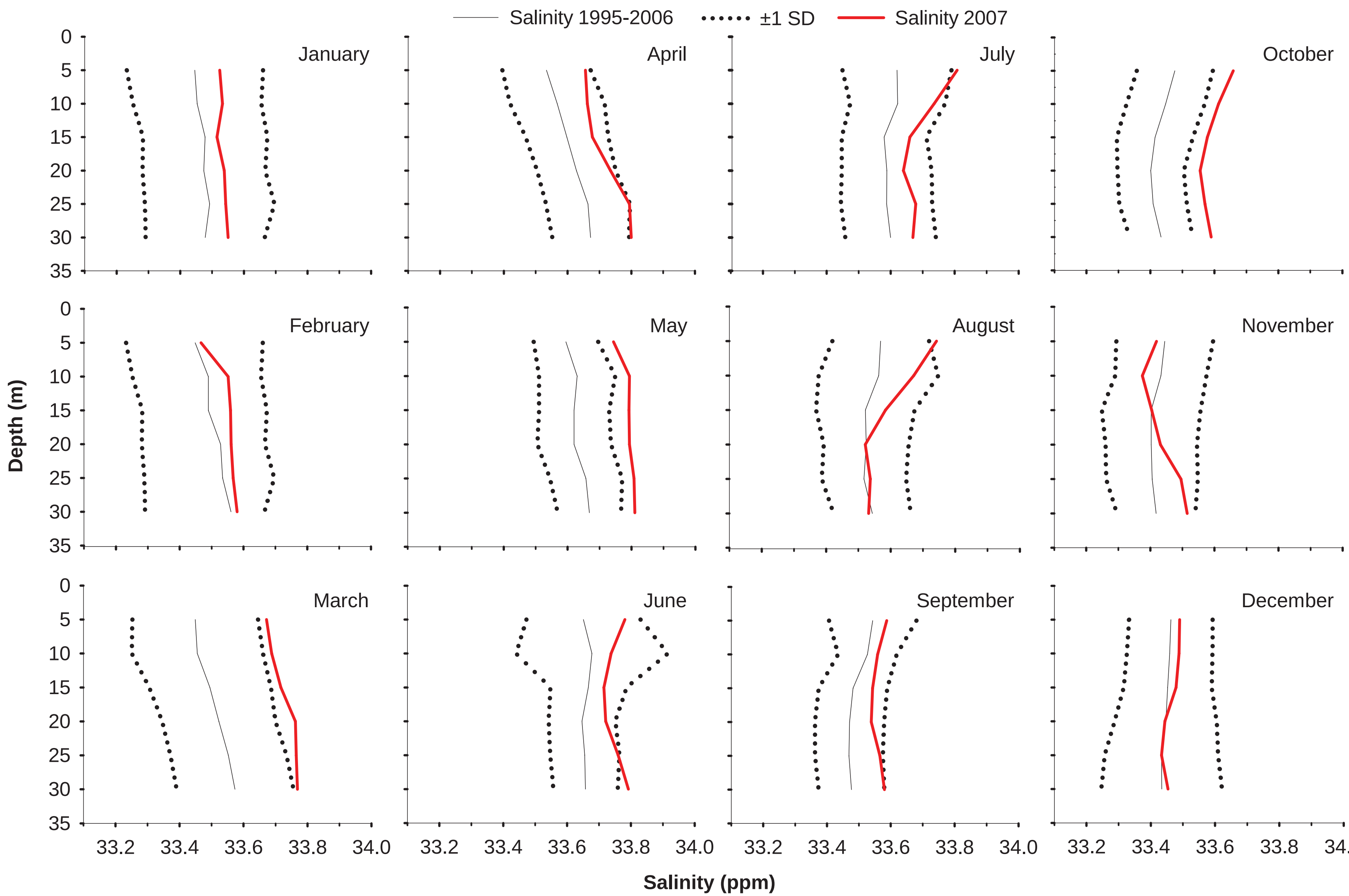

Figure 2.6
Mean salinity CTD profile data for January–December 2007 compared to mean salinity (±1 SD) profiles for the historical period 1995 through 2006 at stations I9, I12, I22, and I27.

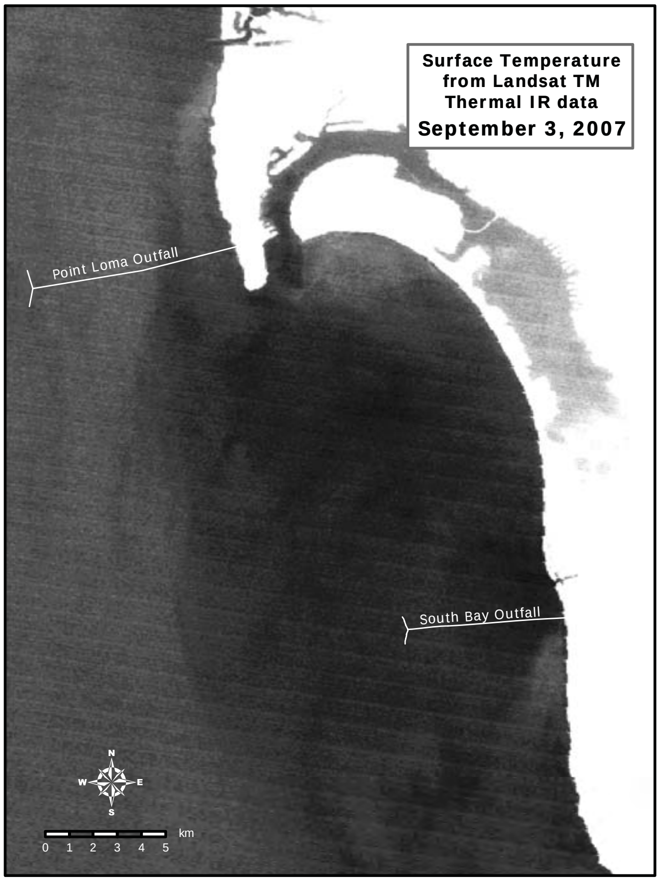

Figure 2.7
TM infrared satellite imagery from September 3, 2007 showing the San Diego water quality monitoring region. Cooler water resulting from upwelling events appears as darker shades of gray.

and fourth CCS events. However, the trend of cooler water beginning in 2005 and continuing through 2007 (Figure 2.8) varies from other surveys of the California Current System and is more consistent with data from northern Baja California (Mexico) where water temperatures were below the decadal mean during 2005 and 2006 (Peterson et al. 2006).

Salinity values within the South Bay region were higher than the historical average (i.e., above "normal") during most of 2007 (Figure 2.8), with the largest deviations occurring in March and October. These results provide further evidence of upwelling events that occurred during these months.

Overall water clarity (transmissivity) has generally increased in the South Bay region since initiation of discharge in 1999, despite several intermittent periods when clarity was below normal (Figure 2.8). Transmissivity was much lower than normal during the winter months of several years (e.g., 1998, 2000); these periods of low transmissivity are likely due to increased suspension of sediments caused by strong storm activity (see NOAA/NWS 2008b). In addition, below average water clarity events that occur in spring and early summer months are probably related to plankton blooms such as those observed throughout the region in 2005 (City of San Diego 2006). In contrast, water clarity during 2006 and 2007 was mostly above the historical average; these results are indicative of reduced turbidity due to the lack of storm activity and rainfall that totaled less than 11 inches for these two years.

Chlorophyll *a* concentrations in the South Bay region have been below average more often than not since measurements began in 1998 (Figure 2.8). These results are consistent with those observed in northern Baja California, and are in contrast to the rest of southern California during recent years (Peterson et al. 2006). Occasional periods of higher than normal chlorophyll concentrations within the South Bay region occurred as a result of red tides 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). During 2007, chlorophyll levels were generally below the historical mean, with the exception of a few spikes that correspond with plankton blooms in March, April, June, and October.

There were no apparent trends in pH values or dissolved oxygen concentration related to the SBOO (Figure 2.8). These parameters are complex, dependent on water temperature and depth, and sensitive to physicochemical and biological processes (Skirrow 1975). Moreover, dissolved oxygen and pH are subject to diurnal and seasonal variations that make temporal

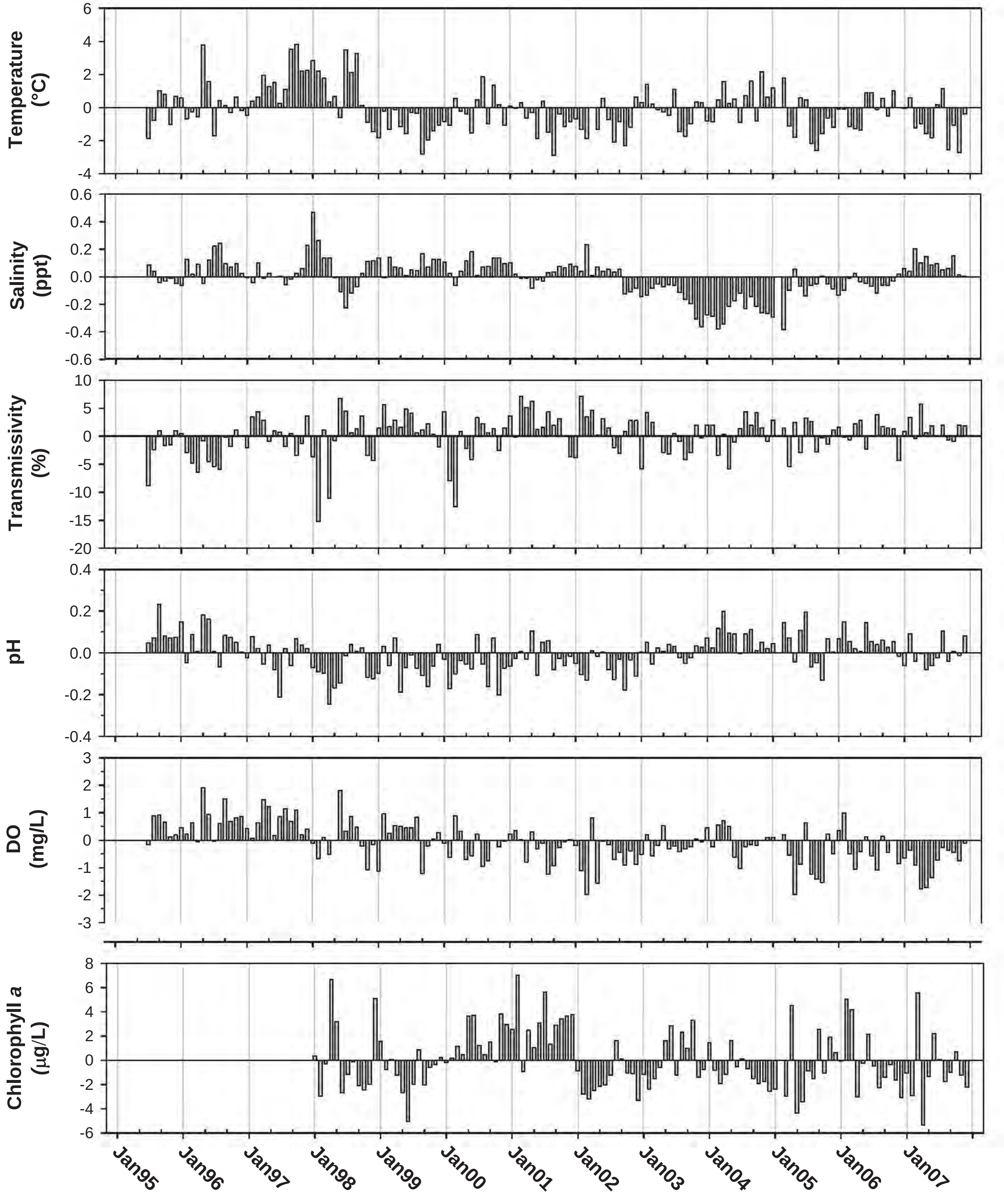

Figure 2.8

Time series of temperature, salinity, transmissivity, pH, dissolved oxygen (DO), and chlorophyll *a* anomalies between 1995 and 2007. Anomalies were calculated by subtracting the monthly means for each year (1995–2007) from the mean of all 13 years combined; data were limited to stations I9, I12, I22, and I27, all depths combined.

changes difficult to evaluate. However, below normal concentrations of dissolved oxygen during 2005–2007 appear to be related to low levels of chlorophyll *a* during these years.

Summary and Conclusions

Oceanographic conditions in 2007 were characterized by strong upwelling and corresponding plankton blooms in the spring and fall and relatively high surface seawater temperatures in August. Upwelling events were indicated by cooler than normal water temperatures, especially at bottom depths, and higher than normal salinity during March–June and September–November. Plankton blooms were indicated by high chlorophyll concentrations and confirmed by remote sensing observations (i.e., aerial and satellite imagery). The relatively high temperatures recorded in surface waters in August may have been influenced by the above average air temperatures that occurred during this month (see NOAA/NWS 2008b).

Thermal stratification of the water column followed typical patterns for the San Diego region with maximum stratification occurring in mid-summer and reduced stratification during the winter. DMSC aerial imagery detected the near-surface signature of the wastewater plume on several occasions between January through March and between November and December above the location of the SBOO southern terminus when the water column was well mixed. In contrast, the plume remained deeply submerged between June and October when the water column was stratified. Results from SBOO microbiology surveys further support that the plume remained offshore and submerged during these months (see Chapter 3).

Long-term analysis of water column data collected between 1995–2007 did not reveal any changes in oceanographic parameters that could be attributed to the discharge of wastewater that began in 1999. Instead, major changes in water temperatures and salinity for the South Bay region corresponded to significant climate events that occurred within the California Current System between 1995 and 2005 (see previous discussion). During late 2006 and early 2007, no clear patterns were observed in the California Current System, and regional or local processes dominated observed patterns. Additionally, water clarity has increased in the SBOO region since initiation of wastewater discharge, chlorophyll *a* levels in the area have remained consistent with water conditions in northern Baja California and changes in pH and dissolved oxygen levels have not exhibited any apparent trends related to wastewater discharge.

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Chapter 3. Microbiology

INTRODUCTION

The City of San Diego performs water quality monitoring along the shoreline and in offshore ocean waters for the region surrounding the South Bay Ocean Outfall (SBOO). This aspect of the City's ocean monitoring program is designed to assess general oceanographic conditions, evaluate patterns in movement and dispersal of the SBOO wastewater plume, and monitor compliance with water contact standards defined in the 2001 California Ocean Plan (COP) as according to NPDES permit specifications (see Chapter 1). Results of all sampling and analyses, including COP compliance summaries, are submitted to the San Diego Regional Water Quality Control Board and the International Boundary and Water Commission in the form of monthly receiving waters monitoring reports. Densities of indicator bacteria (total coliforms, fecal coliforms, enterococcus), along with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged to the Pacific Ocean through the outfall. Analyses of these data may also help identify other point or non-point sources of bacterial contamination in the region (e.g., outflows from rivers or bays, surface runoff from local watersheds). This chapter summarizes and interprets patterns in seawater bacterial concentrations collected for the South Bay region during 2007.

Materials and Methods

Field Sampling

Seawater samples for bacteriological analyses were collected at a total of 51 fixed shore or offshore sampling sites during 2007 (**Figure 3.1**). Sampling was performed weekly at 11 shore stations to monitor bacterial levels along public beaches. Eight of the shore stations (S4, S5, S6, S8, S9, S10, S11, S12), located between the USA/Mexico border and Coronado, southern California, are subject to COP water contact standards (see **Box 3.1**). The other three shore stations (S0, S2, S3) located south of the border are not subject to COP requirements. In addition, 28 stations were sampled in offshore waters to monitor levels of indicator bacteria. These offshore sites are located in a grid surrounding the outfall along the 9, 19, 28, 38, and 55-m depth contours. Three of the offshore sites (stations I25, I26 and I39) are considered kelp bed stations because of their proximity to the Imperial Beach kelp bed. These three stations are subject to the COP water contact standards and are each sampled five times per month. The remaining 25 offshore stations are sampled once a month, usually over a 3-day period.

Seawater samples from the 11 shore stations were collected from the surf zone in sterile

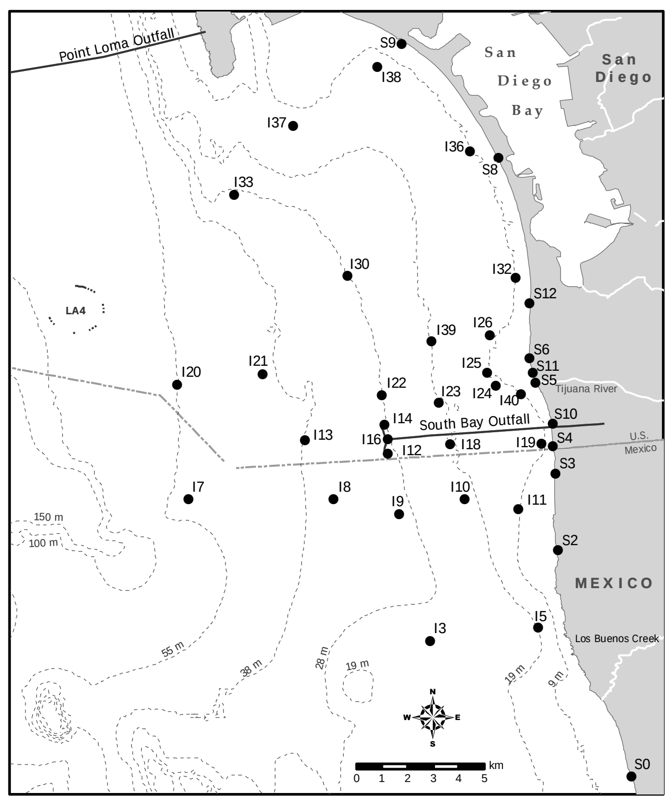

Figure 3.1
Water quality monitoring stations for the South Bay Ocean Outfall Monitoring Program.

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.

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

Seawater samples were collected at three discrete depths at each of the kelp bed and other offshore sites and analyzed for the above indicator bacteria (total and fecal coliforms, enterococcus), total suspended solids (TSS), and oil and grease. These samples were collected using either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Aliquots for each analysis were drawn into appropriate sample containers. Seawater samples for bacteriological analysis were refrigerated on board ship and transported to the CSDMML for analysis. The TSS and oil and grease samples were taken to the City's Wastewater Chemistry Laboratory for analyses. Visual observations of weather conditions, 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 of Solana Beach, California (Svejkovsky 2008; see also 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 CSDMML 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 (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1992).

Colony counting of indicator bacteria, calculation of results, data verification and reporting all follow guidelines established by the EPA (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 calculation of mean values and in determining compliance with COP standards.

Quality assurance tests were performed routinely on seawater samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split bacteriological samples were 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 for 2007 (City of San Diego 2008).

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 benchmarks are: (a) >1000 CFU/100 mL for total coliforms; (b) >400 CFU/100 mL for fecal coliforms; (c) >104 CFU/100 mL for enterococcus. Furthermore, seawater samples with total coliform concentrations ≥1000 CFU/100 mL and fecal:total (F:T) ratios ≥0.1 are considered representative of contaminated waters (see CDHS 2000). Samples that met these latter criteria were used as indicators of the SBOO waste field or other sources of contamination.

Results and Discussion

Shore Stations

Concentrations of indicator bacteria were generally very low along the South Bay shoreline in 2007, which likely reflects the relatively low rainfall that occurred during the year (see **Appendix B.1**). Monthly densities averaged 6 to 10,676 CFU/100 mL for total coliforms, 2 to 4234 CFU/100 mL for fecal coliforms, and 2 to 3018 CFU/100 mL for enterococcus. As expected, the highest bacterial densities occurred during the wet season (**Figure 3.2**). This was particularly true for February, which was the wettest month of the year. MODIS satellite imaging of the region on February 20 showed turbidity plumes from the Tijuana River and Los Buenos Creek (in Mexico) encompassing several of the shore stations, all of which had elevated bacteria levels (**Figure 3.3**). These types of turbidity plumes were observed repeatedly following rain events during the year (Svejkovsky 2008). In contrast to the wet season, bacterial contamination along the shore was sporadic during periods of warmer, dry conditions from May through October. For example, only

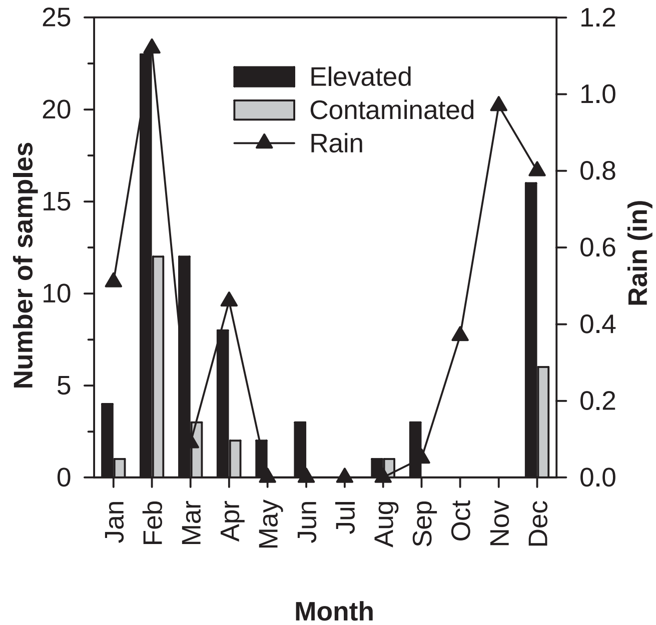

Figure 3.2
Comparison of monthly rainfall to total coliform concentrations in samples from SBOO shore stations collected during 2007. Elevated=number of samples with total colifom densities ≥1000 CFU/100 mL; Contaminated=number of samples with total coliform densities ≥1000 CFU/100 mL plus a F:T ratio ≥0.1. Rain was measured at Lindbergh Field, San Diego, CA. It should be noted 96% of the rainfall in November occurred on November 30.

one out of 30 samples collected in June had total coliform concentrations >10,000 CFU/100 mL, and only one out of 24 samples from August had a F:T ratio ≥0.1 (**Appendix B.2**). Both of these samples were collected at southernmost station S0 located in Mexico.

The general relationship between rainfall and levels of indicator bacteria has remained consistent since sampling began in 1995 (**Figure 3.4**). This is particularly evident at shore stations located nearest the Tijuana River (stations S2-S6, S10, and S11) and Los Buenos Creek (station S0). Historically these stations have had higher levels of fecal coliforms than stations located further north (e.g., S8 and S9; City of San Diego 2007a). Contaminated waters originating from the Tijuana River and Los Buenos Creek during periods of increased flows (e.g., during storms or extreme tidal exchanges) are likely sources of bacteria for nearby monitoring sites (see Largier et al. 2004).

Figure 3.3

MODIS satellite imagery showing the SBOO monitoring region on February 20, 2007 (Svejkovsky 2008) combined with total coliform concentrations at shore stations sampled on the same day. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving north along the coastline, overlapping stations with higher levels of contamination. Waters are clear over the outfall discharge site.

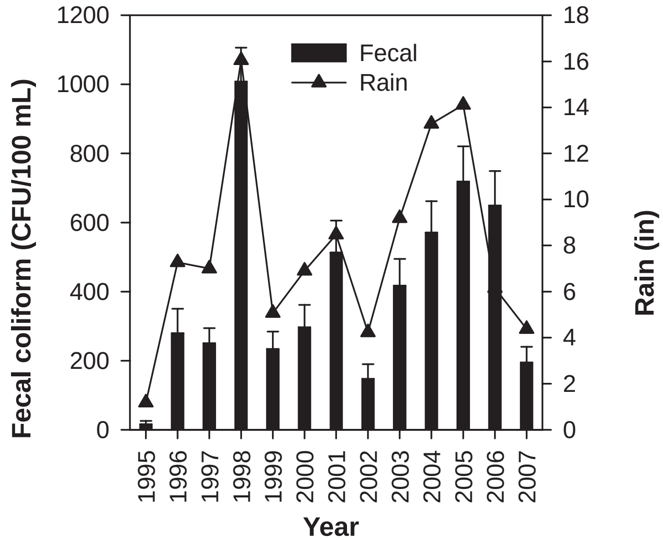

Figure 3.4

Comparison of annual rainfall to fecal coliform concentrations in samples from SBOO shore stations collected between 1995 and 2007. Fecal concentrations are expressed as mean±SE per year. Rain for 1995 includes only October–December. Rain was measured at Lindbergh Field, San Diego, CA.

Such contaminants may be from upstream sources, including sod farms, surface runoff not captured by the canyon collector system, the Tijuana estuary (e.g., decaying plant material), and partially treated effluent from the San Antonio de los Buenos Wastewater Treatment Plant (in Mexico) that ends up in Los Buenos Creek.

Kelp Stations

There was no evidence that the wastewater plume from the SBOO impacted any of the three kelp stations in 2007. Instead, elevated levels of indicator bacteria at these sites corresponded to periods of heavy rainfall similar to the pattern seen at the shore stations. For example, all 13 of the instances where total coliform concentrations were elevated (i.e., ≥ 1,000 CFU/100mL) at the kelp stations occurred during February when rainfall was greatest for the year (**Table 3.1**). Furthermore, MODIS imagery for February 21 indicated such a rain-influenced turbidity plume moving northeast from the Tijuana River and encompassing all of the kelp stations (**Figure 3.5**). While some elevated levels of total coliform bacteria occurred in 2007, enterococcus bacteria exceeded benchmark values (104 CFU/100 mL) on only five occasions during February, March, and July (see City of San Diego 2007b, c, d), and fecal coliforms never exceeded benchmark values (400 CFU/100 mL).

Oil and grease and total suspended solids (TSS) are also measured at the kelp stations as potential indicators of wastewater. However, previous analyses have demonstrated that these parameters have limited utility as indicators of the waste field (City of San Diego 2007a). Oil and grease concentrations were mostly below the detection limit (<1.4 mg/L) in 2007; the only exception was a value of 1.5 mg/L at station I39 in September (**Table 3.2**). TSS varied considerably during the year, ranging between 1.7 and 22.8 mg/L per sample. Of the 15 seawater samples with

Table 3.1 Summary of samples with elevated total coliform concentrations (> 1000 CFU/100 mL) collected at SBOO kelp stations during 2007. Values are expressed as CFU/100 mL; Total=total coliform; Fecal=fecal coliform; F:T=fecal to total coliform ratio.

Station	Date	Depth	Total	Fecal	F:T
I25	February 2	2	11,000	140	0.013
I25	February 2	6	>16,000	100	0.006
I25	February 2	9	3400	34	0.010
I26	February 2	2	4000	18	0.005
I26	February 2	6	2400	28	0.012
I26	February 2	9	2600	16	0.006
I39	February 2	2	1200	2	0.002
I25	February 21	2	5200	160	0.030
I25	February 21	6	4200	94	0.020
I25	February 21	9	5200	110	0.020
I26	February 21	2	3200	74	0.020
I26	February 21	6	1400	50	0.040
I26	February 21	9	1600	72	0.050
I39	February 21	2	2000	56	0.030
I39	February 21	12	2000	58	0.030
I39	February 21	18	1200	26	0.020

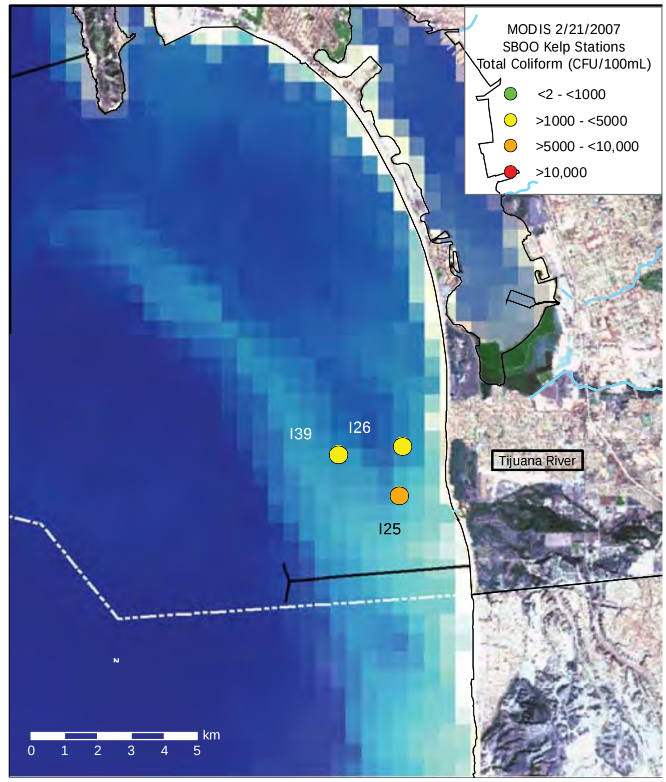

Figure 3.5
MODIS satellite image showing the SBOO monitoring region on February 21, 2007 (Svejkovsky 2008) combined with total coliform concentrations at kelp stations sampled on the same day. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving north along the coastline overlapping the kelp stations. Waters are clear over the outfall discharge site.

elevated TSS concentrations (≥10.0 mg/L), only one corresponded to a sample with elevated levels of indicator bacteria (i.e., total coliforms >1000 CFU/100 mL). In contrast, five of these high TSS samples occurred at bottom depths; were likely due to re-suspension of bottom sediments when the CTD reached the sea floor. The remaining nine represented surface-water samples most likely associated with plankton blooms (see Chapter 2).

Offshore Stations

Monthly sampling of indicator bacteria at the other 25 offshore stations also showed some trends related to rainfall (**Figure 3.6**) or to proximity to the outfall discharge site. Forty-three out of the 900 samples collected at these sites during 2007 had total coliform levels above benchmark values (**Table 3.3**). Of these, 18 samples also exceeded the fecal coliform benchmark, while seven of the samples had a fecal to total coliform ratio indicative of contaminated waters (i.e., F:T ≥0.1). A total of 21 samples were collected during the wet season at depths between 2 and 12 m, 18 of which were from nearshore stations I18, I19, I23, I24, and I40. As with the shore and kelp stations, evidence from the MODIS satellite imaging suggests that the nearshore region is being affected by turbidity (contaminant) plumes originating from the Tijuana River and Los Buenos Creek. For example, a MODIS image taken on February 21 indicated that a turbidity plume associated with increased rainfall had a northeast trajectory that encompassed stations I18, I19, I23, I24, and I40, which were all sampled on the same day (**Figure 3.7**). Samples collected at these five stations on that day were found to have coliform levels that exceeded benchmark values. In contrast, stations located in close proximity to the SBOO (i.e., 12, I14, I16, and I22) sampled on that day had low levels of indicator bacteria at all depths. All other offshore samples also had low coliform levels in February.

Elevated levels of indicator bacteria were also detected at a few other sites during the year.

Table 3.2

Summary of oil and grease and total suspended solid concentrations in samples collected from kelp stations in 2007. The method detection limits are 1.4 mg/L for O&G and 1.6 mg/L for TSS; (n=number of samples with detected concentrations).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oil & Grease												
n	0	0	0	0	0	0	0	0	1	0	0	0
Min	—	—	—	—	—	—	—	—	1.5	—	—	—
Max	—	—	—	—	—	—	—	—	1.5	—	—	—
Mean	—	—	—	—	—	—	—	—	1.5	—	—	—
Total Suspended Solids												
n	9	9	9	9	9	9	9	9	9	9	9	9
Min	3.3	4.7	3.8	2.3	1.7	3.6	4.1	7.5	2.0	2.6	3.8	1.7
Max	8.1	10.2	22.8	6.8	7.6	9.4	10.3	13.2	10.3	15.0	11.5	6.7
Mean	5.1	6.3	8.1	4.1	3.2	5.4	6.5	11.3	3.5	6.4	5.7	3.4

Thirteen of the above 43 samples with elevated total coliforms were collected at stations I12 and I16 located immediately adjacent to the SBOO (see Table 3.3). Eleven of these samples were collected at depths of 18 m or deeper, of which six exceeded the fecal coliform benchmark; three of these samples had F:T ratios indicative of contaminated waters. An additional five samples were collected at stations I9 (located south of the outfall) or I21 (located northwest of the outfall). Overall, these results support the observation that the SBOO wastewater plume remained subsurface and offshore during most of 2007.

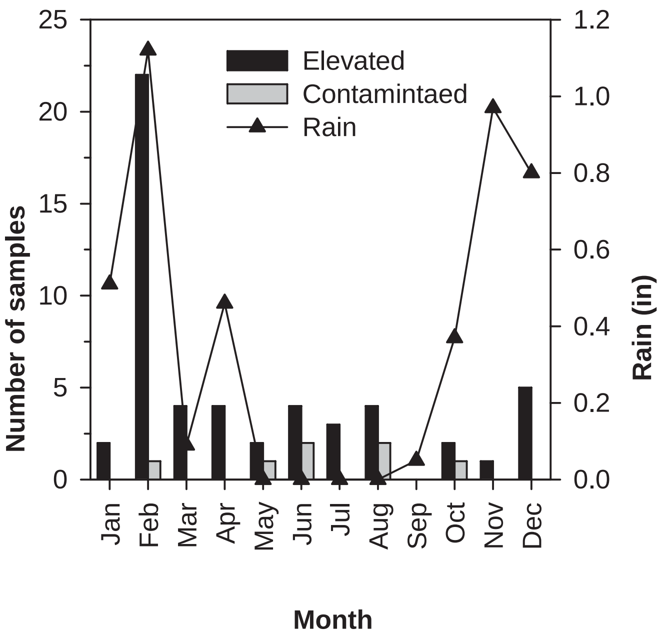

Figure 3.6

Comparison of monthly rainfall to total coliform concentrations in samples from SBOO offshore stations collected during 2007. Elevated=number of samples with total coliform densities ≥1000 CFU/100 mL; Contaminated=number of samples with total coliform densities ≥1000 CFU/100 mL plus a F:T ratio ≥0.1. Rain was measured at Lindbergh Field, San Diego, CA. It should be noted 96% of the rainfall in November occurred on November 30.

A comparison of fecal coliform densities in 2007 to those from both the pre-discharge period (1995-1998) and prior post-discharge period (1999-2006) demonstrates that while bacteria levels were higher during the post-discharge years through 2006 than during the pre-discharge period, concentrations of indicator bacteria in 2007 were quite low compared to both periods at most depths (**Figure 3.8A**). Average fecal densities were highest for samples collected during the post-discharge period at a depth of 18 m (Figure 3.8A), primarily from stations I12, I14 and I16 located near the SBOO diffusers (Figure 3.8B).

As at the kelp stations, oil and grease concentrations were mostly below the detection limit (<1.4 mg/L) at the other offshore stations in 2007, while TSS concentrations varied considerably during the year (**Appendix B.3**). Oil and grease was detected in only four samples, including two from August (3.5 mg/L at station I13; 2.7 mg/L at station I10), one from September (1.9 mg/L at station I14) and one from

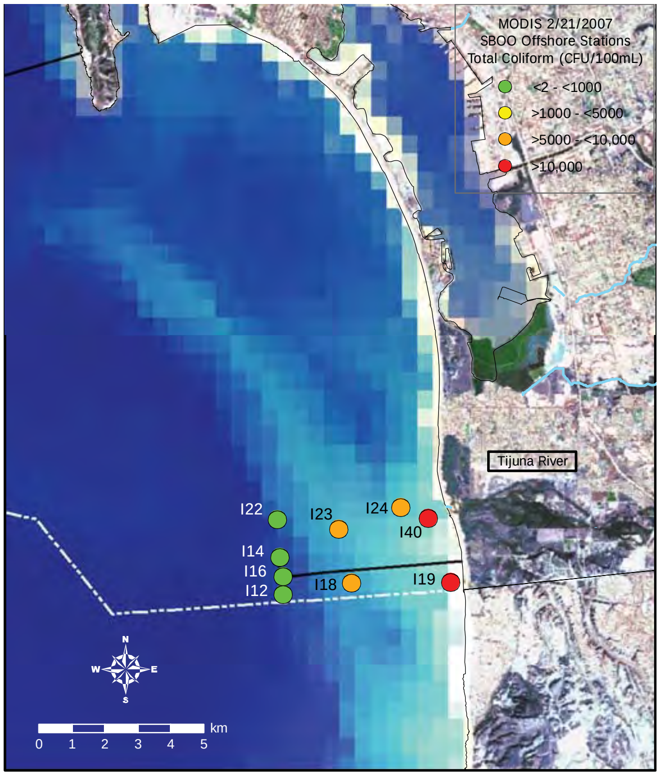

Figure 3.7
MODIS satellite image showing the San Diego monitoring region on February 21, 2007 (Svejkovsky 2008) combined with total coliform concentrations at offshore stations sampled on the same day. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving north along the coastline and overlapping stations where contamination was high. Waters are clear over the outfall discharge site.

October (1.6 mg/L at station I21). Values of TSS ranged between 1.6 and 28.9 mg/L per sample. Of the 77 samples with elevated TSS concentrations (≥10.0 mg/L), only 6% corresponded to samples with total coliform densities >1000 CFU/100 mL. None of these samples had an F:T ratio ≥0.1. In contrast, 30% occurred at bottom depths, likely due to the re-suspension of bottom sediments when the CTD reached the sea floor, and 58% were surface samples, most likely associated with plankton blooms that occurred during the year (see Chapter 2).

California Ocean Plan Compliance

Compliance with the 2001 COP water contact standards for samples collected (in 2007) at the shore and kelp bed stations located north of the USA/Mexico

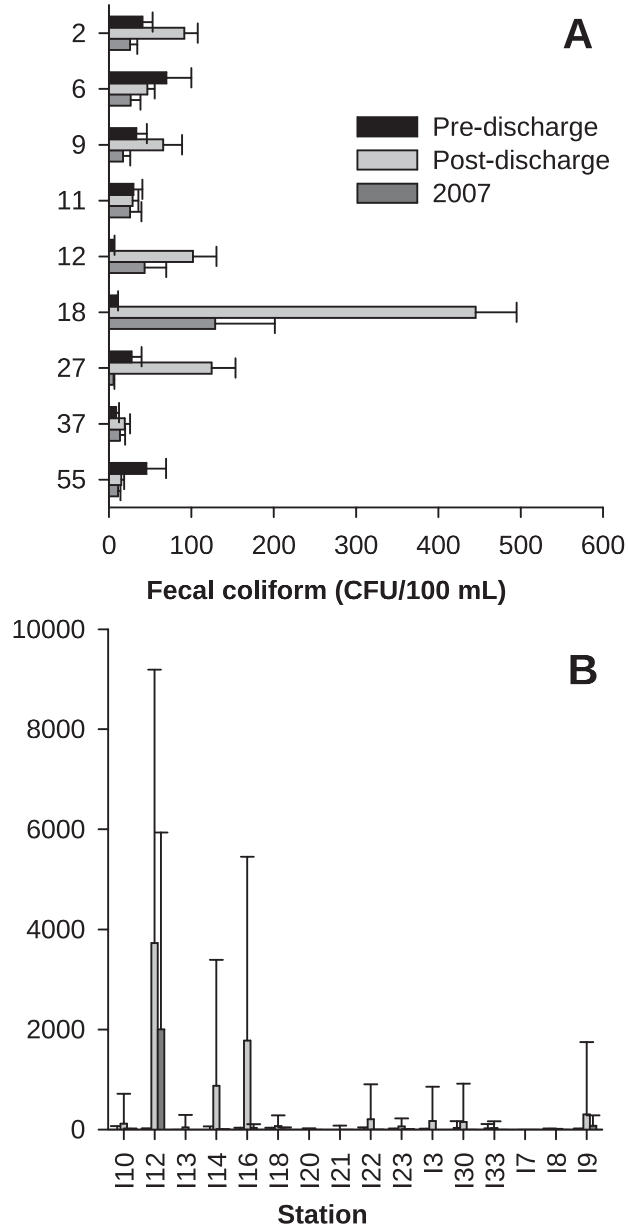

Figure 3.8
Summary of fecal coliform concentrations at SBOO offshore stations sampled in 2007 versus pre-discharge (1995-1998) and post-discharge periods (1999-2006) by depth (A) and by station (B). Values are expressed as means±SE.

border is summarized in **Appendix B.4**. Overall, compliance has increased over the last two years, which is probably related to the drought conditions and relatively low rainfall that occurred during 2006 and 2007 (see City of San Diego 2007a). Compliance for the 30-day total coliform standard at the shore stations ranged from 63 to 100% in 2007 compared to 49-95% in 2006 and 36-81% in 2005. In addition, the number of days that shore samples were out of

Table 3.4

Summary of oil and grease and total suspended solid concentrations in samples collected from offshore stations in 2007. The method detection limits are 1.4 mg/L for O&G and 1.6 mg/L for TSS; n=number of samples with detected concentrations.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oil & Grease												
n	0	0	0	0	0	0	0	2	1	1	0	0
Min	—	—	—	—	—	—	—	2.7	1.9	1.6	—	—
Max	—	—	—	—	—	—	—	3.5	1.9	1.6	—	—
Mean	—	—	—	—	—	—	—	3.1	1.9	1.6	—	—
Total Suspended Soilds												
n	82	82	83	81	74	77	83	82	69	80	68	77
Min	3.1	2.9	3.5	2.3	1.6	1.8	2.4	2.0	2.2	2.2	1.8	2.1
Max	14.1	28.9	18.1	27.6	11.6	14.4	21.4	15.5	14.0	18.6	13.5	18.8
Mean	5.9	6.6	6.8	5.5	4.5	4.9	6.0	7.6	4.8	4.6	3.9	4.6

compliance with the 10,000 total coliform standard decreased from 41 in 2005, to 28 in 2006, to six in 2007. The frequency of compliance with the 30-day total and 30-day geometric mean standards was lowest in February–May and December, which corresponded to periods when the cumulative rainfall was greatest. All shore stations were 100% compliant with the 60-day fecal standard.

As in the previous years, rainfall caused low compliance rates for the shore stations located closest to the Tijuana River, whereas the three northernmost shore stations (S8, S9, S12) were 100% compliant with all coliform standards. Percent compliance at the more southern stations ranged from 63 to 88% for the 30-day total coliform and 30-day geometric mean standards. Stations S4, S5 and S10 were responsible for nearly all of the reduced compliance for three standards. The proximity of these stations to the Tijuana River is considered the likely reason for the frequency with which they are out of compliance (Largier et al. 2004; City of San Diego 2007a). Less surface runoff and more frequent southerly longshore currents during 2007 probably contributed to the increased compliance at stations north of the Tijuana River compared to previous years (see City of San Diego 2007a).

Samples collected at kelp stations I25, I26 and I39 were 100% compliant with the 10,000 total coliform standard, the 60-day fecal coliform standard, and the fecal geometric standard in 2007. In contrast, the 30-day total coliform standard was exceeded at least once at each of these stations in February and March after periods of heavy rainfall. Although there was not a tremendous amount of rain in March, the above exceedences occurred at the beginning of the month following a large storm at the end of February.

Summary and Conclusions

Densities of indicator bacteria at individual shore and kelp stations sampled in the South Bay region were lower overall in 2007 than in previous years. Consequently, this resulted in higher rates of compliance with the 2001 COP standards. Although elevated bacterial densities were detected occasionally along the shore, and at the kelp and other nearshore stations throughout the year, these data do not indicate shoreward transport of the SBOO wastewater plume. Instead, indicator bacteria and satellite imagery data indicate that sources such the Tijuana River, Los Buenos Creek, and surface runoff associated with rainfall events are more likely to impact water quality along and near the shore. For example, shore stations located near the Tijuana River and Los Buenos Creek historically have higher levels of fecal coliform than stations further to the north. Further, long-term analyses of various water quality parameters have demonstrated that the general relationship between rainfall and elevated bacteria levels has remained consistent since ocean monitoring began in 1995.

The infrequent occurrence of indicator bacteria at depths shallower than 12 m at the offshore stations indicates that the wastewater plume from the SBOO rarely reached surface waters in 2007. The majority of water quality samples indicative of wastewater was collected from depths of 18 m and below, at stations nearest the SBOO discharge site, or offshore throughout the year. Thermal stratification present from April through October likely prevented the plume from surfacing most of the year; this was supported by DMSC aerial imagery that detected the outfall plume's near-surface signature on several occasions when the water column was mixed during January–March, November and December (see Chapter 2).

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Chapter 4. Sediment Characteristics

INTRODUCTION

Ocean sediment samples are collected and analyzed as part of the South Bay Ocean Outfall (SBOO) monitoring program to characterize the surrounding physical environment and assess general sediment conditions. These conditions define the primary habitat for benthic invertebrates that live within or on the surface of sediments and can influence their presence and distribution. In addition, many species of demersal fish 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 composition, distribution and stability of seafloor sediments.

Natural factors that affect sediment conditions on the continental shelf include the strength and direction of bottom currents, exposure to wave action, seafloor topography and proximity to geographic features such as submarine basins, canyons and hills, inputs associated with outflows from rivers and bays, beach erosion and runoff from other terrestrial sources, and decomposition of calcareous organisms (e.g., Emery 1960). The analysis of parameters such as sediment grain size and relative percentages of different sediment fractions (e.g., sand, silt and clay) can provide useful information concerning current velocity, amount of wave action and overall habitat stability in an area. Further, understanding sediment grain or particle size distributions allows for better interpretations of the interactions between benthic organisms and the environment. For example, differences in sediment composition (e.g., fine vs. coarse particles) and associated levels of organic loading at specific sites can affect burrowing, tube building and feeding abilities of infaunal invertebrates, thus leading to changes in benthic community structure (Gray 1981, Snelgrove and Butman 1994).

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

Analysis of grain size distributions and the dispersion of sediment particles are useful tools for understanding the hydrodynamic regime of the associated benthos, while other physical properties (e.g., size, shape, density, mineralogy) influence and interact with organic constituents to create new conditions in sediment carbon coupling at the boundary layer. Municipal wastewater outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of sediments through the discharge of treated effluent and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds discharged via ocean 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 their associated ballast materials (e.g., rock, sand) may alter the hydrodynamic regime in surrounding areas.

