Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall
(South Bay Water Reclamation Plant)
2005

City of San Diego
Ocean Monitoring Program

Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

THE CITY OF SAN DIEGO

July 1, 2006

Mr. John Robertus
Executive Officer
Regional Water Quality Control Board
San Diego Region
9174 Sky Park Court, Suite 100
San Diego, CA 92123

Attention: POTW Compliance Unit

Dear Sir:

Enclosed is the 2005 Annual Receiving Waters Monitoring Report for NPDES Permit No. CA0109045, Order No. 2000-129, for the City of San Diego South Bay Water Reclamation Plant (SBWRP) discharge through the South Bay Ocean Outfall. This report contains data summaries and statistical analyses for the various portions of the ocean monitoring program, including oceanographic conditions, microbiology, sediment characteristics, macrobenthic communities, demersal fishes and megabenthic invertebrates, and bioaccumulation of contaminants in fish tissues. These data are also presented in the International Boundary and Water Commission's annual report for discharge from the International Wastewater Treatment Plant (NPDES Permit No. CA0108928, Order No. 96-50).

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

Sincerely,

ALAN C. LANGWORTHY
Deputy Metropolitan Wastewater Director

DP/dp

Enclosure

cc: Department of Environmental Health, County of San Diego
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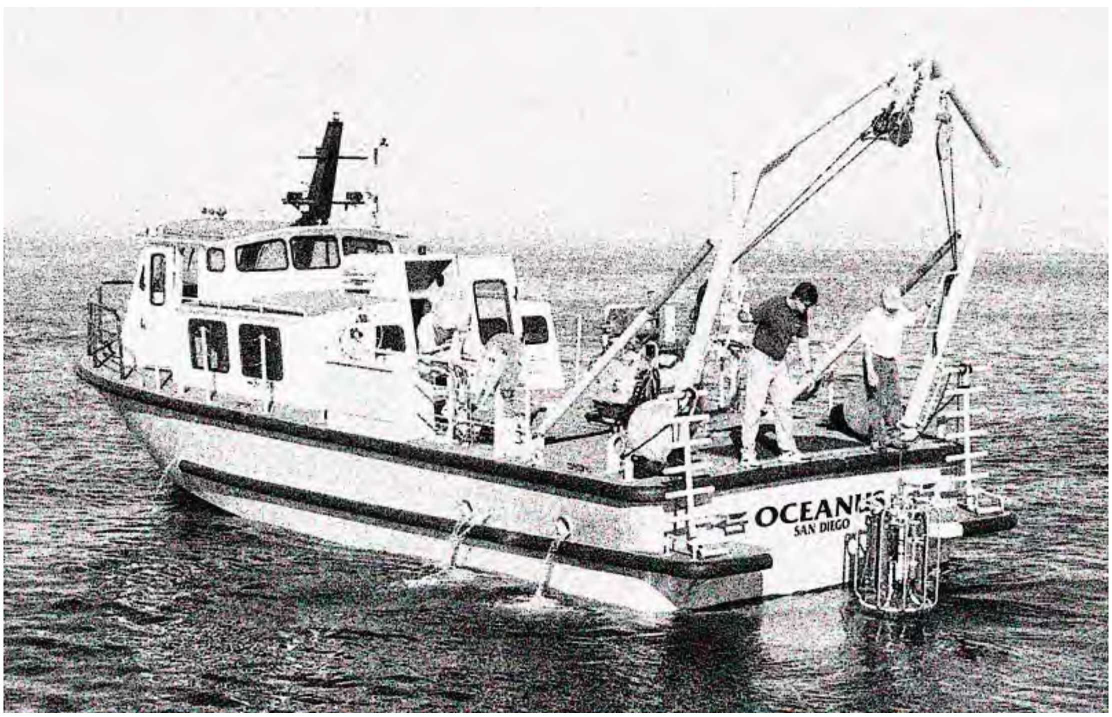

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June 2006

Table of Contents

Table of Contents
(continued)

Credits and Acknowledgments

Technical Editors
Dean Pasko   Tim Stebbins

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Dean Pasko   David James

GIS Graphics
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Executive Summary
Dean Pasko