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2007 at monitoring sites surrounding the South Bay Ocean Outfall (SBOO). The primary goals are to: (1) assess possible effects of wastewater discharge on benthic habitats by analyzing spatial and temporal variability of various sediment parameters, (2) determine the presence or absence of sedimentary and chemical footprints near the discharge site, and (3) evaluate overall sediment quality in the region.

Materials and Methods

Field Sampling

Sediment samples were collected at 27 benthic stations surrounding the SBOO (**Figure 4.1**). These stations range in depth from 18 to 60 m distributed along or adjacent to four main depth contours. Two surveys were conducted in 2007, one during the winter (January-March) and one in the summer (July). Although winter sampling is typically targeted for January, the nine stations located south of the USA/Mexico border could not be sampled until March due to delays in receiving permission to sample in Mexican waters. Each sediment 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).

Laboratory Analyses

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Services Laboratory. Particle size analysis was performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., 11 to -1 phi). Coarser sediments (e.g., 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 "% Coarse" of the total sample sieved.

Output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles ranging 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

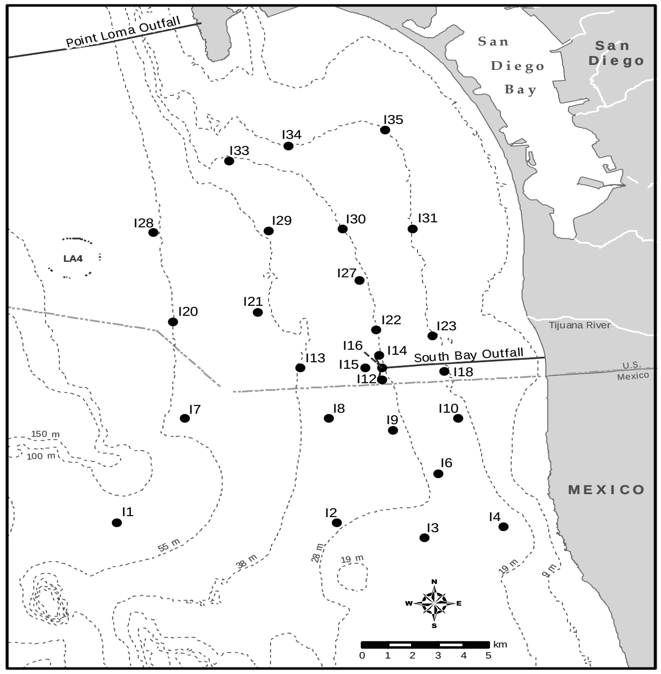

Figure 4.1
Benthic station locations sampled for the South Bay Ocean Outfall Monitoring Program.

were standardized and combined with any sieved coarse fraction (i.e., particles >2.0 mm) 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). These parameters were summarized and expressed as overall mean particle size (mm), phi size (mean, median, skewness, and kurtosis), and the proportion of coarse, sand, silt, and clay. The proportion of fine particles (% fines) was calculated as the sum of all silt and clay fractions.

Sediment samples were analyzed for the chemical constituents specified by the NPDES permits under which sampling was performed. These parameters include total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides (e.g., DDT), polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs; see **Appendix C.1**). TOC and TN were measured as percent weight (%wt) of the sediment sample; sulfides and metals were measured in units of mg/kg and expressed as parts per million (ppm); pesticides and PCBs were measured in units of ng/kg and expressed as parts per trillion (ppt);

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

PAHs were measured in units of µg/kg and expressed as parts per billion (ppb). The data reported herein were generally limited to values above the method detection limit (MDL). However, concentrations below MDLs were included as estimated values if the presence of the specific constituent could be verified by mass-spectrometry (i.e., spectral peaks confirmed). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Services Laboratory (City of San Diego 2008).

Data Analyses

Values for total PAH, total DDT and total PCB were calculated for each sample as the sum of all constituents with reported values. Values for each individual constituent are listed in **Appendix C.2**. Zeroes were substituted for all non-detects (i.e., null values) when calculating means. Summaries of parameters included detection rates (i.e., total number of reported values/total number of samples), annual means by station, annual means for all stations combined (areal mean), and the maximum value of each parameter during the year. Annual means, as well as maximum values, were compared to means and maximum values for the pre-discharge period (1995–1998). Levels of contamination were further evaluated by comparing the results of this study to the Effects Range Low (ERL) sediment quality guidelines of Long et al. (1995) when available. The National Status and Trends Program of the National Oceanic and Atmospheric Administration (NOAA) originally calculated the ERLs to provide a means for interpreting monitoring data. The ERLs are considered to represent chemical concentrations below which adverse biological effects are rarely observed.

Results

Particle Size Distribution

Sediment particle composition was diverse at benthic sites sampled around the SBOO in 2007. Mean grain size ranged from about 0.07 to 0.78 mm

Table 4.2

Summary of particle size parameters and organic loading indicators at SBOO stations during 2007. Data are annual means per station (n=2); SD=standard deviation; TN=total nitrogen; TOC=total organic carbon; nd=not detected; Pre-discharge period=1995–1998.

	Particle Size						Organic Indicators		
	Mean (mm)	Mean (phi)	SD (phi)	Coarse (%)	Sand (%)	Fines (%)	Sulfides ppm	TN %wt	TOC %wt
19 m stations									
I35	0.071	3.9	1.4	0.0	63.8	36.3	14.03	0.036	0.383
I34	0.518	1.1	1.0	17.3	82.4	0.4	0.12	0.003	0.358
I31	0.115	3.1	0.7	0.0	92.0	8.0	0.64	0.014	0.108
I23	0.118	3.1	0.7	0.0	90.2	9.9	1.68	0.016	0.162
I18	0.113	3.2	0.7	0.0	90.1	10.0	0.97	0.012	0.121
I10	0.119	3.1	0.6	0.0	92.1	7.9	0.17	0.013	0.139
I4	0.503	1.0	0.8	7.4	92.4	0.2	nd	0.007	0.103
28 m stations									
I33	0.123	3.0	1.0	0.0	87.9	12.2	3.63	0.024	0.398
I30	0.097	3.4	0.9	0.0	83.3	16.8	0.39	0.022	0.209
I27	0.102	3.3	0.8	0.0	86.4	13.6	0.40	0.018	0.176
I22	0.108	3.2	1.0	0.0	85.0	15.1	0.84	0.022	0.217
I16	0.166	2.6	0.9	0.0	93.5	6.6	0.11	0.013	0.110
I15	0.325	1.7	1.0	2.7	92.1	5.2	0.20	0.007	0.100
I14	0.107	3.3	0.8	0.0	87.2	12.8	4.11	0.019	0.196
I12	0.309	1.8	0.8	2.7	95.6	1.7	nd	0.005	0.048
I9	0.097	3.4	0.8	0.0	83.8	16.2	0.48	0.010	0.144
I6	0.444	1.2	0.9	6.6	92.6	0.9	nd	0.010	0.127
I3	0.522	1.0	0.7	8.8	91.3	0.0	nd	nd	0.044
I2	0.309	1.7	0.8	2.3	97.1	0.6	nd	0.004	0.043
38 m stations									
I29	0.781	0.4	0.7	20.8	75.9	3.4	nd	0.014	0.244
I21	0.504	1.0	0.7	7.3	92.7	0.0	nd	nd	0.035
I13	0.528	0.9	0.7	8.2	91.9	0.0	nd	nd	0.072
I8	0.345	1.6	1.1	5.4	93.4	1.3	nd	0.014	0.162
55 m stations									
I28	0.233	2.1	1.9	13.2	44.4	41.0	0.08	0.053	0.858
I20	0.647	0.7	0.7	13.9	85.8	0.4	nd	nd	0.041
I7	0.561	0.9	0.9	10.3	87.4	2.3	nd	0.006	0.092
I1	0.137	2.9	0.9	0.0	91.3	8.8	nd	0.021	0.260
Detection rate (%)							44	74	100
2007 area mean	0.296	2.1	0.9	4.7	86.7	8.5	1.03	0.014	0.184
2007 area max	0.816	3.9	2.0	30.0	98.8	41.7	18.80	0.056	0.891
Pre-discharge mean	0.213	2.3	0.8	1.4	87.7	10.2	4.59	0.019	0.143
Pre-discharge max	1.000	4.2	2.5	52.5	100.0	47.2	222.00	0.077	0.638

(**Table 4.2**). There was little difference in intra-station particle size composition between the winter and summer surveys (**Appendix C.3**), and there was no clear relationship between sediment composition and proximity to the outfall during the year (**Figure 4.2**). Overall, sediment composition has been highly variable throughout the region since sampling began in 1995, with no significant changes being apparent following the initiation of wastewater discharge in early 1999 (**Figure 4.3**). Instead, intra-station variability near the outfall and at other monitoring sites is most likely attributable

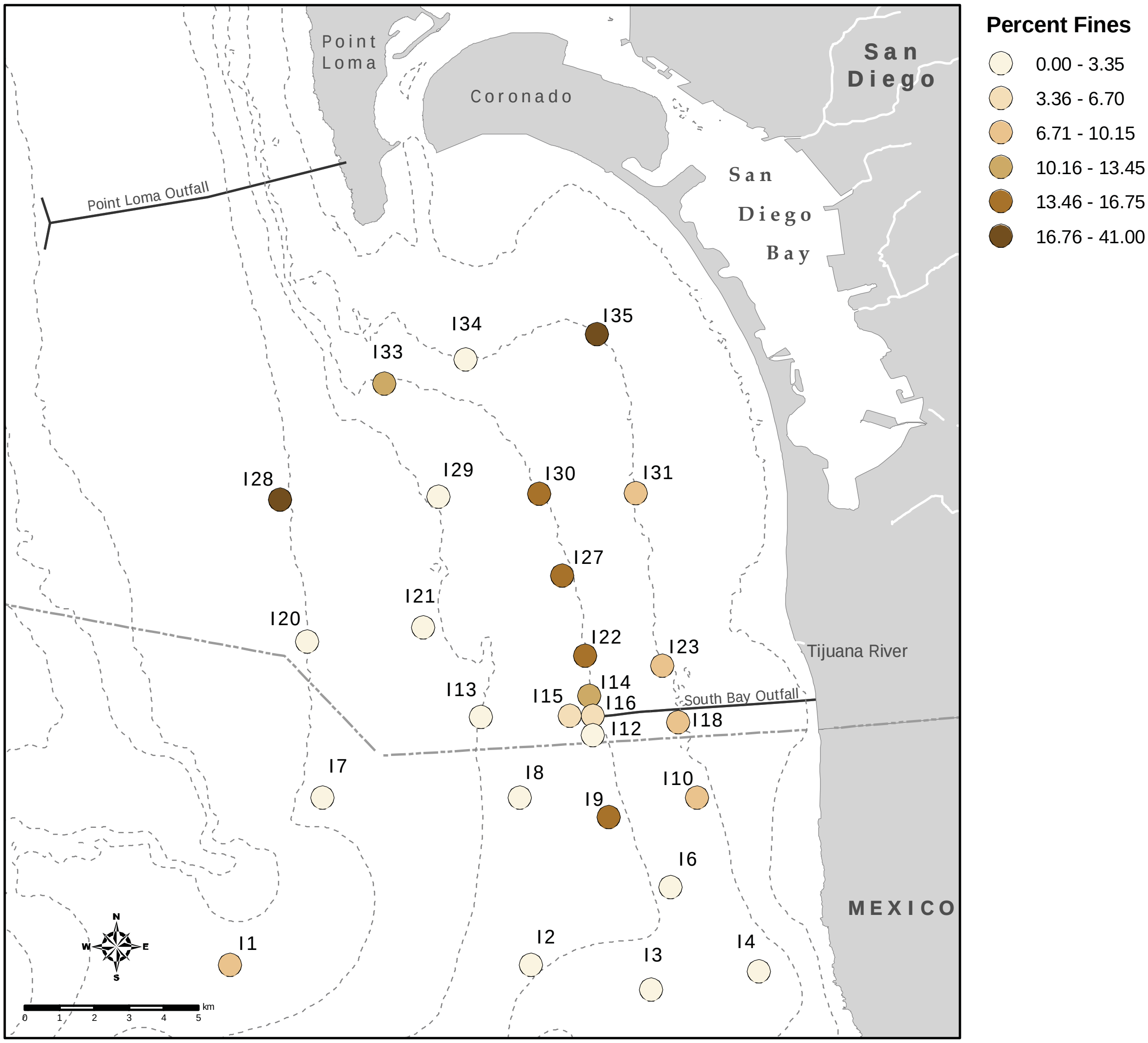

Figure 4.2

Particle size distribution for SBOO benthic stations sampled during 2007. Data are annual means, n=2.

to the different sediment types that occur within the region. For example, the percent fines component (% silt and clay) ranged from 0 to 41% across all SBOO stations in 2007 alone (Figure 4.2). Many sites in the region were also characterized by the presence of different types of coarse sediments, including red relict sands (e.g., stations I7, I13 and I20), black sands (e.g., stations I28 and I29), and shell hash (e.g., stations I2, I3, I4 and I6; see Appendix C.3).

The particle size sorting coefficient reflects the range of grain sizes comprising sediments and is calculated as the standard deviation (SD) in phi size units (see Table 4.1). In general, areas composed of particles of similar size are considered to have well-sorted sediments (i.e., SD≤0.5 phi). In contrast, samples with particles of varied sizes are characteristic of poorly sorted sediments (i.e., SD≥1.0 phi). Sediments in the South Bay region were moderately to poorly sorted in 2007 with sorting coefficients ranging from 0.5 to 2.0 phi (Appendix C.2). Poorly sorted sediments were present at stations I35, I34, I33, I22, I8 and I28 (i.e., SD≥1.0 phi on average; Table 4.2). Of these, station I28 located along the 55-m contour, and station I35 located near the mouth of San Diego Bay, had the highest mean sorting coefficients (SD=1.9 and 1.35 phi, respectively). The sorting coefficients for these two stations have consistently been >1.0 (see City of San Diego 2006).

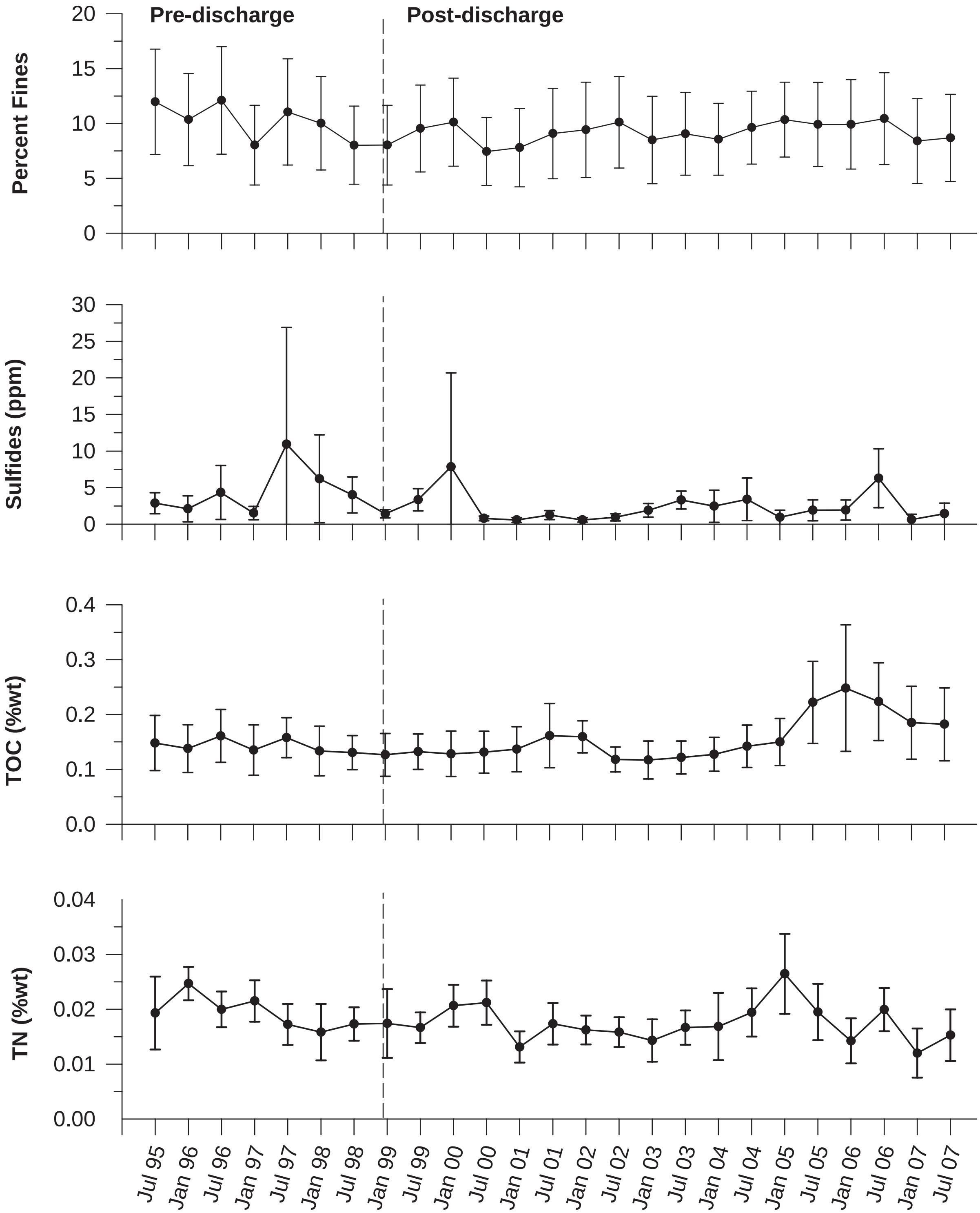

Figure 4.3

Summary of particle size and organic indicator data surrounding the South Bay Ocean Outfall from 1995–2007: TN=total nitrogen, TOC=total organic carbon, %wt=percent weight. Data are expressed as means pooled over all stations for each survey (n=54); error bars represent 95% confidence limits. Some stations from the winter 2007 survey (i.e., January 2007) were actually sampled in March.

Indicators of Organic Loading

Sulfides were detected in 44% of the SBOO samples collected in 2007, with mean concentrations ranging between 0.08–14 ppm per station (Table 4.2). The highest sulfide concentrations occurred in sediments from stations I35 and I14 (14.03 and 4.11 ppm, respectively); I35 is the northernmost 19-m station, while I14 is located near the northern end of the discharge site. In contrast, the three other sites nearest the outfall (i.e., stations I12, I15 and I16) had relatively low sulfide concentrations (≤0.2 ppm). Samples with low sulfide values like these, or perhaps present in concentrations below detection limits (i.e., non-detects), tended to occur in sediments with <10% fines. The maximum reported sulfide value and areal mean for 2007 were lower than detected prior to wastewater discharge. In addition, no major changes appeared to occur in sediments following the initiation of the wastewater discharge in early 1999 (Figure 4.3).

Total nitrogen (TN) and organic carbon (TOC) detection rates were higher than for sulfides at the SBOO stations in 2007 (Table 4.2). TN was detected in 74% of the samples, with concentrations averaging between 0.003 and 0.053% per station. TOC was detected in 100% of the samples, with concentrations averaging between 0.035 and 0.858% per station. With only a few exceptions, TN and TOC concentrations co-varied with higher percentages of fine materials. For example, the highest TN and TOC concentrations were found at station I28, which also had the highest percent fines. As with the sediment composition, there was no clear relationship between TN or TOC concentrations and proximity to the outfall. In addition, mean and maximum values for 2007 were close to or below values reported from the pre-discharge period. There were no major changes in TN or TOC levels following the initiation of wastewater discharge (Figure 4.3).

Trace Metals

Aluminum, arsenic, barium, chromium, iron, manganese, nickel, tin and zinc were detected in 100% of the sediment samples collected in the South Bay region during 2007 (**Table 4.3**). Other metals that were detected in at least 50% of the samples included antimony, copper, lead, silver and thallium. In contrast, mercury, cadmium and selenium were detected less frequently (i.e., 9–41%), while beryllium was not detected at all. Concentrations of each metal were highly variable. For some of the metals, including aluminum, barium, copper, manganese, mercury, nickel and zinc, higher concentrations tended to co-occur at stations with higher proportions of fine particles. Overall, most metals had mean and maximum concentrations in 2007 that were less than pre-discharge values. Exceptions included (a) cadmium, silver and tin, all which exceeded areal mean and maximum pre-discharge values, and (b) antimony, lead, mercury, nickel and thallium, which exceeded just their pre-discharge areal means. Only two metals exceeded environmental threshold values during the year; the ERL for arsenic was exceeded in sediments from a single site located offshore of the SBOO and the ERL for silver was exceeded in sediments from stations located throughout the monitoring area.

Pesticides

Chlorinated pesticides were detected in up to 20 samples collected from 13 different SBOO stations in 2007 (**Table 4.4**, Appendix C.2). Low levels (≤2200 ppt) of BHC (alpha, beta, delta, and gamma isomers), aldrin, and various components of chlordane were detected in sediments from station I16 during the winter survey (Appendix C.2). BHC (gamma isomer) was also detected at station I18 in July. Hexachlorobenzene (HCB) was detected in concentrations ranging from 34 to 340 ppt on average at nine sites (stations I4, I6, I7, I15, I16, I22, I28, I29 and I33) during the year (Table 4.4). Total DDT (primarily p,p-DDE) was detected in sediments from stations I10, I16, I28, I30 and I35, with concentrations ranging between 17 and 579 ppt on average (Table 4.4). Concentrations of total DDT were lower than the ERL (1580 ppt) for this pesticide.

Table 4.3

Concentrations of trace metals (ppm) detected at each SBOO station during 2007. Data are annual means (n=2); ERL=effects range low threshold value; na=not available; nd=not detected; Pre-discharge period=1995–1998. See Appendix C for MDLs and names for each metal represented by periodic table symbol.

Contour	Station	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
	ERL:	na	2.0	8.2	na	na	1.20	81	34	na	46.7	na	0.15	20.9	na	1	na	na	150
19 m	I35	10800	1.2	2.78	48.85	nd	0.20	15.9	4.6	12650	1.80	122.5	0.021	5.6	nd	1.64	0.75	0.9	28.1
	I34	1260	0.8	1.94	6.27	nd	0.06	2.8	0.5	2495	1.05	29.1	nd	0.7	nd	0.07	0.49	0.5	3.9
	I31	4480	0.7	1.11	18.70	nd	0.09	8.3	0.8	4465	0.60	57.8	nd	1.7	nd	1.28	0.85	0.4	7.5
	I23	5425	1.0	1.09	30.20	nd	0.13	9.3	1.2	5805	0.48	65.4	nd	2.5	nd	0.53	0.53	0.8	11.8
	I18	6020	1.3	1.27	37.70	nd	0.17	11.9	1.7	7840	0.52	81.0	nd	2.8	nd	0.91	0.71	1.1	11.8
	I10	6310	1.3	1.32	33.80	nd	0.14	10.6	1.4	6500	0.15	75.9	nd	3.2	nd	1.14	0.39	0.9	16.9
	I4	1125	1.1	1.30	3.47	nd	0.14	5.2	0.5	1820	1.14	14.0	nd	1.1	nd	0.10	0.16	0.8	5.4
28 m	I33	6435	0.2	1.66	26.35	nd	nd	9.8	2.4	7495	4.15	90.6	0.017	2.7	nd	0.91	0.49	1.1	17.8
	I30	8230	1.0	1.66	33.35	nd	0.13	11.9	2.6	7850	0.45	75.1	0.004	4.0	0.128	0.66	0.63	0.5	15.9
	I27	7105	1.1	1.30	29.90	nd	0.12	10.7	1.8	6970	0.55	69.3	0.002	3.2	nd	0.62	0.68	0.5	14.9
	I22	6340	1.1	1.32	27.95	nd	0.13	10.3	1.7	6560	0.77	67.8	0.003	3.3	0.176	0.65	0.52	0.9	13.7
	I16	4475	1.6	1.37	19.30	nd	0.22	8.2	1.7	5560	0.72	57.9	0.002	2.2	nd	0.41	0.59	0.7	10.6
	I15	2240	1.5	2.13	6.14	nd	0.21	8.8	0.4	4890	1.03	28.3	nd	1.4	nd	0.01	0.33	0.8	7.9
	I14	8620	1.0	1.51	40.55	nd	0.12	12.3	2.5	9085	0.29	88.2	0.002	4.2	0.120	1.28	0.73	0.8	19.6
	I12	2745	1.0	1.61	10.63	nd	0.13	7.0	0.5	4405	0.68	35.6	0.001	1.4	nd	0.14	0.63	0.8	8.5
	I9	8875	1.1	1.34	41.95	nd	0.11	12.8	2.3	8155	nd	91.1	0.001	5.0	nd	1.62	0.53	0.8	22.4
	I6	1480	0.9	3.16	5.40	nd	0.08	8.6	0.1	3735	1.45	17.1	nd	1.2	nd	nd	0.16	0.8	6.6
	I3	973	1.1	1.16	2.21	nd	0.16	5.7	0.2	1825	0.91	9.4	nd	0.8	nd	0.08	0.24	0.7	3.4
	I2	1320	1.1	0.80	2.31	nd	0.13	5.7	0.3	1330	0.64	11.5	0.001	0.8	nd	0.08	0.58	0.7	3.8
38 m	I29	4735	0.1	3.13	16.70	nd	nd	10.3	1.4	10495	1.72	55.0	0.001	2.1	nd	0.50	0.36	0.7	14.5
	I21	1615	0.2	9.49	2.80	nd	nd	12.9	nd	9100	2.93	17.3	0.002	0.7	nd	nd	0.36	0.4	8.8
	I13	1245	1.4	6.78	2.41	nd	0.21	10.1	nd	6255	2.11	18.5	nd	0.9	nd	nd	nd	1.5	5.4
	I8	1995	1.1	1.89	4.98	nd	0.13	9.3	0.7	4180	0.88	24.1	nd	1.5	nd	nd	0.28	0.8	10.5
55 m	I28	7480	0.1	2.69	27.85	nd	nd	11.0	4.6	8470	1.92	74.8	0.019	5.0	0.130	0.85	0.89	0.9	19.5
	I20	1720	0.1	3.14	2.89	nd	nd	5.7	nd	5345	1.22	21.0	nd	0.7	nd	nd	0.27	0.6	8.0
	I7	1505	1.0	5.02	3.52	nd	0.10	9.3	0.1	7925	1.90	24.4	nd	1.4	nd	nd	0.26	0.8	6.4
	I1	3585	1.2	1.11	11.60	nd	0.10	7.8	1.0	4410	1.06	51.6	0.004	2.8	0.122	0.50	0.46	0.8	9.2
Detection rate (%)		100	63	100	100	0	41	100	87	100	94	100	37	100	9	56	50	100	100
2007 area mean		4375	0.9	2.34	18.44	0	0.11	9.3	1.3	6134	1.15	50.9	0.003	2.3	0.025	0.52	0.48	0.8	11.6
2007 area max		11200	3.0	9.92	51.10	0	0.446	17.0	4.8	12800	6.52	125	0.027	6.3	0.352	3.12	1.71	2.8	30.3
Pre-discharge mean		5164	0.08	2.47	na	0.13	nd	10.2	2.6	6568	0.09	55.4	0.002	1.9	nd	nd	0.20	nd	12.5
Pre-discharge max		15800	5.6	10.90	54.30	2.14	0.40	33.8	11.1	17100	6.80	162.0	0.078	13.6	0.620	nd	17.0	nd	46.9

PCBs and PAHs

PCBs were detected in sediments from only five SBOO stations during 2007 (Table 4.4). Overall, only 9% of the samples collected had detectable levels of PCBs, all of which were sampled during the winter survey. No PCBs were detected in any sample from the summer July survey. PCBs were most common in sediments at station I18, which had a total PCB concentration of 108,790 ppt comprised of 31 different congeners (Appendix C.2). PCBs were also detected in sediments from stations I2, I4, I28 and I35, although at much lower total PCB concentrations (i.e., ≤85 ppt on average; Table 4.4). Total PCBs at all four of these sites were comprised of three or fewer congeners (Appendix C.2)

In contrast to PCBs, low levels of various PAH compounds were detected in all samples analyzed for 2007 (Table 4.4). Total PAH values were all below the ERL of 4022 ppt. The most prevalent PAH compounds were 1-methylnapthalene, 2,6-dimethylnapthalene, 2-methylnaphthalene, biphenyl, naphhalene, and phenanthrene (Appendix C.2). Each of these PAHs was detected in at least 50% of the samples. There was no apparent relationship between PAH concentrations and proximity to the outfall discharge site.

Table 4.4

Concentrations of total DDT, hexachlorobenzene (HCB), total PCB, and total PAH at SBOO benthic stations in 2007. DDT, HCB and PCB data are expresed in parts per trillion (ppt), while PAH data are expressed in parts per billion (ppb).

Contour	Station	tDDT	HCB	tPCB	tPAH
19 m	I35	145	—	85	74.1
	I34	—	—	—	52.7
	I31	—	—	—	55.1
	I23	—	—	—	78.0
	I18	—	—	54395	97.1
	I10	17	—	—	83.7
	I4	—	65	26	87.3
28 m	I33	—	175	—	64.9
	I30	27	—	—	76.8
	I27	—	—	—	84.7
	I22	—	120	—	77.0
	I16	100	340	—	73.9
	I15	—	85	—	50.9
	I14	—	—	—	76.0
	I12	—	—	—	65.8
	I9	—	—	—	124.6
	I6	—	145	—	69.4
	I3	—	—	—	80.6
	I2	—	—	58	68.6
38 m	I29	—	185	—	49.1
	I21	—	—	—	37.1
	I13	—	—	—	56.6
	I8	—	—	—	86.7
55 m	I28	579	255	26	85.7
	I20	—	—	—	36.0
	I7	—	39	—	59.5
	I1	—	—	—	110.6
Detection rate (%)		13	20	9	100

Summary and Conclusion

Sediment composition in the South Bay outfall region was diverse in 2007, with particle sizes ranging from very fine to very coarse. The diversity of sediment types may be partially attributed to the multiple geological origins of red relict sands, shell hash, coarse sands, and other detrital materials (Emery 1960). In addition, sediment deposition from the Tijuana River and to a lesser extent from San Diego Bay may contribute to the higher content of silt at some of the stations near the outfall, and to the north (see City of San Diego 1988). There was no evident relationship between sediment composition and proximity to the outfall discharge site.

Concentrations of various contaminants, including indicators of organic loading (e.g., sulfides, TN, TOC), trace metals, pesticides (e.g., DDT), PCBs and PAHs in the region remained relatively low compared many other areas of the southern California continental shelf (see Schiff and Gossett 1998, Noblet et al. 2003). Concentrations of sulfides, TN and TOC, as well as several metals, tended to be higher at sites characterized by 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). Two metals exceeded ERL values for southern California; relatively high concentrations of silver occurred in sediments throughout the region, while arsenic was mostly isolated to sediments from a few stations quite distant from the outfall. Other contaminants were detected rarely or in low concentrations during 2007. For example, PCBs and various chlorinated pesticides were detected at only five and seven stations, respectively, during the year. Although PAHs were detected at all stations, these compounds were present at concentrations below ERLs. Overall, there was no pattern in sediment contaminant concentrations relative to the SBOO discharge site.

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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 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 can integrate local environmental conditions (Gray 1979). 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 depth, 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 sediment particle size and/or depth gradients. 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 2007. Descriptions and comparisons of soft-bottom macrofaunal assemblages in the area and analysis of benthic community structure are included.

Material and Methods

Collection and Processing of Samples

Benthic samples were collected during winter (January and March) and summer (July) 2007 at 27 stations surrounding the SBOO. These stations range in depth from 18 to 60 m and are distributed along four 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) (**Figure 5.1**).

Samples for benthic community analyses were collected from two replicate 0.1-m^2 van Veen grabs per station during the 2007 surveys. An additional grab was collected at each station for sediment quality analysis (see Chapter 4). The criteria to ensure consistency of grab samples established by the United States Environmental Protection Agency (USEPA) were followed with regard to sample disturbance and depth of penetration

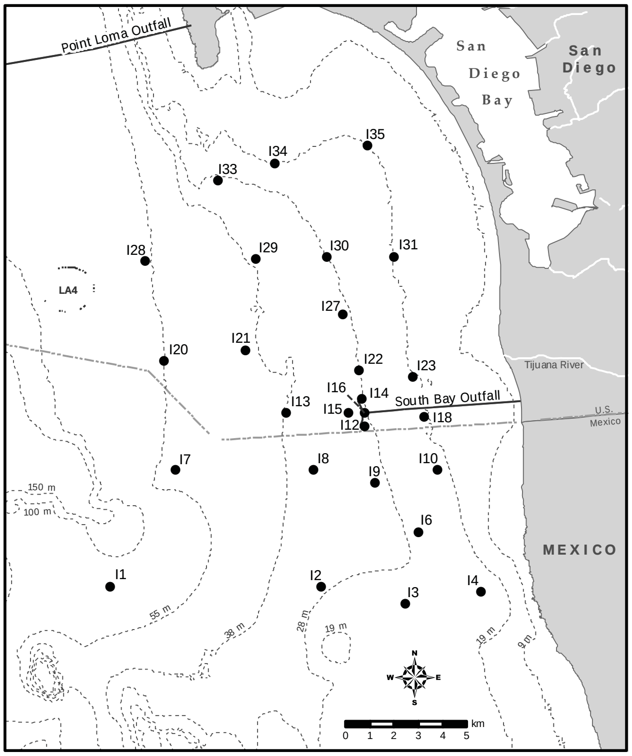

Figure 5.1
Macrobenthic station locations, South Bay Ocean Outfall Monitoring Program.

(USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Organisms retained on the screen were relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups by a subcontractor then 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 (mean number of species per 0.1 m^2), annual total number of species per station, abundance (mean number of individuals per 0.1 m^2), Shannon diversity index (mean H' per 0.1 m^2, see Shannon and Weaver 1949), Pielou's evenness index (mean J' per 0.1 m^2, see Pielou 1966), Swartz dominance (mean minimum number of species accounting for 75% of the total abundance in each 0.1 m^2, see Swartz et al. 1986), Infaunal Trophic Index (mean ITI per 0.1 m^2, see Word 1980), and Benthic Response Index (mean BRI per 0.1 m^2, see Smith et al. 2001).

Multivariate analyses were performed using PRIMER 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

Species Richness

A total of 799 macrobenthic taxa were identified during 2007. Of these, 24% represented rare or unidentifiable taxa that were recorded only once. The average number of taxa per 0.1 m^2 grab ranged from 37 to 146, and the cumulative number of taxa per station ranged from 82 to 289 (**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 region (see City of San Diego 2005, 2006, 2007). Higher numbers of species, for example, have occurred at stations such as I28 and I29 (see City of San Diego 2006). In addition, species richness varied between the 2007 surveys, averaging about 30% higher in summer than in winter (see **Figure 5.2B**). Although species richness varied spatially and

Table 5.1

Benthic community parameters at SBOO stations sampled during 2007. SR=Species richness, no. species/0.1 m^2; Tot Spp=total cumulative no. species for the year; Abun=Abundance, no. individuals/0.1 m^2; H'=Shannon diversity index; J'=Evenness; Dom=Swartz dominance, no. species comprising 75% of a community by abundance; BRI=Benthic response index; ITI=Infaunal trophic index. Data are expressed as annual means, n=4.

Station	SR	Tot spp	Abun	H'	J'	Dom	BRI	ITI
19-m stations								
I35	98	193	842	3.2	0.70	17	32	69
I34	56	148	766	2.8	0.72	9	9	73
I31	73	158	294	3.6	0.85	25	23	77
I23	74	179	210	3.8	0.89	29	22	74
I18	58	125	151	3.6	0.88	25	21	75
I10	65	142	202	3.6	0.88	24	22	81
I4	37	82	186	2.9	0.81	11	2	57
28-m stations								
I33	114	241	553	3.6	0.76	27	28	74
I30	73	164	272	3.7	0.87	27	24	79
I27	80	182	327	3.6	0.85	28	24	80
I22	98	216	462	3.4	0.75	24	26	74
I14	88	194	314	3.7	0.83	29	25	76
I16	81	193	329	3.2	0.72	21	23	74
I15	72	180	603	2.5	0.59	15	22	71
I12	58	145	372	2.6	0.64	14	17	73
I9	115	251	621	3.7	0.78	26	26	77
I6	62	141	1579	2.0	0.51	14	13	74
I2	39	93	125	3.0	0.82	14	14	72
I3	47	102	338	2.3	0.61	7	12	67
38-m stations								
I29	96	262	381	3.7	0.84	30	15	82
I21	49	116	202	3.2	0.84	16	9	85
I13	53	121	174	3.3	0.84	18	11	82
I8	56	118	219	3.1	0.78	17	18	75
55-m stations								
I28	146	289	536	4.4	0.89	50	14	79
I20	60	153	167	3.4	0.86	22	7	89
I7	59	128	165	3.6	0.89	24	4	84
I1	71	162	218	3.7	0.87	25	13	82
Mean	73	166	393	3.3	0.79	22	18	76
SE of Mean	3	10	44	0.1	0.02	1	1	1
Min	37	82	125	2.0	0.51	7	2	57
Max	146	289	1579	4.4	0.89	50	32	89

temporally, there were no apparent patterns relative to distance from the outfall.

Polychaete worms comprised the greatest proportion of species, accounting for 36–57% of the taxa per site during 2007. Crustaceans composed 9–32% of the species, molluscs from 8 to 20%, echinoderms from 2 to 10%, and all other taxa combined about 6–21%. These percentages are generally similar to those observed during previous years (e.g., see City of San Diego 2000, 2004).

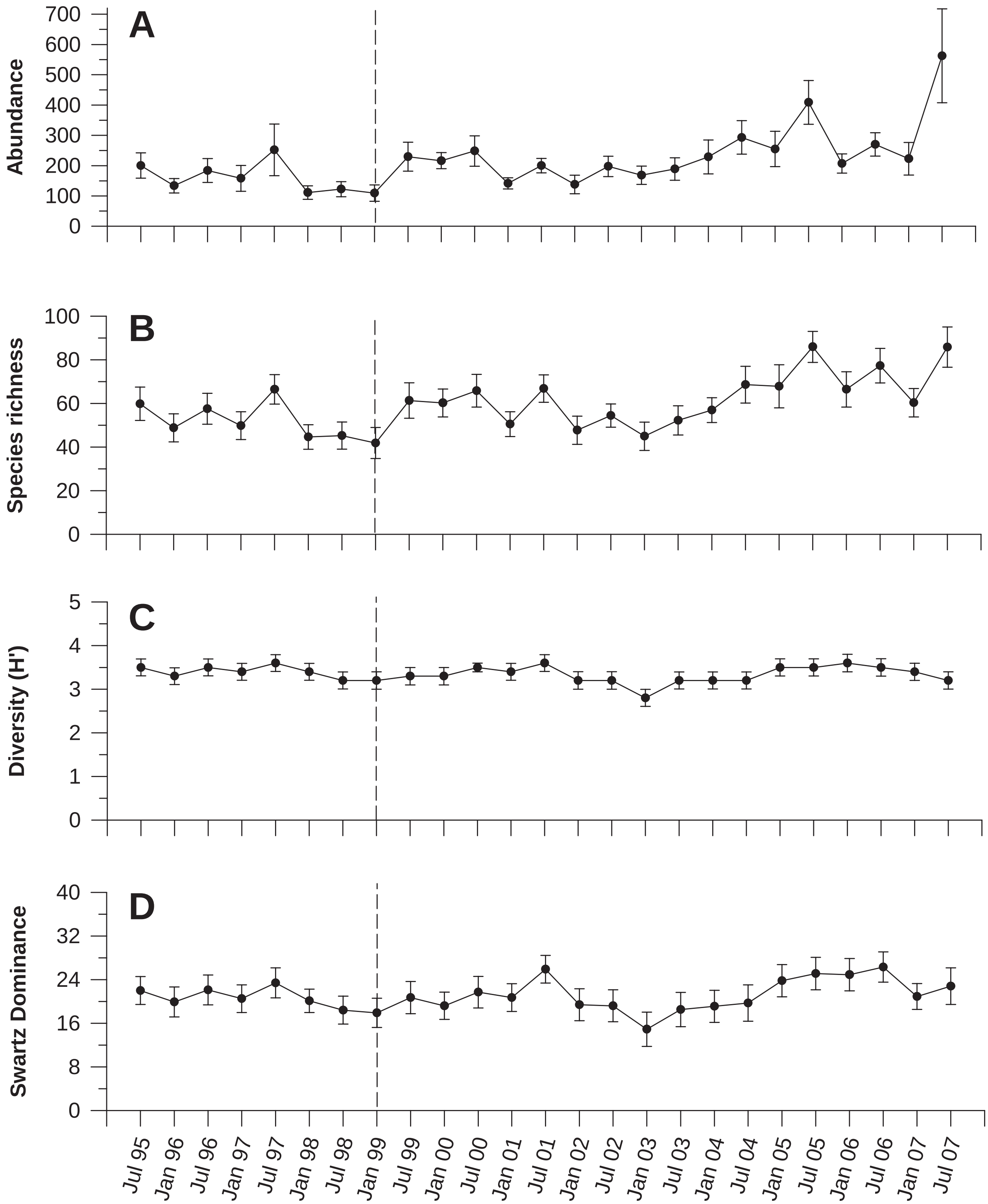

Figure 5.2

Summary of benthic community structure parameters surrounding the South Bay Ocean Outfall from 1995–2007: Abundance; Species richness; Diversity=Shannon diversity index (H'); Swartz dominance index; BRI=Benthic response index; ITI=Infaunal trophic index. Data are expressed as means per 0.1 m^2 pooled over all stations for each survey (n=54). Error bars represent 95% confidence limits. Dashed line indicates onset of discharge from the SBOO. Some stations from the winter 2007 survey (i.e., Jan 07) were sampled in March.

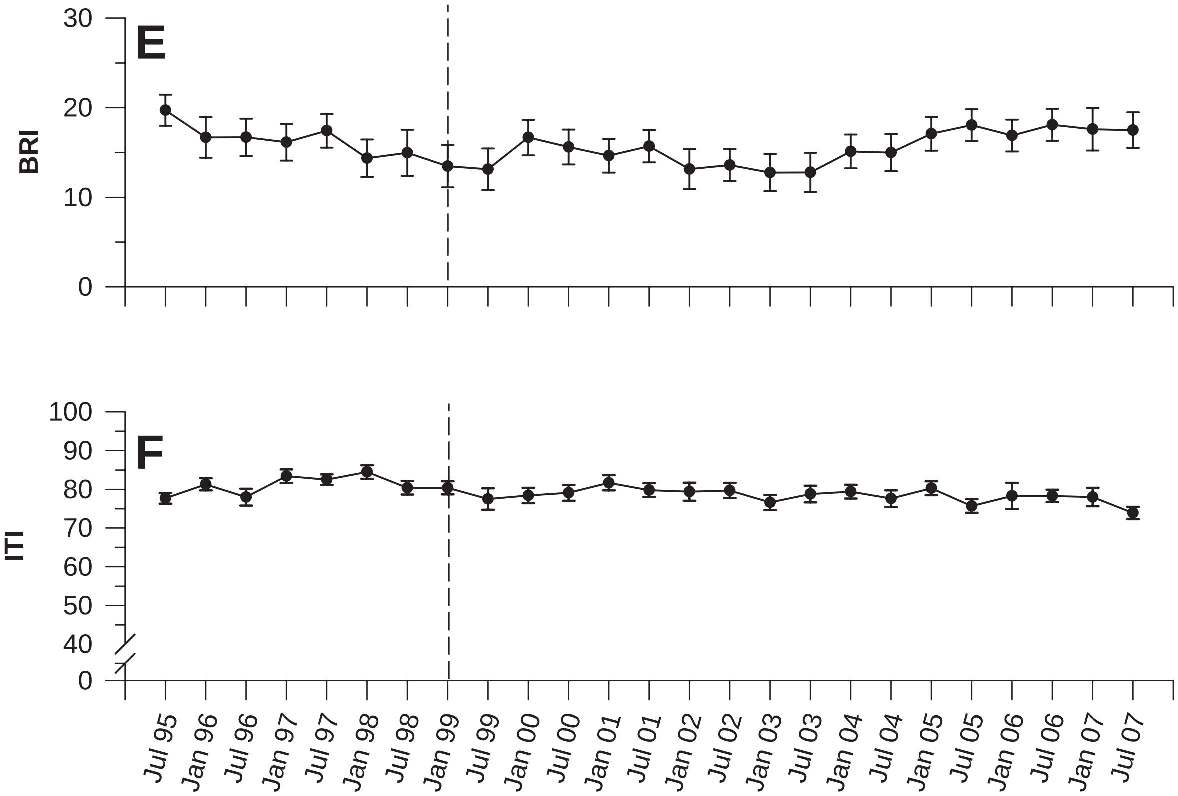

Figure 5.2 *continued*

Macrofaunal abundance

Macrofaunal abundance ranged from a mean of 125 to 1579 animals per 0.1 m^2 in 2007 (Table 5.1). The greatest number of animals occurred at stations I6 and I35, which averaged over 1500 and 800 individuals per sample, respectively. In contrast, station I2 averaged the fewest number of animals (125 per 0.1 m^2). Abundance averaged about 60% higher in summer than in winter (Figure 5.2A). Much of that increase was due to high abundances of the spionid polychaete *Spiophanes bombyx*, which accounted for 37% of all macrofauna collected in July 2007.

Polychaetes were the most abundant animals in the region, accounting for 41–95% of the different samples during 2007. Crustaceans averaged 2–44% of the animals at a station, molluscs averaged 1–16%, echinoderms averaged 0–8%, and all remaining taxa about 1–17% combined.

Species diversity and dominance

The Shannon diversity index (H') describes the abundance weighted number of different species in a sample. H' values increase with increasing number of species in a sample and with their increasing abundances. Diversity varied during 2007, ranging from 2.0 to 4.4 (Table 5.1). Average diversity values in the region generally were similar to previous years (Figure 5.2C), and there were no apparent patterns relative to distance from the outfall. Evenness compliments diversity in that it calculates the amount each species are represented in a sample. Higher J' values indicate that species are evenly distributed (i.e. not dominated by a few highly abundant species). The spatial patterns in evenness were similar to those for diversity and ranged from 0.51 to 0.89. Most sites with evenness values below the mean (0.79) 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, the Swartz dominance index is

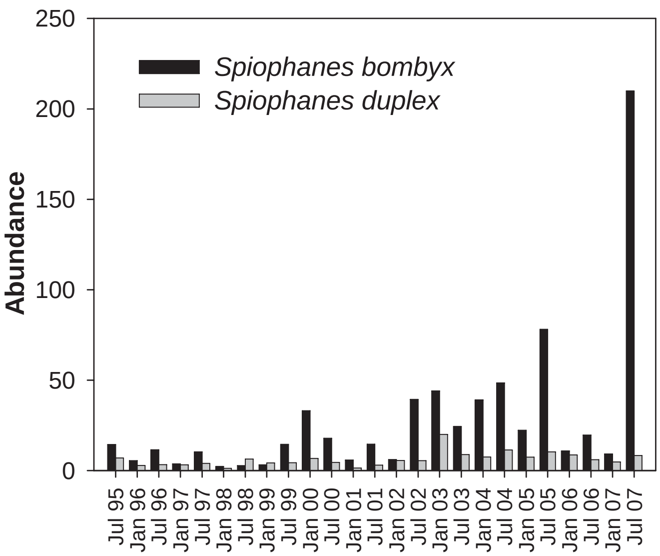

Figure 5.3

Abundance of the polychaetes *Spiophanes bombyx* and *Spiophanes duplex* for each survey at the SBOO benthic stations from July 1995 to July 2007. Data are expressed as mean number per 0.1 m^2, n≥44. Some stations from the winter 2007 survey (i.e., Jan 07) were sampled in March.

inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species. Values at individual stations averaged from 7 to 50 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, I3, and I4) versus other stations with many taxa contributing to the overall abundance (e.g., I28, I29). Dominance values for 2007 were similar to historical values (Figure 5.2D). No clear patterns relative to the outfall were evident in dominance values.

Environmental disturbance indices

Benthic response index (BRI) values averaged from 2 to 32 at the various SBOO stations during 2007 (Table 5.1). Index values below 25 (on a scale of 100) are considered to represent undisturbed communities or “reference conditions,” while those between 25–33 represent “a minor deviation from reference conditions,” and may reflect anthropogenic impact (Smith et al. 2001). Stations I9, I22, I33, and I35 were the only stations that had a BRI value above 25 (i.e., BRI=26–32). There was no gradient of BRI values 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) characterizes infaunal feeding groups within a sample and is used to model benthos response to organic enrichment. ITI averaged from 57 to 89 at the various sites in 2007 (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 I4 (57), located south of the USA/Mexico border. This value was inconsistent with the BRI value of 2 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 5.2F).

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 18 polychaetes, three crustaceans, and nematodes.

The most abundant species collected was the spionid polychaete *Spiophanes bombyx*, which averaged 110 animals per sample. *S. bombyx* also was the most ubiquitous species, occurring in 98% of the samples. Overall, *S. bombyx* accounted for 28% of all individuals collected during 2007, which is much greater than in all previous surveys (**Figure 5.3**).

Polychaetes comprised all of the top ten most abundant species per occurrence (Table 5.2). In addition, the cirratulid polychaete *Monticellina siblina* and the phyllodocid polychaete *Hesionura coineaui difficilis* were found in relatively high numbers at only a few stations. Few macrobenthic species were widely distributed, and of these only *Spiophanes bombyx*, *Mediomastus* sp, *Scoloplos armiger*, and unidentified maldanid polychaetes and nematodes occurred in 80% or more of the samples. Two of the most frequently collected

Table 5.2

Dominant macroinvertebrates at the SBOO benthic stations sampled during 2007. The ten most frequently collected (or widely distributed) species, ten most abundant species overall, the ten most abundant species per occurrence are included. Abundance values are expressed as mean number of individuals per 0.1-m^2 grab sample.

Species	Higher taxa	Percent occurrence	Abundance per sample	Abundance per occurrence
Most frequently collected				
Spiophanes bombyx	Polychaeta: Spionidae	98	109.5	111.6
Mediomastus sp	Polychaeta: Capitellidae	83	11.5	13.8
Maldanidae	Polychaeta: Maldanidae	81	2.9	3.6
Nematoda	Nematoda	81	2.9	3.5
Scoloplos armiger complex	Polychaeta: Orbiniidae	80	2.3	2.9
Prionospio jubata	Polychaeta: Spionidae	78	4.4	5.7
Leptochelia dubia	Crustacea: Tanaidacea	78	4.2	5.4
Ampelisca cristata cristata	Crustacea: Amphipoda	78	3.5	4.5
Euphilomedes carcharodonta	Crustacea: Ostracoda	78	3.3	4.2
Onuphis sp A	Polychaeta: Onuphidae	74	2.4	3.2
Most abundant				
Spiophanes bombyx	Polychaeta: Spionidae	98	109.5	111.6
Monticellina siblina	Polychaeta: Cirratulidae	67	25.8	38.8
Mediomastus sp	Polychaeta: Capitellidae	83	11.5	13.8
Polycirrus sp	Polychaeta: Terebellidae	44	8.7	19.6
Spiophanes berkeleyorum	Polychaeta: Spionidae	67	7.8	11.7
Euclymeninae sp A	Polychaeta: Maldanidae	70	4.7	6.7
Protodorvillea gracilis	Polychaeta: Dorvilleidae	39	4.6	11.8
Prionospio jubata	Polychaeta: Spionidae	78	4.4	5.7
Nereis procera	Polychaeta: Nereididae	50	4.4	8.8
Apoprionospio pygmaea	Polychaeta: Spionidae	52	4.3	8.3
Most abundant per occurrence				
Spiophanes bombyx	Polychaeta: Spionidae	98	109.5	111.6
Monticellina siblina	Polychaeta: Cirratulidae	67	25.8	38.8
Saccocirrus sp	Polychaeta: Saccocirridae	7	1.6	22.0
Hesionura coineaui difficilis	Polychaeta: Phyllodocidae	19	3.6	19.7
Polycirrus sp	Polychaeta: Terebellidae	44	8.7	19.6
Mediomastus sp	Polychaeta: Capitellidae	83	11.5	13.8
Protodorvillea gracilis	Polychaeta: Dorvilleidae	39	4.6	11.8
Spiophanes berkeleyorum	Polychaeta: Spionidae	67	7.8	11.7
Eulalia sp SD1	Polychaeta: Phyllodocidae	4	0.4	11.5
Micropodarke dubia	Polychaeta: Hesionidae	4	0.4	10.8

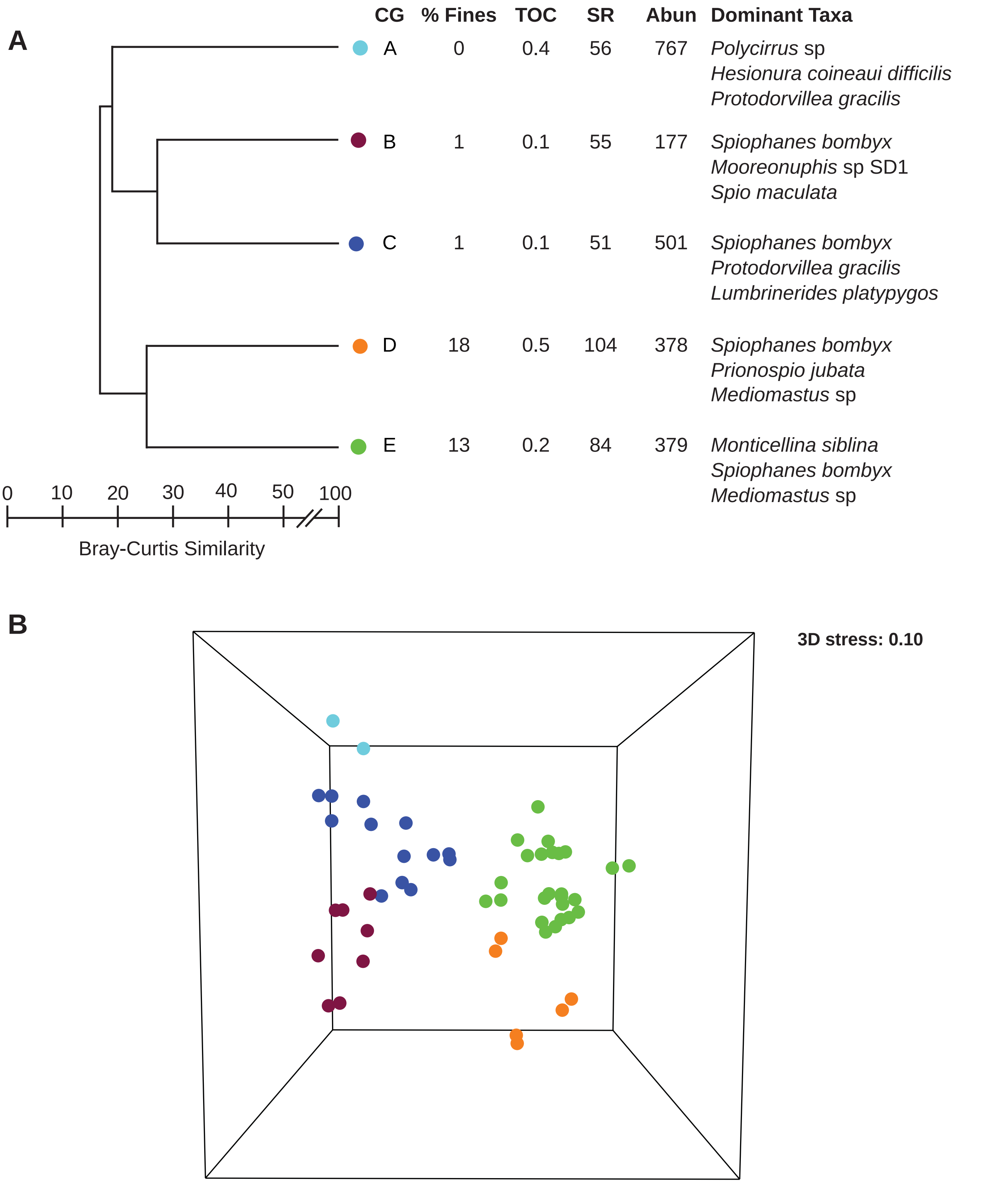

Figure 5.4

(A) Cluster results of the macrofaunal abundance data for the SBOO benthic stations sampled during winter and summer 2007. 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.

species were also among the top ten taxa in terms of abundance (i.e., *S. bombyx* and *Mediomastus* sp).

Multivariate Analyses

Classification analysis discriminated between five habitat-related benthic assemblages (cluster groups A–E) during 2007 (**Figure 5.4**). These assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances. An MDS ordination of the station/survey entities confirmed the validity of cluster groups A–E (Figure 5.4). These analyses identified no significant patterns regarding proximity to the discharge site but showed some separation based on depth gradients (**Figure 5.5**). Further, the distribution of cluster groups varied based on sediment types, and to some degree, total organic carbon (**Figure 5.6**). The dominant species composing each group are listed in **Table 5.3**.

Cluster group A represented the winter and summer surveys for station I34 located along the 19-m contour. Sediments for these samples were comprised almost entirely of sand and coarse materials (i.e., <1% fines). Species richness averaged 56 taxa and 767 individuals per 0.1 m^2. Total organic carbon (TOC) concentrations for the sediment samples from this site averaged 0.4%. The polychaete *Polycirrus* sp was the most abundant species in the group. As in previous years this assemblage was somewhat unique for the region (see City of San Diego 2006, 2007); it was dominated by nematode worms and several polychaete species commonly found in sediments with coarse particles and/or high organic content (e.g., *Hesionura coineaui difficilis*, *Protodorvillea gracilis*, and *Pisione* sp).

Cluster group B comprised two stations located along the 55-m depth contour and at two stations along the 38-m contour. Sediments at these mid-shelf sites contained <1% of fine particles. TOC concentrations for this group averaged 0.1%. The group B assemblage was characterized by the second lowest species richness and lowest abundance, averaging 55 taxa and 177 individuals per 0.1^2 m. The

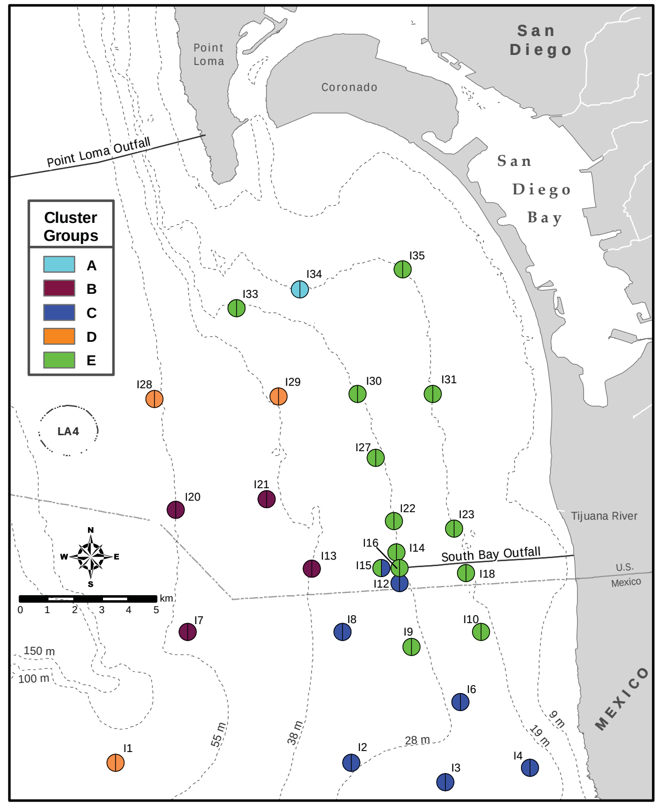

Figure 5.5
Results of ordination and classification analyses of macrofaunal abundance data during 2007. Cluster groups are color-coded on the map to reveal spatial patterns in the distribution of benthic assemblages.

three most abundant species were the polychaetes *Spiophanes bombyx*, *Mooreonuphis* sp SD1, and *Spio maculata*.

Cluster group C comprised sites that were located on or near the 28-m depth contour, mostly located south of the SBOO. Sediments at these sites had a low percentage of fines, with some stations containing relict red sands and shell hash. TOC concentrations at group C were low (0.1%). The group C assemblage averaged 51 taxa and 501 individuals per 0.1 m^2. *Spiophanes bombyx* was numerically dominant in this group, followed by the polychaetes *Protodorvillea gracilis* and *Lumbrinerides platypygos*.

Cluster group D comprised stations located along the 38-m and 55-m contour that were characterized by mixed sediments (i.e., coarse particles, fines, and relict red sand). TOC concentrations for this

Table 5.3

Summary of the most abundant taxa composing cluster groups A–E from the 2007 surveys of SBOO benthic stations. Data are expressed as mean abundance per sample (no./0.1 m^2) and represent the most abundant taxa in each group. Values for the three most abundant species in each cluster group are in bold, (n)=number of station/survey entities per cluster group.

		Cluster Group				
Species/Taxa	Taxa	A (2)	B (8)	C (13)	D (6)	E (25)
Ampelisca agassizi	Crustacea	—	—	—	11.4	0.9
Ampelisca careyi	Crustacea	—	—	—	5.1	—
Ampelisca cristata cristata	Crustacea	—	7.4	2.3	—	—
Apoprionospio pygmaea	Polychaeta	—	—	0.8	—	8.6
Axinopsida serricata	Mollusca	—	—	—	10.7	—
Branchiostoma californiense	Chordata	33.5	—	1.2	0.7	—
Cnemidocarpa rhizopus	Chordata	—	1.8	3.6	—	—
Dendraster terminalis	Echinodermata	—	0.5	5.4	—	—
Euclymeninae sp A	Polychaeta	—	0.6	—	—	8.7
Eusyllis sp SD2	Polychaeta	—	7.9	—	0.5	—
Hesionura coineaui difficilis	Polychaeta	**84.3**	0.6	0.7	2.5	—
Lanassa venusta venusta	Polychaeta	—	4.6	—	—	—
Leptochelia dubia	Crustacea	25.8	1.8	4.3	9.7	1.8
Lumbrinerides platypygos	Polychaeta	—	—	**6.9**	—	—
Mediomastus sp	Polychaeta	—	0.6	1.6	**12.1**	**20.8**
Monticellina siblina	Polychaeta	—	—	3.4	4.9	**52.9**
Mooreonuphis sp SD1	Polychaeta	—	**10.9**	0.9	0.8	—
Nematoda	Nematoda	31.5	1.3	2.2	1.9	1.7
Nereis procera	Polychaeta	—	—	0.6	—	9.1
Pisione sp	Polychaeta	22.3	—	—	0.8	—
Polycirrus sp	Polychaeta	**214.5**	3.5	—	0.5	—
Prionospio jubata	Polychaeta	—	1.0	0.5	**12.3**	6.1
Protodorvillea gracilis	Polychaeta	**61.0**	2.1	**8.2**	—	—
Saccocirrus sp	Polychaeta	40.3	—	—	1.3	—
Scoloplos armiger complex	Polychaeta	—	—	6.5	—	—
Spio maculata	Polychaeta	—	**9.8**	4.4	4.0	—
Spiophanes berkeleyorum	Polychaeta	—	3.4	2.7	4.7	13.2
Spiophanes bombyx	Polychaeta	13.8	**18.8**	**348.2**	**21.4**	**43.2**
Spiophanes duplex	Polychaeta	—	0.8	—	11.8	6.1
Syllis sp SD1	Polychaeta	23.0	2.8	—	—	—

group averaged 0.5%. This group averaged 104 taxa and 378 individual organisms per 0.1 m^2. Polychaetes numerically dominated this group, with *Spiophanes bombyx*, *Prionospio jubata*, and *Mediomastus* sp comprising the three most abundant taxa.

Cluster group E included sites primarily located along the 19 and 28-m depth contours, where sediments contained the second highest amount of fine particles (13% fines). TOC concentrations at stations within this group averaged 0.2%. This assemblage averaged 84 taxa and 379 individuals

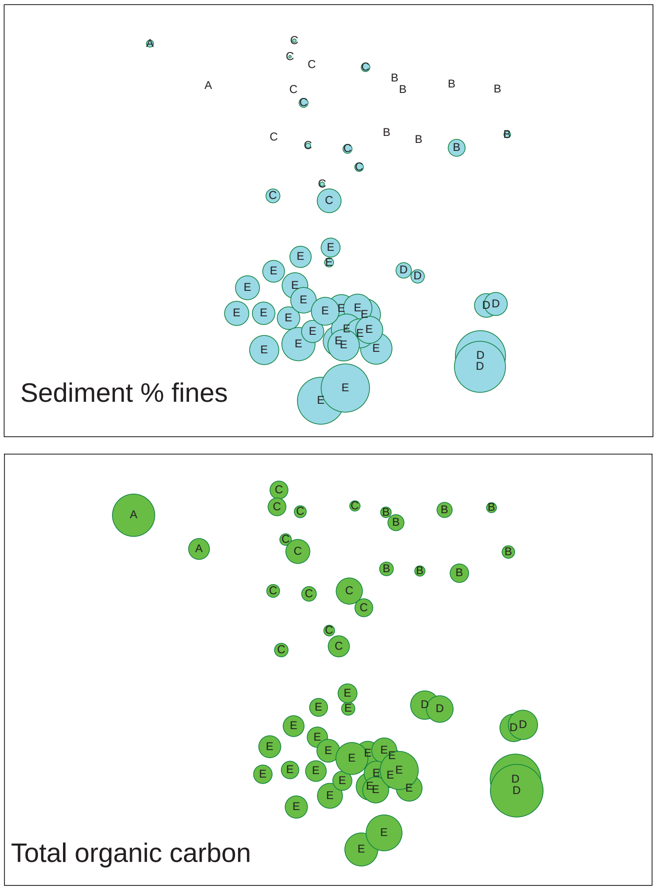

Figure 5.6
MDS ordination of SBOO benthic stations sampled during winter and summer 2007. Cluster groups A–E are superimposed on station/surveys. Percentages of fine particles and total organic carbon in the sediments are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of benthic assemblages with habitats that differ in sediment grain size. Stress=0.15.

per 0.1 m^2. The numerically dominant species in this group were the polychaetes *Monticellina siblina*, *Spiophanes bombyx*, and *Mediomastus* sp.

Summary and Conclusions

Benthic macrofaunal assemblages surrounding the SBOO were similar in 2007 to those that occurred during previous years including the period before initiation of wastewater discharge (e.g., see City of San Diego 2000, 2007). In addition, these assemblages were typical of those occurring in other sandy, shallow- and mid-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). These two groups represented sub-assemblages of the shallow SCB benthos that differed in the relative abundances of dominant and co-dominant species. Such differences probably reflect variation in sediment structure. 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 B 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). A second mid-depth assemblage (group D) occurred where black coarse sands and relict red sands were present. Polychaetes dominated group D, including the ubiquitous *S. bombyx*. The group A assemblage at station I34 was different from assemblages found at any other station. Nematode worms and several species of polychaetes (i.e., *Polycirrus* sp, *Protodorvillea gracilis*, *Hesionura coineaui difficilis*, *Saccocirrus* sp, *Syllis* (*Typosyllis*) sp SD1, and *Pisione* sp) in these samples were not common elsewhere in the region. This assemblage is similar to that sampled previously at station I34 in 2003, 2004, 2005, and 2006. Analysis of the sediment chemistry data provides some evidence to explain the occurrence of this assemblage (Figure 5.6) as mean sediment grain sizes were the highest measured among all stations for 2007 (see Chapter 4). The presence of animals associated with coarse sediments and/or high organic content can reflect the variation in microhabitats or the amounts of shell hash and organic detritus at a site.

Results from 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 (see Hyland et al. 2005 for a discussion on TOC as an indicator of benthos stress). Numbers of *Spiophanes bombyx* collected during 2007 were the highest recorded since monitoring began in 1995. The high numbers of this species influenced overall abundance values in the SBOO region. Patterns of region-wide abundance fluctuations over time appear to mirror historical abundance patterns of *S. bombyx* (see Figures 5.2A and 5.3). However, temporal fluctuations in the populations of this and similar taxa occur elsewhere in the region and 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, while mean values for species richness and abundance during 2007 were at their historical highs, they were still similar to those seen in previous years (see City of San Diego 2005, 2006, 2007). In addition, environmental disturbance index values such as the BRI and 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 2007. 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 have occurred near the SBOO over time, 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

Marine fishes and 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. Assemblages of bottom dwelling (demersal) fishes and relatively large (megabenthic), mobile invertebrates that live on the surface of the seafloor 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, 2002, 2007). 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 various echinoderms (e.g., sea stars, sea urchins, sea cucumbers, and sand dollars), crustaceans (e.g., crabs and shrimp), molluscs (e.g., marine snails and octopuses), and other taxa.

Demersal fish and megabenthic invertebrate communities are inherently variable and may be influenced by both anthropogenic and natural factors. These organisms live in close proximity to the seafloor and are therefore exposed to contaminants of anthropogenic origin that may accumulate in the sediments via both point and non-point sources (e.g., discharges from ocean outfalls and storm drains, surface runoff from watersheds, outflows from rivers and bays, disposal of dredge materials). Natural factors that may affect assemblages of these fish and invertebrates include prey availability (Cross et al. 1985), bottom relief and sediment structure (Helvey and Smith 1985), and changes in water temperatures associated with large scale oceanographic events such as El Niño/La Niña oscillations (Karinen et al. 1985). These factors can affect migration patterns of adult fish or the recruitment of juveniles into an area (Murawski 1993). Population fluctuations that affect species 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 trawl-caught fish and invertebrate communities. This chapter presents analyses and interpretations of the data collected during the 2007 trawl surveys.

Materials and Methods

Field Sampling

Trawl surveys were conducted at seven fixed monitoring sites around the SBOO (**Figure 6.1**). These surveys were conducted primarily during January, April, July, and October in 2007, although for the first quarter two stations (SD15 and SD16) were sampled in March instead of January. The seven stations, designated SD15–SD21, are located along the 28-m isobath, and encompass an area ranging form south of Point Loma, California (USA) to an area off Punta Bandera, Baja California (Mexico). During 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 fish and invertebrates 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.

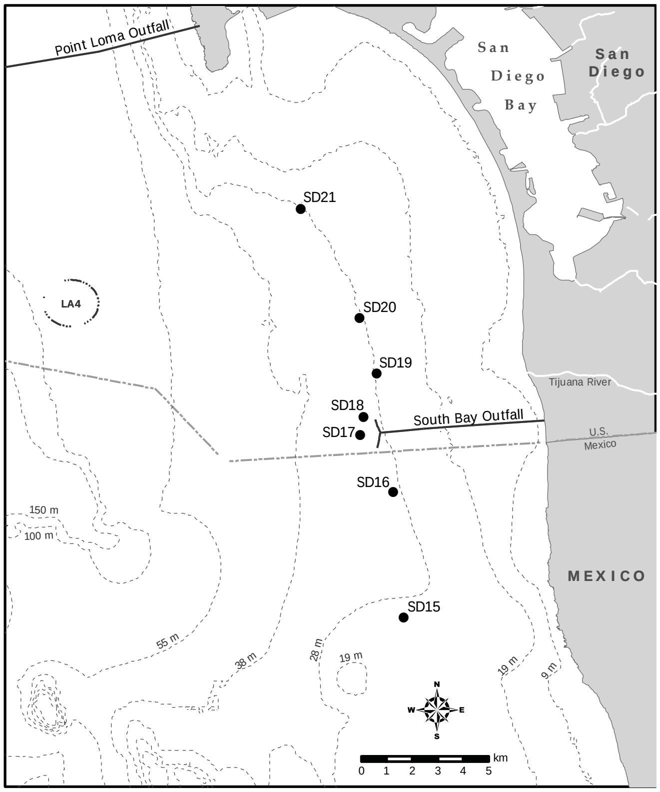

Figure 6.1
Otter trawl station locations, South Bay Ocean Outfall Monitoring Program.

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

Multivariate analyses were performed on 13 years of data from the July surveys of all seven stations. Data were limited to July surveys to eliminate seasonal differences. PRIMER 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 five or greater. The fish abundance 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 one was added to all samples prior to computing similarities (see Clarke and Gorley 2006).

Results

Fish Community

Twenty-nine species of fish were collected in the area surrounding the SBOO in 2007 (**Table 6.1**). The total catch for the year was 5260 individuals, representing an average of about 188 fish per trawl. Speckled sanddabs were the dominant fish captured, occurring in every haul and accounting for 68% of the total number of fishes collected during the year. Whereas speckled sanddabs averaged 128 fish per trawl, all other species averaged less than 15 per haul and less than 25 per occurrence. No other species contributed more than 7% of the total catch. Only hornyhead turbot, roughback sculpin, California lizardfish, longfin sanddab, English sole, yellowchin sculpin, California tonguefish, and California scorpionfish occurred in at least 50% of the trawls. The majority of species tended to be relatively small (average length <20 cm, see **Appendix D.1**). Larger species such as sharks, skates, and rays were relatively rare. These included the Pacific electric ray, thornback,

Table 6.1

Demersal fish species collected in 28 trawls in the SBOO region during 2007. PA=percent abundance; FO=frequency of occurrence; MAH=mean abundance per haul; MAO=mean abundance per occurrence.

Species	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Speckled sanddab	68	100	128	128	Bigmouth sole	<1	11	<1	2
Roughback sculpin	7	89	12	14	Kelp pipefish	<1	18	<1	1
Yellowchin sculpin	6	61	12	19	Spotted turbot	<1	21	<1	1
Longfin sanddab	5	75	10	13	Round stingray	<1	11	<1	1
California lizardfish	4	79	8	11	California skate	<1	11	<1	1
Hornyhead turbot	3	96	5	5	Shovelnose guitarfish	<1	7	<1	1
English sole	2	68	3	4	Specklefin midshipman	<1	7	<1	1
Longspine combfish	1	36	2	7	Unidentified flatfish	<1	7	<1	1
California scorpionfish	1	50	2	5	Big skate	<1	4	<1	1
California tonguefish	1	57	1	2	Giant kelpfish	<1	4	<1	1
Shiner perch	<1	4	1	21	Pacific electric ray	<1	4	<1	1
California halibut	<1	43	1	2	Pygmy poacher	<1	4	<1	1
Fantail sole	<1	43	1	1	Spotted cusk-eel	<1	4	<1	1
Plainfin midshipman	<1	43	1	1	Thornback	<1	4	<1	1
Pacific sanddab	<1	18	<1	2	White croaker	<1	4	<1	1

shovelnose guitarfish, California skate, big skate, and round sting ray.

During 2007, the number of fish species (species richness) and diversity (H') of fishes were relatively low, while abundance and biomass values varied widely in the region (**Table 6.2**). No more than 13 species occurred in any one haul, and H' values were less than ≤2.0 for the entire SBOO region. Station SD15 the lowest average species richness (7 species) and diversity (H'=0.51) values of all sites. Total abundance ranged from 62 to 397 fishes per haul, and co-varied with speckled sanddab populations that ranged from 28 to 275 fish per catch (City of San Diego 2008). Biomass ranged from 1.5 to 13 kg per haul, with higher biomass values coincident with either high numbers of fishes or the size of individual fishes. For example, the highest biomass value occurred at station SD21 in January when an 11 kg Pacific electric ray was captured (City of San Diego 2008). As with species richness and diversity, the lowest abundance and biomass values tended to occur at station SD15.

Although average species richness values for demersal fish in the SBOO region have remained within a narrow range over the years (i.e., 5–14 species per station per year), the total abundance per haul has fluctuated greatly (i.e., 28–275 individuals per station per year) in response to population fluctuations of a few dominant species (see **Figure 6.2, 6.3**). For example, the increase in average abundance per station that occurred between 2006 and 2007 (Figure 6.2), reflects a similar pattern in speckled sanddab populations (Figure 6.3). This trend reverses the substantial drop in the speckled sanddab catches that occurred from 2004 to 2006. Population fluctuations of common species such as the speckled sanddab tend to occur across the entire study area. In contrast, intra-station variability is most often associated with large hauls of schooling species that occur infrequently. For example, large hauls of white croaker were responsible for the high abundance at station SD21 in 1996, while a large haul of northern anchovy caused the relatively high abundance at station SD16 in 2001. Overall, none of the observed changes appear to be associated with the South Bay outfall.

Ordination and classification analyses were used to further examine changes in fish assemblages between 1995 and 2007. These analyses resulted in seven major cluster groups or assemblages (cluster

Table 6.2

Summary of demersal fish community parameters for SBOO stations sampled during 2007. Data are included for species richness (# of species), abundance (# of individuals), diversity (H'), and biomass (kg, wet weight).

Station	Jan*	Apr	Jul	Oct	Annual Mean	Annual SD	Station	Jan*	Apr	Jul	Oct	Annual Mean	Annual SD
Species richness							*Abundance*						
SD15	5	7	6	8	7	1	SD15	170	149	86	139	136	36
SD16	7	13	8	11	10	3	SD16	124	182	172	261	185	57
SD17	9	12	10	11	11	1	SD17	159	179	208	357	226	90
SD18	12	11	10	9	11	1	SD18	123	178	155	238	174	49
SD19	11	10	13	11	11	1	SD19	105	259	195	333	223	97
SD20	10	11	13	8	11	2	SD20	117	204	195	98	154	54
SD21	7	12	10	9	10	2	SD21	62	141	274	397	219	148
Survey Mean	9	11	10	10			Survey Mean	123	185	184	260		
Survey SD	2	2	3	1			Survey SD	36	39	57	112		
Diversity							*Biomass*						
SD15	0.33	0.56	0.44	0.72	0.51	0.17	SD15	2.3	4.7	5.3	1.5	3.4	1.8
SD16	0.45	1.23	0.61	0.94	0.81	0.35	SD16	1.6	4.5	3.4	3.1	3.1	1.2
SD17	1.39	1.51	1.02	1.27	1.30	0.21	SD17	3.1	3.3	3.9	8.2	4.6	2.4
SD18	1.41	1.61	0.98	1.13	1.28	0.28	SD18	4.1	7.6	5.9	4.9	5.6	1.5
SD19	0.90	1.03	1.00	1.11	1.01	0.09	SD19	2.0	4.0	5.1	5.7	4.2	1.6
SD20	1.17	1.59	1.28	1.28	1.33	0.18	SD20	2.6	5.6	6.4	10.4	6.2	3.2
SD21	1.34	1.77	1.27	1.04	1.36	0.30	SD21	13.0	5.2	5.3	3.7	6.8	4.2
Survey Mean	1.00	1.33	0.94	1.07			Survey Mean	4.1	5.0	5.0	5.4		
Survey SD	0.45	0.42	0.32	0.20			Survey SD	4.0	1.4	1.1	3.1		

* Stations SD15 and SD16 were actually sampled in March for the winter (i.e., January) survey.

groups A–G) (see **Figure 6.4**). The assemblages can be distinguished by differences in the relative abundances of common species that were present, although most are dominated by speckled sanddabs. The distribution of assemblages in 2007 was generally similar to that seen in previous years, especially during 2005 and 2006, and no patterns of change in fish assemblages in the SBOO region appear to be associated with the outfall. Instead, differences in the assemblages seem to be more closely related to large-scale oceanographic events (e.g., El Niño conditions in 1998) or specific station location. For example, station SD15 located far south of the outfall in northern Baja California waters often grouped apart from the remaining stations. The composition and characteristics of each cluster group are described below (**Table 6.3**).

Cluster group A comprised assemblages from the two northernmost stations (SD20 and SD21) sampled in 1995 as well as from every station except SD15 sampled during El Niño conditions in 1998. This group averaged the second fewest fish per haul (~64 individuals representing 9 species) and was characterized by the lowest abundance of speckled sanddabs (~12 fish/haul). The dominant species in this group was California lizardfish (~24 fish/haul) followed by longfin sanddabs (~12 fish/haul) and speckled sanddabs (as above).

Cluster group B comprised assemblages sampled from four stations sampled in 1997 (i.e., the southern stations SD15 and SD16, station SD17 near the outfall, and northern station SD20), station SD15 from 1998, and every station except SD21 during July 2001. Overall, this group averaged the fewest fish per haul (36 fishes representing 7 species). The dominant species in this group was the speckled sanddab (~23 fish/haul), although this species occurred in relatively low numbers compared to most other groups (i.e., cluster groups C–G). Overall, this group was

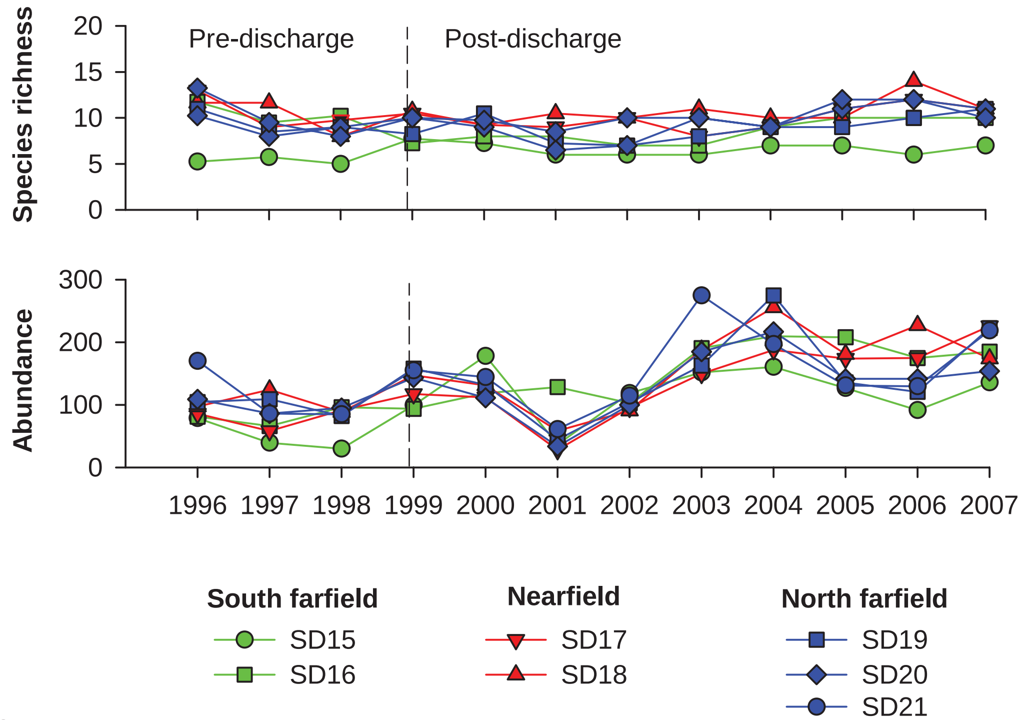

Figure 6.2

Species richness (number of species) and abundance (number of individuals) of demersal fish collected at each SBOO trawl station between 1996 through 2007. Data are annual means, n=4. Dotted line represents initiation of wastewater discharge.

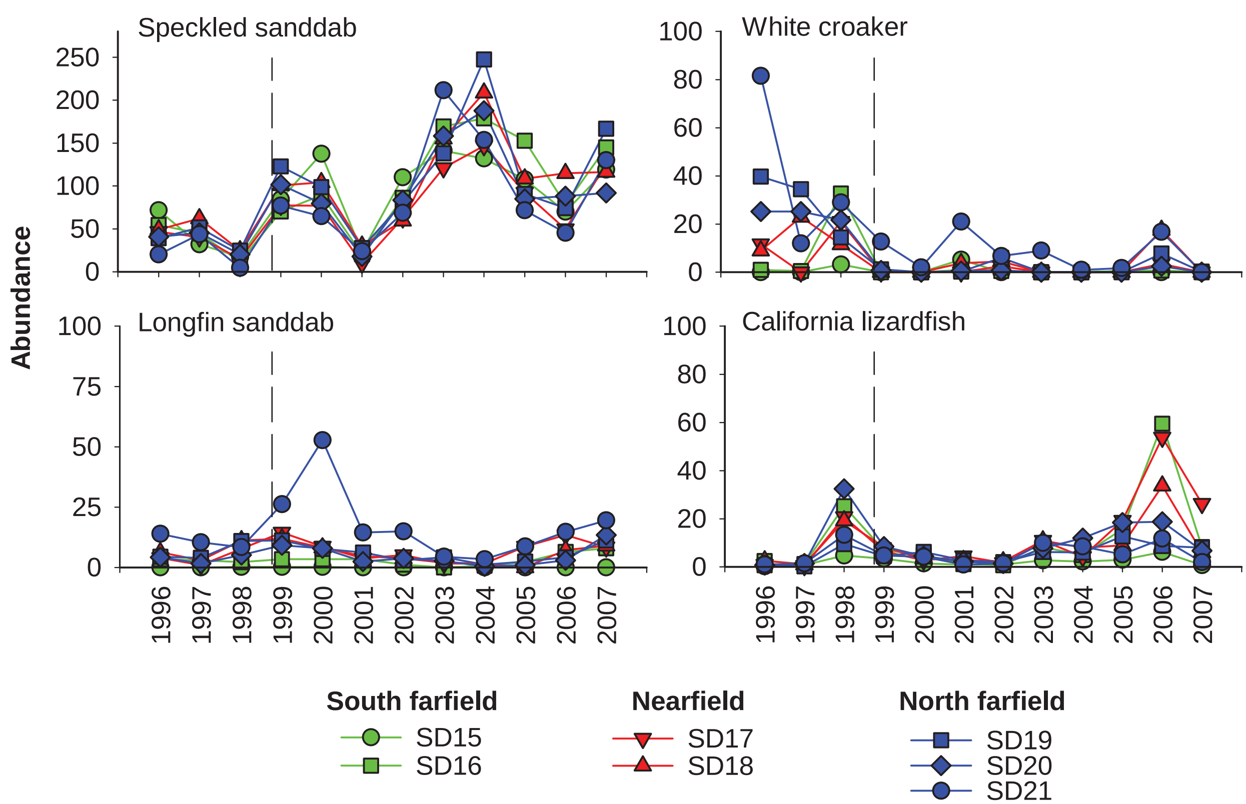

Figure 6.3

Abundance (number of individuals) of the four most abundant fish species collected in the SBOO region from 1996 through 2007. Data are annual means per station, n=4. Dotted line represents initiation of wastewater discharge.

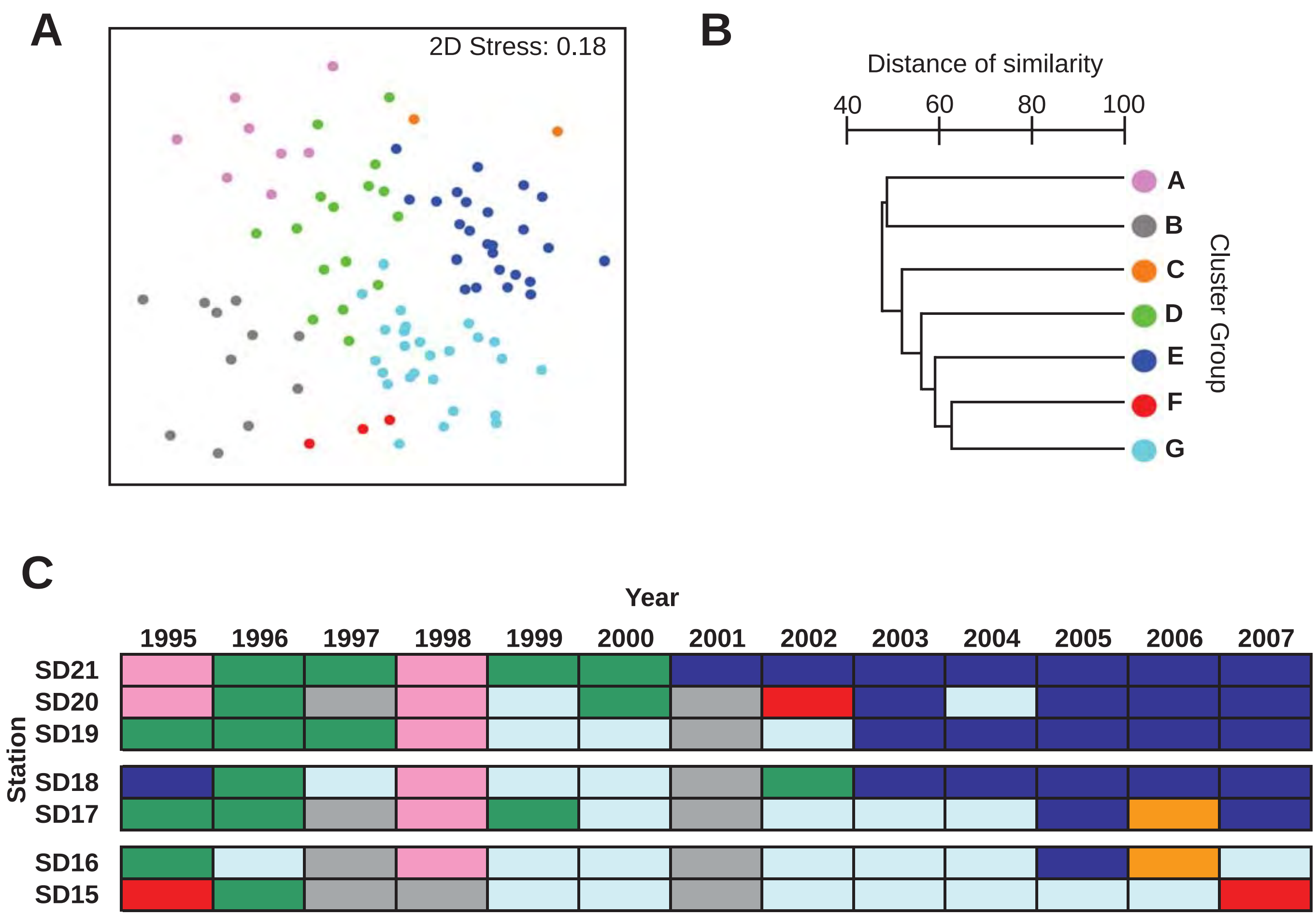

Figure 6.4
Results of classification analysis of demersal fish assemblages collected at SBOO stations SD15–SD21 between 1995 and 2006 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major cluster groups and (C) a matrix showing distribution of cluster groups over time.

characterized by low average abundances (≤3 fish/haul) for all other species.

Cluster group C consisted of assemblages from only stations SD16 and SD17 sampled in July 2006. This group was unique in that it was characterized by more than 200 California lizardfish per haul, which was almost twice as many as captured in any other trawl analyzed herein. The second and third most abundant species in this group were the speckled sanddab (~56 fish/haul) and yellowchin sculpin (~15 fish/haul).

Cluster group D represented assemblages from a mix of stations surveyed between 1995 and 2002. These included nine of the 14 station-surveys during 1995–1996 (i.e., representing all seven sites), two stations each during 1997 (SD19, SD21), 1999 (SD17, SD21) and 2000 (SD20, SD21), and one station in 2002 (SD18). Similar to most other groups, the dominant species was the speckled sanddab (~55 fish/haul). Group D was also characterized by about twice as many longfin sanddabs (~24 fish/haul) as that occurred in other groups.

Cluster group E comprised assemblages from about 63% of the trawls performed from 2003 through 2007, as well as one trawl each during 1995, 2001 and 2002. This group averaged the highest number of species overall (~10 species/haul) and was characterized by the highest number of speckled sanddabs (~140 fish/haul). Aside from speckled sandabs, the second and third most abundant species characterizing this group were yellowchin sculpin (~20 fish/haul) and California lizardfish (~14 fish/haul).

Table 6.3

Description of cluster groups A–G defined in Figure 6.4. Data include number of hauls, mean species richness, mean total abundance, and mean abundance of the five most abundant species for each station group (indicated in bold).