Chapter 1. General Introduction
Dean Pasko

Chapter 2. Oceanographic Conditions
Dan Ituarte   Dean Pasko

Chapter 3. Microbiology
David James

Chapter 4. Sediment Characteristics
Daniel Ituarte

Chapter 5. Macrobenthic Communities
Nick Haring

Chapter 6. Demersal Fishes & Megabenthic Invertebrates
Ami Groce   Robin Gartman

Chapter 7. Bioaccumulation of Contaminants in Fish Tissues
Ami Groce

Chapter 8. San Diego Regional Survey- Sediment Characteristics
Dean Pasko

Chapter 9. San Diego Regional Survey- Macrobenthic Communities
Nick Haring

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Executive Summary

The ocean monitoring program for the South Bay Ocean Outfall (SBOO) is conducted in accordance with NPDES permit requirements for the South Bay Water Reclamation Plant (SBWRP) operated by the City of San Diego and the International Wastewater Treatment Plant (IWTP) operated by the International Boundary and Water Commission. These documents specify the terms and conditions that allow treated effluent originating from the SBWRP and IWTP to be discharged into the Pacific Ocean via the SBOO. In addition, the Monitoring and Reporting Programs contained within each permit define the requirements for monitoring the receiving waters environment, including sampling plans, compliance criteria, laboratory methods, data analysis and reporting guidelines.

The main objectives of the South Bay monitoring program are to provide data that satisfy the requirements of the NPDES permits, demonstrate compliance with the 2001 California Ocean Plan (COP), monitor dispersion of the waste field, and identify environmental changes that may be associated with wastewater discharge. Specifically, the program is designed to assess the impact of wastewater on the marine environment off southern San Diego, including the effects on water quality, sediment conditions, and the marine biota. The study area centers around the SBOO discharge site, which is located approximately 5.6 km offshore at a depth of about 27 m. Monitoring at sites along the shore extends from Coronado southward to Playa Blanca, Mexico. Offshore monitoring is conducted in an adjacent area overlying the coastal continental shelf at sites ranging in depth from about 9 to 55 m.

Prior to the initiation of wastewater discharge from the IWTP 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 about Del Mar to the US/Mexico border as part of the NPDES permit requirements. 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 2005 annual survey of randomly selected stations are presented herein.

The receiving waters monitoring effort for the South Bay region may be divided into several major components, each comprising a separate chapter in this report: Oceanographic Conditions, Microbiology, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, and Bioaccumulation of Contaminants in Fish Tissues. Data regarding various physical and chemical oceanographic parameters are evaluated to characterize water mass transport potential in the region. Water quality monitoring along the shore and in offshore waters includes the measurement of bacteriological indicators to assess both natural (e.g., river and streams) and anthropogenic (e.g., storm water and wastewater) impacts. Benthic monitoring includes sampling and analyses of soft-bottom macrofaunal communities and their associated sediments, while communities of demersal fish and megabenthic invertebrates are the focus of trawling activities. The monitoring of fish populations is supplemented by bioaccumulation studies to determine whether or not contaminants are present in the tissues of “local” species. In addition to the above activities, the City, the International Boundary and Water Commission, and the San Diego Regional Water Quality Control Board (RWQCB) 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, the results which are incorporated herein into the interpretations of oceanographic and microbiological data (see Chapters 2 and 3).

The present report focuses on the results of the ocean monitoring activities conducted in the South Bay region during calendar year 2005, including results of the July 2005 random sample. An overview and summary of the main findings for each of the major components are included below.

OCEANOGRAPHIC CONDITIONS

Oceanographic conditions in the South Bay region were generally similar to previously observed seasonal patterns. Thermal stratification of the water column followed the typical cycle with maximum stratification in mid-summer and reduced stratification during winter. Higher-than-normal air temperatures from January through March yielded slightly warmer than normal surface waters early in the year. In contrast, water clarity was negatively impacted by the pattern of record rainfall that began in October 2004 and continued through February 2005. These persistent rains generated heavy runoff into nearshore waters and long-lasting turbid conditions. Aerial imagery from the remote sensing study indicated that runoff from the Tijuana River was the most significant contributor to increased turbidity through May 2005. This runoff, which contained agricultural and effluent materials from the Tijuana River, combined with cooler, nutrient-rich upwelled water to create favorable conditions for an intense plankton bloom. These storm and plankton bloom events lead to decreased surface water clarity in 2005 relative to 2004. In general, data from both oceanographic measurements and aerial imagery provide no evidence that any water quality parameter (e.g., dissolved oxygen, pH) has changed because of wastewater discharged from the SBOO. Instead, these data indicate that natural events such as storm water runoff or plankton blooms were significant factors in increased turbidity and changed water quality parameters to the South Bay region in 2005.