	Group A	Group B	Group C	Group D	Group E	Group F	Group G
Number of hauls	8	11	2	16	25	3	26
Mean species richness	9	7	8	9	10	4	6
Mean abundance	64	36	298	106	207	69	141
Species				**Mean Abundance**			
Speckled sanddab	**12**	**23**	**56**	**55**	**140**	**63**	**126**
California lizardfish	**24**	**2**	**212**	2	**14**		**4**
Hornyhead turbot	**3**	**3**	**4**	**5**	**5**	**2**	**4**
Spotted turbot	1	**2**		2	1		**2**
Roughback sculpin			3		4		**1**
California tonguefish	2	1	3	**4**	3		**1**
California scorpionfish	<1	**2**	1	1	1	**1**	**1**
Fantail sole	1	<1		1	<1	<1	**1**
English sole	**5**	<1	2	3	4		<1
Longfin sanddab	**12**	<1	**5**	**24**	**12**		<1
Yellowchin sculpin	1		**15**	<1	**20**	<1	<1
California skate	<1	<1			<1	**1**	<1
White croaker				**4**			<1
Plainfin midshipman				1	1	<1	<1
Thornback	<1	<1				<1	<1

Cluster group F consisted of assemblages from only three trawls, including those from station SD15 sampled in 1995 and 2007, and station SD20 sampled in 2002. Overall, this group was characterized by the lowest species richness (~4 species/haul) and the third lowest average abundance (~69 fish/haul). The dominant species in this group was the speckled sanddab (~63 fish/haul), while all other species occurred in very low numbers (≤2 fish/haul).

Cluster group G was represented by assemblages that occurred at a mix of sites sampled during all years except 1995, 1998 and 2001. This included a majority of stations from 1999, 2000, 2002 and 2004. Group G was characterized by third highest average abundance (~141 fish/haul), but the second lowest species richness (~6 species/haul). This group was similar to group E in that it was dominated almost exclusively by speckled sanddabs (~126 fish/haul), although all other species, including longfin sanddabs, occurred in much lower numbers (≤4 fish/haul).

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the SBOO region during 2007. There were no incidences of fin rot, discoloration, skin lesions, tumors or any other physical abnormalities or indicators of disease among fishes collected during the year. Evidence of parasitism was also very low for trawl-caught fishes in the region. Only one external parasite was observed still attached to its host; a leech (Annelida, Hirudinea) was found attached to a hornyhead turbot at station SD21. However, other leeches, as well the cymothoid isopod *Elthusa vulgaris*, were observed loose in some trawls. Both types of ectoparasites often become detached from their hosts during sorting of the trawl catch, and therefore it is unknown which fishes were actually parasitized. Although *E. vulgaris* is known to occur on a variety of fish species in southern California waters, 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 867 megabenthic invertebrates (~31 per trawl), representing 53 taxa, were collected during 2007 (**Appendix D.2**). The sea star *Astropecten verrilli* was the most abundant and most frequently captured species. This sea star

Table 6.4

Species of megabenthic invertebrates collected in 28 trawls in the SBOO region during 2007. PA=percent abundance; FO=frequency of occurrence; MAH=mean abundance per haul; MAO=mean abundance per occurrence.

Species	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Astropecten verrilli	55	89	17	19	*Megastraea turbanica*	<1	7	<1	2
Philine auriformis	6	18	2	10	*Pugettia producta*	<1	7	<1	2
Cancer gracilis	4	32	1	4	HIRUDINEA	<1	11	<1	1
Crangon nigromaculata	4	54	1	2	*Luidia armata*	<1	7	<1	2
Cancer sp	2	11	1	7	*Acanthodoris rhodoceras*	<1	7	<1	1
Pisaster brevispinus	2	50	1	1	*Calliostoma gloriosum*	<1	7	<1	1
Lytechinus pictus	2	21	1	3	*Crangon alba*	<1	7	<1	1
Heterocrypta occidentalis	2	21	1	3	*Dendronotus iris*	<1	7	<1	1
Acanthodoris brunnea	2	7	1	7	*Paguristes bakeri*	<1	7	<1	1
Elthusa vulgaris	2	29	1	2	*Thesea* sp B	<1	7	<1	1
Kelletia kelletii	1	32	<1	1	*Alpheus clamator*	<1	4	<1	1
Pyromaia tuberculata	1	18	<1	3	*Aphrodita refulgida*	<1	4	<1	1
Hemisquilla californiensis	1	32	<1	1	*Aphrodita* sp	<1	4	<1	1
Ophiothrix spiculata	1	18	<1	2	ASCIDIACEA	<1	4	<1	1
Platynereis bicanaliculata	1	4	<1	10	*Cancellaria crawfordiana*	<1	4	<1	1
Platymera gaudichaudii	1	21	<1	2	*Crangon alaskensis*	<1	4	<1	1
Farfantepenaeus californiensis	1	11	<1	3	*Flabellina iodinea*	<1	4	<1	1
Crossata californica	1	14	<1	2	*Flabellina pricei*	<1	4	<1	1
Octopus rubescens	1	11	<1	2	*Florometra serratissima*	<1	4	<1	1
Podochela hemphillii	1	21	<1	1	*Luidia asthenosoma*	<1	4	<1	1
Dendraster terminalis	1	14	<1	1	*Norrisia norrisi*	<1	4	<1	1
Heptacarpus palpator	1	11	<1	2	*Ocinebrina foveolata*	<1	4	<1	1
Pagurus spilocarpus	1	18	<1	1	*Pinnixa franciscana*	<1	4	<1	1
Randallia ornata	1	14	<1	1	*Pylopagurus holmesi*	<1	4	<1	1
Cancer anthonyi	<1	11	<1	1	*Sicyonia penicillata*	<1	4	<1	1
Euspira lewisii	<1	14	<1	1	*Triopha maculata*	<1	4	<1	1
Loxorhynchus grandis	<1	11	<1	1					

was captured in 89% of the trawls and accounted for 55% of the total invertebrate abundance (**Table 6.4**). Another sea star, *Pisaster brevispinus*, occurred in 50% of the trawls but accounted for only 2% of the total abundance. The shrimp, *Crangon nigromaculata*, occurred in 54% of the trawls. The remaining taxa occurred infrequently, with only eight occurring in 20% or more of the hauls. With the exception of *A. verrilli*, all of the species collected averaged no more than two individuals per haul or 10 individuals per occurrence. Two species that usually do not occur in South Bay trawls, the nereid polychaete *Platynereis bicanaliculata*, and the pea crab *Pinnixa franciscana*, were collected at station SD20 in October 2007. These two species were apparently feeding on squid eggs that were also collected at this trawl site.

Megabenthic invertebrate community structure varied among stations and between surveys during the year (**Table 6.5**). Species richness ranged from 4 to 12 species per haul, diversity (H') values ranged from 0.3 to 2.29 per haul, and total abundance ranged from 11 to 120 individuals per haul. The biggest hauls were characterized by large numbers of *A. verrilli*, particularly during October when abundances of this sea star reached 108 individuals per haul. Although biomass was also somewhat variable (0.1–3.0 kg), the highest values generally corresponded to the collection of relatively large sea stars (e.g., *P. brevispinus*) or crabs (e.g., *Cancer* sp, *Loxorhynchus grandis*).

Table 6.5

Summary of megabenthic invertebrate community parameters for SBOO stations sampled during 2007. Data are included for species richness (number of species), abundance (number of individuals), diversity (H') and biomass (kg, wet weight).

					Annual							Annual	
Station	Jan*	Apr	Jul	Oct	Mean	SD	Station	Jan*	Apr	Jul	Oct	Mean	SD
Species richness							*Abundance*						
SD15	6	5	7	6	6	1	SD15	34	55	84	120	73	37
SD16	10	4	5	5	6	3	SD16	14	63	18	13	27	24
SD17	9	8	10	4	8	3	SD17	14	14	51	31	28	18
SD18	9	7	12	11	10	2	SD18	14	19	37	29	25	10
SD19	6	4	9	6	6	2	SD19	11	17	39	19	22	12
SD20	9	7	6	6	7	1	SD20	20	11	20	42	23	13
SD21	6	8	11	11	9	2	SD21	14	15	20	29	20	7
Survey Mean	8	6	9	7			Survey Mean	17	28	38	40		
Survey SD	2	2	3	3			Survey SD	8	22	24	36		
Diversity							*Biomass*						
SD15	0.98	0.53	0.47	0.45	0.61	0.25	SD15	0.9	0.1	0.9	0.4	0.6	0.4
SD16	2.14	0.30	0.84	1.26	1.14	0.78	SD16	1.0	0.7	0.5	1.1	0.8	0.3
SD17	2.07	1.91	1.32	1.09	1.60	0.46	SD17	1.1	1.3	0.3	0.1	0.7	0.6
SD18	1.97	1.51	1.89	2.10	1.87	0.25	SD18	0.1	0.6	0.6	0.7	0.5	0.3
SD19	1.42	0.66	1.23	1.57	1.22	0.40	SD19	0.3	0.5	1.2	0.4	0.6	0.4
SD20	1.99	1.77	1.33	1.38	1.62	0.32	SD20	2.3	0.5	0.2	0.2	0.8	1.0
SD21	1.57	1.77	2.29	2.12	1.94	0.33	SD21	0.8	0.6	0.1	3.0	1.1	1.3
Survey Mean	1.73	1.21	1.34	1.43			Survey Mean	0.9	0.6	0.5	0.8		
Survey SD	0.43	0.68	0.61	0.59			Survey SD	0.7	0.4	0.4	1.0		

* Stations SD15 and SD16 were actually sampled in March for the winter (i.e., January) survey.

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/trawl), annual abundance values have averaged between 7 and 273 individuals per haul. These large differences are generally due to fluctuations in populations of several dominant species, especially the sea star *A. verrilli*, the sea urchin *Lytechinus pictus*, the sand dollar *Dendraster terminalis*, and the shrimp *C. nigromaculata* (Figure 6.6). For example, station SD15 has had the highest average abundance compared to the other stations for seven out of 13 years due to relatively high abundances of *A. verrilli*, *L. pictus* and *D. terminalis*. In addition, the high abundances recorded at station SD17 in 1996 were due to large hauls of *L. pictus*. None of the observed variability in the invertebrate communities appears to be related to the South Bay outfall.

Summary and Conclusion

As in previous years, speckled sanddabs continued to dominate fish assemblages surrounding the SBOO during 2007. This species occurred at all stations and accounted for 68% of the total catch. Other characteristic, but less abundant species included the hornyhead turbot, roughback sculpin, California lizardfish, longfin sanddab, English sole, yellowchin sculpin, California tonguefish, and California scorpionfish. 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 populations.

Assemblages of relatively large (megabenthic) trawl-caught invertebrates in the region were similarly dominated by one prominent species,

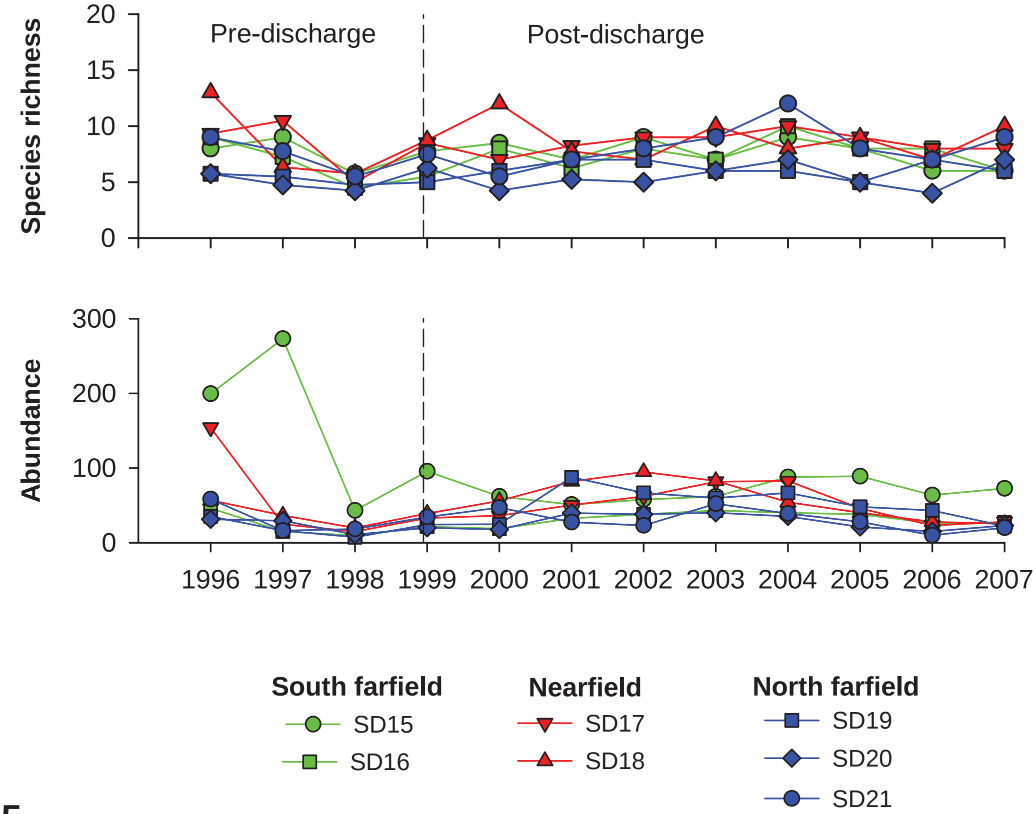

Figure 6.5
Species richness (number of species) and abundance (number of individuals) of megabenthic invertebrates collected at each station between 1996 through 2007. Data are annual means, n=4. Dotted line represents initiation of wastewater discharge.

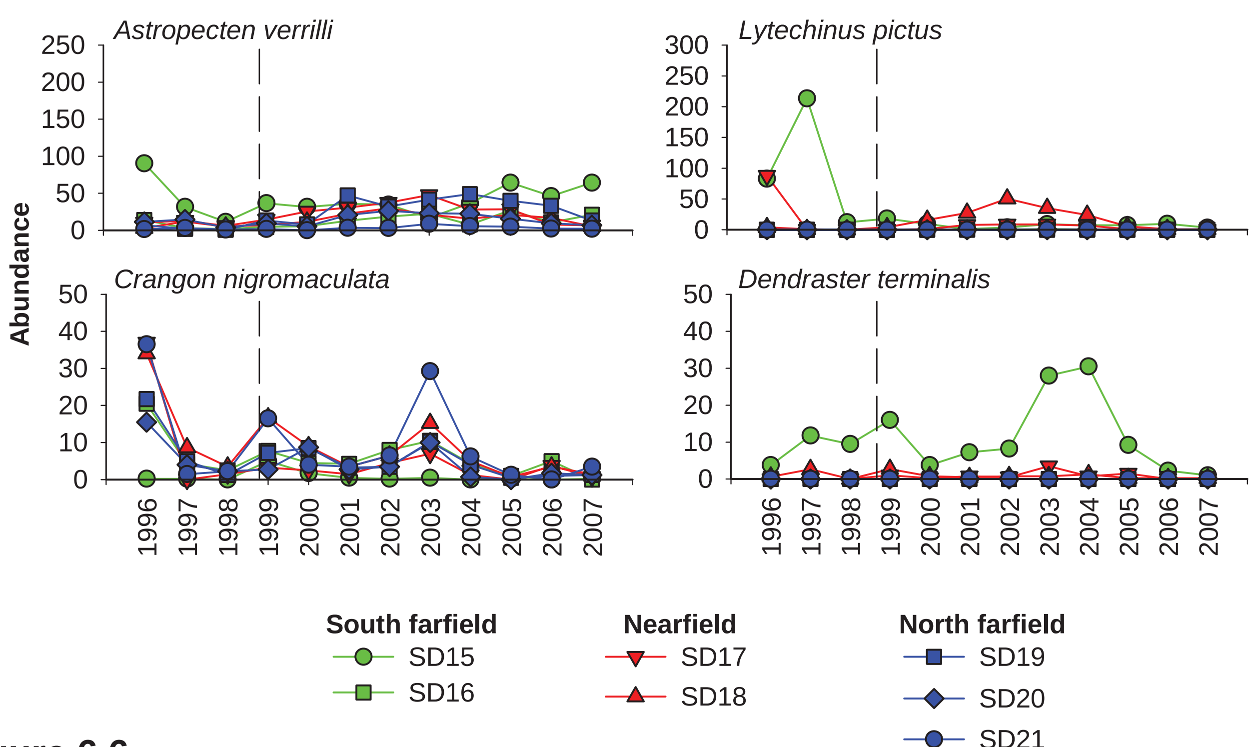

Figure 6.6
Abundance (number of individuals) of the four most abundant megabenthic species collected in the SBOO region from 1996 through 2007. Data are annual means per station, n=4. Dotted line represents initiation of wastewater discharge.

Astropectin verrilli. Variations in community structure of these trawl-caught invertebrates generally reflect changes in the abundance of this sea star, as well as other dominant species such as *Lytechinus pictus*, *Dendraster terminalis*, and *Crangon nigromaculata*.

The low species richness and abundances of fish and invertebrates found during the 2007 surveys are consistent with what is expected for the relatively shallow, sandy habitats in which the SBOO stations are located (see Allen et al. 1998, 2002, 2007). In contrast, trawl surveys for the Point Loma Ocean Outfall region include deeper stations located farther offshore on the mainland shelf that contain finer sediments, and that typically result in higher species richness and abundance values. For example, 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 (see City of San Diego 2006).

Overall, results of the 2007 trawl surveys provide no evidence that wastewater discharged through the SBOO has affected either demersal 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 any significant influence due to the outfall. Changes in these communities appear to be more likely due to natural factors such as changes in water temperature associated with large-scale oceanographic events (e.g., El Niño) or to the mobile nature of many of the resident 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 can accumulate contaminants 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 two components: (1) liver tissues are analyzed for trawl-caught fishes; (2) muscle tissues are analyzed for fishes collected by rig fishing. Fishes collected from trawls are considered representative of the general 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 it is typically the organ where contaminants concentrate. 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 may 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 National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program. NOAA initiated this program to detect changes in the environmental quality of the nation's estuarine and coastal waters by tracking contaminants thought to be of concern for the environment (Lauenstein and Cantillo 1993). This chapter presents the results of all tissue analyses that were performed during 2007.

Materials and Methods

Field Collection

Fishes were collected during April and October of 2007 at seven trawl and two rig fishing stations (**Figure 7.1**). Trawl-caught fishes were collected, measured, and weighed following City of San Diego guidelines (see Chapter 6 for a description of

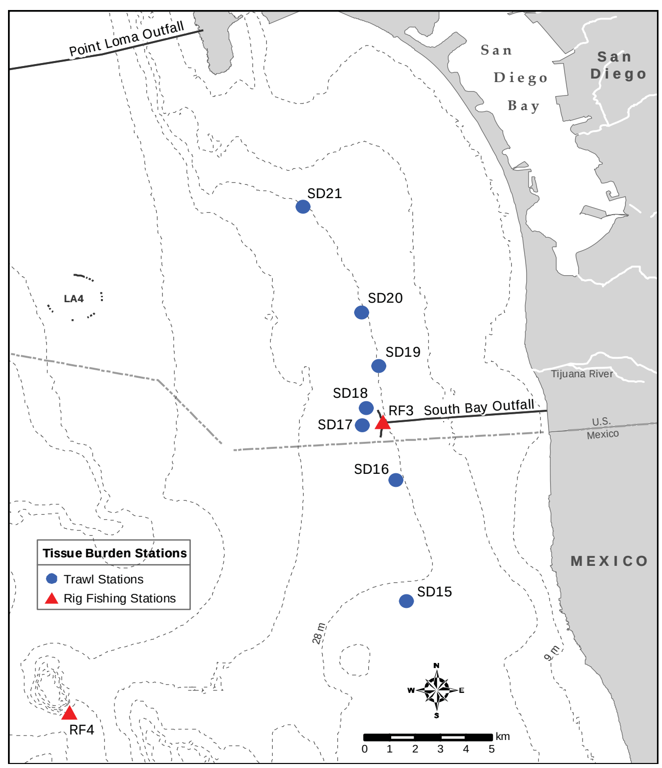

Figure 7.1
Otter trawl and rig fishing station locations for the South Bay Ocean Outfall Monitoring Program.

Table 7.1
Species of fish collected at each SBOO trawl and rig fishing station during April and October 2007.

Station	Rep 1	Rep 2	Rep 3
April 2007			
SD15	Hornyhead turbot	Pacific sanddab	(no sample)
SD16	Longfin sanddab	Hornyhead turbot	Hornyhead turbot
SD17	Longfin sanddab	Hornyhead turbot	English sole
SD18	English sole	Longfin sanddab	Pacific sanddab
SD19	Longfin sanddab	English sole	English sole
SD20	Hornyhead turbot	English sole	Longfin sanddab
SD21	English sole	English sole	Hornyhead turbot
RF3	Brown rockfish	Vermilion rockfish	Mixed rockfish
RF4	California scorpionfish	(no sample)	(no sample)
SD15	Hornyhead turbot	(no sample)	(no sample)
SD16	Longfin sanddab	Longfin sanddab	Longfin sanddab
SD17	Longfin sanddab	Longfin sanddab	Hornyhead turbot
SD18	Longfin sanddab	Longfin sanddab	Hornyhead turbot
SD19	Longfin sanddab	Hornyhead turbot	Longfin sanddab
SD20	Longfin sanddab	California scorpionfish	California scorpionfish
SD21	Longfin sanddab	Hornyhead turbot	Hornyhead turbot
RF3	Brown rockfish	Vermilion rockfish	Mixed rockfish*
RF4	California scorpionfish	California scorpionfish	California scorpionfish

* No PAHs were analyzed from this sample

collection methods). Fishes targeted at rig fishing sites were collected using rod and reel fishing tackle, and then measured and weighed. Species analyzed from each station are summarized in **Table 7.1**. The effort to collect targeted fishes was limited to five 10-minute trawls (bottom time) at each trawl station. Occasionally, insufficient numbers of target species were obtained despite this effort, thus resulting in reduced number of replicates at a station. Only fish ≥13 cm standard lengths were retained for tissue analyses. These fish were sorted into no more than three composite samples per station, each containing a minimum of three individuals. Composite samples are typically made up of a single species; the only exceptions are samples that consist of mixed species of rockfish. 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 dissection and tissue processing.

Tissue Processing and Chemical Analyses

All dissections were performed according to the following 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 Services Laboratory within 10 days of dissection.

Tissue samples were analyzed for the chemical constituents specified by the NPDES permits under which this sampling was performed. Chemical constituents analyzed included trace metals, chlorinated pesticides, polychlorinated biphynel compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (see **Appendix E.2**). Metals were measured as mg/kg or parts per million (ppm), while pesticides, PCBs, and PAHs were measured as µg/kg or parts per billion (ppb). Totals for DDT, PCB, BHC (=Lindane and derivatives) and chlordane were calculated as the sum of detected constituents (i.e., total PCB = sum of detected congeners). Values for each individual constituent 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 confirmed by mass-spectrometry), but at levels below the method detection limit (MDL). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Services Laboratory (City of San Diego 2008).

Results

Contaminants in Trawl-Caught Fishes

Metals

Twelve metals, including antimony, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, selenium, tin, and zinc occurred in ≥85% of the liver samples analyzed from trawl-caught fishes in 2007 (**Table 7.2**). Aluminum, beryllium, lead, nickel, silver, and thallium were also detected, but less frequently (i.e., detection rates of 18-69%). Concentrations of most metals were <10 ppm. Exceptions occurred for aluminum, arsenic, copper, iron, and zinc, which all had concentrations >15 ppm in at least one sample. Of all the metals detected, iron was present in the highest concentrations in all five species of fish analyzed.

Intra-species comparisons of frequently detected metals in liver tissues of fish from the two stations located nearest the SBOO (SD17, SD18) and those from stations located farther away to the south (SD15, SD16) or north (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 several of the tissue samples. However, these relatively high concentration of arsenic occurred in multiple species throughout the region and also showed no pattern relative to the outfall.

Pesticides

Several chlorinated pesticides were detected during the 2007 trawl surveys (**Table 7.3**). Individual components of total chlordane and total DDT are listed in Appendix E.2, while detected values of all pesticides are included in Appendix E.3. DDT was detected in all samples with total DDT concentrations ranging from about 57 to 1059 ppb. Other pesticides that were detected included hexachlorobenzene (HCB) and chlordane, which occurred at maximum concentrations of 2.9 and 15.8 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 pesticide concentrations were close to or below the maximum levels detected in the same species prior to wastewater discharge.

PAHs and PCBs

PAHs were not detected in fish liver samples during 2007. In contrast, PCBs occurred in every tissue sample. All detected PCB congeners are summarized in Appendix E.3. Total PCB concentrations were highly variable, ranging from about 21 to 545 ppb (Table 7.3). There was no clear relationship between PCB concentrations in fish livers and proximity to the outfall (Figure 7.3).

Contaminants in Fishes Collected by Rig Fishing

Arsenic, barium, chromium, copper, iron, manganese, mercury, selenium, tin, and zinc occurred in ≥75% of the muscle tissue samples collected from various rockfish at the two rig fishing stations in 2007 (**Table 7.4**). Aluminum, antimony,

Table 7.2

Metals detected in liver tissues from fishes collected at SBOO trawl stations during 2007. Values are expressed as parts per million (ppm); n=number of detected values, nd=not detected. See Appendix E.1 for names and periodic table symbols.

	Al	Sb	As	Ba	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
California scorpionfish																		
n (out of 2)	2	2	nd	2	nd	2	2	2	2	nd	2	2	2	2	2	2	2	2
Min	11.90	1.57	—	0.473	—	1.53	0.57	17.5	82.9	—	0.70	0.120	0.577	0.65	0.14	2.020	2.24	90.9
Max	19.60	1.68	—	0.584	—	3.29	0.62	17.7	127.0	—	0.80	0.140	0.769	0.72	0.15	2.260	2.31	103.0
Mean	15.75	1.62	—	0.528	—	2.41	0.60	17.6	104.9	—	0.75	0.130	0.673	0.68	0.14	2.140	2.27	96.9
English sole																		
n (out of 7)	4	5	7	7	5	7	7	7	7	4	7	7	nd	7	1	nd	7	7
Min	0.69	0.48	5.41	0.066	0.004	0.98	0.25	2.3	85.2	0.40	1.00	0.070	—	1.24	0.06	—	1.15	21.2
Max	12.50	1.31	45.40	0.103	0.015	1.88	0.46	11.3	256.0	1.45	2.34	0.147	—	1.72	0.06	—	1.38	47.0
Mean	6.53	0.83	18.96	0.081	0.010	1.27	0.35	6.4	198.9	0.84	1.73	0.099	—	1.53	0.06	—	1.25	35.4
Hornyhead turbot																		
n (out of 12)	8	11	12	12	5	12	12	12	12	nd	12	11	6	12	9	5	12	12
Min	0.85	0.55	2.48	0.056	0.003	2.77	0.28	4.8	29.7	—	0.91	0.084	0.260	0.58	0.07	0.853	1.13	35.1
Max	15.10	1.77	13.50	0.291	0.018	8.49	1.32	13.2	146.0	—	1.84	0.246	0.587	1.31	0.66	1.790	2.11	81.3
Mean	7.26	1.26	6.42	0.126	0.011	4.53	0.58	6.0	70.9	—	1.35	0.153	0.476	0.88	0.18	1.243	1.64	50.0
Longfin sanddab																		
n (out of 16)	12	16	16	16	5	16	16	16	16	3	16	11	12	16	2	10	16	16
Min	1.33	0.70	3.36	0.098	0.008	0.86	0.21	3.4	46.6	0.15	0.90	0.019	0.366	0.66	0.04	0.600	1.48	24.9
Max	28.40	2.38	22.10	0.518	0.025	3.59	0.95	9.8	323.0	0.60	3.14	0.095	4.500	1.56	0.07	2.740	2.89	68.0
Mean	16.19	1.65	7.13	0.272	0.014	1.92	0.60	5.3	104.7	0.42	1.31	0.050	1.031	0.98	0.05	1.721	2.30	31.9
Pacific sanddab																		
n (out of 2)	1	1	2	2	2	2	2	2	2	nd	2	2	nd	2	nd	nd	2	2
Min	10.50	0.60	3.06	0.072	0.014	3.42	0.29	3.6	138.0	—	1.21	0.086	—	0.89	—	—	1.69	30.1
Max	10.50	0.60	10.50	0.089	0.016	3.61	0.54	3.8	148.0	—	1.65	0.119	—	1.24	—	—	1.73	34.7
Mean	10.50	0.60	6.78	0.080	0.015	3.51	0.42	3.7	143.0	—	1.43	0.103	—	1.06	—	—	1.71	32.4
All species:																		
Detection rate (%)	69	90	95	100	44	100	100	100	100	18	100	85	51	100	36	44	100	100
Max value	28.40	2.38	45.40	0.584	0.025	8.49	1.32	17.7	323.0	1.45	3.14	0.246	4.500	1.72	0.66	2.740	2.89	103.0

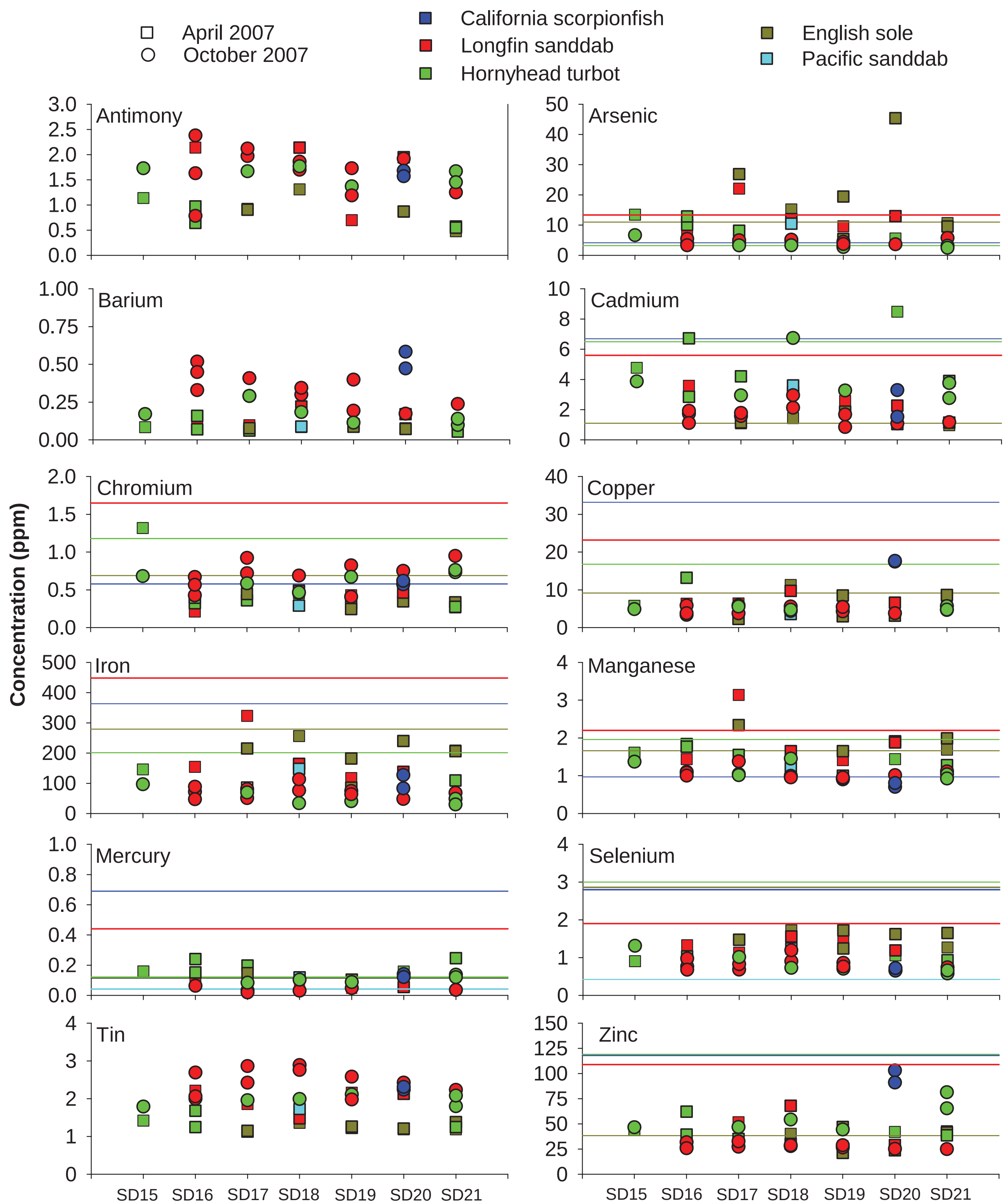

Figure 7.2

Concentrations of frequently detected metals in liver tissues of fishes collected from each SBOO trawl station during 2007. Reference lines are maximum values detected during the pre-discharge period (1995–1998); antimony, barium, and tin were not detected during the pre-discharge period because of substantially higher detection limits. Therefore, no reference lines are present for these contaminants.

Table 7.3

Concentrations of chlorinated pesticides, total PCB, and lipids detected in liver tissues from fishes collected at SBOO trawl stations during 2007. HCB=hexachlorobenzene; tChl=total chlordane; tDDT=total DDT; tPCB=total PCB. 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				
	HCB	tChl	tDDT	tPCB	Lipids
Ca. scorpionfish					
n (out of 2)	2	2	2	2	2
Min	0.9	6.7	444.1	196.2	16.1
Max	1.0	11.7	487.7	273.0	18.7
Mean	0.9	9.2	465.9	234.6	17.4
English sole					
n (out of 7)	3	nd	7	7	7
Min	0.7	—	63.4	54.2	4.3
Max	1.2	—	631.3	187.8	7.9
Mean	0.9	—	224.3	96.0	5.7
Hornyhead turbot					
n (out of 12)	6	nd	12	12	12
Min	0.4	—	57.1	21.2	4.0
Max	0.8	—	146.0	82.2	10.9
Mean	0.6	—	97.9	43.1	6.7
Longfin sanddab					
n (out of 16)	16	15	16	16	16
Min	1.6	2.8	340.4	148.8	13.6
Max	2.9	15.8	1059.0	545.4	48.8
Mean	2.2	8.6	610.3	324.8	33.6
Pacific sanddab					
n (out of 2)	2	2	2	2	2
Min	1.6	4.4	326.2	148.1	12.4
Max	2.4	12.4	552.5	209.3	21.2
Mean	2.0	8.4	439.4	178.7	16.8
All species:					
Detection rate (%)	74	49	100	100	100
Max value	2.9	15.8	1059.0	545.4	48.8

beryllium, nickel, silver, and thallium were also detected, but less frequently (i.e., detection rates of 10-70%). Metals that were present in the highest concentrations were aluminum (16.1 ppm), iron (15.1 ppm), zinc (6.6 ppm) and arsenic (3.8 ppm). DDT and PCBs were detected in 100% of the muscle samples, while the pesticides HCB, BHC (lindane) and chlordane were detected in 50% or less of the samples (**Table 7.5**). Each of these contaminants was detected in relatively low concentrations, which ranged from 0.1 ppb for HCB to 19.4 ppb for total DDT.

To address human health concerns, contaminant concentrations found in muscle tissues 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, while there are also international standards for acceptable concentrations of various metals (see Mearns et al. 1991). Of the contaminants detected in muscle tissues of fish collected as part of the SBOO monitoring program, only arsenic and selenium occurred in concentrations equal to or slightly higher than median international standards.

In addition to addressing health concerns, spatial patterns were analyzed for total DDT and total PCB, as well as for all metals that occurred frequently in muscle tissues (**Figure 7.4**). Overall, concentrations of DDT, PCB and various metals in the muscle tissue of fishes captured at both rig fishing stations were fairly similar, which suggests that there is no relationship with proximity to the outfall. Comparisons of contaminant loads in fishes from stations RF3 and RF4 should be considered with caution since different species of fish were collected at the two sites, and the bioaccumulation of contaminants may differ between species due to differences in physiology and diet. However, this potential problem may be minimal here as all fish specimens belong to the same family (Scorpaenidae), have similar life histories (i.e., bottom dwelling tertiary carnivores), and therefore likely have similar mechanisms of exposure to and uptake of contaminants (e.g., direct contact with sediments, similar food sources).

Summary and Conclusions

Twelve trace metals, DDT, and a combination of PCB congeners were each detected in ≥75% of the

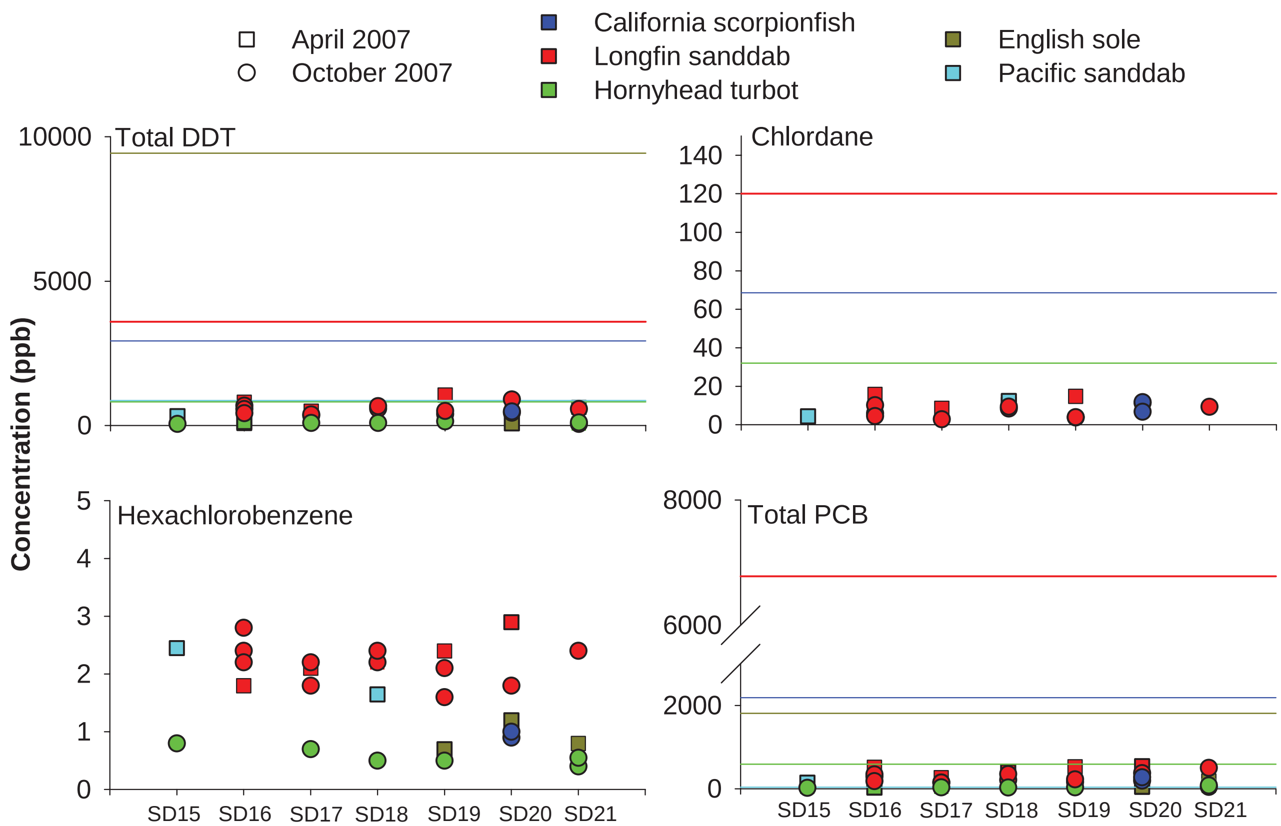

Figure 7.3
Concentrations of frequently detected chlorinated pesticides (total DDT, chlordane, hexachlorobenzene) and total PCBs in liver tissues of fishes collected from each SBOO trawl station during 2007. Reference lines are maximum values detected during the pre-discharge period (1995–1998); chlordane and hexachlorobenzene were not detected as frequently during the pre-discharge period because of substantially higher detection limits. Therefore, reference lines for these two contaminants are absent for some or all of the species.

liver tissue samples collected from five species of fish around the SBOO in 2007. 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 tissue samples contained concentrations of some metals that exceeded pre-discharge maximums, concentrations of most contaminants were not substantially different from pre-discharge levels (see City of San Diego 2000b). In addition, the few tissue samples that did exceed pre-discharge values were widely distributed among the sampled stations and showed no patterns that could be attributed to wastewater discharge via the SBOO.

The frequent occurrence of metals and chlorinated hydrocarbons in SBOO fish tissues may be due to multiple 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 information is available on 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 (see 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. Exposure

Table 7.4

Metals detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2007. Values are expressed as parts per million (ppm); 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. Bold values meet or exceed these standards. See Appendix E.1 for names and periodic table symbols.

	Al	**Sb**	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Hg**	**Ni**	**Se**	**Ag**	**Tl**	**Sn**	**Zn**
Brown rockfish																	
n (out of 2)	1	nd	2	2	1	1	2	1	2	2	2	1	2	nd	nd	2	2
Min	16.10	—	0.76	0.056	0.006	0.03	0.33	0.652	6.28	0.18	0.101	0.10	0.14	—	—	1.07	4.82
Max	16.10	—	**2.18**	0.128	0.006	0.03	0.38	0.652	7.48	0.21	0.125	0.10	0.15	—	—	1.76	6.16
Mean	16.10	—	**1.47**	0.092	0.006	0.03	0.36	0.652	6.88	0.19	0.113	0.10	0.15	—	—	1.41	5.49
California scorpionfish																	
n (out of 4)	4	nd	4	4	1	3	4	4	4	4	4	2	4	1	1	4	4
Min	8.17	—	**1.70**	0.077	0.007	0.04	0.26	0.150	5.09	0.13	0.147	0.12	0.22	0.06	0.91	1.13	4.41
Max	14.20	—	**3.79**	0.151	0.007	0.08	0.40	0.789	15.10	0.18	0.243	0.22	0.24	0.06	0.91	1.89	6.58
Mean	11.37	—	**2.62**	0.111	0.007	0.06	0.32	0.489	8.66	0.16	0.187	0.17	0.23	0.06	0.91	1.45	5.56
Mixed rockfish																	
n (out of 2)	1	1	2	2	1	1	2	1	2	2	2	nd	2	nd	nd	2	2
Min	8.73	0.55	1.20	0.050	0.010	0.06	0.18	0.529	1.93	0.11	0.060	—	0.16	—	—	0.83	3.50
Max	8.73	0.55	**1.68**	0.075	0.010	0.06	0.22	0.529	5.74	0.12	0.180	—	0.28	—	—	1.54	4.57
Mean	8.73	0.55	**1.44**	0.062	0.010	0.06	0.20	0.529	3.83	0.11	0.120	—	0.22	—	—	1.18	4.03
Vermilion rockfish																	
n (out of 2)	1	2	1	2	1	1	2	2	2	2	2	1	2	nd	1	2	2
Min	12.60	1.57	**1.69**	0.061	0.007	0.20	0.27	0.120	6.35	0.13	0.036	0.23	0.16	—	1.70	0.99	4.42
Max	12.60	1.75	**1.69**	0.202	0.007	0.20	0.46	0.355	7.85	0.21	0.060	0.23	**0.30**	—	1.70	2.43	5.55
Mean	12.60	1.66	**1.69**	0.131	0.007	0.20	0.37	0.237	7.10	0.17	0.048	0.23	0.23	—	1.70	1.71	4.98
All species:																	
Detection rate (%)	70	30	90	100	40	60	100	80	100	100	100	40	100	10	20	100	100
Max	16.10	1.75	3.79	0.202	0.010	0.20	0.46	0.789	15.10	0.21	0.243	0.23	0.30	0.06	1.70	2.43	6.58
US FDA action limit*											1.0						
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

Chlorinated pesticides, total PCB, and lipids detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2007. tBHC=total BHC (lindane); tChlor= total chlordane; HCB=hexachlorobenzene; tDDT=total DDT; tPCB=total PCB. 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					
	tBHC	tChlor	HCB	tDDT	tPCB	Lipids
Brown rockfish						
n (out of 2)	2	nd	nd	2	2	2
Min	0.5	—	—	1.2	0.2	0.3
Max	1.4	—	—	3.0	2.1	0.5
Mean	0.9	—	—	2.1	1.1	0.4
Ca. scorpionfish						
n (out of 4)	nd	1	3	4	4	4
Min	—	1.0	0.1	2.2	0.3	0.5
Max	—	1.0	0.2	19.4	6.5	2.3
Mean	—	1.0	0.1	8.2	3.1	1.3
Mixed rockfish						
n (out of 2)	2	nd	1	2	2	2
Min	0.9	—	0.1	1.2	0.2	0.3
Max	1.1	—	0.1	2.0	0.9	0.5
Mean	1.0	—	0.1	1.6	0.5	0.4
Vermilion rockfish						
n (out of 2)	1	nd	1	2	2	2
Min	1.4	—	0.4	1.6	0.7	0.3
Max	1.4	—	0.4	3.7	1.1	1.6
Mean	1.4	—	0.4	2.6	0.9	0.9
All species:						
Detection (%)	50	10	50	100	100	100
Max	1.4	1.0	0.4	19.4	6.5	2.3
FDA action limits*		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.

to contaminants can vary greatly between different species and among individuals of the same species depending on migration habits (Otway 1991). Fishes may be exposed to contaminants in an area that is highly contaminated and then move into an area that is not. For example, California scorpionfish are known to migrate long distances (Hartmann 1987, Love et al. 1987). 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); 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 2007 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 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, other indicators of disease, or any physical anomalies (see Chapter 6).

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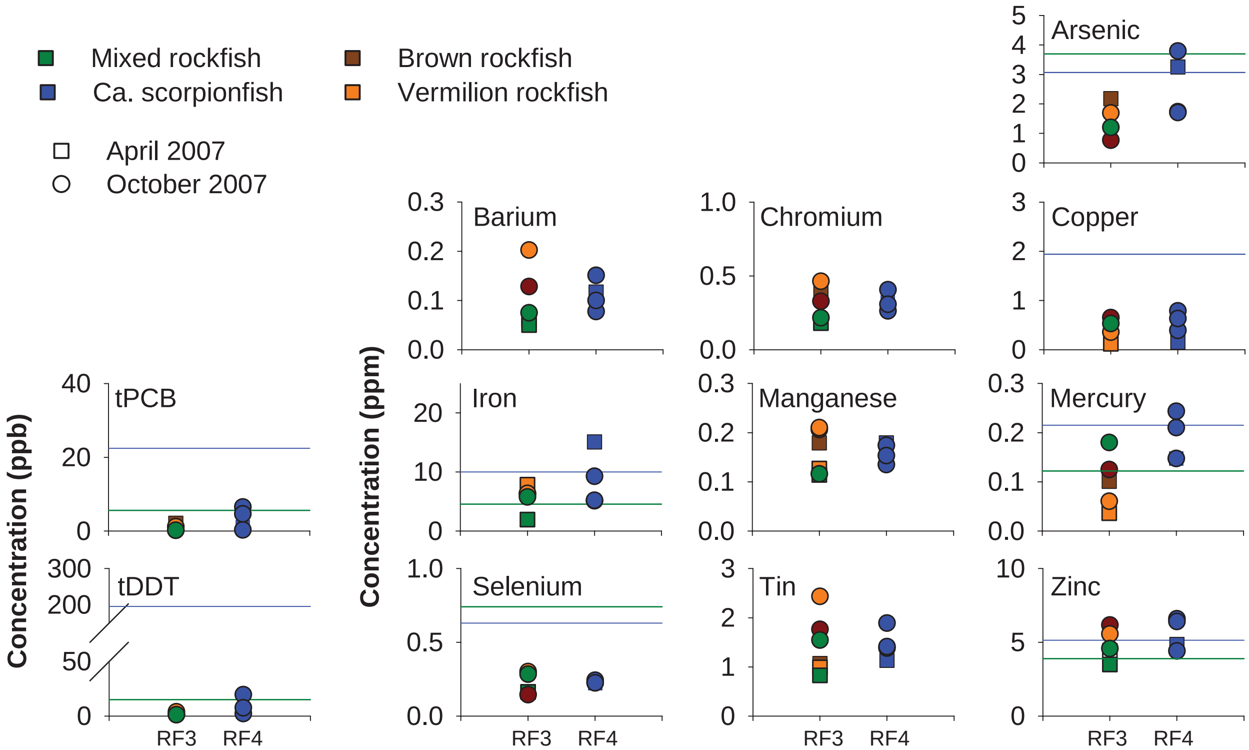

Figure 7.4
Concentrations of frequently detected metals, total DDT, and total PCB in muscle tissues of fishes collected from each SBOO rig fishing station during 2007. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for California scorpionfish and mixed rockfish. Vermilion and brown rockfish were not collected during that period.

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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 regional surveys are based on arrays of stations that are randomly selected for each year using the USEPA probability-based EMAP design. The 1994, 1998, and 2003 surveys off San Diego were conducted as part of larger, multi-agency surveys of the entire Southern California Bight (SCB), including the 1994 Southern California Bight Pilot Project (SCBPP), and the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight'98 and Bight'03, respectively). Results of sediment conditions from previous bightwide surveys are available in Noblet et al. (2002) and Schiff et al. (2006). The same randomized sampling design was used for surveys limited to the San Diego region in 1995–1997, 1999–2002, and 2005–2007. Additionally, during 2005, 2006 and 2007, the City revisited the same sites sampled 10 years earlier (i.e., 1995-1997, respectively) in order to facilitate comparisons of long-term changes in sediment conditions for the region.

This chapter presents analysis and interpretation of sediment particle size and chemistry data collected during the 2007 San Diego regional survey of randomized sites. Descriptions and comparisons of sediment conditions present in 2007 are included with analyses of levels and patterns of contamination relative to known and presumed sources.

Materials and Methods

Field Sampling

The summer 2007 survey covered an area from off Del Mar in northern San Diego County southward to the USA/Mexico border (**Figure 8.1**). This survey revisited the sites selected for the 1997 regional survey, which was based on the USEPA probability-based EMAP sampling design (see City of San Diego 1998). The monitoring area included the section of the mainland shelf ranging from nearshore waters to shallow slope depths (13–216 m). Although 40 sites were initially selected for the 1997 and 2007 surveys, sampling at three sites in 1997

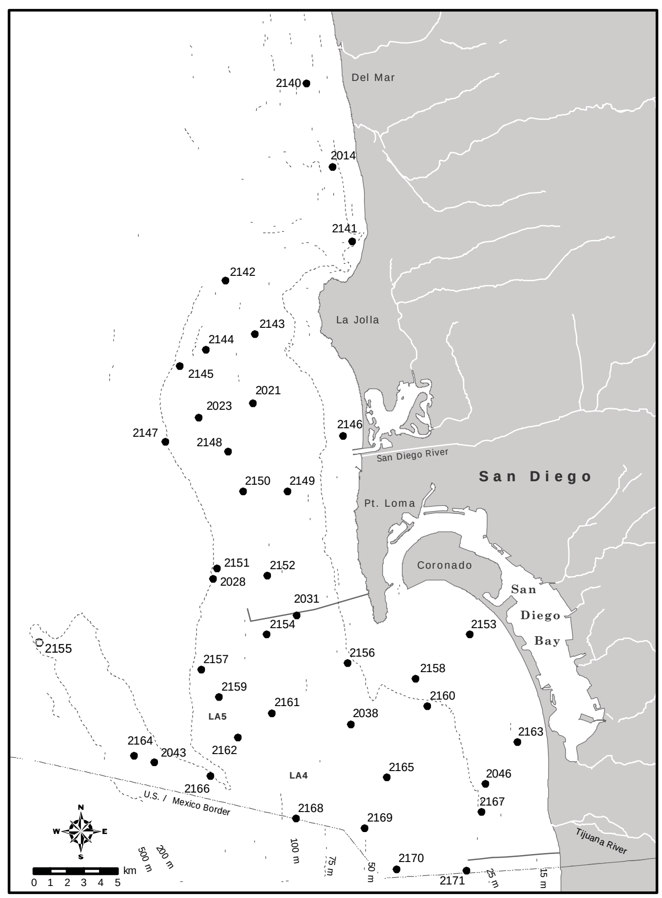

Figure 8.1
Randomly selected regional benthic stations sampled off San Diego, CA (July 2007). Open circles represent abandoned stations (see text).

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

and one site in 2007 was unsuccessful due to the presence of rocky reefs. In addition, seven of the sites (stations 2014, 2021, 2023, 2028, 2031, 2038, 2046) were repeat stations that were sampled each year (i.e., 1995–1997, 2005–2007).

Each sample for sediment analysis 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).

Laboratory Analyses

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Services Laboratory. Particle size analysis was performed using a Horiba LA–920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., 11 to -1 phi). Coarser sediments (e.g., 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 "% Coarse" of the total sample sieved.

Output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles ranging 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 8.1**). These data were standardized and combined with any sieved coarse fraction (i.e., particles >2.0 mm) 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). These parameters were summarized and expressed as overall mean particle size (mm), phi size (mean, median, skewness, and kurtosis), and the proportion of coarse, sand, silt, and clay. The proportion of fine particles (% fines) was calculated as the sum of all silt and clay fractions.

Sediment samples were analyzed for the chemical constituents specified by the NPDES permits under which sampling was performed. These parameters include total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides (e.g., DDT), polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (see **Appendix C.1**). TOC and TN were measured as percent weight (%wt) of the sediment sample; sulfides and metals were measured in units of mg/kg and expressed as parts per million (ppm); pesticides and PCBs were measured in units of ng/kg and expressed as parts per trillion (ppt); PAHs were measured in units of µg/kg and expressed as parts per billion (ppb). The data reported herein were generally limited to values above the method detection limit (MDL). However, concentrations below MDLs were included as estimated values if the presence of the specific constituent could be verified by mass-spectrometry (i.e., spectral peaks confirmed). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Services Laboratory (City of San Diego 2008).

Data Analyses

Values for total PAH, total DDT and total PCB were calculated for each sample as the sum of all constituents with reported values. Zeroes were substituted for all non-detects (i.e., null values) when calculating means. Summaries of parameters included detection rates (i.e., total number of reported values/total number of samples), the minimum and maximum value of each parameter during the year, and annual means for all stations combined (areal mean). Data are also summarized by depth strata used in the Bight'98 and Bight'03 regional surveys of the entire SCB including shallow shelf (5–30 m), mid-shelf (30–120 m), and deep shelf (120–200 m). Annual means from 2007 were compared to mean values from the 1997 Regional Survey.

Results

Particle Size Analysis

With few exceptions, the overall composition of sediments off San Diego in 2007 consisted of fine sands and silts (**Figure 8.2, Table 8.2**). Geographic distributions were similar to those observed in previous surveys: i.e., higher sand content in shallow nearshore areas, and decreasing to a mixture of mostly coarse silt and very fine sand at the mid-shelf region and at deeper offshore sites (see City of San Diego 1998, 2000–2003, 2006, 2007). Overall, these sediments reflect the diverse and patchy habitats common to the SCB. Eight of the 2007 sites were located in shallow shelf depths ≤30 m. The sediments at these shallow sites were composed of about 90% sands and 9% fines with an average particle size of approximately 0.15 mm (Table 8.2). Mid-shelf stations located at depths of 30–120 m represented most of the sites sampled off San Diego during the year (n=22). These sites generally had finer sediments composed of about 60% sands and 37% fines with a mean particle size of about 0.13 mm. The nine deepest sites that occurred at depths of 120–200 m contained sediments of about 52% sands and 47% fines with an average particle size of about 0.08 mm.

Almost all of the 2007 survey sites located south of Point Loma and at depths of 19–55 m had sediments composed of <25% fines (Figure 8.2). These results are very similar to those from the regular fixed-grid stations surrounding the SBOO (see Chapter 4). Sediments from deeper mid-shelf sites in this South Bay region tended to be coarser and have less fine materials than regional stations at similar depths located off of Point Loma and further to the north. This may be due at least in part to the multiple geological origins of red relict sands, shell hash, coarse sands, and other detrital sediments in the South Bay region (Emery 1960).

Sediment particle size composition along the San Diego shelf in 2007 was generally similar to that sampled at the same sites in 1997 (**Table 8.3**). Only seven of the stations sampled in 2007 had sediments differing by more than 0.05 mm in mean particle size from the 1997 samples **(Appendix F.2)**. For these seven stations, average particle size decreased at three sites (stations 2043, 2156 and 2146) between 1997 and 2007, and increased at four other sites (stations 2169, 2165, 2170 and 2023).

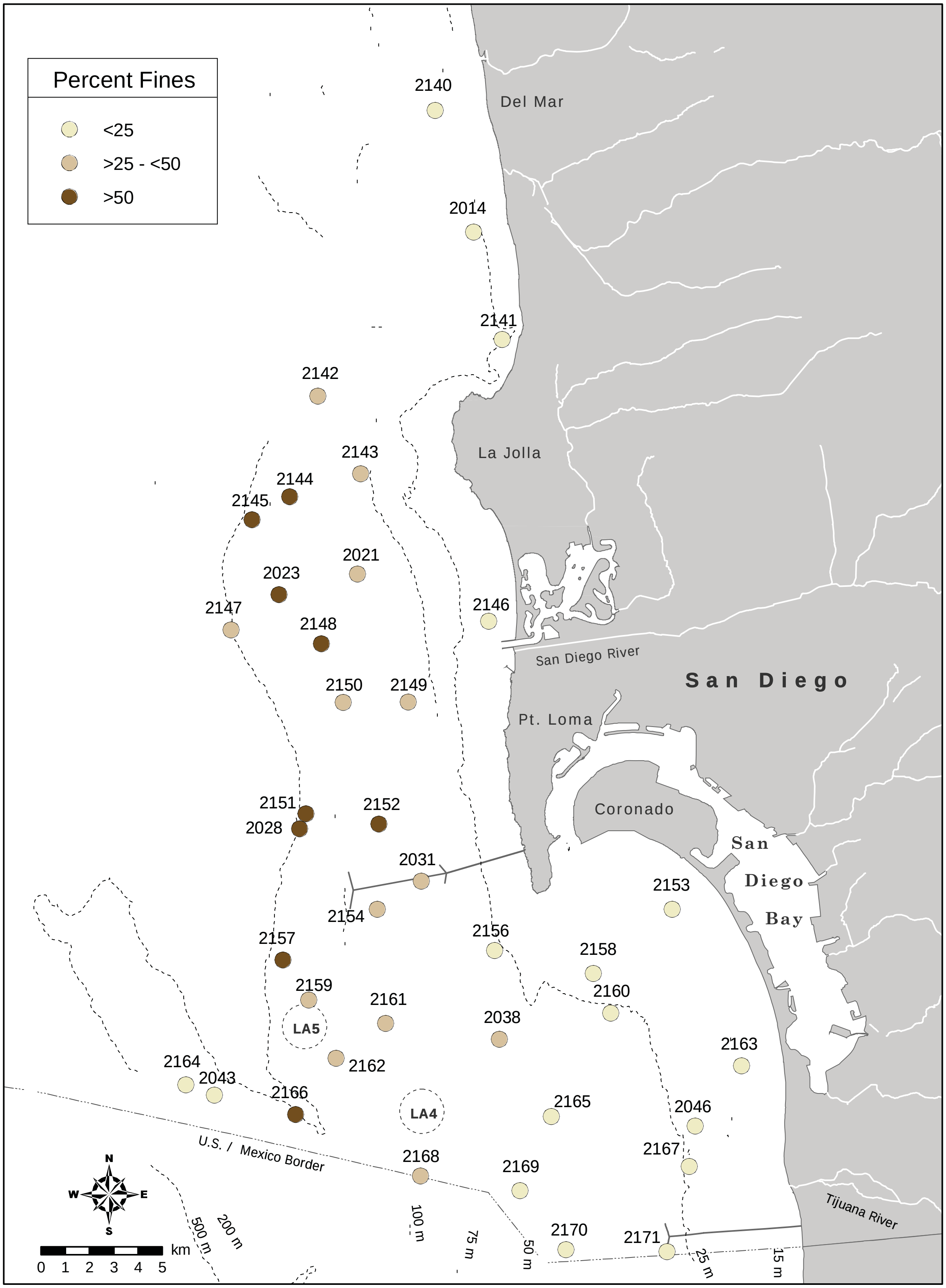

Figure 8.2
Particle size distribution for regional benthic stations sampled off San Diego, CA (July 2007).

Table 8.2

Summary of particle size parameters for the 2007 regional survey stations. Abbreviated observations are: Sh=shell hash; G=gravel; R=rock; Od=organic debris; Sg=surfgrass; Rrs=red relic sand; Cbs=coarse black sand; M=mud; Cs=coarse sand; Ct=chaetopterid tubes.

	Station	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Fines (%)	Observations
Shallow Shelf	2153	13	0.159	2.6	0.7	0.0	94.1	5.9	0.0	5.9	Sh, G, R
	2146	14	0.137	2.9	0.5	0.0	93.8	6.2	0.0	6.2	
	2163	15	0.116	3.1	1.0	3.3	82.8	13.4	0.5	13.9	Sh
	2158	16	0.286	1.8	0.9	3.5	96.2	0.3	0.0	0.3	Sh
	2046	22	0.122	3.0	0.5	0.0	91.6	8.3	0.1	8.4	
	2167	25	0.102	3.3	0.8	0.0	86.1	13.5	0.4	13.9	Od
	2160	26	0.109	3.2	1.0	0.0	83.3	15.8	0.8	16.6	Od
	2171	29	0.204	2.3	1.2	2.5	92.1	5.4	0.0	5.4	Sh
	Mean	20	0.154	2.8	0.8	1.2	90.0	8.6	0.2	8.8	
Mid-shelf	2141	36	0.096	3.4	1.5	0.0	75.4	23.0	1.6	24.6	Od, Sg
	2156	36	0.130	2.9	1.1	0.0	85.4	13.7	0.9	14.6	Od, Sh
	2014	38	0.088	3.5	1.2	0.0	75.3	23.3	1.4	24.7	Od, Sh
	2140	38	0.088	3.5	1.2	0.0	78.1	20.4	1.4	21.8	
	2170	42	0.528	0.9	0.7	8.8	90.2	0.9	0.0	0.9	Rrs, Sh
	2165	43	0.280	1.8	1.1	0.2	92.3	7.3	0.2	7.5	Cbs, Sh
	2169	49	0.615	0.7	0.7	12.7	86.7	0.5	0.0	0.5	Rrs, Sh
	2038	52	0.063	4.0	1.4	0.0	66.4	31.3	2.3	33.6	Sh, M, G
	2143	57	0.056	4.2	1.6	0.0	61.9	35.2	2.8	38.0	Od, Sh
	2149	63	0.049	4.3	1.5	0.0	52.3	44.9	2.8	47.7	Od, Sh
	2021	67	0.048	4.4	1.7	2.2	49.2	44.6	4.0	48.6	Sh, M, G
	2031	74	0.050	4.3	1.5	0.0	53.8	43.4	2.9	46.3	
	2150	82	0.048	4.4	1.6	0.0	50.1	46.7	3.2	49.9	
	2152	82	0.044	4.5	1.5	0.0	45.9	51.1	3.0	54.1	
	2148	83	0.038	4.7	1.5	0.0	37.1	58.7	4.2	62.9	
	2154	88	0.053	4.2	1.5	0.0	57.3	40.0	2.7	42.7	
	2168	88	0.059	4.1	1.6	0.0	65.4	32.0	2.6	34.6	
	2161	89	0.055	4.2	1.9	3.4	52.5	40.3	3.8	44.1	Cs, Sh, G, R
	2023	90	0.190	2.4	2.2	23.8	21.6	54.6	0.0	54.6	M, G
	2144	93	0.043	4.5	1.6	0.0	46.4	49.9	3.7	53.6	
	2142	96	0.047	4.4	1.5	0.0	51.7	44.8	3.5	48.3	
	2145	116	0.109	3.2	1.4	5.5	28.7	65.8	0.0	65.8	Sh, G, R
	Mean	68	0.126	3.6	1.4	2.6	60.2	35.1	2.1	37.2	
Deep shelf	2162	130	0.053	4.2	2.0	2.1	51.9	41.7	4.3	46.0	Cs, Sh, G, R
	2164	136	0.281	1.8	1.1	4.3	83.5	12.2	0.0	12.2	Sh, M, G
	2159	160	0.048	4.4	1.9	0.0	50.7	44.4	4.9	49.3	Cs, Sh, G, R
	2043	171	0.157	2.7	1.6	0.0	83.4	15.4	1.2	16.6	Od, Sh
	2151	177	0.038	4.7	1.6	0.0	40.3	55.3	4.3	59.6	Od, Ct
	2157	186	0.030	5.0	1.6	0.0	29.4	65.4	5.3	70.7	Od, Ct
	2028	190	0.037	4.8	1.6	0.0	38.2	57.5	4.3	61.8	Od, Ct
	2147	193	0.048	4.4	1.9	0.0	54.5	40.2	5.3	45.5	Sh, G
	2166	216	0.036	4.8	1.9	0.0	40.1	54.2	5.7	59.9	Od, M, G, Sh
	Mean	173	0.081	4.1	1.7	0.7	52.4	42.9	3.9	46.8	

Table 8.3

Summary of sediment contaminants from the 1997 and 2007 regional surveys. Parameters are summarized as mean values per major depth strata for 2007; minimum (Min), maximum (Max) and mean values for the 2007 and 1997 survey areas.

		2007 by Strata			2007 Survey Area			1997 Survey Area		
	Units	Shallow	Mid	Deep	Min	Max	Mean	Min	Max	Mean
Depth	m	20	68	173	13	216	83	13	194	77
Fines	%	9	37	47	0	71	34	nd	78	31
Sulfides	ppm	7.1	9.4	12.9	nd	97.3	9.8	nd	272.0	16.8
TN	%wt	0.02	0.06	0.10	nd	0.15	0.06	nd	0.15	0.05
TOC	%wt	0.18	0.83	2.52	0.05	8.17	1.09	nd	1.53	0.50
HCB	ppt	14	153	74	nd	1100	106	nd	nd	nd
tDDT	ppt	7	153	30	nd	580	95	nd	1600	43
tPCB	ppt	nd	299	371	nd	6360	254	na	na	na
tPAH	ppb	57.6	35.0	52.3	nd	176.7	43.6	nd	nd	nd
Metals										
Al	ppm	4498	10877	15089	991	22400	10541	1150	23500	10793
Sb	ppm	1.73	0.60	0.56	nd	2.45	0.82	nd	13.80	1.76
As	ppm	1.84	3.51	2.83	0.96	7.35	3.01	1.1	6.95	3.42
Ba	ppm	20.9	48.1	58.0	2.4	142.0	44.8	na	na	na
Cd	ppm	0.23	0.06	0.15	nd	0.32	0.12	nd	0.75	0.06
Cr	ppm	7.9	18.1	26.7	4.2	38.2	18.0	7.4	36.4	18.2
Cu	ppm	1.3	5.0	12.3	nd	25.4	5.9	nd	40.6	8.9
Fe	ppm	5729	14375	18466	3210	37500	13546	4530	22500	11577
Pb	ppm	1.41	2.92	7.34	0.15	33.90	3.63	nd	8.00	0.83
Mn	ppm	63.2	112.9	121.9	13.5	183.0	105.1	13.2	149.0	89.2
Hg	ppm	0.003	0.025	0.062	nd	0.169	0.029	nd	0.113	0.011
Ni	ppm	2.5	6.6	10.9	0.9	16.0	6.8	nd	21.4	7.1
Se	ppm	nd	0.09	0.28	nd	0.67	0.12	nd	0.84	0.24
Ag	ppm	1.31	3.28	2.30	nd	8.35	2.65	nd	nd	nd
Tl	ppm	0.13	0.47	0.18	nd	1.01	0.34	nd	nd	nd
Sn	ppm	0.86	1.58	1.76	nd	2.69	1.44	nd	nd	nd
Zn	ppm	13.5	31.9	45.4	6.5	61.9	31.3	5.3	71.8	30.4

Organic Indicators

Concentrations of total organic carbon (TOC) and nitrogen (TN) increased with depth, corresponding to the percent fines in each depth strata (see Table 8.3). TOC averaged 0.18% at the shallow water stations, 0.8% at the mid-shelf stations, and 2.52% at the deep shelf stations. TN averaged 0.02% at the shallow sites, 0.06% at the mid-shelf sites, and 0.1% at the deep shelf sites. Sediments at two stations located along the Coronado Bank had the highest concentrations of TOC (8.17% at station 2164) and TN (0.15% at station 2166; **Table 8.4**); sediments in this area have consistently had high concentrations of organics despite the presence of overall coarse sediments relative to other deep shelf stations (see City of San Diego 2007). Most other regional sites with relatively high TOC concentrations (>1.5%) occurred along the 200-m depth contour from Point Loma northward (i.e., stations 2157, 2028, 2151, 2147). Sediments at these stations also had some of the highest TN concentrations (>0.10%). As with particle size, TOC and TN concentrations at South Bay regional sites were similar to results from the fixed-grid stations surrounding the SBOO (see Chapter 4). The region-wide mean concentration of TN (0.06%) in 2007 was slightly higher than the 1997 average (0.05%; see Table 8.3). In contrast, the 2007 region-wide mean for

TOC (1.09%) was more than 50% above the 1997 average (0.5%; Table 8.3). The higher average TOC value for 2007 reflects the much higher TOC concentrations that occurred at the deep shelf stations (i.e., mean=2.52%; maximum=8.17%).

Concentrations of sulfides also increased between depth strata. For example, sulfide concentrations averaged about 7.1 ppm at the shallow water stations, 9.4 ppm at the mid-shelf stations, and 12.9 ppm at the deep shelf sites (Table 8.3). The highest sulfide concentration (97.3 ppm) was found in sediments from station 2141 located at a depth of 36 m west of La Jolla Shores (see Table 8.4 and Figure 8.1). Other relatively high sulfide values (i.e., ≥19.4 ppm) occurred in sediments off of Mission Beach (station 2146), near the Point Loma outfall (station 2154), near LA-5 dredge disposal site (stations 2162 and 2159), and at a depth of 186 m located between the Point Loma outfall and LA-5 (station 2157). In contrast, sulfides were very low or not-detected in sediments from regional and fixed-grid stations surrounding the SBOO (see Table 8.4 and Chapter 4). Region-wide sulfide concentrations from this study were well within the range of values reported for 1997 (Table 8.3).

Trace Metals

Fifteen different metals (i.e., aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, tin, and zinc) were detected in sediments at more than 75% of the regional stations sampled in 2007 (Table 8.4). Two additional metals, selenium and thallium, were detected at only 26% and 59% of the stations, respectively, while beryllium was not detected at any site. Concentrations of several metals, including aluminum, barium, chromium, copper, iron, lead, manganese, mercury, nickel, tin and zinc increased with depth and percent fines (Table 8.3), a pattern similar to that observed for various indicators of organic loading. For these metals, the highest concentrations tended to occur at the deeper sites that had the largest proportion of fine particles (see above). Concentrations of some metals also appeared to be associated with the LA-5 dredge spoils disposal site. For example, stations 2159 and 2162 located nearest LA-5, and station 2161 located just inshore of the disposal site, had sediments with some of the highest concentrations of several metals (i.e., aluminum, arsenic, chromium, copper, lead, mercury, thallium, and zinc); however, sediments at these sites had only moderate proportions of fine particles (i.e., 44-49%, see Table 8.2).

No associations were apparent between high values of metals and distance from the ocean outfalls in either the Point Loma or South Bay regions. Even though the site located closest to the SBOO (station 2171) had sediments with relatively high concentrations of antimony and cadmium, values of these two metals were high throughout the entire SBOO area (Table 8.4). In fact, mean concentrations of these and all other metals from the regular SBOO fixed grid program (see Chapter 4) were similar to, or lower than, regional survey averages (Table 8.3). Additionally, most metals occurred in sediments during 2007 at concentrations similar to, or lower than, values detected in 1997 (Table 8.3). All of the exceptions (i.e., cadmium, lead, mercury, silver, thallium and tin) had substantially higher detection limits in 1997. For example, lead had an MDL of 5 ppm in 1997 versus 0.142 ppm in 2007. Since zeros are substituted for non-detects when calculating means, lower detection limits result in higher detection rates and therefore higher mean concentrations.

Pesticides, PCBs and PAHs

Pesticides had low detection rates (≤23%) in regional sediments during 2007 (Table 8.4). Hexachlorobenzene (HCB) was detected at up to four stations per depth strata and at maximum concentrations of 1100 ppt. This pesticide was detected in sediments from two sites located to the north or offshore of La Jolla (stations 2141 and 2142), two sites located southwest of the mouth of the San Diego River (stations 2149

Table 8.4

Concentrations of contaminants in sediments from 2007 regional stations. TN=total nitrogen; TOC=total organic carbon; HCB=hexachlorobenzene; tDDT=total DDT; tPCB= total PCB; tPAH=total PAH; No.=number of PAH detected in each sample; CDF=cumulative distribution function; nd=not detected. See Appendix C.1 for names and periodic table symbols.

		Depth	Sulfides	TN	TOC	HCB	tDDT	tPCB	tPAH	
Station		**(m)**	**(ppm)**	**(%)**	**(%)**	**(ppt)**	**(ppt)**	**(ppt)**	**(ppb)**	**No.**
Shallow shelf	2153	13	8.33	0.02	0.19	nd	nd	nd	57.6	3
	2146	14	19.40	0.02	0.19	nd	nd	nd	18.3	2
	2163	15	10.60	0.02	0.15	nd	nd	nd	61.8	4
	2158	16	nd	nd	0.09	nd	nd	nd	24.1	2
	2046	22	1.78	0.01	0.12	110	59	nd	38.3	3
	2167	25	3.50	0.02	0.24	nd	nd	nd	176.7	9
	2160	26	13.50	0.04	0.36	nd	nd	nd	33.9	2
	2171	29	nd	0.01	0.11	nd	nd	nd	50.5	3
Mid-shelf	2141	36	97.30	0.05	0.58	260	450	nd	32.8	2
	2156	36	5.24	0.03	0.71	nd	nd	nd	29.4	2
	2014	38	10.30	0.04	0.38	nd	nd	nd	41.4	3
	2140	38	6.69	0.03	0.30	nd	nd	nd	59.1	4
	2170	42	nd	0.01	0.08	nd	nd	nd	59.4	4
	2165	43	nd	0.01	0.08	nd	410	nd	20.0	1
	2169	49	nd	nd	0.05	nd	nd	nd	17.0	1
	2038	52	0.90	0.05	0.54	190	nd	6360	38.8	3
	2143	57	3.29	0.06	0.59	nd	nd	nd	22.9	2
	2149	63	1.51	0.07	0.72	1000	nd	nd	24.7	2
	2021	67	0.68	0.07	1.39	nd	nd	nd	25.6	2
	2031	74	6.32	0.07	1.84	nd	540	nd	54.4	3
	2150	82	9.18	0.07	0.78	1100	nd	nd	28.2	2
	2152	82	5.48	0.08	0.88	nd	580	220	27.4	2
	2148	83	2.40	0.09	0.99	nd	nd	nd	61.5	4
	2154	87	27.60	0.07	0.75	nd	490	nd	45.3	2
	2168	88	7.37	0.06	0.77	nd	520	nd	25.9	2
	2161	89	6.36	0.06	0.75	nd	380	nd	nd	0
	2023	90	0.30	0.07	1.28	nd	nd	nd	24.3	2
	2144	93	5.22	0.07	0.88	nd	nd	nd	22.5	2
	2142	96	4.71	0.07	0.77	810	nd	nd	76.1	5
	2145	116	6.04	0.06	3.10	nd	nd	nd	32.6	3
Deep shelf	2162	130	29.40	0.06	0.67	nd	nd	1020	27.8	1
	2164	136	0.21	0.06	8.17	nd	nd	nd	22.4	1
	2159	160	35.10	0.07	0.88	nd	270	1870	126.6	4
	2043	171	5.64	0.04	1.48	670	nd	nd	32.4	3
	2151	177	6.79	0.12	1.59	nd	nd	nd	28.5	2
	2157	186	25.00	0.14	2.04	nd	nd	450	47.1	2
	2028	190	11.30	0.13	1.70	nd	nd	nd	46.3	2
	2147	193	1.93	0.10	3.06	nd	nd	nd	109.6	6
	2166	216	0.97	0.15	3.08	nd	nd	nd	29.8	2
Detection rate (%)			87	95	100	18	23	13	97	

Table 8.4 *continued*.

Al	Sb	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Metals (ppm)																
9400	0.20	4.8	na	0.29	34.0	12.0	16800	na	na	0.40	na	0.29	0.2	na	na	56.0
4110	1.75	1.9	15.7	0.26	6.5	1.0	4820	0.9	53.9	nd	2.2	nd	0.7	nd	0.88	12.6
4390	0.22	1.0	22.8	nd	9.6	0.2	8100	1.3	116.0	nd	1.6	nd	4.4	1.01	1.20	15.2
4080	1.78	1.8	18.9	0.30	7.0	1.3	4150	0.5	50.4	nd	2.3	nd	0.8	nd	0.67	11.1
2050	1.74	1.6	9.6	0.20	4.2	0.6	3210	1.5	33.5	0.001	1.3	nd	0.3	nd	0.68	6.9
4580	1.47	1.5	22.0	0.18	7.0	0.9	4560	0.2	52.6	nd	2.2	nd	1.0	nd	0.54	10.3
6600	2.45	2.0	27.8	0.32	9.9	1.7	6870	0.7	67.6	0.001	4.0	nd	1.1	nd	1.26	16.5
7400	2.13	2.7	36.6	0.31	11.6	3.9	9410	5.5	94.8	0.01	4.5	nd	1.8	nd	0.55	24.7
2770	2.28	2.3	13.5	0.28	7.4	0.5	4710	0.8	36.9	nd	2.0	nd	0.3	nd	1.10	10.9
12400	2.08	2.4	73.7	0.07	18.8	6.1	16500	2.1	154.0	0.01	6.5	nd	5.5	0.53	1.42	44.1
6350	0.23	2.2	33.6	0.04	10.1	3.3	7700	2.2	97.4	0.02	2.9	nd	2.0	0.53	1.11	24.3
12700	0.29	2.8	67.1	0.06	19.4	5.3	15100	2.1	149.0	0.005	6.4	nd	5.3	0.49	1.57	40.6
9830	0.31	2.0	47.9	0.07	15.3	3.8	11200	1.7	120.0	nd	4.8	nd	4.4	0.63	1.39	28.0
991	2.36	6.3	2.4	0.31	10.0	nd	6940	1.9	13.5	nd	1.3	nd	nd	nd	1.04	6.5
3540	0.16	2.7	9.3	0.01	7.9	2.0	5810	1.2	40.8	0.003	1.9	nd	1.3	0.29	0.92	12.0
1980	0.21	7.0	3.3	nd	8.7	nd	7670	2.3	25.0	nd	0.9	nd	nd	nd	0.90	10.5
11200	0.26	3.5	40.0	0.06	16.0	4.5	11400	3.2	121.0	0.03	6.2	nd	8.3	0.81	1.47	29.1
11400	0.23	2.7	51.7	0.07	18.8	4.7	14900	3.7	120.0	0.02	6.4	nd	2.8	0.70	1.87	33.8
13700	0.73	3.8	59.1	0.10	22.0	6.4	16800	4.1	147.0	0.04	8.8	nd	4.6	0.72	2.28	38.0
13700	0.78	4.7	52.6	0.09	22.3	7.1	17300	4.0	145.0	0.03	8.6	0.41	4.0	0.68	2.20	39.8
8630	nd	3.4	36.0	nd	12.6	4.8	9240	2.9	79.8	0.05	5.4	nd	2.3	0.24	0.85	23.1
13400	0.87	3.3	50.5	0.05	22.1	6.6	16700	3.8	143.0	0.04	9.5	0.56	6.1	0.84	2.69	36.0
17300	0.53	2.6	63.2	0.09	24.2	8.9	18500	5.0	148.0	0.05	10.4	nd	4.7	0.69	2.05	51.0
16600	0.84	2.7	64.9	0.04	26.7	9.2	20300	4.3	162.0	0.05	11.6	0.45	5.4	0.71	2.22	44.1
12100	0.40	2.9	46.1	0.07	18.9	7.3	14400	3.8	107.0	0.03	8.2	0.28	2.0	0.40	1.77	33.2
9030	0.23	3.0	28.4	0.03	14.4	4.7	10300	2.2	92.4	0.02	7.0	nd	1.7	0.45	1.18	27.4
11300	0.15	4.1	47.3	nd	11.8	6.0	11200	0.2	86.0	0.04	4.9	nd	2.0	0.81	0.76	23.6
16900	1.39	7.3	142.0	0.02	38.2	3.1	37500	5.1	183.0	0.04	11.2	0.28	1.9	nd	2.23	55.0
13500	0.53	2.6	54.6	0.03	21.4	6.3	16500	3.2	123.0	0.03	8.6	nd	2.6	0.40	1.60	36.9
13400	0.41	2.5	49.2	0.10	21.1	5.6	16300	2.9	131.0	0.03	8.1	nd	3.8	nd	1.81	35.8
9350	0.27	2.7	34.7	0.09	17.5	4.4	14000	2.4	96.6	0.02	6.1	nd	1.2	0.52	1.46	29.7
16900	0.50	2.7	72.7	0.03	23.3	13.3	18100	33.9	145.0	0.06	8.3	nd	2.0	0.41	1.81	46.1
5810	0.67	2.9	20.8	0.24	27.1	2.6	18600	2.7	40.8	0.02	6.4	nd	nd	nd	0.71	40.0
19900	0.59	5.3	79.2	0.03	26.3	25.1	21200	5.1	171.0	0.11	9.7	nd	2.5	0.82	1.81	52.8
3890	nd	2.5	17.1	0.04	13.3	1.9	6990	1.7	31.3	0.01	3.7	nd	0.3	nd	0.90	15.5
16900	0.38	2.2	58.0	0.18	27.2	11.5	18700	4.4	137.0	0.05	13.7	0.40	3.2	0.17	2.21	47.7
22400	0.93	3.1	81.8	0.19	34.5	25.4	23700	8.0	164.0	0.17	15.7	0.67	4.2	0.23	2.65	61.9
18800	0.51	2.2	62.2	0.18	28.5	11.8	19800	3.9	148.0	0.05	14.4	0.44	4.2	nd	2.05	49.0
12100	0.63	1.9	42.0	0.28	26.0	7.1	18500	3.0	106.0	0.03	9.9	0.52	1.9	nd	1.96	41.9
100	95	100	100	90	100	95	100	100	95	79	100	26	92	59	100	100

and 2150), one southern site on the Coronado Bank (station 2043), and two stations located in the regular (fixed grid) SBOO monitoring area (stations 2038 and 2046). The pesticide DDT was also detected in sediments from each depth strata. These included three stations located relatively close to the Point Loma outfall (stations 2031, 2152 and 2154), two stations located adjacent to or just inshore of the LA-5 disposal site (stations 2159 and 2161), two stations within the regular SBOO monitoring area (stations 2046 and 2165), one station just south of the old LA-4 disposal site (station 2168), and one station located just north of Scripps Canyon (station 2141). The mean concentration of total DDT was 95 ppt, which is slightly higher than the mean concentration of 43 ppt from 1997 (see Table .3). This difference is likely due to the inclusion of estimated values in the analyses performed in 2007 (see Methods), a practice that was not begun until 2003. Total DDT concentrations at the regular fixed grid SBOO stations were well within values found during the 2007 regional survey.

PCBs were detected in sediments from a total of five sites located in the mid and deep shelf strata. Sediments at station 2038 located south of Point Loma between the mouth of San Diego Bay and the LA-4 disposal site had the highest total PCB concentration of 6360 ppt. The four other sites with detectable PCBs had concentrations <2000 ppt. These sites included stations 2159 and 2162 located near LA-5, station 2157 located southwest of the Point Loma outfall discharge area, and station 2152 located north of the Point Loma outfall. Total PCB from the SBOO grid stations (see Chapter 4) was much lower than from these regional sites. None of the PCB data from 2007 can be compared to historical data from 1997 since PCBs were analyzed as Arochlors and not congeners prior to 1999.

In contrast to pesticides and PCBs, PAHs were widely distributed in regional sediments but at low concentrations (≤177 ppb). Station 2167, located on the shallow shelf north of the SBOO, had sediments with the highest total PAH concentration. Other sites with PAH concentrations >100 ppb included station 2159 located adjacent to the LA-5 disposal site, and station 2147 located offshore of Mission Beach at a depth of 193 m. No PAHs were detected in 1997, which was likely due to higher detection limits at the time (Table 8.3).

Summary and Conclusions

Grain-size distribution at the regional benthic stations sampled in 2007 was similar to that seen in previous years. For example, substantial changes in average particle size between 1997 and 2007 were observed for only seven sites. As in the past, there was a trend towards higher sand content in nearshore areas compared to finer sands and silt at deeper offshore sites. Sediments from depths ≤30 m were composed of about 90% sands and 9% fines, whereas sediments at depths of 30–120 m were about 60% sands and 37% fines. Deeper sites occurring at depths of 120–200 m had sediments composed of about 52% sands and 47% fines. Exceptions to the general pattern occurred in some mid-shelf sediments further offshore of the SBOO, as well as along the Coronado Bank, a southern rocky ridge located southwest of Point Loma at a depth of 150–170 m. Sediment composition at stations from these areas tended to be coarser than regional mid-shelf stations located off of Point Loma and further to the north. Overall, the sediments throughout the San Diego region reflect the diverse and patchy types of habitats that are common to the Southern California Bight.

Patterns in sediment chemistries at the regional sites in 2007 generally followed the expected relationship of increasing concentrations with decreasing particle size. 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. The regional sediment survey data did not show any pattern of contamination relative to wastewater discharges off San Diego.

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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 regional surveys are based on arrays of stations that are randomly selected for each year using the USEPA probability-based EMAP sampling design. The 1994, 1998, and 2003 surveys off San Diego were conducted as part of larger, multi-agency surveys of the entire Southern California Bight (SCB), including the 1994 Southern California Bight Pilot Project (SCBPP), and the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight'98, Bight'03, respectively). Results of these three bight wide surveys are available in Bergen et al. (1998, 2001) and Ranasinghe et al. (2003, 2007). The same randomized sampling design was used in surveys limited to the San Diego region in 1995–1997, 1999–2002, and 2005–2007. Additionally, during 2005, 2006 and 2007, the City revisited the same sites sampled 10 years earlier (i.e., 1995–1997, respectively) in order to facilitate comparisons of long-term changes in benthic conditions for the region.

This chapter presents an analysis and interpretation of the benthic macrofaunal data collected during the San Diego 2007 regional survey of randomized sites. 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 2007 survey covered an area from off Del Mar in northern San Diego County southward to the USA/Mexico international border (**Figure 9.1**). Site selection was based on the USEPA probability-based EMAP sampling design used in 1997 (City of San Diego 1997). The monitoring area included the section of the mainland continental shelf ranging from nearshore waters to shallow slope depths (13–216 m). Although 40 sites were initially selected for the 1997 and 2007 surveys, sampling at three sites

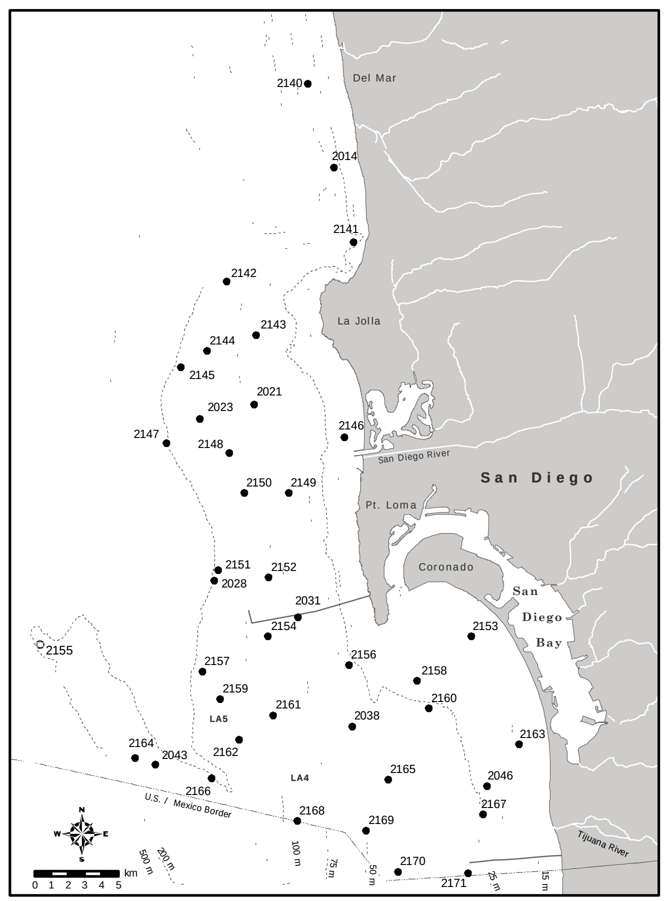


Figure 9.1
Map of regional macrobenthic stations sampled off San Diego, CA in 2007. Open circles represent abandoned stations (see text).

in 1997 and one site in 2007 was unsuccessful due to the presence of rocky reefs. In addition, seven of the sites (stations 2014, 2021, 2023, 2028, 2031, 2038, 2046) were repeat stations that were sampled each year (i.e., 1995–1997, 2005–2007).

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 in a magnesium sulfate and seawater solution for 30 minutes 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 per 0.1-m^2 grab: species richness (number of species), abundance (total number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (minimum number of species accounting for 75% of the total abundance in each grab; see Swartz et al. 1986, Ferraro et al. 1994), Infaunal Trophic Index (ITI; see Word 1980), and Benthic Response Index (BRI; see Smith et al. 2001). These data are summarized according to depth strata used in the Bight'98 and Bight'03 surveys: shallow (5–30 m), mid-depth (31–120 m), and deep (121–200 m). The macrofauna data for 2007 were based on one benthic grab sample per station. In contrast, two grabs per station were sampled for macrofauna in 1997; thus data for 1997 are reported as the average of two grabs.

Multivariate analyses were performed using PRIMER V6 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

Species richness

A total of 693 macrobenthic taxa were identified during 2007. Of these, 32% represented rare taxa that were recorded only once (i.e., rare species or unidentifiable animals). The number of species (taxa) per station ranged from 37 to 200 in 2007 (**Table 9.1a**). This variation in species richness generally is consistent with that observed in recent years and similar to values in 1997 (see **Table 9.1b**). Polychaete worms made up the greatest proportion of species, accounting for 51% during 2007. Crustaceans represented 21% of the species, molluscs 15%, echinoderms 6%, and all other taxa combined about 7%. These percentages generally are similar to those observed during previous years (e.g., City of San Diego 2007).

Macrofaunal abundance

Macrofaunal abundance ranged from 116 to 1385 individuals per 0.1-m^2 grab in 2007 compared to 79–1467 individuals in 1997 (Table 9.1a,b). The greatest number of animals in 2007 occurred at mid-shelf stations 2141 and 2156, both of which contained over 1100 individuals per 0.1 m^2. Four other sites (i.e., stations 2163, 2160, 2171 and 2038) had abundance values greater than 500 individuals

Table 9.1a

Benthic community parameters at regional stations sampled during 2007. Abun=Abundance, number/0.1 m^2; SR=Species richness, no. species/0.1 m^2; H'=Shannon diversity index; J'=Evenness; Dom=Swartz dominance, no. species comprising 75% of a community by abundance; BRI=Benthic response index; ITI=Infaunal trophic index, n=1.