MICROBIOLOGY

The greatest effects on nearshore water quality conditions in the South Bay region in 2005 appeared to be associated with the above average rainfall during winter. The resultant runoff from the Tijuana River and Los Buenos Creek generated elevated bacterial densities that contributed to the low overall rates of shore and kelp station compliance with COP standards. This pattern was similar to that seen in 2004 when record rainfall in February, October, and December affected nearshore bacteriological densities. Data from monthly offshore monitoring sites suggested that the wastewater plume was predominantly confined below a stratified water column from March through October. Bacterial counts indicative of wastewater were evident in surface waters during January when the water column was well-mixed, and in June when upwelling was apparently responsible for bringing the wastewater plume to surface waters. Overall, data from shore, kelp, and monthly water quality stations suggest that elevated bacterial counts detected along the shore in 2005 were not caused by the shoreward transport of wastewater from the outfall. Instead, the distribution and frequency of high bacterial counts in nearshore waters correspond to inputs and transport of materials from the Tijuana River and Los Buenos Creek, particularly during the rainy season.

SEDIMENT QUALITY

The composition and quality of ocean sediments in the South Bay area were similar in 2005 to those observed during previous years. Sediments at most sites were dominated by fine sands with grain size tending to increase with depth within the sampling region. Stations located offshore and southward of the SBOO discharge area consisted of very coarse sediments, while sites located in shallower water and north of the outfall towards San Diego Bay had finer sediments. Spatial differences in sediment composition can be partly attributed to patches of sediments associated with different origins (e.g., relict red sands, other detrital material). For example, the deposition of sediments from the Tijuana River and to a lesser extent from San Diego Bay probably contributes to the higher content of silt at nearby stations. In contrast, the strong and persistent storms of 2004–2005 contributed to the erosion of beach sand from the Silver Strand area. This beach erosion seems to be reflected in greater number of stations categorized as having poorly sorted sediments since July 2004.

As in previous years, there was no evidence that discharged wastewater from the SBOO negatively impacted contaminant concentrations in South Bay area sediments. Concentrations of organic indicators such as total organic carbon, total nitrogen and sulfides, as well as various trace metals were generally low in South Bay sediments relative to other coastal areas off southern California. However, there was an overall increase in total organic carbon relative to the previous year that may be related to the increased turbid discharge from San Diego Bay and the Tijuana River, as well as a strong and persistent plankton bloom. In general, the highest organic indicator and metal concentrations were generally associated with finer sediments. In addition, other contaminants (e.g., pesticides, PCBs) were detected infrequently or at low levels. For example, derivatives of the pesticide DDT were found in sediment samples from only three sites in 2005. The presence of DDT does not appear to be related to wastewater discharge since it was present at these sites prior to outfall construction. In addition, seven PCBs were detected in sediments from one station near the entrance to San Diego Bay in 2005. Finally, although PAH compounds were detected more frequently than in previous years, their concentrations were very low. Overall analyses of particle size or sediment chemistry data collected in 2005 provide no indication of contamination attributable to the SBOO.

MACROBENTHIC INVERTEBRATE COMMUNITIES

Benthic communities in the SBOO region included macrofaunal assemblages that varied along gradients of sediment structure (e.g., grain size) and depth (e.g., shallow vs. mid-depth waters). During 2005, assemblages surrounding the SBOO were similar to those that occurred during previous years. Most sites (70%) were represented by 2 groups of stations with very similar species composition. These sites were dominated by the spionid polychaete *Spiophanes bombyx*, a species characteristic of other shallow-water assemblages in the Southern California Bight (SCB). Another type of assemblage occurred at 6 sites from slightly deeper water where the sediments contained finer particles. Although this assemblage was also dominated by *S. bombyx*, it was distinguished from the shallow-water assemblage by more dense populations of the polychaetes *Myriochele gracilis* and *Sthenelanella uniformis*, the amphipod *Ampelisca agassizi,* and the tanaid *Leptochelia dubia*. This assemblage probably represents a transition between assemblages occurring in shallow sandy habitats and those occurring in finer mid-depth sediments off southern California. Finally, sites with sediments composed of relict red sands or varied amounts of coarse sand and shell hash were also characterized by unique assemblages.

Patterns of species richness and abundance also varied with depth and sediment type in the region, although there were no clear patterns with respect to the outfall. The range of values for most community parameters in 2005 was similar to that seen in previous years, and values of environmental disturbance indices such as the BRI and ITI were characteristic of undisturbed sediments. In addition, changes in benthic community structure near the SBOO that occurred in 2005 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 discharge and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf. The data from present monitoring efforts provide no evidence that the SBOO wastewater discharge has caused any substantial degradation of the benthos in the area.