	Station	Depth (m)	Abun	SR	H'	J'	Dom	BRI	ITI
Inner shelf	2153	13	252	61	3.3	0.8	17	26.6	71
	2146	14	144	59	3.6	0.9	23	20.6	75
	2163	15	548	96	3.5	0.8	18	27.1	75
	2158	16	136	37	3.1	0.9	13	4.5	76
	2046	22	257	75	3.7	0.9	25	23.0	77
	2167	25	342	100	4.1	0.9	37	25.7	79
	2160	26	570	119	3.8	0.8	34	27.5	75
	2171	29	516	68	2.2	0.5	6	16.6	72
	Mean	20	346	77	3.4	0.8	22	21.5	75
Mid shelf	2141	36	1101	155	3.2	0.6	13	27.9	69
	2156	36	1385	200	4.4	0.8	51	19.2	82
	2014	38	340	127	4.2	0.9	44	19.4	79
	2140	38	381	97	3.8	0.8	31	18.7	85
	2170	42	227	58	3.4	0.8	19	4.8	75
	2165	43	289	80	3.4	0.8	27	19.1	76
	2169	49	116	42	3.0	0.8	15	4.3	80
	2038	52	710	156	4.3	0.8	45	17.1	80
	2143	57	405	113	4.1	0.9	34	13.3	81
	2149	63	385	101	3.9	0.9	33	11.5	84
	2021	67	458	123	4.1	0.8	40	9.4	82
	2031	74	424	74	3.2	0.7	14	14.5	91
	2150	82	225	79	3.6	0.8	26	9.2	82
	2152	82	308	81	3.4	0.8	21	10.0	86
	2148	83	313	74	3.6	0.8	25	9.5	84
	2154	87	189	73	3.9	0.9	31	7.7	82
	2168	88	321	108	4.2	0.9	41	10.1	75
	2161	89	365	107	4.0	0.9	34	4.9	83
	2023	90	295	109	4.3	0.9	47	3.8	81
	2144	93	192	82	4.0	0.9	35	8.6	80
	2142	96	155	70	4.0	0.9	33	7.0	81
	2145	116	294	97	4.1	0.9	37	10.1	73
	Mean	68	404	100	3.8	0.8	32	11.8	81
Outer shelf	2162	130	280	101	4.2	0.9	44	7.0	79
	2164	136	412	78	3.6	0.8	20	5.3	70
	2159	160	158	69	3.9	0.9	34	14.7	81
	2043	171	378	72	3.3	0.8	19	4.9	71
	2151	177	136	60	3.8	0.9	27	15.6	77
	2157	186	195	65	3.5	0.8	22	14.7	82
	2028	190	173	57	3.6	0.9	22	14.2	78
	2147	193	282	93	3.9	0.9	35	15.3	74
	2166	216	411	121	4.1	0.9	40	7.3	80
	Mean	173	269	80	3.8	0.9	29	11.0	77
All stations	**Mean**	81	361	91	3.7	0.8	29	13.6	79
	Min	13	116	37	2.2	0.5	6	3.8	69
	Max	216	1385	200	4.4	0.9	51	27.9	91

Table 9.1b

Benthic community parameters at regional stations sampled during 1997. SR=Species richness, no. species/0.1 m^2; Abun=Abundance, no. individuals/0.1 m^2; H'=Shannon diversity index; J'=Evenness; Dom=Swartz dominance, no. species comprising 75% of a community by abundance; BRI=Benthic response index; ITI=Infaunal trophic index, n=2.

	Station	Depth (m)	Abun	SR	H'	J'	Dom	BRI	ITI
Inner shelf	2153	13	111	47	3.4	0.9	20	17.5	78
	2146	14	260	55	3.3	0.8	16	5.2	82
	2163	15	79	30	2.9	0.9	13	10.1	74
	2158	16	364	65	3.3	0.8	17	10.4	50
	2046	22	106	48	3.5	0.9	22	12.5	77
	2167	25	113	59	3.8	0.9	31	17.3	83
	2160	26	226	84	4.0	0.9	35	27.8	81
	2171	29	233	66	3.3	0.8	19	19.0	76
	Mean	20	187	57	3.5	0.9	22	15.0	75
Mid shelf	2141	36	1467	161	4.0	0.8	35	22.6	77
	2156	36	1139	165	4.1	0.8	35	16.3	81
	2014	38	379	110	4.2	0.9	40	21.7	80
	2140	38	434	125	4.2	0.9	42	17.1	86
	2170	42	163	55	3.5	0.9	21	5.6	91
	2165	43	562	120	3.9	0.8	33	19.8	85
	2169	49	359	97	4.0	0.9	32	8.4	92
	2038	52	482	118	3.8	0.8	32	18.6	89
	2143	57	402	85	3.5	0.8	22	10.7	90
	2149	63	484	78	3.0	0.7	14	14.1	90
	2021	67	471	111	3.7	0.8	28	6.9	86
	2031	74	323	59	2.6	0.6	8	10.7	95
	2150	82	369	75	3.3	0.8	19	5.7	88
	2152	82	431	78	3.1	0.7	13	8.3	88
	2148	83	313	70	3.3	0.8	17	2.5	90
	2154	87	277	59	2.9	0.7	12	9.2	88
	2168	88	318	77	3.3	0.7	21	3.8	82
	2161	89	349	98	4.1	0.9	34	6.4	84
	2023	90	233	90	4.0	0.9	37	8.0	85
	2144	93	290	80	3.6	0.8	27	1.2	84
	2142	96	321	92	3.8	0.8	30	3.8	81
	2145	116	500	123	4.1	0.9	36	2.1	78
	Mean	68	458	97	3.6	0.8	27	10.2	86
Outer shelf	2162	130	269	92	4.1	0.9	39	4.2	84
	2159	160	290	91	4.0	0.9	34	10.0	85
	2043	171	91	42	3.3	0.9	20	-4.3	82
	2151	177	106	47	3.5	0.9	21	12.9	87
	2157	186	99	47	3.6	0.9	23	13.0	81
	2028	190	169	51	3.4	0.9	18	10.1	80
	2147	193	430	116	3.9	0.8	32	9.5	76
	Mean	172	208	69	3.7	0.9	27	7.9	82
All stations	**Mean**	81	352	83	3.6	0.8	26	10.8	83
	Min	13	79	30	2.6	0.6	8	-4.3	50
	Max	193	1467	165	4.2	0.9	42	27.8	95

per 0.1 m^2, while most sites had abundance values between 200–500 individuals per grab.

Polychaetes were the most abundant animals in the region, accounting for about 59% of the individuals during 2007. Crustaceans averaged 16% of the animals at a station, molluscs about 11%, echinoderms 9%, and all remaining taxa combined about 5%. These values were similar to those observed in previous years (see City of San Diego 2007).

Species diversity and dominance

Species diversity (H') varied among stations, and ranged from 2.2 to 4.4 during the year (Table 9.1a). Although most of the stations had H' values between 3.0 and 4.0, stations with the highest diversity (i.e., H'≥4.0, n=11) were found predominantly at mid-shelf sites. The lowest H' value occurred at station 2171, a shallow-water station located near the USA/Mexico border. Diversity values were similar to averages for 1997 stations that ranged from 2.6 to 4.2 (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. 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 throughout the region, averaging from 6 to 51 species per station in 2007. The pattern of dominance across depth strata was similar to that of diversity. The eight stations with dominance values <20 also had lower H' values. Dominance at stations in 1997 averaged from 8 to 42 species per station, similar to 2007 (Table 9.1b).

Environmental disturbance indices

Benthic Response Index (BRI) values at most stations were indicative of undisturbed communities or “reference conditions” (see Smith et al. 2001). BRI values <25 suggest undisturbed communities or “reference conditions,” while those between 25–33 represent “a minor deviation from reference condition,” values >44 indicate a loss of community function. BRI values throughout the San Diego region generally were indicative of reference conditions in 2007 (see Table 9.1a). For example, all but one of the mid and outer shelf stations (depths >30 m) had BRI values <25. Index values ≥25 were restricted to five stations located in shallower depths where the BRI is less reliable (see Smith et al. 2001). One station, 2160, located south of the mouth of San Diego Bay, had BRI values ≥25 in 1997 (see Table 9.1b).

Average Infaunal Trophic Index (ITI) values ranged from 69 to 91 throughout the San Diego region during 2007 (Table 9.1a). The lowest value occurred at station 2141. ITI values >60 are generally considered characteristic of “normal” benthic conditions (Bascom et al. 1979, Word 1980). Overall, ITI values in 1997 were very similar to those in 2007, averaging from 50 to 95.

Dominant Species

Most macrofaunal assemblages in the San Diego region were dominated by polychaete worms and brittlestars. For example, the list of dominant animals in **Table 9.2** includes 14 polychaete and four echinoderm species. Unidentified capitellid polychaetes in the genus *Mediomastus* (i.e., *Mediomastus* sp) were the most abundant animals, averaging 21 individuals per sample. The ophiuroid *Amphiodia urtica* averaged 15 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*. If values for total *A. urtica* abundance are adjusted to include putative *A. urtica* juveniles, then the estimated density increases from 15 to 21 brittlestars per grab sample. The spionid polychaete, *Spiophanes bombyx*, was third in total abundance for the region. Polychaetes comprised eight of the 10 most frequently collected species per occurrence. Additionally, few polychaete species occurred in high numbers at only a few stations (e.g., *Cossura* sp A, *Mooreonuphis exigua*).

Table 9.2

Summary of dominant macroinvertebrates at regional benthic stations sampled during 2007. Included are the most abundant species per sample, the most abundant per occurrence, and species with the highest percent occurence. 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
Amphiuridae	Echinodermata: Ophiuroidea	85	4.5	5.4
Mediomastus sp	Polychaeta: Capitellidae	82	21.3	26.1
Prionospio jubata	Polychaeta: Spionidae	80	7.8	9.9
Paraprionospio pinnata	Polychaeta: Spionidae	77	2.7	3.3
Maldanidae	Polychaeta: Maldanidae	69	2.4	3.6
Spiophanes berkeleyorum	Polychaeta: Spionidae	64	8.1	12.9
Amphiodia sp	Echinodermata: Ophiuroidea	64	7.8	12.0
Euclymeninae sp *A*	Polychaeta: Maldanidae	64	3.9	6.0
Aricidea catherinae	Polychaeta: Paraonidae	64	2.7	4.2
Spiophanes duplex	Polychaeta: Spionidae	62	6.0	9.9
Monticellina siblina	Polychaeta: Cirratulidae	54	17.1	31.5
Amphiodia urtica	Echinodermata: Ophiuroidea	51	15.0	29.1
Axinopsida serricata	Mollusca: Bivalvia	49	6.0	12.6
Spiophanes bombyx	Polychaeta: Spionidae	44	17.7	40.2
Diopatra sp	Polychaeta: Onuphidae	23	4.5	19.2
Nematoda	Nematoda	23	4.2	17.7
Paradoneis sp SD1	Polychaeta: Paraonidae	8	1.8	23.1
Cossura sp A	Polychaeta: Cossuridae	3	0.9	36.0
Nephasoma diaphanes	Sipuncula: Golfingiidae	3	0.9	30.0
Mooreonuphis exigua	Polychaeta: Onuphidae	3	0.6	18.0
Dougaloplus sp SD1	Echinodermata: Ophiuroidea	3	0.4	14.0

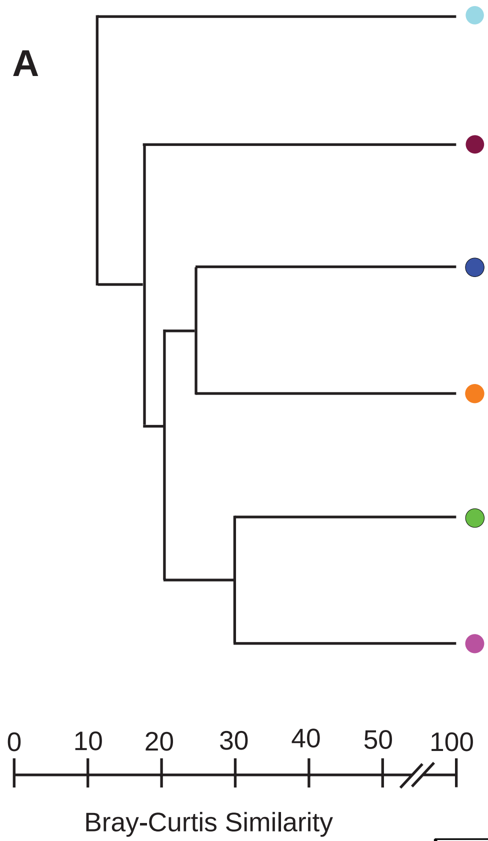
Multivariate analysis

Classification analysis discriminated between six habitat-related benthic assemblages (cluster groups A–F; **Figures 9.2, 9.3**). A MDS ordination of the station/survey entities confirmed the validity of the cluster groups. SIMPER analysis was used to identify species that were characteristic, though not always the most abundant, within each assemblage (Figure 9.2A). The most abundant species within each group are listed in **Table 9.3**. Similar to previous regional surveys off San Diego, station depth, sediment grain size, and organic composition were the primary factors that appeared to affect the distribution of assemblages (e.g., Bergen et al. 1998; see **Figure 9.4**). These assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances. Descriptions of the cluster groups are given below.

Cluster group A represented assemblages from five stations that were characterized by coarse sediments (i.e., mean=3% fine) and TOC concentrations of about 0.1%. These sites averaged 57 species and 257 individuals per grab sample. The dominant species in this group was the spionid polychaete *Spiophanes bombyx*, followed by another spionid, *Spio maculata*, and the tanaid *Leptochelia dubia*.

Cluster group B represented assemblages from two stations located on the Coronado bank at depths of 136–171 m. Sediments at these stations were relatively coarse and contained pea gravel, rock, and shell hash (see Chapter 4 for descriptions of

A



CG	% Fines	TOC	SR	Abun	Dominant taxa
A	3	0.1	57	257	*Spiophanes bombyx* *Spio maculata* *Leptochelia dubia*
B	14	4.8	75	395	*Chaetozone* sp SD3 *Mediomastus* sp *Aphelochaeta glandaria*
C	22	0.4	127	610	*Spiophanes berkeleyorum* *Mediomastus* sp *Monticellina siblina*
D	9	0.2	72	315	*Spiophanes bombyx* *Scoletoma* sp *Mediomastus* sp
E	50	1.1	91	302	*Amphiodia urtica* *Amphiodia* sp *Ampelisca pacifica*
F	56	1.9	81	234	*Mediomastus* sp *Paraprionospio pinnata* *Tellina cadieni*

B

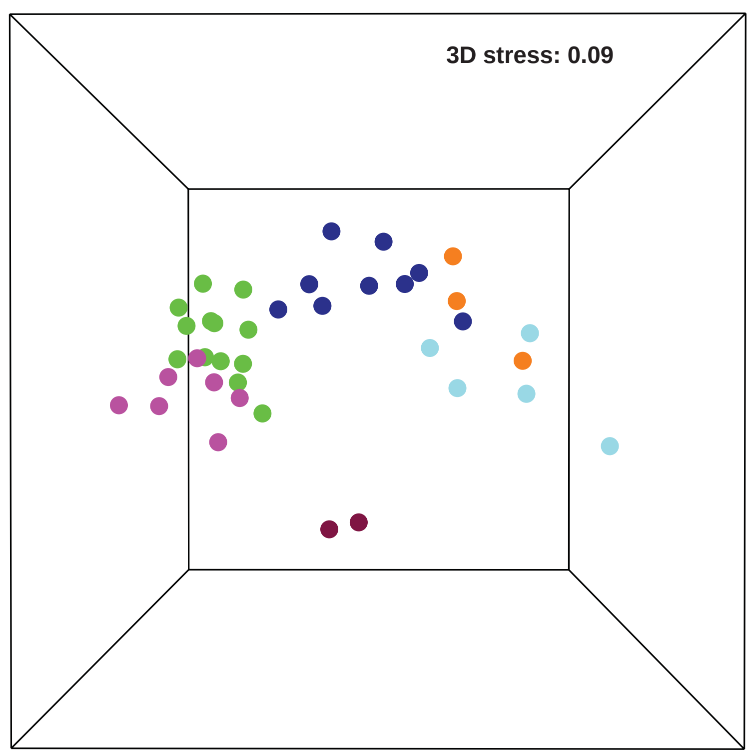


Figure 9.2

(A) Cluster results of the macrofaunal abundance data for the regional benthic stations sampled during July 2007. 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. Cluster groups superimposed on station/ surveys illustrate a clear distinction between faunal assemblages.

sediment components at each station). These sites averaged 14% fines and had the highest organic load (e.g., TOC=4.8%). Species richness for this assemblage averaged 75 taxa per grab and abundance averaged 395 individuals per sample. The dominant species included three polychaetes, *Chaetozone* sp SD3, *Mediomastus* sp, and *Aphelochaeta glandaria*.

Cluster group C represented assemblages from nine sites located primarily between depths of 25 and 50 m, and where sediments were composed of about 22% fines. TOC levels at stations within this group averaged 0.4%. This assemblage averaged the highest species richness (127 taxa) and abundance (610 individuals per 0.1 m^2) values. Three polychaetes, *Spiophanes berkeleyorum*, *Mediomastus* sp, and *Monticellina siblina* were the dominant species in group C.

Cluster group D represented assemblages from three nearshore stations that ranged in depth from 13 to 15 m. Sediments at stations within this group averaged 9% 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 315 individuals per 0.1 m^2 grab. The dominant species included the polychaetes *Spiophanes bombyx*, *Scoletoma* sp, and *Mediomastus* sp.

Cluster group E comprised assemblages from most of the mid-shelf sites (n=13) that ranged in depth from 63 to 116 m. This group, characterized by sites with mixed sediments averaging 50% fines, had the second highest average species richness (91 species), and averaged 302 individuals per sample. This assemblage is typical of the ophiuroid dominated community that occurs along the mainland shelf off southern California (City of San Diego 2007, Mikel et al. 2007). The dominant species representing this mid-shelf group were the ophiuroid *Amphiodia urtica* and the amphipod *Ampelisca pacifica*.

Cluster group F represented assemblages from seven of the nine outer shelf stations, including

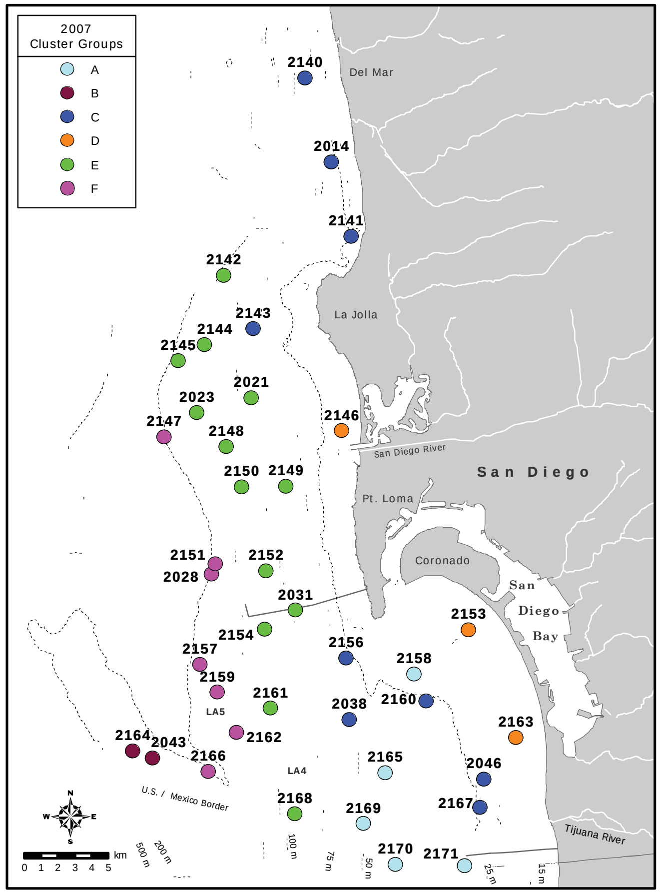


Figure 9.3

Regional benthic stations sampled during July 2007, color-coded to represent affiliation with benthic cluster groups.

five of the deepest sites (depths ≥177 m). This group included sites averaging 56% fines and the second highest concentrations of TOC (1.9%). The group F assemblage averaged 81 species and 234 individuals per 0.1-m^2. The dominant species were the polychaetes *Mediomastus* sp and *Paraprionospio pinnata*, and the bivalve *Tellina cadieni*.

Summary and Conclusions

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

Table 9.3

Summary of the most abundant taxa composing cluster groups A–F from the 2007 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 three 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
Species/Taxa	Taxa	(n=5)	(n=2)	(n=9)	(n=3)	(n=13)	(n=7)
Ampharete labrops	Polychaeta	1.2	—	0.6	21.0	—	—
Amphiodia sp	Echinodermata	0.4	—	6.4	0.7	**17.9**	0.9
Amphiodia urtica	Echinodermata	0.6	—	10.0	—	**37.4**	0.1
Amphiuridae	Echinodermata	0.4	2.5	3.3	1.3	7.8	5.0
Aphelochaeta glandaria	Polychaeta	—	**53.0**	3.4	—	0.9	0.3
Axinopsida serricata	Mollusca	—	—	7.1	—	**12.8**	0.9
Caecum crebricinctum	Polychaeta	—	25.0	—	—	0.3	—
Chaetozone sp SD3	Polychaeta	—	**26.0**	1.0	—	—	—
Chaetozone sp SD5	Polychaeta	0.6	10.0	2.6	**27.0**	—	—
Euphilomedes producta	Crustacea	—	—	0.2	—	8.1	1.6
Leptochelia dubia	Crustacea	3.0	18.5	2.3	—	2.8	0.4
Lumbrinerides platypygos	Polychaeta	**7.8**	0.5	—	—	—	—
Mediomastus sp	Polychaeta	0.8	16.0	**49.2**	**29.0**	6.2	**27.0**
Monticellina siblina	Polychaeta	4.4	**28.0**	**60.2**	2.7	2.2	1.1
Paradiopatra parva	Polychaeta	—	—	0.7	—	1.2	7.0
Paraprionospio pinnata	Polychaeta	0.4	1.0	2.7	1.0	1.6	**7.3**
Polycirrus sp	Polychaeta	6.2	2.5	1.4	—	—	0.6
Prionospio jubata	Polychaeta	2.2	3.5	20.4	0.3	6.3	2.9
Scoletoma sp	Polychaeta	—	—	1.6	21.0	1.5	2.1
Spio maculata	Polychaeta	**11.8**	—	—	—	—	—
Spiophanes berkeleyorum	Polychaeta	6.0	—	**27.7**	1.0	2.2	1.1
Spiophanes bombyx	Polychaeta	**92.8**	—	13.7	**32.0**	0.2	—
Spiophanes duplex	Polychaeta	0.8	1.0	19.8	6.0	2.3	0.3
Spiophanes kimballi	Polychaeta	—	1.0	0.1	—	1.1	**10.6**
Tellina cadieni	Mollusca	—	7.0	0.1	—	3.0	6.7

determined by differences in substrate type and microhabitat. Results of the 2007 and previous regional surveys off San Diego generally support this characterization. The 2007 benthic assemblages segregated mostly by habitat characteristics (e.g., depth, sediment grain size, and TOC) and were similar to those sampled in the past.

One third of the benthos sampled in 2007 was characterized by an assemblage dominated by the ophiuroid *Amphiodia urtica*, a common species along the mainland shelf of southern California (cluster group E). Total *Amphiodia urtica* abundance (i.e., adults and juveniles) averaged 21 animals per 0.1 m^2. Co-dominant species within this assemblage included other taxa common to the region such as the mollusc *Axinopsida serricata*.

Nearshore assemblages off San Diego varied depending upon the sediment type and depth, but generally were similar to other shallow, sandy communities in the SCB (see Barnard 1963, Jones 1969, Thompson et al. 1987, 1992, ES Engineering-Science 1988, Mikel et al. 2007). Polychaete species such as *Mediomastus* sp and *Monticellina siblina* were numerically dominant in mixed, sandy sediments such as those found in cluster groups C and D. Sites that constituted another shallow-shelf group (station group A) were characterized by coarser sediments. The assemblage at these stations was dominated by the polychaete *Spiophanes bombyx*.

Sediments at the deepest stations (group F, depth >130 m) had the highest percentage of fine particles and second highest TOC concentrations. These sites had a relatively lower species richness and abundance values and were dominated by polychaetes such as *Mediomastus* sp and *Paraprionospio pinnata*. In contrast, the other deep-water assemblage (group B) occurred at stations where the sediments had a lower percentage of fine particles and much higher TOC concentrations. This assemblage contained high abundances of species found infrequently in other assemblages (e.g. *Aphelochaeta glandaria*, *Chaetozone* sp SD3, *Caecum crebricinctum*).

The results of the 2007 regional survey suggest that benthic assemblages in the vicinity of the South Bay and Point Loma outfalls, as well as dredge spoils disposal sites off San Diego, have maintained an overall community structure consistent with those sampled in the past (e.g., City of San Diego 2005, 2007) and elsewhere throughout the Southern California Bight (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 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.

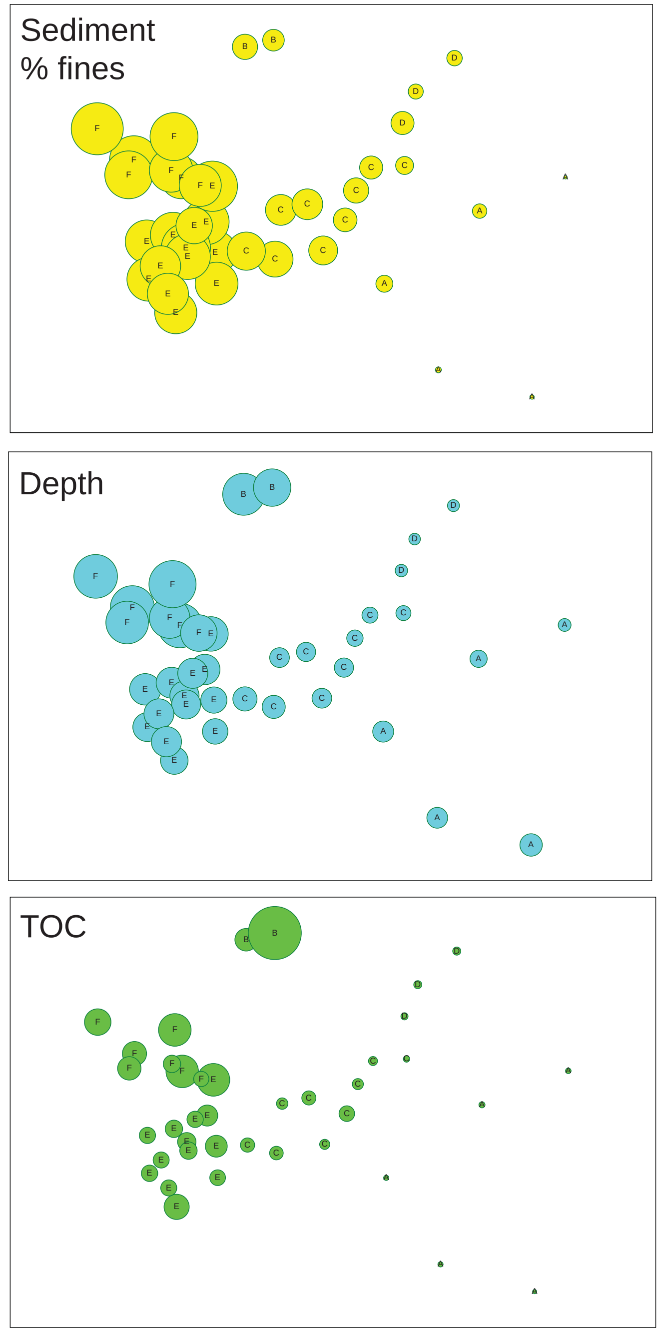


Figure 9.4
MDS ordination of regional benthic stations sampled in July 2007. Cluster groups A–F are superimposed on stations. Percentage of fine particles in the sediments, station depth, and total organic carbon (TOC) are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of macrobenthic assemblages with habitats that differ in sediment grain size and depth. Stress=0.14.

There were no substantial changes in community parameters between the 1997 and 2007 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 associated diversity indices. However, the similarities between macrofaunal community parameters for 1997 and 2007 suggest that benthic assemblages have not changed substantially over the past decade.

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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 Analysis
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.

Biota
The living organisms within a habitat or region.

BOD
Biochemical oxygen demand (BOD) is 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.

BRI
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 (SCB).

CFU
The colony-forming unit (CFU) is a 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.

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. Data collected from control sites are used as a reference and compared to impacted sites.

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

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

CTD
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.

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
A measurement of community structure which describes the abundances of different species within a community, taking into account their relative rarity or commonness.

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

Megabenthic invertebrate
A larger, usually epibenthic and motile, bottom-dwelling animal such as a sea urchin, crab, or snail. These animals are typically collected by otter trawl nets 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.

Niskin bottle
A long plastic tube allowing seawater 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.

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

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

PAHs
The USGS defines polycyclic aromatic hydrocarbons (PAHs) as, “hydrocarbon compounds with multiple benzene rings. PAHs are typical components of asphalts, fuels, oils, and greases.”

PCBs
The EPA defines polychlorinated biphenyls (PCBs) as, “a category, or family, of chemical compounds formed by the addition of chlorine (C_{l2}) to biphenyl ($C_{12}H_{10}$), which is a dual-ring structure comprising two 6-carbon benzene rings linked by a single carbon-carbon bond.”

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

Phi
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
The Point Loma Ocean Outfall (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 sea water density changes rapidly with depth and typically is associated with a decline in temperature and increase in salinity.

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.

SBOO
The South Bay Ocean Outfall (SBOO) is 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
The South Bay Water Reclamation Plant (SBWRP) 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
The Southern California Bight (SCB) is 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.

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).

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 changes 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
The United States Geological Survey (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
The zone of initial dilution (ZID) is 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

2007 SBOO Stations

Oceanographic Conditions

Appendix A.1

Summary of temperature (=temp; °C), salinity (ppt), density (δ/θ), dissolved oxygen (=DO; mg/L), pH, chlorophyll *a* (=Chl *a*; µg/L), and transmissivity (=XMS; %) for surface (≤2 m) and bottom (10-20 m) waters at all SBOO kelp stations during 2007. Values are expressed as means.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp	*Surface*	14.7	14.7	14.4	15.3	16.3	17.8	20.0	22.4	18.3	17.8	15.3	14.4
	Bottom	14.4	13.9	12.3	12.0	12.0	12.7	14.7	15.1	13.6	13.8	13.2	13.9
Density	*Surface*	24.95	24.92	25.05	24.91	24.71	24.40	23.81	23.21	24.14	24.23	24.75	24.92
	Bottom	25.00	25.10	25.54	25.64	25.65	25.52	25.02	24.91	25.16	25.10	25.17	25.02
Salinity	*Surface*	33.58	33.55	33.63	33.70	33.75	33.81	33.77	33.82	33.65	33.59	33.51	33.47
	Bottom	33.58	33.57	33.73	33.79	33.82	33.80	33.72	33.68	33.60	33.54	33.49	33.47
DO	*Surface*	7.9	7.8	8.4	8.5	9.4	9.4	8.3	8.1	8.3	8.0	7.8	7.8
	Bottom	7.6	6.9	5.8	5.0	5.0	5.6	7.6	7.6	7.4	7.1	6.7	7.2
pH	*Surface*	8.2	8.2	8.2	8.2	8.4	8.4	8.2	8.2	8.2	8.2	8.1	8.1
	Bottom	8.1	8.1	8.0	7.9	8.0	8.0	8.1	8.1	8.1	8.1	8.0	8.0
XMS	*Surface*	84	76	78	75	77	73	78	81	82	82	80	82
	Bottom	85	79	82	85	85	82	83	85	85	85	84	83
Chl a	*Surface*	2.2	2.0	4.0	8.4	10.4	15.8	3.4	3.0	2.8	2.2	4.2	3.1
	Bottom	3.0	2.8	6.8	3.8	5.6	12.9	6.1	5.0	4.8	3.1	3.6	3.3

Appendix A.2

Summary of temperature (=temp; °C), salinity (ppt), density (δ/θ), dissolved oxygen (=DO; mg/L), pH, chlorophyll *a* (=Chlor *a*; µg/L), and transmissivity (=XMS; %) for surface (≤2 m), mid-depth (10-20 m) and bottom (≥27 m) waters at all SBOO offshore stations during 2007. Values are expressed as means.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp	*Surface*	14.9	14.8	13.1	14.6	15.9	16.9	20.2	20.9	16.5	18.3	14.7	15.3
	Mid	14.7	14.2	11.9	12.0	11.0	11.5	13.4	14.7	12.7	14.2	12.8	14.7
	Bottom	14.3	13.0	10.9	11.0	10.4	10.4	11.4	12.3	11.7	12.3	11.9	12.9
Density	*Surface*	24.87	24.88	25.32	25.04	24.78	24.60	23.69	23.51	24.54	24.16	24.85	24.73
	Mid	24.90	25.04	25.62	25.58	25.83	25.70	25.26	24.90	25.33	25.04	25.20	24.86
	Bottom	24.99	25.28	25.88	25.78	25.97	25.93	25.69	25.38	25.54	25.41	25.43	25.21
Salinity	*Surface*	33.55	33.53	33.65	33.68	33.73	33.79	33.80	33.68	33.59	33.66	33.47	33.48
	Mid	33.54	33.57	33.72	33.71	33.78	33.74	33.68	33.56	33.56	33.58	33.41	33.47
	Bottom	33.54	33.58	33.83	33.73	33.82	33.78	33.69	33.51	33.57	33.56	33.48	33.45
DO	*Surface*	7.5	7.5	8.6	8.0	8.5	9.3	7.4	8.2	8.7	8.1	8.0	7.9
	Mid	7.3	7.4	6.1	5.5	4.3	5.2	8.0	8.1	7.7	8.3	7.0	7.8
	Bottom	6.4	5.9	4.1	4.3	3.7	3.9	5.6	6.5	6.4	7.0	6.3	6.8
pH	*Surface*	8.1	8.1	8.1	8.2	8.2	8.2	8.2	8.2	8.1	8.2	8.2	8.2
	Mid	8.1	8.1	8.0	8.0	7.8	7.8	8.1	8.1	8.0	8.1	8.1	8.2
	Bottom	8.0	8.0	7.8	7.9	7.8	7.7	7.9	8.0	7.9	8.0	8.0	8.1
XMS	*Surface*	81	75	75	81	74	82	80	80	79	85	79	81
	Mid	84	84	82	85	85	84	82	86	85	84	87	83
	Bottom	85	89	88	90	89	89	89	90	89	87	89	85
Chl *a*	*Surface*	2.9	1.7	8.1	3.6	5.8	3.9	2.8	3.6	2.6	2.0	7.0	2.5
	Mid	3.7	3.5	11.2	3.5	4.7	7.2	7.8	4.2	5.8	5.9	2.9	3.3
	Bottom	1.7	1.7	2.7	1.1	1.3	1.8	2.4	2.5	2.1	4.6	1.6	2.0

Appendix A.3

Wind data are presented for each month of 2007 with direction and date of the maximum recorded speed, and the overall average wind speed in miles per hour.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max Speed	26	25	32	26	20	18	18	23	21	21	24	24
Direction	W	SW	NW	W	N	W	W	NW	S	W	S	S
Date	5-Jan	19-Feb	27-Mar	12-Apr	6-May	20-Jun	13-Jul	26-Aug	21-Sep	10-Oct	30-Nov	7-Dec
Ave Speed	5.2	6.1	6	6.8	7	6.6	6.3	6.3	5.8	4.7	4	4.3

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Appendix B

Supporting Data

2007 SBOO Stations

Microbiology

Appendix B.1

Summary of rainfall and bacteria levels at shore stations in the SBOO region during 2007. Rain data are from Lindbergh Field, San Diego, CA. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) densities are expressed as mean CFU/100 mL per month and for the entire year (n=52-57). Stations are listed north to south from left to right.

Month	Rain (in)		S9	S8	S12	S6	S11	S5	S10	S4	S3	S2	S0
Jan	0.51	*Total*	13	8	17	14	9	73	6	65	3209	338	4336
		Fecal	6	6	3	3	2	42	2	3	524	36	186
		Entero	3	2	223	7	4	15	2	6	1327	71	156
Feb	1.12	*Total*	15	10	64	2106	5166	8134	10,676	10,674	4406	6624	7801
		Fecal	2	2	3	63	158	473	4234	2267	1212	371	822
		Entero	3	3	19	43	96	140	2567	1718	3018	631	1023
Mar	0.09	*Total*	21	7	11	25	93	5017	6269	4684	1952	202	4010
		Fecal	2	2	4	3	7	368	436	67	76	5	2202
		Entero	3	2	2	3	2	36	17	11	34	3	213
Apr	0.46	*Total*	16	16	65	20	21	1074	6412	3778	357	147	2110
		Fecal	2	2	4	7	2	19	1442	167	10	4	89
		Entero	9	2	2	3	2	6	2	2	3	3	23
May	Trace	*Total*	54	14	70	48	68	54	54	47	53	706	1136
		Fecal	2	4	10	7	15	38	10	7	10	62	105
		Entero	3	38	2	5	2	12	3	3	9	3	7
Jun	0.00	*Total*	61	65	25	20	20	55	25	20	28	34	7205
		Fecal	2	2	3	5	3	25	2	2	3	3	281
		Entero	8	3	4	15	2	22	5	2	5	3	170
Jul	0.00	*Total*	96	92	56	20	20	52	20	15	45	21	136
		Fecal	3	9	14	2	2	2	6	2	12	3	12
		Entero	5	2	6	3	4	2	2	2	70	2	18
Aug	0.00	*Total*	30	155	70	25	20	25	16	40	16	35	265
		Fecal	2	7	31	3	2	3	7	12	2	3	67
		Entero	5	3	48	2	7	2	3	28	6	6	83
Sep	0.05	*Total*	70	20	30	18	16	20	110	131	436	1518	265
		Fecal	3	3	7	2	2	2	7	9	5	15	7
		Entero	5	4	9	3	15	4	11	10	21	49	3
Oct	0.37	*Total*	14	12	55	13	6	9	9	10	7	8	53
		Fecal	2	3	10	4	2	2	2	3	2	3	4
		Entero	3	2	8	2	2	2	2	2	7	11	4
Nov	0.97	*Total*	206	11	36	51	25	13	16	11	27	145	445
		Fecal	13	7	14	6	5	13	6	2	3	42	20
		Entero	14	7	34	9	4	4	10	3	4	202	31
Dec	0.80	*Total*	17	16	30	1090	710	5204	4884	4124	980	385	5310
		Fecal	3	3	7	79	47	2553	1953	1133	161	27	410
		Entero	9	2	29	39	23	713	153	87	27	12	64
		n	52	52	52	52	53	56	58	57	52	52	52
Annual means		***Total***	51	35	44	287	514	1644	2375	1966	960	847	2756
		Fecal	3	4	9	15	21	295	675	306	168	48	350
		Entero	6	6	32	11	14	80	231	156	377	83	149

Appendix B.2

Summary of samples with elevated total coliform concentrations ≥10,000 CFU/100 mL (or >1000 CFU/100 mL and F:T ≥ 0.1) collected at SBOO shore stations during 2007. Values are expressed as CFU/100 mL; Total=total coliform; Fecal=fecal coliform; F:T=fecal to total coliform ratio.

Station	Month	Total	Fecal	F:T
S0	January	>16,000	800	0.05
S3	January	>16,000	2600	0.16
S0	February	>16,000	620	0.04
S11	February	>16,000	460	0.03
S2	February	>16,000	1000	0.06
S5	February	>16,000	580	0.04
S0	February	12,000	2600	0.22
S10	February	>16,000	9400	0.59
S10	February	>16,000	1600	0.10
S10	February	>16,000	>12,000	0.75
S10	February	>16,000	2400	0.15
S2	February	2000	280	0.14
S3	February	>16,000	4800	0.30
S4	February	>16,000	2400	0.15
S4	February	>16,000	2000	0.13
S4	February	>16,000	7600	0.48
S4	February	>16,000	1600	0.10
S5	February	>16,000	1600	0.10
S5	March	13,000	960	0.07
S4	March	15,000	100	0.01
S10	March	>16,000	1000	0.06
S10	March	>16,000	480	0.03
S5	March	>16,000	1200	0.08
S0	March	>16,000	8800	0.55
S10	March	4800	1100	0.23
S3	March	1200	160	0.13
S4	April	>16,000	680	0.04
S10	April	>16,000	2000	0.13
S10	April	>16,000	5200	0.33
S0	June	18,000	860	0.05
S0	August	1000	260	0.26
S0	December	13,000	820	0.06
S0	December	4400	620	0.14
S10	December	>16,000	9000	0.56
S10	December	5000	560	0.11
S3	December	3000	500	0.17
S4	December	>16,000	5200	0.33
S5	December	>16,000	>12,000	0.75

Appendix B.3

Summary of samples with elevated total coliform concentrations (> 1000 CFU/100 mL) collected at SBOO offshore stations during 2007. Values are expressed as CFU/100 mL; Total=total coliform; Fecal=fecal coliform; F:T=fecal to total coliform ratio; — indicate missing data.

Station	Date	Depth	TOTAL	FECAL	F:T
I12	January 8	2	>16000	60	0.00
I12	January 8	18	>16000	120	0.01
I19	February 1	2	>16000	1600	0.10
I11	February 15	2	3000	22	0.01
I11	February 15	6	1200	12	0.01
I18	February 21	2	6600	96	0.01
I19	February 21	6	>16000	1200	0.08
I19	February 21	11	>16000	940	0.06
I23	February 21	2	7000	260	0.04
I24	February 21	2	8400	140	0.02
I24	February 21	6	9400	200	0.02
I24	February 21	11	2200	96	0.04
I40	February 21	2	>16000	720	0.05
I40	February 21	6	12000	440	0.04
I40	February 21	9	11000	400	0.04
I18	March 6	2	>16000	1400	0.09
I24	March 6	11	2400	14	0.01
I40	March 6	2	>16000	380	0.02
I12	April 2	18	>16000	—	—
I12	April 2	27	1700	28	0.02
I16	April 2	18	17000	260	0.02
I9	April 3	18	2800	2	0.00
I9	May 1	18	2800	720	0.26
I12	May 10	18	7000	560	0.08
I10	June 1	12	9200	1200	0.13
I12	June 1	18	>16000	2600	0.16
I12	June 5	2	7800	580	0.07
I11	June 6	11	7600	140	0.02
I5	July 11	6	8800	200	0.02
I12	July 12	18	7800	520	0.07
I16	July 12	18	9400	74	0.01
I12	August 1	18	>16000	8200	0.51
I21	August 1	37	1300	200	0.15
I5	August 9	6	12000	60	0.01
I9	August 9	18	4000	68	0.02
I12	October 1	18	>16000	>12000	0.75
I9	October 4	18	1800	96	0.05
I12	November 6	18	4000	22	0.01
I18	December 4	2	>16000	1200	0.08
I18	December 4	12	5800	360	0.06
I19	December 4	2	14000	1100	0.08
I19	December 4	6	10000	900	0.09
I19	December 4	11	12000	680	0.06

Appendix B.4

2001 California Ocean Plan water contact standards for SBOO shore and kelp bed stations during 2007. Values reflect the number of days that the standards were exceeded at each station (the 30-day total coliform, 10,000 total coliform, the 60-day fecal coliform, and geometric mean standards; see Box 3.1). Shore stations are listed north to south 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	0	0	0	0	0	15	15	0	0	5
February	28	0	0	0	19	19	19	8	8	13	13	8
March	31	0	0	0	17	7	27	31	31	3	3	3
April	30	0	0	0	0	0	10	30	26	0	0	0
May	31	0	0	0	0	0	15	23	23	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	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	16	16	27	27	21	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**86%**	**88%**	**73%**	**63%**	**66%**	**96%**	**96%**	**96%**
10,000 Total coliform standard												
January	31	0	0	0	0	0	0	0	0	0	0	0
February	28	0	0	0	0	0	1	2	2	0	0	0
March	31	0	0	0	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	1	0	0	0	0
May	31	0	0	0	0	0	0	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	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
Total		**0**	**0**	**0**	**0**	**0**	**1**	**3**	**2**	**0**	**0**	**0**

Appendix B.4 *continued*

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	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	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	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	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%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Geometric mean standard												
January	31	0	0	0	0	0	10	11	11	0	0	0
February	28	0	0	0	0	0	8	9	9	0	0	0
March	31	0	0	0	0	0	27	31	29	0	0	0
April	30	0	0	0	0	0	25	30	0	0	0	0
May	31	0	0	0	0	0	0	24	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	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	28	28	28	0	0	0
Percent compliance		**100%**	**100%**	**100%**	**100%**	**100%**	**73%**	**64%**	**79%**	**100%**	**100%**	**100%**

Appendix C

Supporting Data

2007 SBOO Stations

Sediment Characteristics

Appendix C.1

Constituents and method detection limits (MDL) for sediment samples analyzed for the SBOO monitoring program during 2007.

Parameter	MDL	Parameter	MDL
Sulfides-Total (ppm)	0.14	Total Solids (%wt)	0.24
Total Nitrogen (%wt)	0.01	Total Volatile Solids (%wt)	0.11
Total Organic Carbon (%wt)	0.01		
Metals (ppm)			
Aluminum (Al)	1.20	Lead (Pb)	0.14
Antimony (Sb)	0.13	Manganese (Mn)	0.00
Arsenic (As)	0.33	Mercury (Hg)	0.00
Barium (Ba)	0.00	Nickel (Ni)	0.04
Beryllium (Be)	0.00	Selenium (Se)	0.24
Cadmium (Cd)	0.01	Silver (Ag)	0.01
Chromium (Cr)	0.02	Thallium (Tl)	0.22
Copper (Cu)	0.03	Tin (Sn)	0.06
Iron (Fe)	0.76	Zinc (Zn)	0.05
Pesticides (ppt)			
Aldrin	700	Cis Nonachlor	700
Alpha Endosulfan	700	Gamma (trans) Chlordane	700
Beta Endosulfan	700	Heptachlor	700
Dieldrin	700	Heptachlor epoxide	700
Endosulfan Sulfate	700	Methoxychlor	700
Endrin	700	Oxychlordane	700
Endrin aldehyde	700	Trans Nonachlor	700
Hexachlorobenzene	400	o,p-DDD	400
Mirex	700	o,p-DDE	700
BHC, Alpha isomer	400	o,p-DDT	700
BHC, Beta isomer	400	p,-p-DDMU	*
BHC, Delta isomer	400	p,p-DDD	700
BHC, Gamma isomer	400	p,p-DDE	400
Alpha (cis) Chlordane	700	p,p-DDT	700

* No MDL available for this parameter

Appendix C.1 *continued*.

Parameter	MDL	Parameter	MDL
Polychlorinated Biphenyl Congeners (PCBs) (ppt)			
PCB 18	700	PCB 126	1500
PCB 28	700	PCB 128	700
PCB 37	700	PCB 138	700
PCB 44	700	PCB 149	700
PCB 49	700	PCB 151	700
PCB 52	700	PCB 153/168	700
PCB 66	700	PCB 156	700
PCB 70	700	PCB 157	700
PCB 74	700	PCB 158	700
PCB 77	700	PCB 167	700
PCB 81	700	PCB 169	700
PCB 87	700	PCB 170	700
PCB 99	700	PCB 177	700
PCB 101	700	PCB 180	400
PCB 105	700	PCB 183	700
PCB 110	700	PCB 187	700
PCB 114	700	PCB 189	400
PCB 118	700	PCB 194	700
PCB 119	700	PCB 201	700
PCB 123	700	PCB 206	700
Polycyclic Aromatic Hydrocarbons (PAHs) (ppb)			
1-methylnaphthalene	70	Benzo[K]fluoranthene	82
1-methylphenanthrene	41	Benzo[e]pyrene	57
2,3,5-trimethylnaphthalene	134	Biphenyl	89
2,6-dimethylnaphthalene	106	Chrysene	36
2-methylnaphthalene	102	Dibenzo(A,H)anthracene	32
3,4-benzo(B)fluoranthene	63	Fluoranthene	24
Acenaphthene	11	Fluorene	18
Acenaphthylene	11	Indeno(1,2,3-CD)pyrene	76
Anthracene	14	Naphthalene	21
Benzo[A]anthracene	34	Perylene	58
Benzo[A]pyrene	55	Phenanthrene	32
Benzo[G,H,I]perylene	56	Pyrene	35

Appendix C.2

Summary of detected pesticides and the constituents that make up total DDT, total PCB, and total PAH in each sediment sample collected as part SBOO monitoring program during 2007.

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-1	I-1	PAH	1-methylnaphthalene	8.65	µg/kg
2007-1	I-1	PAH	2,6-dimethylnaphthalene	7.85	µg/kg
2007-1	I-1	PAH	2-methylnaphthalene	24.00	µg/kg
2007-1	I-1	PAH	Biphenyl	5.10	µg/kg
2007-1	I-1	PAH	Naphthalene	27.90	µg/kg
2007-1	I-1	PAH	Perylene	13.00	µg/kg
2007-1	I-10	DDT	p,p-DDE	34.50	ng/kg
2007-1	I-10	PAH	1-methylnaphthalene	9.00	µg/kg
2007-1	I-10	PAH	2,6-dimethylnaphthalene	11.40	µg/kg
2007-1	I-10	PAH	2-methylnaphthalene	24.40	µg/kg
2007-1	I-10	PAH	Biphenyl	15.00	µg/kg
2007-1	I-10	PAH	Naphthalene	18.70	µg/kg
2007-1	I-10	PAH	Phenanthrene	9.10	µg/kg
2007-1	I-12	PAH	1-methylnaphthalene	4.80	µg/kg
2007-1	I-12	PAH	1-methylphenanthrene	1.98	µg/kg
2007-1	I-12	PAH	2-methylnaphthalene	19.60	µg/kg
2007-1	I-12	PAH	Anthracene	1.80	µg/kg
2007-1	I-12	PAH	Benzo[A]anthracene	4.83	µg/kg
2007-1	I-12	PAH	Biphenyl	6.70	µg/kg
2007-1	I-12	PAH	Fluoranthene	1.60	µg/kg
2007-1	I-12	PAH	Naphthalene	17.80	µg/kg
2007-1	I-12	PAH	Phenanthrene	6.45	µg/kg
2007-1	I-13	PAH	1-methylnaphthalene	3.75	µg/kg
2007-1	I-13	PAH	2-methylnaphthalene	16.40	µg/kg
2007-1	I-13	PAH	Biphenyl	5.35	µg/kg
2007-1	I-13	PAH	Naphthalene	18.20	µg/kg
2007-1	I-13	PAH	Phenanthrene	2.50	µg/kg
2007-1	I-14	PAH	1-methylnaphthalene	4.60	µg/kg
2007-1	I-14	PAH	2,6-dimethylnaphthalene	4.75	µg/kg
2007-1	I-14	PAH	2-methylnaphthalene	23.80	µg/kg
2007-1	I-14	PAH	Biphenyl	5.25	µg/kg
2007-1	I-14	PAH	Naphthalene	16.90	µg/kg
2007-1	I-14	PAH	Phenanthrene	5.65	µg/kg
2007-1	I-15	PAH	1-methylnaphthalene	3.15	µg/kg
2007-1	I-15	PAH	2,6-dimethylnaphthalene	6.10	µg/kg
2007-1	I-15	PAH	2-methylnaphthalene	18.00	µg/kg
2007-1	I-15	PAH	Benzo[A]anthracene	8.30	µg/kg
2007-1	I-15	PAH	Biphenyl	5.10	µg/kg
2007-1	I-15	PAH	Naphthalene	16.30	µg/kg
2007-1	I-15	PAH	Phenanthrene	4.35	µg/kg

Appendix C.2 *continued*

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-1	I-15	PESTICIDE	Hexachlorobenzene	170.00	ng/kg
2007-1	I-16	BHC	BHC, Alpha isomer	780.00	ng/kg
2007-1	I-16	BHC	BHC, Beta isomer	2200.00	ng/kg
2007-1	I-16	BHC	BHC, Delta isomer	330.00	ng/kg
2007-1	I-16	BHC	BHC, Gamma isomer	570.00	ng/kg
2007-1	I-16	CHLORDANE	Gamma (trans) Chlordane	380.00	ng/kg
2007-1	I-16	CHLORDANE	Heptachlor	1000.00	ng/kg
2007-1	I-16	CHLORDANE	Heptachlor epoxide	240.00	ng/kg
2007-1	I-16	DDT	p,p-DDE	200.00	ng/kg
2007-1	I-16	PAH	1-methylnaphthalene	3.80	µg/kg
2007-1	I-16	PAH	2,6-dimethylnaphthalene	7.35	µg/kg
2007-1	I-16	PAH	2-methylnaphthalene	19.70	µg/kg
2007-1	I-16	PAH	Biphenyl	10.30	µg/kg
2007-1	I-16	PAH	Fluorene	1.00	µg/kg
2007-1	I-16	PAH	Naphthalene	31.50	µg/kg
2007-1	I-16	PAH	Phenanthrene	6.25	µg/kg
2007-1	I-16	PESTICIDE	Aldrin	500.00	ng/kg
2007-1	I-16	PESTICIDE	Hexachlorobenzene	520.00	ng/kg
2007-1	I-18	PAH	1-methylnaphthalene	16.60	µg/kg
2007-1	I-18	PAH	2,6-dimethylnaphthalene	6.15	µg/kg
2007-1	I-18	PAH	2-methylnaphthalene	33.40	µg/kg
2007-1	I-18	PAH	Biphenyl	16.10	µg/kg
2007-1	I-18	PAH	Naphthalene	43.20	µg/kg
2007-1	I-18	PCB	PCB 101	14000.00	ng/kg
2007-1	I-18	PCB	PCB 105	3700.00	ng/kg
2007-1	I-18	PCB	PCB 110	12000.00	ng/kg
2007-1	I-18	PCB	PCB 118	11000.00	ng/kg
2007-1	I-18	PCB	PCB 119	810.00	ng/kg
2007-1	I-18	PCB	PCB 123	900.00	ng/kg
2007-1	I-18	PCB	PCB 128	2300.00	ng/kg
2007-1	I-18	PCB	PCB 138	8500.00	ng/kg
2007-1	I-18	PCB	PCB 149	7900.00	ng/kg
2007-1	I-18	PCB	PCB 151	3500.00	ng/kg
2007-1	I-18	PCB	PCB 153/168	3500.00	ng/kg
2007-1	I-18	PCB	PCB 156	1400.00	ng/kg
2007-1	I-18	PCB	PCB 158	1500.00	ng/kg
2007-1	I-18	PCB	PCB 167	690.00	ng/kg
2007-1	I-18	PCB	PCB 170	1200.00	ng/kg
2007-1	I-18	PCB	PCB 177	630.00	ng/kg
2007-1	I-18	PCB	PCB 180	1900.00	ng/kg
2007-1	I-18	PCB	PCB 183	670.00	ng/kg
2007-1	I-18	PCB	PCB 187	900.00	ng/kg

Appendix C.2 *continued*

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-1	I-18	PCB	PCB 189	91.00	ng/kg
2007-1	I-18	PCB	PCB 194	170.00	ng/kg
2007-1	I-18	PCB	PCB 201	73.00	ng/kg
2007-1	I-18	PCB	PCB 206	76.00	ng/kg
2007-1	I-18	PCB	PCB 44	2800.00	ng/kg
2007-1	I-18	PCB	PCB 49	2000.00	ng/kg
2007-1	I-18	PCB	PCB 52	7700.00	ng/kg
2007-1	I-18	PCB	PCB 66	2500.00	ng/kg
2007-1	I-18	PCB	PCB 70	4300.00	ng/kg
2007-1	I-18	PCB	PCB 74	980.00	ng/kg
2007-1	I-18	PCB	PCB 87	6500.00	ng/kg
2007-1	I-18	PCB	PCB 99	4600.00	ng/kg
2007-1	I-2	PAH	1-methylnaphthalene	4.50	µg/kg
2007-1	I-2	PAH	2,6-dimethylnaphthalene	5.65	µg/kg
2007-1	I-2	PAH	2-methylnaphthalene	19.90	µg/kg
2007-1	I-2	PAH	Anthracene	2.80	µg/kg
2007-1	I-2	PAH	Benzo[A]anthracene	11.10	µg/kg
2007-1	I-2	PAH	Biphenyl	9.55	µg/kg
2007-1	I-2	PAH	Naphthalene	17.90	µg/kg
2007-1	I-2	PAH	Phenanthrene	8.45	µg/kg
2007-1	I-2	PCB	PCB 194	34.00	ng/kg
2007-1	I-2	PCB	PCB 201	30.00	ng/kg
2007-1	I-2	PCB	PCB 206	52.00	ng/kg
2007-1	I-20	PAH	1-methylnaphthalene	2.70	µg/kg
2007-1	I-20	PAH	2,6-dimethylnaphthalene	5.05	µg/kg
2007-1	I-20	PAH	2-methylnaphthalene	14.90	µg/kg
2007-1	I-20	PAH	Biphenyl	4.75	µg/kg
2007-1	I-20	PAH	Naphthalene	13.00	µg/kg
2007-1	I-21	PAH	1-methylnaphthalene	2.60	µg/kg
2007-1	I-21	PAH	2,6-dimethylnaphthalene	4.15	µg/kg
2007-1	I-21	PAH	2-methylnaphthalene	14.00	µg/kg
2007-1	I-21	PAH	Biphenyl	4.70	µg/kg
2007-1	I-21	PAH	Naphthalene	13.50	µg/kg
2007-1	I-21	PAH	Phenanthrene	2.80	µg/kg
2007-1	I-22	PAH	1-methylnaphthalene	4.55	µg/kg
2007-1	I-22	PAH	2,6-dimethylnaphthalene	8.25	µg/kg
2007-1	I-22	PAH	2-methylnaphthalene	27.50	µg/kg
2007-1	I-22	PAH	Biphenyl	5.70	µg/kg
2007-1	I-22	PAH	Naphthalene	27.80	µg/kg
2007-1	I-22	PAH	Phenanthrene	7.20	µg/kg
2007-1	I-23	PAH	1-methylnaphthalene	3.25	µg/kg
2007-1	I-23	PAH	2,6-dimethylnaphthalene	6.55	µg/kg

Appendix C.2 *continued*

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-1	I-23	PAH	2-methylnaphthalene	19.20	µg/kg
2007-1	I-23	PAH	Biphenyl	3.95	µg/kg
2007-1	I-23	PAH	Naphthalene	7.90	µg/kg
2007-1	I-23	PAH	Phenanthrene	5.85	µg/kg
2007-1	I-27	PAH	1-methylnaphthalene	9.25	µg/kg
2007-1	I-27	PAH	1-methylphenanthrene	3.23	µg/kg
2007-1	I-27	PAH	2,6-dimethylnaphthalene	8.00	µg/kg
2007-1	I-27	PAH	2-methylnaphthalene	27.60	µg/kg
2007-1	I-27	PAH	Anthracene	1.03	µg/kg
2007-1	I-27	PAH	Benzo[A]anthracene	12.10	µg/kg
2007-1	I-27	PAH	Biphenyl	13.00	µg/kg
2007-1	I-27	PAH	Naphthalene	30.10	µg/kg
2007-1	I-27	PAH	Phenanthrene	6.30	µg/kg
2007-1	I-27	PAH	Pyrene	2.95	µg/kg
2007-1	I-28	DDT	p,p-DDE	400.00	ng/kg
2007-1	I-28	DDT	p,p-DDT	98.00	ng/kg
2007-1	I-28	PAH	1-methylnaphthalene	6.60	µg/kg
2007-1	I-28	PAH	2,6-dimethylnaphthalene	6.95	µg/kg
2007-1	I-28	PAH	2-methylnaphthalene	23.40	µg/kg
2007-1	I-28	PAH	Acenaphthene	0.80	µg/kg
2007-1	I-28	PAH	Anthracene	2.63	µg/kg
2007-1	I-28	PAH	Benzo[A]anthracene	16.50	µg/kg
2007-1	I-28	PAH	Biphenyl	11.90	µg/kg
2007-1	I-28	PAH	Fluoranthene	4.33	µg/kg
2007-1	I-28	PAH	Naphthalene	25.10	µg/kg
2007-1	I-28	PAH	Perylene	8.93	µg/kg
2007-1	I-28	PAH	Phenanthrene	6.98	µg/kg
2007-1	I-28	PAH	Pyrene	16.00	µg/kg
2007-1	I-28	PCB	PCB 101	52.00	ng/kg
2007-1	I-28	PESTICIDE	Hexachlorobenzene	510.00	ng/kg
2007-1	I-29	PAH	1-methylnaphthalene	7.40	µg/kg
2007-1	I-29	PAH	2-methylnaphthalene	20.70	µg/kg
2007-1	I-29	PAH	Biphenyl	10.80	µg/kg
2007-1	I-29	PAH	Naphthalene	22.40	µg/kg
2007-1	I-29	PESTICIDE	Hexachlorobenzene	200.00	ng/kg
2007-1	I-3	PAH	1-methylnaphthalene	6.25	µg/kg
2007-1	I-3	PAH	2,6-dimethylnaphthalene	7.95	µg/kg
2007-1	I-3	PAH	2-methylnaphthalene	20.50	µg/kg
2007-1	I-3	PAH	Biphenyl	11.00	µg/kg
2007-1	I-3	PAH	Naphthalene	18.70	µg/kg
2007-1	I-3	PAH	Phenanthrene	6.40	µg/kg
2007-1	I-30	DDT	p,p-DDE	55.00	ng/kg

Appendix C.2 *continued*

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-1	I-30	PAH	1-methylnaphthalene	9.30	µg/kg
2007-1	I-30	PAH	2,6-dimethylnaphthalene	7.90	µg/kg
2007-1	I-30	PAH	2-methylnaphthalene	25.90	µg/kg
2007-1	I-30	PAH	Anthracene	1.45	µg/kg
2007-1	I-30	PAH	Benzo[A]anthracene	11.70	µg/kg
2007-1	I-30	PAH	Biphenyl	11.10	µg/kg
2007-1	I-30	PAH	Naphthalene	23.40	µg/kg
2007-1	I-30	PAH	Phenanthrene	7.30	µg/kg
2007-1	I-31	PAH	1-methylnaphthalene	4.15	µg/kg
2007-1	I-31	PAH	2,6-dimethylnaphthalene	5.90	µg/kg
2007-1	I-31	PAH	2-methylnaphthalene	18.60	µg/kg
2007-1	I-31	PAH	Biphenyl	9.90	µg/kg
2007-1	I-31	PAH	Naphthalene	17.70	µg/kg
2007-1	I-31	PAH	Phenanthrene	2.15	µg/kg
2007-1	I-33	PAH	1-methylnaphthalene	8.30	µg/kg
2007-1	I-33	PAH	2,6-dimethylnaphthalene	7.15	µg/kg
2007-1	I-33	PAH	2-methylnaphthalene	22.40	µg/kg
2007-1	I-33	PAH	Anthracene	0.95	µg/kg
2007-1	I-33	PAH	Benzo[A]anthracene	11.70	µg/kg
2007-1	I-33	PAH	Benzo[K]fluoranthene	3.65	µg/kg
2007-1	I-33	PAH	Biphenyl	6.00	µg/kg
2007-1	I-33	PAH	Naphthalene	22.00	µg/kg
2007-1	I-33	PAH	Phenanthrene	2.45	µg/kg
2007-1	I-34	PAH	1-methylnaphthalene	7.65	µg/kg
2007-1	I-34	PAH	2,6-dimethylnaphthalene	4.95	µg/kg
2007-1	I-34	PAH	2-methylnaphthalene	17.90	µg/kg
2007-1	I-34	PAH	Biphenyl	9.70	µg/kg
2007-1	I-34	PAH	Naphthalene	22.40	µg/kg
2007-1	I-34	PAH	Phenanthrene	4.80	µg/kg
2007-1	I-35	DDT	p,p-DDE	150.00	ng/kg
2007-1	I-35	PAH	1-methylnaphthalene	9.60	µg/kg
2007-1	I-35	PAH	2,6-dimethylnaphthalene	8.00	µg/kg
2007-1	I-35	PAH	2-methylnaphthalene	29.40	µg/kg
2007-1	I-35	PAH	Anthracene	1.90	µg/kg
2007-1	I-35	PAH	Benzo[A]anthracene	11.30	µg/kg
2007-1	I-35	PAH	Biphenyl	10.60	µg/kg
2007-1	I-35	PAH	Naphthalene	25.80	µg/kg
2007-1	I-35	PAH	Phenanthrene	17.20	µg/kg
2007-1	I-35	PAH	Pyrene	19.60	µg/kg
2007-1	I-35	PCB	PCB 138	82.00	ng/kg
2007-1	I-35	PCB	PCB 180	38.00	ng/kg
2007-1	I-35	PCB	PCB 206	49.00	ng/kg

Appendix C.2 *continued*

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-1	I-4	PAH	1-methylnaphthalene	8.80	µg/kg
2007-1	I-4	PAH	2,6-dimethylnaphthalene	13.10	µg/kg
2007-1	I-4	PAH	2-methylnaphthalene	25.60	µg/kg
2007-1	I-4	PAH	Benzo[A]anthracene	10.80	µg/kg
2007-1	I-4	PAH	Biphenyl	18.80	µg/kg
2007-1	I-4	PAH	Naphthalene	16.60	µg/kg
2007-1	I-4	PAH	Phenanthrene	9.55	µg/kg
2007-1	I-4	PCB	PCB 169	51.00	ng/kg
2007-1	I-6	PAH	1-methylnaphthalene	5.20	µg/kg
2007-1	I-6	PAH	2,6-dimethylnaphthalene	11.10	µg/kg
2007-1	I-6	PAH	2-methylnaphthalene	19.90	µg/kg
2007-1	I-6	PAH	Biphenyl	15.30	µg/kg
2007-1	I-6	PAH	Naphthalene	13.00	µg/kg
2007-1	I-6	PAH	Phenanthrene	10.50	µg/kg
2007-1	I-7	PAH	1-methylnaphthalene	6.35	µg/kg
2007-1	I-7	PAH	2,6-dimethylnaphthalene	6.00	µg/kg
2007-1	I-7	PAH	2-methylnaphthalene	18.20	µg/kg
2007-1	I-7	PAH	Biphenyl	5.10	µg/kg
2007-1	I-7	PAH	Naphthalene	17.80	µg/kg
2007-1	I-7	PAH	Phenanthrene	3.85	µg/kg
2007-1	I-7	PESTICIDE	Hexachlorobenzene	77.00	ng/kg
2007-1	I-8	PAH	1-methylnaphthalene	7.50	µg/kg
2007-1	I-8	PAH	2,6-dimethylnaphthalene	10.60	µg/kg
2007-1	I-8	PAH	2-methylnaphthalene	20.40	µg/kg
2007-1	I-8	PAH	Biphenyl	14.00	µg/kg
2007-1	I-8	PAH	Naphthalene	19.10	µg/kg
2007-1	I-9	PAH	1-methylnaphthalene	15.20	µg/kg
2007-1	I-9	PAH	2,6-dimethylnaphthalene	16.80	µg/kg
2007-1	I-9	PAH	2-methylnaphthalene	35.60	µg/kg
2007-1	I-9	PAH	Benzo[A]anthracene	24.20	µg/kg
2007-1	I-9	PAH	Biphenyl	20.10	µg/kg
2007-1	I-9	PAH	Naphthalene	38.20	µg/kg
2007-1	I-9	PAH	Phenanthrene	15.80	µg/kg
2007-3	I-1	PAH	1-methylnaphthalene	8.65	µg/kg
2007-3	I-1	PAH	1-methylphenanthrene	3.25	µg/kg
2007-3	I-1	PAH	2,6-dimethylnaphthalene	14.90	µg/kg
2007-3	I-1	PAH	2-methylnaphthalene	30.10	µg/kg
2007-3	I-1	PAH	Anthracene	3.10	µg/kg
2007-3	I-1	PAH	Benzo[A]anthracene	12.60	µg/kg
2007-3	I-1	PAH	Biphenyl	15.50	µg/kg
2007-3	I-1	PAH	Naphthalene	20.50	µg/kg
2007-3	I-1	PAH	Perylene	12.70	µg/kg

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-3	I-1	PAH	Phenanthrene	13.50	µg/kg
2007-3	I-10	PAH	1-methylnaphthalene	5.70	µg/kg
2007-3	I-10	PAH	2,6-dimethylnaphthalene	11.00	µg/kg
2007-3	I-10	PAH	2-methylnaphthalene	23.30	µg/kg
2007-3	I-10	PAH	Biphenyl	13.30	µg/kg
2007-3	I-10	PAH	Naphthalene	15.20	µg/kg
2007-3	I-10	PAH	Phenanthrene	11.30	µg/kg
2007-3	I-12	PAH	1-methylnaphthalene	6.35	µg/kg
2007-3	I-12	PAH	2-methylnaphthalene	17.00	µg/kg
2007-3	I-12	PAH	Biphenyl	19.20	µg/kg
2007-3	I-12	PAH	Naphthalene	23.40	µg/kg
2007-3	I-13	PAH	1-methylnaphthalene	5.50	µg/kg
2007-3	I-13	PAH	2,6-dimethylnaphthalene	8.50	µg/kg
2007-3	I-13	PAH	2-methylnaphthalene	16.80	µg/kg
2007-3	I-13	PAH	Biphenyl	11.70	µg/kg
2007-3	I-13	PAH	Naphthalene	14.60	µg/kg
2007-3	I-13	PAH	Phenanthrene	10.00	µg/kg
2007-3	I-14	PAH	1-methylnaphthalene	8.90	µg/kg
2007-3	I-14	PAH	2-methylnaphthalene	20.80	µg/kg
2007-3	I-14	PAH	Biphenyl	19.40	µg/kg
2007-3	I-14	PAH	Naphthalene	42.00	µg/kg
2007-3	I-15	PAH	2-methylnaphthalene	10.30	µg/kg
2007-3	I-15	PAH	Biphenyl	14.20	µg/kg
2007-3	I-15	PAH	Naphthalene	16.10	µg/kg
2007-3	I-16	PAH	1-methylnaphthalene	7.30	µg/kg
2007-3	I-16	PAH	2-methylnaphthalene	19.90	µg/kg
2007-3	I-16	PAH	Biphenyl	15.50	µg/kg
2007-3	I-16	PAH	Naphthalene	25.30	µg/kg
2007-3	I-16	PESTICIDE	Hexachlorobenzene	160.00	ng/kg
2007-3	I-18	BHC	BHC, Gamma isomer	240.00	ng/kg
2007-3	I-18	PAH	1-methylnaphthalene	7.40	µg/kg
2007-3	I-18	PAH	2-methylnaphthalene	28.50	µg/kg
2007-3	I-18	PAH	Biphenyl	17.80	µg/kg
2007-3	I-18	PAH	Naphthalene	25.10	µg/kg
2007-3	I-2	PAH	1-methylnaphthalene	5.60	µg/kg
2007-3	I-2	PAH	2-methylnaphthalene	18.30	µg/kg
2007-3	I-2	PAH	Biphenyl	13.10	µg/kg
2007-3	I-2	PAH	Naphthalene	12.10	µg/kg
2007-3	I-2	PAH	Phenanthrene	8.30	µg/kg
2007-3	I-20	PAH	1-methylnaphthalene	1.90	µg/kg
2007-3	I-20	PAH	2-methylnaphthalene	5.25	µg/kg
2007-3	I-20	PAH	Naphthalene	24.40	µg/kg

Appendix C.2 *continued*

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-3	I-21	PAH	2-methylnaphthalene	9.70	µg/kg
2007-3	I-21	PAH	Naphthalene	22.80	µg/kg
2007-3	I-22	PAH	1-methylnaphthalene	9.90	µg/kg
2007-3	I-22	PAH	2-methylnaphthalene	26.00	µg/kg
2007-3	I-22	PAH	Biphenyl	16.00	µg/kg
2007-3	I-22	PAH	Naphthalene	21.20	µg/kg
2007-3	I-22	PESTICIDE	Hexachlorobenzene	240.00	ng/kg
2007-3	I-23	PAH	1-methylnaphthalene	16.00	µg/kg
2007-3	I-23	PAH	2-methylnaphthalene	30.80	µg/kg
2007-3	I-23	PAH	Biphenyl	17.70	µg/kg
2007-3	I-23	PAH	Naphthalene	44.80	µg/kg
2007-3	I-27	PAH	1-methylnaphthalene	2.05	µg/kg
2007-3	I-27	PAH	2-methylnaphthalene	10.30	µg/kg
2007-3	I-27	PAH	Biphenyl	11.20	µg/kg
2007-3	I-27	PAH	Naphthalene	25.80	µg/kg
2007-3	I-27	PAH	Phenanthrene	6.40	µg/kg
2007-3	I-28	DDT	p,p-DDE	660.00	ng/kg
2007-3	I-28	PAH	2-methylnaphthalene	7.60	µg/kg
2007-3	I-28	PAH	Biphenyl	11.20	µg/kg
2007-3	I-28	PAH	Naphthalene	22.50	µg/kg
2007-3	I-29	PAH	2-methylnaphthalene	8.10	µg/kg
2007-3	I-29	PAH	Biphenyl	9.40	µg/kg
2007-3	I-29	PAH	Naphthalene	19.40	µg/kg
2007-3	I-29	PESTICIDE	Hexachlorobenzene	170.00	ng/kg
2007-3	I-3	PAH	1-methylnaphthalene	6.80	µg/kg
2007-3	I-3	PAH	2,6-dimethylnaphthalene	12.80	µg/kg
2007-3	I-3	PAH	2-methylnaphthalene	20.10	µg/kg
2007-3	I-3	PAH	Benzo[A]anthracene	17.80	µg/kg
2007-3	I-3	PAH	Biphenyl	9.40	µg/kg
2007-3	I-3	PAH	Naphthalene	13.70	µg/kg
2007-3	I-3	PAH	Phenanthrene	9.90	µg/kg
2007-3	I-30	PAH	1-methylnaphthalene	4.70	µg/kg
2007-3	I-30	PAH	2-methylnaphthalene	11.10	µg/kg
2007-3	I-30	PAH	Biphenyl	11.70	µg/kg
2007-3	I-30	PAH	Naphthalene	28.00	µg/kg
2007-3	I-31	PAH	2-methylnaphthalene	10.50	µg/kg
2007-3	I-31	PAH	Biphenyl	11.30	µg/kg
2007-3	I-31	PAH	Naphthalene	30.00	µg/kg
2007-3	I-33	PAH	2-methylnaphthalene	9.50	µg/kg
2007-3	I-33	PAH	Biphenyl	10.90	µg/kg
2007-3	I-33	PAH	Naphthalene	24.90	µg/kg
2007-3	I-33	PESTICIDE	Hexachlorobenzene	350.00	ng/kg

Appendix C.2 *continued*

Year-Qtr	Station	Parameter Type	Parameter	Value	Units
2007-3	I-34	PAH	2-methylnaphthalene	7.90	µg/kg
2007-3	I-34	PAH	Biphenyl	10.50	µg/kg
2007-3	I-34	PAH	Naphthalene	19.70	µg/kg
2007-3	I-35	DDT	p,p-DDE	140.00	ng/kg
2007-3	I-35	PAH	Naphthalene	14.80	µg/kg
2007-3	I-4	PAH	1-methylnaphthalene	6.80	µg/kg
2007-3	I-4	PAH	2,6-dimethylnaphthalene	6.30	µg/kg
2007-3	I-4	PAH	2-methylnaphthalene	21.00	µg/kg
2007-3	I-4	PAH	Biphenyl	14.50	µg/kg
2007-3	I-4	PAH	Naphthalene	13.50	µg/kg
2007-3	I-4	PAH	Phenanthrene	9.20	µg/kg
2007-3	I-4	PESTICIDE	Hexachlorobenzene	130.00	ng/kg
2007-3	I-6	PAH	1-methylnaphthalene	5.70	µg/kg
2007-3	I-6	PAH	2-methylnaphthalene	22.80	µg/kg
2007-3	I-6	PAH	Biphenyl	14.60	µg/kg
2007-3	I-6	PAH	Naphthalene	15.00	µg/kg
2007-3	I-6	PAH	Phenanthrene	5.70	µg/kg
2007-3	I-6	PESTICIDE	Hexachlorobenzene	290.00	ng/kg
2007-3	I-7	PAH	1-methylnaphthalene	6.90	µg/kg
2007-3	I-7	PAH	2-methylnaphthalene	16.40	µg/kg
2007-3	I-7	PAH	Biphenyl	12.10	µg/kg
2007-3	I-7	PAH	Naphthalene	18.50	µg/kg
2007-3	I-7	PAH	Phenanthrene	7.90	µg/kg
2007-3	I-8	PAH	1-methylnaphthalene	9.40	µg/kg
2007-3	I-8	PAH	2,6-dimethylnaphthalene	11.10	µg/kg
2007-3	I-8	PAH	2-methylnaphthalene	19.30	µg/kg
2007-3	I-8	PAH	Benzo[A]anthracene	16.40	µg/kg
2007-3	I-8	PAH	Biphenyl	13.80	µg/kg
2007-3	I-8	PAH	Naphthalene	21.60	µg/kg
2007-3	I-8	PAH	Phenanthrene	10.30	µg/kg
2007-3	I-9	PAH	1-methylnaphthalene	9.15	µg/kg
2007-3	I-9	PAH	2,6-dimethylnaphthalene	5.70	µg/kg
2007-3	I-9	PAH	2-methylnaphthalene	29.10	µg/kg
2007-3	I-9	PAH	Biphenyl	13.20	µg/kg
2007-3	I-9	PAH	Naphthalene	20.70	µg/kg
2007-3	I-9	PAH	Phenanthrene	5.40	µg/kg

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Appendix C.3

SBOO sediment statistics for the January/March 2007 survey.

Station	Mean (mm)	Mean (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
19 m stations										
I35	0.07	3.8	3.5	0.4	1.1	0.0	64.8	33.6	1.6	Organics
I34	0.69	0.5	0.5	0.0	1.0	30.0	69.2	0.8	0.0	Sand, shell hash
I31	0.12	3.1	3.1	0.2	1.2	0.0	91.9	8.0	0.1	
I23	0.12	3.0	3.0	0.2	4.0	0.0	90.8	9.0	0.2	Coarse sand, shell hash
I18	0.12	3.1	3.1	0.3	1.7	0.0	90.7	9.3	0.1	
I10	0.12	3.1	3.0	0.2	1.8	0.0	92.4	7.6	0.0	
I4	0.52	1.0	0.9	0.2	1.1	7.4	92.4	0.2	0.0	Shell hash
28 m stations										
I33	0.12	3.0	3.0	0.3	4.4	0.0	87.6	11.7	0.7	Organics
I30	0.10	3.4	3.4	0.3	1.7	0.0	82.3	16.8	0.9	
I27	0.10	3.3	3.3	0.2	1.4	0.0	86.3	13.1	0.5	
I22	0.11	3.2	3.2	0.3	1.6	0.0	85.0	14.4	0.6	
I16	0.16	2.6	2.6	0.2	1.4	0.0	92.7	7.2	0.1	Shell hash
I15	0.42	1.2	1.2	0.1	1.0	5.4	93.3	1.3	0.0	
I14	0.10	3.3	3.3	0.1	1.3	0.0	87.2	12.5	0.2	
I12	0.23	2.1	2.1	0.1	1.1	0.0	96.9	3.1	0.0	Shell hash
I9	0.10	3.4	3.3	0.3	1.5	0.0	83.5	16.0	0.4	
I6	0.38	1.4	1.4	0.1	1.0	5.1	93.6	1.3	0.0	Red relict sand, shell hash
I3	0.59	0.8	0.7	0.2	1.0	11.0	89.0	0.0	0.0	Red relict sand, shell hash
I2	0.27	1.9	1.9	-0.1	0.9	0.0	98.8	1.2	0.0	
38 m stations										
I29	0.75	0.4	0.4	0.3	1.9	21.6	74.6	3.8	0.0	Coarse red relict sand
I21	0.47	1.1	1.0	0.1	1.0	6.3	93.7	0.0	0.0	
I13	0.53	0.9	0.9	0.1	1.0	8.0	92.0	0.0	0.0	Red relict sand, shell hash, rocks
I8	0.33	1.6	1.5	0.1	0.9	4.5	94.2	1.3	0.0	
55 m stations										
I28	0.23	2.1	1.8	0.1	0.6	14.2	42.7	40.3	0.0	Coarse black sand
I20	0.64	0.7	0.5	0.4	1.1	13.1	86.9	0.0	0.0	Coarse red relict sand, shell hash
I7	0.62	0.7	0.6	0.3	1.1	10.6	89.4	0.0	0.0	Red relict sand, shell hash
I1	0.13	2.9	2.8	0.4	1.8	0.0	91.0	8.7	0.3	

Appendix C.3 *continued*

SBOO sediment statistics for the July 2007 survey.

Station	Mean (mm)	Mean (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
19 m stations										
I35	0.07	3.9	3.6	0.4	1.1	0.0	62.7	35.5	1.8	Organic debris
I34	0.34	1.6	1.6	-0.1	0.9	4.5	95.5	0.0	0.0	Shell hash/coarse sand, gravel, cobble
I31	0.11	3.1	3.1	0.2	1.2	0.0	92.1	7.8	0.1	
I23	0.11	3.2	3.1	0.3	1.5	0.0	89.5	10.2	0.3	Coarse black sand , shell hash
I18	0.11	3.2	3.1	0.2	1.3	0.0	89.4	10.4	0.2	
I10	0.12	3.1	3.0	0.2	1.2	0.0	91.8	8.2	0.0	
I4	0.49	1.0	1.0	0.1	1.0	7.4	92.4	0.1	0.0	Shell hash
28 m stations										
I33	0.12	3.0	2.9	0.4	1.8	0.0	88.1	11.1	0.7	Organic hash
I30	0.10	3.4	3.3	0.3	1.6	0.0	84.2	15.3	0.5	
I27	0.10	3.3	3.3	0.2	1.5	0.0	86.4	13.0	0.5	Organic debris
I22	0.11	3.2	3.1	0.5	2.3	0.0	84.9	14.5	0.5	Organic debris
I16	0.17	2.5	2.5	0.1	1.3	0.0	94.2	5.8	0.0	Coarse black sand, shell hash
I15	0.23	2.1	2.1	0.3	1.7	0.0	90.9	8.9	0.2	Organic debris
I14	0.11	3.2	3.2	0.2	1.4	0.0	87.2	12.5	0.4	Organic debris
I12	0.39	1.4	1.4	0.0	0.9	5.4	94.2	0.3	0.0	
I9	0.10	3.4	3.3	0.2	1.5	0.0	84.1	15.4	0.5	Organic debris
I6	0.51	1.0	0.9	0.2	1.0	8.0	91.5	0.4	0.0	Coarse sand, shell hash
I3	0.45	1.1	1.1	0.0	0.9	6.5	93.5	0.0	0.0	
I2	0.35	1.5	1.6	-0.1	0.9	4.6	95.4	0.0	0.0	
38 m stations										
I29	0.82	0.3	0.1	0.8	2.5	19.9	77.2	2.9	0.0	Coarse red relict sand/Coarse black sand
I21	0.53	0.9	0.8	0.1	1.0	8.3	91.7	0.0	0.0	
I13	0.53	0.9	0.9	0.2	1.0	8.3	91.7	0.0	0.0	Coarse sand, shell hash
I8	0.36	1.5	1.2	0.3	1.0	6.3	92.5	1.2	0.0	
55 m stations										
I28	0.24	2.1	1.8	0.1	0.6	12.1	46.1	41.7	0.0	Coarse black sand
I20	0.66	0.6	0.6	0.2	1.2	14.6	84.6	0.7	0.0	Red relict sand
I7	0.50	1.0	0.8	0.4	1.1	10.0	85.3	4.6	0.0	Red relict sand
I1	0.14	2.8	2.7	0.4	1.8	0.0	91.5	8.1	0.4	

Appendix D

Supporting Data

2007 SBOO Stations

Demersal Fishes and Megabenthic Invertebrates

Appendix D.1

Summary of demersal fish species captured during 2007 at SBOO stations. Data are number of fish (n), biomass (BM, wet weight), minimum (Min), maximum (Max), and mean length. Taxonomic arrangement and scientific names are of Eschmeyer and Herald (1998) and Allen (2005).*

				LENGTH		
Taxon/Species	**Common Name**	**n**	**BM**	**Min**	**Max**	**Mean**
TORPEDINIFORMES						
Torpedinidae						
Torpedo californica	Pacific electric ray	1	11.0	67	67	67
RAJIFORMES						
Platyrhynidea						
Platyrhinoidis triseriata	thornback	1	1.2	53	53	53
Rhinobatidae						
Rhinobatos productus	shovelnose guitarfish	2	0.8	31	49	40
Rajidae						
Raja binoculata	big skate	1	0.1	29	29	29
Raja inornata	California skate	3	1.9	37	45	41
MYLIOBATIFORMES						
Urolophidae						
Urobatis haller	round stingray	4	2.1	29	40	35
AULOPIFORMES						
Synodontidae						
Synodus lucioceps	California lizardfish	232	5.2	7	34	12
OPHIDIIFORMES						
Ophidiidae						
Chilara taylori	spotted cusk-eel	1	0.1	16	16	16
BATRACHOIDIFORMES						
Batrachoididae						
Porichthys myriaster	specklefin midshipman	2	0.5	17	32	25
Porichthys notatus	plainfin midshipman	15	1.2	5	18	10
SYNGNATHIFORMIES						
Syngnathidae						
Syngnathus californiensis	kelp pipefish	6	0.5	13	20	16
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	63	22.6	3	28	22
Hexagrammidae						
Zaniolepis latipinnis	longspine combfish	66	2.2	8	23	14
Cottidae						
Chitonotus pugetensis	roughback sculpin	343	3.1	4	12	7
Icelinus quadriseriatus	yellowchin sculpin	329	2.1	3	8	6
Agonidae						
Odontopyxis trispinosa	pygmy poacher	1	0.1	7	7	7
PERCIFORMES						
Sciaenidae						
Genyonemus lineatus	white croaker	1	0.1	17	17	17
Embiotocidae						
Cymatogaster aggregata	shiner perch	21	0.4	8	12	10
Clinidae						
Heterostichus rostratus	giant kelpfish	1	0.1	11	11	11

Appendix D.1 *continued*

Taxon/Species	Common Name	n	BM	LENGTH Min	Max	Mean
PLEURONECTIFORMES		2	0.2	15	18	17
Paralichthyidae						
Citharichthys sordidus	Pacific sanddab	10	0.7	8	19	14
Citharichthys stigmaeus	speckled sanddab	3578	28.1	3	12	7
Citharichthys xanthostigma	longfin sanddab	279	12.4	4	18	12
Hippoglossina stomata	bigmouth sole	6	0.9	17	23	19
Paralichthys californicus	California halibut	19	9.3	26	43	31
Xystreurys liolepis	fantail sole	16	5.2	6	33	21
Pleuronectidae						
Parophrys vetulus	English sole	83	6.3	8	28	15
Pleuronichthys ritteri	spotted turbot	6	0.8	14	20	17
Pleuronichthys verticalis	hornyhead turbot	140	15.6	4	22	13
Cynoglossidae						
Symphurus atricauda	California tonguefish	28	1.6	6	16	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 captured during 2007 at SBOO stations. Data are number of individuals (n). Taxonomic arrangement from SCAMIT 2001.*

Taxon/ Species					n
CNIDARIA					
	ANTHOZOA				
		ALCYONACEA			
			Muriceidae		
				Thesea sp B	2
MOLLUSCA					
	GASTROPODA				
		VETIGASTROPODA			
			Calliostomatidae		
				Calliostoma gloriosum	2
			Turbinidae		
				Megastraea turbanica	4
			Trochidae		
				Norrisia norrisi	1
		NEOTAENIOGLOSSA			
			Naticidae		
				Euspira lewisii	4
			Bursidae		
				Crossata californica	6
		NEOGASTROPODA			
			Muricidae		
				Ocinebrina foveolata	1
			Buccinidae		
				Kelletia kelletii	13
			Cancellariidae		
				Cancellaria crawfordiana	1
		CEPHALASPIDEA			
			Philinidae		
				Philine auriformis	49
		NUDIBRANCHIA			
			Onchidorididae		
				Acanthodoris brunnea	14
				Acanthodoris rhodoceras	2
			Polyceratidae		
				Triopha maculata	1
			Dendronotidae		
				Dendronotus iris	2
			Flabellinidae		
				Flabellina iodinea	1
				Flabellina pricei	1
		OCTOPODA			
			Octopodidae		
				Octopus rubescens	6

Appendix D.2 *continued*

Taxon/ Species	n
ANNELIDA	
POLYCHAETA	
PHYLLODOCIA	
Aphroditidae	
Aphrodita refulgida	1
Aphrodita sp	1
Nereididae	
Platynereis bicanaliculata	10
HIRUDINEA	3
ARTHROPODA	
MALACOSTRACA	
STOMATOPODA	
Hemisquillidae	
Hemisquilla californiensis	11
ISOPODA	
Cymothoidae	
Elthusa vulgaris	14
DECAPODA	
Penaeidae	
Farfantepenaeus californiensis	8
Sicyoniidae	
Sicyonia pencillata	1
Alpheidae	
Alpheus clamator	1
Hippolytidae	
Heptacarpus palpator	5
Crangonidae	
Crangon alaskensis	1
Crangon alba	2
Crangon nigromaculata	34
Diogenidae	
Paguristes bakeri	2
Paguridae	
Pagurus spilocarpus	5
Pylopagurus holmesi	1
Calappidae	
Platymera gaudichaudii	9
Leucosiidae	
Randallia ornata	5
Majidae	
Loxorhynchus grandis	4
Podochela hemphillii	6
Pugettia producta	4
Pyromaia tuberculata	13
Parthenopidae	
Heterocrypta occidentalis	16

Appendix D.2 *continued*

Taxon/ Species	n
Cancridae	
Cancer anthonyi	4
Cancer gracilis	34
Cancer sp	20
Pinnotheridae	
Pinnixa franciscana	1
ECHINODERMATA	
CRINOIDEA	
COMATULIDA	
Antedonidae	
Florometra serratissima	1
ASTEROIDEA	
PAXILLOSIDA	
Luidiidae	
Luidia armata	3
Luidia asthenosoma	1
Astropectinidae	
Astropecten verrilli	481
FORCIPULATIDA	
Asteriidae	
Pisaster brevispinus	20
OPHIUROIDEA	
OPHIURIDA	
Ophiotricidae	
Ophiothrix spiculata	10
ECHINOIDEA	
TEMNOPLEUROIDA	
Toxopneustidae	
Lytechinus pictus	19
CLYPEASTEROIDA	
Dendrasteridae	
Dendraster terminalis	5
CHORDATA	
ASCIDIACEA	1

*[SCAMIT] The Southern California Association of Marine Invertebrate Taxomists. (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.

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Appendix E

Supporting Data

2007 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 2007.

Station	Rep	Species	N	min L	max L	mean L	min WT	max WT	mean WT
April 2007									
RF3	1	Brown rockfish	3	20	27	24	189	529	396
RF3	2	Vermilion rockfish	3	17	23	19	111	256	168
RF3	3	Sebastes spp.	3	18	21	20	167	245	205
RF4	1	California scorpionfish	3	23	28	26	354	623	518
SD15	1	Hornyhead turbot	10	15	19	17	66	169	122
SD15	2	Pacific sanddab	7	16	24	18	55	260	95
SD16	1	Longfin sanddab	12	12	19	15	42	125	67
SD16	2	Hornyhead turbot	8	14	19	17	14	181	133
SD16	3	Hornyhead turbot	6	14	19	16	60	170	97
SD17	1	Longfin sanddab	9	15	19	16	46	116	77
SD17	2	Hornyhead turbot	8	16	20	18	89	207	149
SD17	3	English sole	7	17	24	21	80	210	145
SD18	1	English sole	13	16	24	19	63	219	99
SD18	2	Longfin sanddab	11	14	18	16	53	106	71
SD18	3	Pacific sanddab	13	13	20	16	32	105	65
SD19	1	Longfin sanddab	12	13	18	15	48	96	69
SD19	2	English sole	6	17	25	21	65	226	128
SD19	3	English sole	7	18	25	20	82	230	117
SD20	1	Hornyhead turbot	8	14	20	17	66	197	125
SD20	2	English sole	4	20	28	23	111	300	184
SD20	3	Longfin sanddab	11	14	16	15	50	84	65
SD21	1	English sole	11	17	20	18	64	127	88
SD21	2	English sole	8	18	25	21	74	183	112
SD21	3	Hornyhead turbot	9	13	21	132	65	290	132
October 2007									
RF3	1	Brown rockfish	3	22	22	22	262	279	270
RF3	2	Vermilion rockfish	3	30	31	30	636	842	752
RF3	3	Sebastes spp.	3	17	31	25	174	764	452
RF4	1	California scorpionfish	3	28	29	29	402	690	586
RF4	2	California scorpionfish	3	27	30	28	601	958	750
RF4	3	California scorpionfish	3	25	32	29	510	1180	872
SD15	1	Hornyhead turbot	7	12	19	17	42	148	107
SD16	1	Longfin sanddab	8	13	16	14	52	92	61
SD16	2	Longfin sanddab	6	14	18	16	58	134	77
SD16	3	Longfin sanddab	11	12	14	13	32	52	45
SD17	1	Longfin sanddab	7	12	18	14	36	121	60
SD17	2	Longfin sanddab	4	13	18	16	35	106	75
SD17	3	Hornyhead turbot	8	14	17	16	72	148	96

Appendix E.1 *continued*

Station	Rep	Species	N	min L	max L	mean L	min WT	max WT	mean WT
October 2007 *continued*									
SD18	1	Longfin sanddab	8	13	16	14	43	71	54
SD18	2	Longfin sanddab	8	12	17	14	39	90	57
SD18	3	Hornyhead turbot	6	15	20	18	91	201	131
SD19	1	Longfin sanddab	6	13	18	15	40	138	80
SD19	2	Hornyhead turbot	7	17	20	18	117	152	138
SD19	3	Longfin sanddab	8	13	17	14	45	90	57
SD20	1	Longfin sanddab	11	12	14	13	32	67	44
SD20	2	California scorpionfish	3	23	26	24	372	438	412
SD20	3	California scorpionfish	3	23	25	24	353	448	416
SD21	1	Longfin sanddab	8	13	15	14	42	65	54
SD21	2	Hornyhead turbot	5	15	20	18	81	232	151
SD21	3	Hornyhead turbot	4	15	21	19	75	256	172

Appendix E.2

Constituents and method detection limits (MDL) for fish tissue samples analyzed for the SBOO monitoring program during April and October 2007.

	MDL			MDL	
Parameter	**Liver**	**Muscle**	**Parameter**	**Liver**	**Muscle**
Metals (ppm)					
Aluminum	0.580	0.580	Lead	0.300	0.300
Antimony	0.480	0.480	Manganese	0.007	0.007
Arsenic	0.380	0.380	Mercury	0.030	0.030
Barium	0.007	0.007	Nickel	0.094	0.094
Beryllium	0.003	0.003	Selenium	0.060	0.060
Cadmium	0.029	0.029	Silver	0.057	0.057
Chromium	0.080	0.080	Thallium	0.850	0.850
Copper	0.068	0.068	Tin	0.240	0.240
Iron	0.096	0.096	Zinc	0.049	0.049
Chlorinated Pesticides (ppb)					
Aldrin	*	6.67	Hexachlorobenzene	13.30	1.33
Alpha (cis) Chlordane	13.30	2.00	Mirex	13.30	1.33
Alpha Endosulfan	167.00	33.00	o,p-DDD	13.30	1.33
BHC, Alpha isomer	33.30	2.00	o,p-DDE	13.30	1.33
BHC, Beta isomer	13.30	2.00	o,p-DDT	13.30	1.33
BHC, Delta isomer	20.00	2.00	Oxychlordane	66.70	6.67
BHC, Gamma isomer	167.00	3.33	p,p-DDD	13.30	1.33
Cis Nonachlor	20.00	3.33	p,p-DDE	13.30	1.33
Dieldrin	13.30	1.33	p,-p-DDMU	13.30	1.33
Endrin	13.30	1.33	p,p-DDT	13.30	1.33
Gamma (trans) Chlordane	20.00	2.00	Toxaphene	3333.00	333.00
Heptachlor	33.30	3.33	Trans Nonachlor	13.30	2.00
Heptachlor epoxide	100.00	6.67			
PCB Congeners (ppb)					
PCB 18	33.3	1.33	PCB 126	13.3	1.33
PCB 28	13.3	1.33	PCB 128	13.3	1.33
PCB 37	13.3	1.33	PCB 138	13.3	*
PCB 44	13.3	1.33	PCB 149	13.3	1.33
PCB 49	13.3	1.33	PCB 151	13.3	1.33
PCB 52	13.3	1.33	PCB 153/168	13.3	*
PCB 66	13.3	1.33	PCB 156	13.3	1.33
PCB 70	13.3	1.33	PCB 157	13.3	1.33
PCB 74	13.3	1.33	PCB 158	13.3	1.33
PCB 77	13.3	1.33	PCB 167	13.3	1.33
PCB 81	13.3	1.33	PCB 169	13.3	1.33
PCB 87	13.3	1.33	PCB 170	13.3	1.33
PCB 99	13.3	1.33	PCB 177	13.3	1.33
PCB 101	13.3	1.33	PCB 180	13.3	1.33
PCB 105	13.3	1.33	PCB 183	13.3	1.33
PCB 110	13.3	1.33	PCB 187	13.3	1.33
PCB 114	13.3	1.33	PCB 189	13.3	1.33
PCB 118	13.3	1.33	PCB 194	13.3	1.33
PCB 119	13.3	1.33	PCB 201	13.3	1.33
PCB 123	13.3	1.33	PCB 206	13.3	1.33

* no MDL available for this parameter

Appendix E.2 *continued*

Parameter	MDL Liver	MDL Muscle	Parameter	MDL Liver	MDL Muscle
Polycyclic Aromatic Hydrocarbons (PAH's, ppb)					
1-methylnaphthalene	100	30	Benzo[G,H,I]perylene	100	30
1-methylphenanthrene	100	30	Benzo[K]fluoranthene	100	30
2,3,5-trimethylnaphthalene	100	30	Biphenyl	100	30
2,6-dimethylnaphthalene	100	30	Chrysene	100	30
2-methylnaphthalene	100	30	Dibenzo(A,H)anthracene	100	30
3,4-benzo(B)fluoranthene	100	30	Fluoranthene	100	30
Acenaphthene	100	30	Fluorene	100	30
Acenaphthylene	100	30	Indeno(1,2,3-CD)pyrene	100	30
Anthracene	100	30	Naphthalene	100	30
Benzo[A]anthracene	100	30	Perylene	100	30
Benzo[A]pyrene	100	30	Phenanthrene	100	30
Benzo[e]pyrene	100	30	Pyrene	100	30

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 2007.

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	RF3	1	Brown rockfish	Muscle	BHC, Gamma isomer	1.4	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 105	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 110	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 118	0.2	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 128	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 138	0.2	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 149	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 153/168	0.4	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 170	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 180	0.2	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 183	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 187	0.2	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 49	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 52	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	PCB 99	0.1	µg/kg
2007-2	RF3	1	Brown rockfish	Muscle	p,p-DDE	3.0	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	BHC, Gamma isomer	1.4	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	PCB 101	0.1	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	PCB 118	0.1	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	PCB 138	0.1	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	PCB 149	0.1	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	PCB 153/168	0.2	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	PCB 180	0.1	µg/kg
2007-2	RF3	2	Vermilion rockfish	Muscle	p,p-DDE	1.6	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	BHC, Gamma isomer	1.1	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	PCB 105	0.1	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	PCB 138	0.1	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	PCB 149	0.1	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	PCB 153/168	0.3	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	PCB 180	0.1	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	PCB 187	0.1	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	PCB 99	0.1	µg/kg
2007-2	RF3	3	Mixed rockfish	Muscle	p,p-DDE	2.0	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	PCB 101	0.1	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	PCB 118	0.2	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	PCB 138	0.1	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	PCB 149	0.1	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	PCB 153/168	0.4	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	PCB 180	0.1	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	PCB 187	0.1	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	RF4	1	California scorpionfish	Muscle	p,-p-DDMU	0.1	µg/kg
2007-2	RF4	1	California scorpionfish	Muscle	p,p-DDE	3.8	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 101	2.6	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 105	0.9	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 118	2.8	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 138	4.7	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 149	1.4	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 151	0.9	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 153/168	11.0	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 158	0.6	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 170	1.7	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 180	5.2	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 183	1.9	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 187	5.2	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 194	1.7	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 201	2.1	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 206	0.7	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 66	0.5	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 70	0.3	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	PCB 99	2.2	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	o,p-DDE	1.0	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	p,-p-DDMU	3.3	µg/kg
2007-2	SD15	1	Hornyhead turbot	Liver	p,p-DDE	100.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 101	7.6	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 105	2.9	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 110	4.3	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 118	11.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 123	1.5	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 128	2.6	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 138	13.5	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 149	4.6	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 151	3.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 153/168	32.5	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 158	1.4	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 167	1.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 170	4.1	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 177	2.5	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 180	13.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 183	3.9	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 187	13.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 194	3.3	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD15	2	Pacific sanddab	Liver	PCB 201	3.8	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 206	1.5	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 49	1.4	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 52	2.3	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 66	1.8	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 70	1.5	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 74	1.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 87	1.8	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	PCB 99	6.9	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	Trans Nonachlor	4.4	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	o,p-DDE	7.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	p,-p-DDMU	19.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	p,p-DDD	5.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	p,p-DDE	290.0	µg/kg
2007-2	SD15	2	Pacific sanddab	Liver	p,p-DDT	5.2	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	Alpha (cis) Chlordane	4.8	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 101	13.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 105	10.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 110	8.3	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 118	39.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 123	5.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 128	12.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 138	64.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 149	12.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 151	8.7	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 153/168	110.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 158	4.7	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 167	4.1	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 170	19.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 177	9.5	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 180	50.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 183	14.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 187	46.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 189	1.4	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 194	14.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 201	16.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 206	7.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 28	1.4	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 49	2.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 52	4.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 66	5.2	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD16	1	Longfin sanddab	Liver	PCB 70	2.2	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 74	2.8	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 87	2.6	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	PCB 99	28.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	Trans Nonachlor	11.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	o,p-DDD	1.2	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	o,p-DDE	11.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	p,-p-DDMU	21.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	p,p-DDD	9.2	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	p,p-DDE	750.0	µg/kg
2007-2	SD16	1	Longfin sanddab	Liver	p,p-DDT	12.0	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 101	1.5	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 105	0.7	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 118	2.3	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 138	4.2	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 149	1.1	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 153/168	7.4	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 158	0.4	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 170	1.5	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 180	3.4	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 183	1.0	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 187	3.0	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 194	0.8	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 201	1.2	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	PCB 99	1.5	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	o,p-DDE	1.1	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	p,-p-DDMU	3.0	µg/kg
2007-2	SD16	2	Hornyhead turbot	Liver	p,p-DDE	88.0	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 101	1.6	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 105	0.8	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 118	2.5	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 138	4.2	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 149	1.2	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 151	0.4	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 153/168	8.7	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 158	0.4	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 170	1.6	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 180	4.5	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 183	1.4	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 187	3.3	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 194	0.9	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 201	1.6	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 206	0.8	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 52	0.5	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	PCB 99	1.5	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	o,p-DDE	1.2	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	p,-p-DDMU	3.3	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	p,p-DDD	2.3	µg/kg
2007-2	SD16	3	Hornyhead turbot	Liver	p,p-DDE	120.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	Alpha (cis) Chlordane	3.1	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 101	9.1	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 105	5.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 110	5.7	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 118	18.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 123	2.1	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 128	6.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 138	29.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 149	7.6	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 151	4.9	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 153/168	60.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 158	2.9	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 167	1.9	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 170	10.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 177	5.2	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 180	27.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 183	8.1	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 187	24.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 194	7.6	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 201	8.5	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 206	3.6	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 28	0.9	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 49	1.6	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 52	2.8	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 66	2.9	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 70	1.4	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 74	1.7	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	PCB 99	13.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	Trans Nonachlor	5.5	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	o,p-DDE	7.2	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	p,-p-DDMU	17.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	p,p-DDD	5.8	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	p,p-DDE	470.0	µg/kg
2007-2	SD17	1	Longfin sanddab	Liver	p,p-DDT	4.9	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 101	2.1	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 105	1.1	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 110	0.9	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 118	3.7	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 128	1.0	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 138	7.0	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 149	1.6	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 153/168	11.0	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 158	0.8	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 170	2.5	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 177	0.7	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 180	6.6	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 183	1.8	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 187	4.4	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 194	1.6	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 201	2.2	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 206	0.9	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 49	0.6	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 52	0.7	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 66	0.6	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	PCB 99	2.8	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	o,p-DDE	1.4	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	p,-p-DDMU	4.6	µg/kg
2007-2	SD17	2	Hornyhead turbot	Liver	p,p-DDE	140.0	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 101	4.3	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 105	1.4	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 110	2.1	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 118	5.2	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 138	6.9	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 149	4.5	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 151	1.6	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 153/168	12.0	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 158	0.7	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 170	2.0	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 177	1.8	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 180	6.4	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 183	2.2	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 187	6.6	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 194	1.8	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 201	2.5	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 206	0.9	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 49	0.8	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 52	0.9	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD17	3	English sole	Liver	PCB 66	1.0	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 70	0.7	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 74	0.5	µg/kg
2007-2	SD17	3	English sole	Liver	PCB 99	3.7	µg/kg
2007-2	SD17	3	English sole	Liver	o,p-DDE	2.0	µg/kg
2007-2	SD17	3	English sole	Liver	p,-p-DDMU	2.3	µg/kg
2007-2	SD17	3	English sole	Liver	p,p-DDE	100.0	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 101	4.4	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 105	1.8	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 110	2.8	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 118	6.2	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 123	1.1	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 128	1.5	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 138	9.5	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 149	4.3	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 153/168	16.0	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 158	1.2	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 167	0.6	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 170	2.9	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 177	1.8	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 180	6.4	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 183	2.5	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 187	7.0	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 194	2.1	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 201	2.7	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 206	0.8	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 49	1.2	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 52	0.9	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 66	2.3	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 70	1.3	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 74	1.3	µg/kg
2007-2	SD18	1	English sole	Liver	PCB 99	4.8	µg/kg
2007-2	SD18	1	English sole	Liver	o,p-DDE	3.9	µg/kg
2007-2	SD18	1	English sole	Liver	p,-p-DDMU	6.3	µg/kg
2007-2	SD18	1	English sole	Liver	p,p-DDD	2.6	µg/kg
2007-2	SD18	1	English sole	Liver	p,p-DDE	140.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	Alpha (cis) Chlordane	4.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 101	11.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 105	8.7	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 110	8.4	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 118	32.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 123	3.5	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD18	2	Longfin sanddab	Liver	PCB 128	8.9	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 138	51.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 149	9.9	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 151	7.2	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 153/168	84.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 158	3.8	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 167	3.4	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 170	14.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 177	7.6	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 180	40.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 183	10.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 187	38.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 194	11.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 201	13.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 206	4.7	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 28	1.5	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 49	1.9	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 52	3.7	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 66	4.1	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 70	1.9	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 74	2.9	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	PCB 99	22.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	Trans Nonachlor	6.5	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	o,p-DDD	1.7	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	o,p-DDE	8.9	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	p,-p-DDMU	18.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	p,p-DDD	7.8	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	p,p-DDE	580.0	µg/kg
2007-2	SD18	2	Longfin sanddab	Liver	p,p-DDT	8.2	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	Alpha (cis) Chlordane	4.8	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 101	7.0	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 105	4.3	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 110	4.8	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 118	15.5	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 123	2.0	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 128	4.5	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 138	25.5	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 149	5.0	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 151	3.8	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 153/168	47.5	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 158	2.4	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 167	1.5	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD18	3	Pacific sanddab	Liver	PCB 170	7.1	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 177	3.3	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 180	19.5	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 183	5.6	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 187	17.0	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 194	4.6	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 201	5.9	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 206	2.3	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 49	1.6	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 52	2.3	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 66	2.1	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 70	1.3	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 74	1.5	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	PCB 99	11.0	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	Trans Nonachlor	7.7	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	o,p-DDE	5.1	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	p,-p-DDMU	16.5	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	p,p-DDD	4.9	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	p,p-DDE	520.0	µg/kg
2007-2	SD18	3	Pacific sanddab	Liver	p,p-DDT	6.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	Alpha (cis) Chlordane	4.8	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 101	14.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 105	12.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 110	10.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 118	47.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 123	4.2	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 128	12.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 138	64.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 149	11.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 151	9.7	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 153/168	110.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 156	7.1	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 157	1.9	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 158	6.5	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 167	4.2	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 170	16.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 177	8.5	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 180	50.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 183	14.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 187	43.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 194	11.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 201	15.0	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD19	1	Longfin sanddab	Liver	PCB 206	4.9	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 49	2.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 52	4.8	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 66	4.8	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 70	1.3	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 74	3.3	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 87	2.7	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	PCB 99	31.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	Trans Nonachlor	10.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	o,p-DDE	13.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	p,-p-DDMU	25.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	p,p-DDD	12.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	p,p-DDE	1000.0	µg/kg
2007-2	SD19	1	Longfin sanddab	Liver	p,p-DDT	9.0	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 101	6.8	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 105	2.7	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 110	3.9	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 118	9.4	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 128	2.3	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 138	12.0	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 149	6.5	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 151	2.0	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 153/168	18.0	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 158	1.0	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 167	0.9	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 170	2.4	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 177	2.1	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 180	6.8	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 183	2.4	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 187	7.2	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 194	1.6	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 201	2.4	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 49	2.4	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 52	1.8	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 66	3.3	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 70	2.1	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 74	1.6	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 87	2.0	µg/kg
2007-2	SD19	2	English sole	Liver	PCB 99	6.4	µg/kg
2007-2	SD19	2	English sole	Liver	o,p-DDE	17.0	µg/kg
2007-2	SD19	2	English sole	Liver	p,-p-DDMU	48.0	µg/kg
2007-2	SD19	2	English sole	Liver	p,p-DDD	7.2	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD19	2	English sole	Liver	p,p-DDE	310.0	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 101	4.6	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 105	2.0	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 110	2.6	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 118	6.1	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 128	1.7	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 138	8.9	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 149	4.9	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 151	2.3	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 153/168	16.0	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 158	1.0	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 167	0.9	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 170	2.6	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 177	2.2	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 180	6.4	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 183	2.4	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 187	7.3	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 194	1.6	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 201	1.9	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 49	1.0	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 52	1.0	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 66	1.5	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 70	1.1	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 74	1.0	µg/kg
2007-2	SD19	3	English sole	Liver	PCB 99	4.6	µg/kg
2007-2	SD19	3	English sole	Liver	o,p-DDE	4.2	µg/kg
2007-2	SD19	3	English sole	Liver	p,-p-DDMU	5.6	µg/kg
2007-2	SD19	3	English sole	Liver	p,p-DDD	3.2	µg/kg
2007-2	SD19	3	English sole	Liver	p,p-DDE	150.0	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 105	0.8	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 118	2.5	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 128	1.0	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 138	4.2	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 149	1.5	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 151	0.6	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 153/168	9.3	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 158	0.8	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 170	1.6	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 180	3.6	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 183	1.4	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 187	3.8	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 194	0.9	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 201	1.3	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 206	0.4	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 52	0.5	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 66	0.7	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	PCB 99	2.0	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	o,p-DDE	1.5	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	p,-p-DDMU	3.5	µg/kg
2007-2	SD20	1	Hornyhead turbot	Liver	p,p-DDE	76.0	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 101	3.4	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 105	1.4	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 110	2.5	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 118	4.8	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 138	6.1	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 149	3.1	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 151	1.0	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 153/168	9.9	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 158	0.6	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 170	1.4	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 177	1.5	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 180	3.6	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 183	0.7	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 187	4.1	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 194	1.1	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 201	1.2	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 49	1.1	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 52	0.9	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 66	1.0	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 70	1.0	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 74	0.5	µg/kg
2007-2	SD20	2	English sole	Liver	PCB 99	3.3	µg/kg
2007-2	SD20	2	English sole	Liver	o,p-DDE	2.1	µg/kg
2007-2	SD20	2	English sole	Liver	p,-p-DDMU	2.2	µg/kg
2007-2	SD20	2	English sole	Liver	p,p-DDE	69.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	Alpha (cis) Chlordane	4.8	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 101	18.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 105	12.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 110	12.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 118	43.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 123	4.5	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 128	13.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 138	66.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 149	14.0	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD20	3	Longfin sanddab	Liver	PCB 151	9.9	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 153/168	110.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 156	6.7	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 157	1.9	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 158	6.6	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 167	4.2	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 169	3.9	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 170	18.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 177	9.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 180	48.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 183	14.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 187	42.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 194	13.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 201	15.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 206	5.7	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 28	1.4	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 49	2.7	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 52	6.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 66	5.3	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 70	1.8	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 74	3.4	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 87	3.4	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	PCB 99	31.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	Trans Nonachlor	5.6	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	o,p-DDE	11.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	p,-p-DDMU	22.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	p,p-DDD	12.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	p,p-DDE	690.0	µg/kg
2007-2	SD20	3	Longfin sanddab	Liver	p,p-DDT	7.1	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 101	11.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 105	4.1	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 110	7.1	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 118	15.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 119	0.9	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 123	1.4	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 128	3.2	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 138	20.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 149	11.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 151	4.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 153/168	30.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 158	1.9	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 167	1.4	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD21	1	English sole	Liver	PCB 170	4.7	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 177	4.3	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 180	11.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 183	3.6	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 187	14.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 194	4.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 201	5.8	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 206	1.8	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 28	1.2	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 49	2.9	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 52	2.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 66	4.6	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 70	2.5	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 74	2.0	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 87	2.4	µg/kg
2007-2	SD21	1	English sole	Liver	PCB 99	10.0	µg/kg
2007-2	SD21	1	English sole	Liver	o,p-DDE	23.0	µg/kg
2007-2	SD21	1	English sole	Liver	p,-p-DDMU	39.0	µg/kg
2007-2	SD21	1	English sole	Liver	p,p-DDD	9.3	µg/kg
2007-2	SD21	1	English sole	Liver	p,p-DDE	560.0	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 101	4.2	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 105	1.7	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 110	2.4	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 118	5.3	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 128	1.7	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 138	7.4	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 149	4.7	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 151	1.3	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 153/168	14.0	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 158	1.0	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 167	0.7	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 170	2.6	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 177	1.5	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 180	5.4	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 183	1.8	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 187	6.5	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 194	2.0	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 201	2.4	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 206	1.3	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 49	1.4	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 66	1.4	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 70	0.8	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-2	SD21	2	English sole	Liver	PCB 74	0.6	µg/kg
2007-2	SD21	2	English sole	Liver	PCB 99	4.1	µg/kg
2007-2	SD21	2	English sole	Liver	o,p-DDE	1.5	µg/kg
2007-2	SD21	2	English sole	Liver	p,-p-DDMU	2.1	µg/kg
2007-2	SD21	2	English sole	Liver	p,p-DDD	1.8	µg/kg
2007-2	SD21	2	English sole	Liver	p,p-DDE	58.0	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 101	2.2	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 105	1.4	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 110	1.4	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 118	5.0	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 128	1.4	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 138	11.0	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 149	2.2	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 151	0.8	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 153/168	15.0	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 158	0.8	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 170	2.9	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 177	0.9	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 180	6.1	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 183	2.6	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 187	6.4	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 194	1.8	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 201	1.6	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 206	0.9	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 49	1.1	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 52	0.9	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 66	1.1	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 70	0.5	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 74	0.4	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	PCB 99	3.2	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	o,p-DDE	1.5	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	p,-p-DDMU	2.2	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	p,p-DDD	3.0	µg/kg
2007-2	SD21	3	Hornyhead turbot	Liver	p,p-DDE	68.0	µg/kg
2007-4	RF3	1	Brown rockfish	Muscle	BHC, Gamma isomer	0.5	µg/kg
2007-4	RF3	1	Brown rockfish	Muscle	PCB 138	0.1	µg/kg
2007-4	RF3	1	Brown rockfish	Muscle	PCB 153/168	0.1	µg/kg
2007-4	RF3	1	Brown rockfish	Muscle	p,p-DDE	1.2	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 105	0.1	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 110	0.1	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 118	0.1	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 138	0.2	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 149	0.1	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 153/168	0.3	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 180	0.1	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	PCB 187	0.1	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	p,p-DDD	0.3	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	p,p-DDE	3.0	µg/kg
2007-4	RF3	2	Vermilion rockfish	Muscle	p,p-DDT	0.4	µg/kg
2007-4	RF3	3	Mixed rockfish	Muscle	BHC, Beta isomer	0.4	µg/kg
2007-4	RF3	3	Mixed rockfish	Muscle	BHC, Gamma isomer	0.5	µg/kg
2007-4	RF3	3	Mixed rockfish	Muscle	PCB 138	0.1	µg/kg
2007-4	RF3	3	Mixed rockfish	Muscle	PCB 153/168	0.1	µg/kg
2007-4	RF3	3	Mixed rockfish	Muscle	p,p-DDE	1.2	µg/kg
2007-4	RF4	1	California scorpionfish	Muscle	PCB 138	0.1	µg/kg
2007-4	RF4	1	California scorpionfish	Muscle	PCB 153/168	0.2	µg/kg
2007-4	RF4	1	California scorpionfish	Muscle	p,p-DDE	2.2	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	Alpha (cis) Chlordane	0.4	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 101	0.6	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 105	0.2	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 110	0.2	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 118	0.7	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 138	0.7	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 149	0.3	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 151	0.2	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 153/168	1.3	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 170	0.2	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 180	0.4	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 183	0.1	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 187	0.5	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 194	0.1	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 49	0.1	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 52	0.2	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 66	0.1	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 70	0.1	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 74	0.1	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	PCB 99	0.4	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	Trans Nonachlor	0.6	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	o,p-DDE	0.1	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	p,-p-DDMU	0.8	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	p,p-DDD	0.5	µg/kg
2007-4	RF4	2	California scorpionfish	Muscle	p,p-DDE	18.0	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 101	0.2	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 105	0.2	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	RF4	3	California scorpionfish	Muscle	PCB 110	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 118	0.5	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 138	0.6	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 149	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 151	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 153/168	1.2	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 170	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 180	0.3	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 183	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 187	0.5	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 194	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 52	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 66	0.1	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	PCB 99	0.3	µg/kg
2007-4	RF4	3	California scorpionfish	Muscle	p,p-DDE	7.4	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 101	1.7	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 118	1.6	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 138	3.0	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 149	0.7	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 153/168	5.3	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 180	2.2	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 183	1.1	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 187	2.8	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 201	1.2	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	PCB 99	1.6	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	p,-p-DDMU	2.1	µg/kg
2007-4	SD15	1	Hornyhead turbot	Liver	p,p-DDE	55.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 101	6.9	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 105	5.2	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 110	3.9	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 118	20.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 123	2.8	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 128	7.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 138	39.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 149	7.7	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 151	5.5	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 153/168	60.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 156	3.5	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 158	2.5	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 170	11.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 177	5.7	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 180	27.0	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD16	1	Longfin sanddab	Liver	PCB 183	8.1	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 187	30.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 194	7.6	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 201	10.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 206	3.4	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 28	0.9	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 49	1.4	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 52	2.3	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 66	3.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 70	1.3	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 74	1.8	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	PCB 99	14.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	Trans Nonachlor	5.9	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	o,p-DDE	7.4	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	p,-p-DDMU	17.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	p,p-DDD	8.3	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	p,p-DDE	650.0	µg/kg
2007-4	SD16	1	Longfin sanddab	Liver	p,p-DDT	7.2	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	Alpha (cis) Chlordane	3.7	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 101	8.8	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 105	6.5	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 110	5.2	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 118	24.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 123	3.1	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 128	8.2	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 138	47.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 149	9.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 151	6.5	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 153/168	72.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 156	4.1	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 158	2.8	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 170	13.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 177	6.3	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 180	29.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 183	8.8	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 187	32.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 189	1.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 194	8.5	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 201	11.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 206	4.2	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 49	1.7	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 52	2.6	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD16	2	Longfin sanddab	Liver	PCB 66	3.7	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 70	1.4	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 74	2.2	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 87	2.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	PCB 99	17.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	Trans Nonachlor	6.4	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	o,p-DDE	7.9	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	p,-p-DDMU	16.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	p,p-DDD	8.4	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	p,p-DDE	530.0	µg/kg
2007-4	SD16	2	Longfin sanddab	Liver	p,p-DDT	7.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 101	6.4	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 105	4.2	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 110	2.8	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 118	15.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 123	1.9	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 128	4.1	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 138	19.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 149	6.2	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 151	3.3	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 153/168	32.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 156	2.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 158	1.1	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 170	7.2	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 177	4.7	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 180	15.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 183	4.3	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 187	20.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 194	4.1	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 201	5.6	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 206	1.8	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 28	1.2	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 49	1.3	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 52	2.3	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 66	2.9	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 70	1.1	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 74	1.4	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	PCB 99	9.9	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	Trans Nonachlor	4.5	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	o,p-DDE	6.5	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	p,-p-DDMU	16.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	p,p-DDD	7.1	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD16	3	Longfin sanddab	Liver	p,p-DDE	390.0	µg/kg
2007-4	SD16	3	Longfin sanddab	Liver	p,p-DDT	6.8	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 101	5.1	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 105	2.9	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 110	3.1	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 118	11.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 128	3.6	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 138	18.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 149	5.6	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 151	2.7	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 153/168	29.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 158	1.4	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 170	4.9	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 177	3.2	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 180	13.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 183	3.3	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 187	16.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 194	2.9	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 201	4.4	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 206	1.6	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 28	1.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 49	1.2	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 52	2.1	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 66	2.3	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 70	1.1	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 74	1.3	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	PCB 99	8.1	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	o,p-DDE	5.9	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	p,-p-DDMU	14.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	p,p-DDD	6.7	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	p,p-DDE	310.0	µg/kg
2007-4	SD17	1	Longfin sanddab	Liver	p,p-DDT	3.8	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 101	6.3	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 105	2.7	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 110	2.8	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 118	11.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 123	1.4	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 128	3.3	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 138	18.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 149	5.5	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 151	3.1	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 153/168	29.0	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD17	2	Longfin sanddab	Liver	PCB 158	1.2	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 170	4.9	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 177	3.2	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 180	11.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 183	3.6	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 187	16.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 194	3.6	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 201	4.5	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 206	1.8	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 28	1.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 49	1.4	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 52	1.8	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 66	2.1	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 70	1.2	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 74	0.9	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	PCB 99	8.4	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	Trans Nonachlor	2.8	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	o,p-DDE	7.1	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	p,-p-DDMU	16.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	p,p-DDD	6.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	p,p-DDE	350.0	µg/kg
2007-4	SD17	2	Longfin sanddab	Liver	p,p-DDT	4.9	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 101	1.8	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 105	0.7	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 118	2.4	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 138	5.5	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 149	1.1	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 151	0.6	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 153/168	6.1	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 170	1.2	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 180	3.6	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 183	1.2	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 187	3.1	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 194	1.2	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 206	0.7	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 49	0.6	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 52	0.7	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	PCB 99	2.1	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	o,p-DDE	1.2	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	p,-p-DDMU	4.2	µg/kg
2007-4	SD17	3	Hornyhead turbot	Liver	p,p-DDE	87.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	Alpha (cis) Chlordane	3.9	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD18	1	Longfin sanddab	Liver	PCB 101	6.6	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 105	3.9	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 110	3.5	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 118	15.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 123	1.7	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 128	4.7	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 138	26.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 149	7.1	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 151	4.6	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 153/168	40.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 158	1.6	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 170	7.7	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 177	4.7	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 180	18.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 183	5.7	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 187	22.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 194	6.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 201	7.4	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 206	2.3	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 28	1.2	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 49	1.6	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 52	2.4	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 66	2.6	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 70	1.5	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 74	1.6	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	PCB 99	10.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	Trans Nonachlor	4.5	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	o,p-DDD	1.8	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	o,p-DDE	8.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	p,-p-DDMU	17.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	p,p-DDD	9.4	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	p,p-DDE	540.0	µg/kg
2007-4	SD18	1	Longfin sanddab	Liver	p,p-DDT	6.5	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	Alpha (cis) Chlordane	4.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 101	8.8	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 105	7.4	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 110	5.3	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 118	34.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 123	2.9	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 128	8.5	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 138	50.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 149	9.0	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD18	2	Longfin sanddab	Liver	PCB 151	7.3	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 153/168	77.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 158	3.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 170	12.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 177	6.6	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 180	28.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 183	8.7	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 187	30.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 194	7.4	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 201	8.9	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 206	3.1	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 28	1.5	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 49	1.8	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 52	3.2	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 66	3.1	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 70	1.4	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 74	2.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	PCB 99	22.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	Trans Nonachlor	5.4	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	o,p-DDD	2.2	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	o,p-DDE	8.9	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	p,-p-DDMU	20.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	p,p-DDD	11.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	p,p-DDE	620.0	µg/kg
2007-4	SD18	2	Longfin sanddab	Liver	p,p-DDT	6.1	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 118	3.0	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 138	3.6	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 149	1.0	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 153/168	5.8	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 170	1.5	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 180	3.4	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 183	1.4	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 187	3.3	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 194	1.2	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 201	1.4	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 49	0.5	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 52	0.6	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	PCB 99	1.8	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	o,p-DDE	1.2	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	p,-p-DDMU	3.8	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	p,p-DDD	1.6	µg/kg
2007-4	SD18	3	Hornyhead turbot	Liver	p,p-DDE	85.5	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD19	1	Longfin sanddab	Liver	PCB 101	4.5	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 105	3.1	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 110	2.5	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 118	12.0	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 123	1.7	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 128	3.6	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 138	18.0	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 149	5.2	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 151	3.1	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 153/168	32.0	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 158	1.4	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 170	5.2	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 177	3.5	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 180	12.0	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 183	3.7	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 187	17.0	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 194	3.7	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 201	4.9	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 206	1.8	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 28	0.8	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 37	0.6	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 49	1.3	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 52	1.7	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 66	2.4	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 70	1.3	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 74	1.5	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 77	1.5	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 81	1.2	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	PCB 99	8.8	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	Trans Nonachlor	3.7	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	o,p-DDE	5.4	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	p,-p-DDMU	12.0	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	p,p-DDD	5.3	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	p,p-DDE	370.0	µg/kg
2007-4	SD19	1	Longfin sanddab	Liver	p,p-DDT	4.0	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 101	2.2	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 105	1.0	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 118	2.9	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 138	4.8	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 149	1.6	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 153/168	7.5	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 170	1.9	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 180	3.5	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 183	1.1	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 187	4.1	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 194	1.5	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 66	1.0	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	PCB 99	2.4	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	o,p-DDE	2.1	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	p,-p-DDMU	6.2	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	p,p-DDD	5.2	µg/kg
2007-4	SD19	2	Hornyhead turbot	Liver	p,p-DDE	130.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	Alpha (cis) Chlordane	3.9	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 101	8.7	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 105	4.3	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 110	4.5	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 118	17.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 123	2.1	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 128	5.1	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 138	28.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 149	7.1	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 151	4.9	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 153/168	44.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 158	2.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 170	8.4	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 177	5.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 180	18.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 183	5.3	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 187	20.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 194	5.9	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 201	7.4	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 206	2.7	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 28	1.4	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 49	2.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 52	2.4	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 66	3.1	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 70	1.4	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 74	1.4	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	PCB 99	12.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	o,p-DDE	5.9	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	p,-p-DDMU	14.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	p,p-DDD	8.5	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	p,p-DDE	470.0	µg/kg
2007-4	SD19	3	Longfin sanddab	Liver	p,p-DDT	4.5	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD20	1	Longfin sanddab	Liver	Alpha (cis) Chlordane	4.3	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 101	10.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 105	8.4	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 110	5.3	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 118	32.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 123	2.7	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 128	9.6	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 138	46.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 149	11.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 151	7.2	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 153/168	85.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 156	4.4	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 158	3.7	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 170	14.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 177	7.8	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 180	30.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 183	8.5	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 187	38.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 194	2.2	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 201	12.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 206	3.3	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 28	1.8	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 49	2.2	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 52	2.6	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 66	3.4	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 70	1.4	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 74	2.2	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	PCB 99	19.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	Trans Nonachlor	7.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	o,p-DDD	1.8	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	o,p-DDE	8.4	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	p,-p-DDMU	22.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	p,p-DDD	11.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	p,p-DDE	850.0	µg/kg
2007-4	SD20	1	Longfin sanddab	Liver	p,p-DDT	7.0	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	Alpha (cis) Chlordane	4.2	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 101	10.0	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 105	4.2	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 110	4.7	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 118	16.0	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 128	4.1	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 138	24.0	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD20	2	California scorpionfish	Liver	PCB 149	5.7	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 151	4.2	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 153/168	40.0	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 158	1.8	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 170	6.2	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 177	4.3	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 180	17.0	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 183	5.1	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 187	17.0	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 194	3.9	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 201	5.4	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 206	1.5	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 49	1.9	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 52	2.6	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 66	2.5	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 70	0.8	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 74	1.4	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 87	2.5	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	PCB 99	9.4	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	Trans Nonachlor	7.5	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	p,-p-DDMU	6.9	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	p,p-DDD	7.2	µg/kg
2007-4	SD20	2	California scorpionfish	Liver	p,p-DDE	430.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 101	13.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 105	6.6	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 110	6.3	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 118	26.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 123	2.9	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 128	6.5	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 138	35.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 149	7.6	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 151	5.1	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 153/168	59.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 158	3.2	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 170	7.2	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 177	5.1	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 180	18.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 183	5.6	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 187	22.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 194	4.3	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 201	6.4	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 206	1.8	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD20	3	California scorpionfish	Liver	PCB 49	2.6	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 52	3.5	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 66	4.3	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 70	1.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 74	1.9	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 87	3.1	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	PCB 99	15.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	Trans Nonachlor	6.7	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	p,-p-DDMU	8.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	p,p-DDD	6.1	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	p,p-DDE	470.0	µg/kg
2007-4	SD20	3	California scorpionfish	Liver	p,p-DDT	3.6	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	Alpha (cis) Chlordane	4.7	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 101	17.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 105	10.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 110	7.8	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 118	38.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 119	1.3	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 123	5.1	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 128	12.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 138	65.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 149	15.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 151	9.4	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 153/168	98.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 156	5.4	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 158	4.7	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 170	17.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 177	9.4	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 180	35.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 183	11.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 187	47.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 189	1.1	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 194	12.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 201	15.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 206	5.4	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 28	3.3	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 49	4.3	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 52	5.4	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 66	7.3	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 70	2.3	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 74	3.5	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	PCB 87	2.5	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD21	1	Longfin sanddab	Liver	PCB 99	29.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	Trans Nonachlor	4.6	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	o,p-DDD	2.1	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	o,p-DDE	9.4	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	p,-p-DDMU	18.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	p,p-DDD	12.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	p,p-DDE	520.0	µg/kg
2007-4	SD21	1	Longfin sanddab	Liver	p,p-DDT	7.3	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 101	2.0	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 105	0.9	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 118	3.7	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 138	5.6	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 149	1.5	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 153/168	9.2	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 170	1.4	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 180	3.8	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 183	1.1	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 187	4.8	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 194	1.3	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 201	1.2	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 206	0.8	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 49	0.8	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 52	0.7	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 66	0.7	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	PCB 99	2.1	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	o,p-DDE	1.2	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	p,-p-DDMU	2.2	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	p,p-DDD	1.3	µg/kg
2007-4	SD21	2	Hornyhead turbot	Liver	p,p-DDE	55.0	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 101	3.0	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 105	1.8	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 110	1.4	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 118	6.1	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 138	12.0	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 149	2.8	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 153/168	16.5	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 158	0.8	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 170	3.3	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 180	6.8	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 183	2.3	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 187	9.1	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 194	2.5	µg/kg

Appendix E.3 *continued*

YR-QTR	Station	Rep	Species	Tissue	Parameter	Value	Units
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 201	2.4	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 206	1.3	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 28	0.8	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 49	1.1	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 52	1.1	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 66	1.4	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 70	0.5	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 74	0.8	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	PCB 99	4.3	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	o,p-DDE	1.8	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	p,-p-DDMU	5.0	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	p,p-DDD	3.3	µg/kg
2007-4	SD21	3	Hornyhead turbot	Liver	p,p-DDE	94.5	µg/kg

Appendix F

Supporting Data

2007 Regional Stations

Sediment Characteristics

Appendix F.2

Particle size statistics from randomly selected regional stations July 1997. Stations 2164 and 2166 from the 2007 regional survey are missing from this list because they were not sampled in 1997.

Station	Depth (m)	Mean (mm)	Mean (phi)	SD (phi)	Median (phi)	Skewness (phi)	Kurtosis (phi)	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Fines (%)
2153	13	0.134	2.9	0.6	2.9	-0.1	2.3	0.0	95.1	4.6	0.3	4.9
2146	14	0.268	1.9	0.7	1.9	0.0	1.0	0.0	99.0	1.0	0.0	1.0
2163	15	0.125	3.0	0.7	2.9	0.3	1.3	0.0	92.9	6.6	0.4	7.0
2158	16	0.250	2.0	0.6	2.0	0.0	1.0	0.0	99.4	0.6	0.0	0.6
2046	21	0.134	2.9	0.5	2.9	0.2	2.6	0.0	93.4	6.3	0.3	6.6
2167	25	0.095	3.4	0.8	3.3	0.3	1.8	0.0	85.3	13.7	0.9	14.6
2160	26	0.102	3.3	1.1	3.1	0.4	2.0	0.0	81.2	17.4	1.3	18.7
2171	29	0.165	2.6	1.1	2.6	0.0	1.1	0.0	91.9	7.7	0.4	8.1
2141	36	0.102	3.3	0.8	3.0	0.9	2.2	0.0	86.5	12.4	1.1	13.5
2156	36	0.500	1.0	0.7	1.3	-0.5	1.8	16.6	83.4	0.0	0.0	0.0
2014	37	0.082	3.6	0.7	3.6	0.3	2.7	0.0	86.5	12.3	1.2	13.5
2140	38	0.088	3.5	0.7	3.5	0.3	2.4	0.0	91.5	7.4	1.1	8.5
2170	42	0.379	1.4	0.3	1.4	0.0	1.0	0.0	99.2	0.0	0.0	0.0
2165	44	0.067	3.9	1.5	3.7	0.3	1.2	0.0	60.2	36.9	2.9	39.8
2169	50	0.308	1.7	0.5	1.8	-0.7	5.4	5.0	95.0	0.0	0.0	0.0
2038	52	0.058	4.1	1.4	3.7	0.5	1.4	0.0	61.0	35.7	3.3	39.0
2143	57	0.058	4.1	1.5	3.6	0.5	1.4	0.0	63.4	33.1	3.4	36.5
2149	63	0.051	4.3	1.3	4.0	0.4	1.7	0.0	47.2	49.4	3.4	52.8
2021	66	0.047	4.4	1.6	3.9	0.5	1.1	0.0	53.2	42.2	4.6	46.8
2031	72	0.047	4.4	1.4	4.0	0.5	1.3	0.0	50.1	46.1	3.8	49.9
2150	82	0.047	4.4	1.5	4.0	0.4	1.2	0.0	48.9	47.2	3.8	51.0
2152	82	0.041	4.6	1.2	4.1	0.7	1.9	0.0	30.6	65.6	3.7	69.3
2148	84	0.041	4.6	1.4	4.3	0.4	1.2	0.0	39.0	57.0	4.0	61.0
2154	88	0.054	4.2	1.4	3.9	0.5	1.5	0.0	55.8	41.0	3.2	44.2
2168	88	0.072	3.8	1.6	3.2	0.6	1.4	0.0	70.0	26.7	3.2	29.9
2023	89	0.044	4.5	1.8	4.0	0.4	1.0	0.0	48.7	46.5	4.8	51.3
2161	89	0.067	3.9	1.7	3.4	0.4	1.2	0.0	64.5	32.0	3.5	35.5
2144	94	0.047	4.4	1.5	4.0	0.4	1.3	0.0	48.4	47.9	3.7	51.6
2142	96	0.063	4.0	1.1	3.7	0.5	2.2	0.0	67.4	30.2	2.4	32.6
2145	117	0.058	4.1	1.8	3.5	0.5	1.3	0.0	62.9	32.3	4.8	37.1
2162	130	0.063	4.0	2.3	3.4	0.4	0.8	0.0	58.7	35.0	6.3	41.3
2159	161	0.041	4.6	2.1	4.3	0.2	0.9	0.0	45.9	47.3	6.8	54.1
2043	166	0.574	0.8	0.2	0.8	0.1	1.1	0.0	100.0	0.0	0.0	0.0
2151	178	0.036	4.8	1.6	4.3	0.5	1.0	0.0	38.9	55.8	5.3	61.1
2157	187	0.024	5.4	1.6	5.1	0.3	0.8	0.0	22.4	70.0	7.6	77.6
2028	189	0.033	4.9	1.5	4.4	0.5	0.9	0.0	34.5	60.2	5.3	65.5
2147	194	0.054	4.2	1.8	3.5	0.5	1.2	0.0	61.8	32.8	5.4	38.2