DEMERSAL FISH AND MEGABENTHIC INVERTEBRATE COMMUNITIES

As in previous years, speckled sanddabs continued to dominate South Bay fish assemblages in 2005. Although the numbers of speckled sanddabs declined markedly from the previous year, this species occurred at all stations and accounted for 65% of the total catch. Other characteristic, but less abundant, species included the yellowchin sculpin, California lizardfish, roughback sculpin, longfin sanddab, English sole, Californa scorpionfish, and California tonguefish. Most of these common fishes were relatively small, averaging less than 23 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 were similarly dominated by one prominent species, the sea star *Astropecten verrilli.* Two other echinoderms, the white urchin *Lytechinus pictus* and the sea star *Pisaster brevispinus* were also common. Although megabenthic community structure also varied between sites, these assemblages were generally characterized by low species richness, abundance, biomass and diversity.

Overall, results of the trawl surveys conducted in 2005 provide no evidence that the discharge of wastewater has affected either fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of species were similar at stations located near the outfall and further away. Finally, the absence of any physical abnormalities or evidence of disease on local fishes suggests that populations remain healthy in the region.

TISSUE CONTAMINANTS IN FISHES

There was no clear evidence to suggest that tissue contaminant loads were affected by the discharge of wastewater from the SBOO in 2005. Although various contaminants were detected in both liver and muscle tissues, concentrations of most contaminants were not substantially different from those reported prior to discharge. In addition, samples of muscle tissues from sport fish collected in the area were found to be within FDA human consumption limits for both mercury and DDT.

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

SAN DIEGO REGIONAL SURVEY

Sediment Conditions

Thirty-six randomly selected sites ranging in depth from 12 to 190 m were sampled during the 2005 regional survey. Overall, the sediments reflect the diverse and patchy habitats common to the SCB. The data were summarized according to depth strata used in the 1998 and 2003 SCB region wide surveys (Bight′98, Bight′03). Stations between about 31 and 120 m in depth represent most of the mid-shelf region off San Diego (n=24). Sediments at these sites were composed primarily of fine particles (36% fines) with an average particle size of 0.088 mm. By comparison, sites occurring at depths ≤30 m (n=7) had coarser sediments with only 8.5% fines and an average particle size of approximately 0.262 mm. Deeper sites (>120 m, n=5) contained sediments of 0.175 mm average particle size, including 73% sand and 30% fines.

Coarse sediments (~85% sand) occurred in 2 distinct locations: (1) in shallow waters, and (2) along a the Coronado Bank, a southern rocky ridge located offshore of Point Loma at a depth of 150–170 m. Relict sediments typical of the area offshore of the Tijuana River were found at 1 site located west of the SBOO. These results were similar to the patterns seen during previous annual surveys. Shallow water (19 and 28-m) stations included in the regular semi-annual sampling grid surrounding the SBOO were generally similar to the shallow water sites from the survey. In contrast, stations from the two deeper semi-annual transects (38 and 55-m) were composed of more sand and less fine materials than comparable mid-shelf samples. This difference may relate to the greater number of grid stations located south of the SBOO and U.S.-Mexico border where relict sands are more common.

Sediment chemistries followed the expected relationship of elevated concentrations with decreasing particle size and increasing depth. The highest values for total organic carbon (TOC), total nitrogen (TN), sulfides, and trace metals occurred in the mid-shelf region where fine sediments were prevalent. For example, mean TOC values were 0.35% at the shallow water stations, 0.73% at the mid-shelf stations, and 3.87% at the 5 deep water sites. Similarly average concentrations of trace metals in the sediments from the mid-shelf and deep water strata were much higher than sediments in the shallow water areas. Concentrations of organic indicators and trace metals were higher and more widespread in 2005 compared to the 1995 survey of the same randomly selected stations. Sediments at 24 of the stations sampled in 2005 contained percentages of TOC or TN that exceeded the median CDF for the SCB established in 1994, while only 4 stations exceeded this benchmark in 1995. In addition, 21 stations contained concentrations of 3 or more metals that exceeded the median CDF values in 2005, while 11 did so in 1995. Contaminant levels at the shallow stations included in the SBOO semi-annual sampling grid were similar to the shallow water strata samples, whereas sediments at the 38 and 55-m stations had lower levels of organics or trace metals than comparable mid-shelf samples. Overall, the 2005 regional survey data did not show any pattern of impact relative to wastewater discharge from the SBOO.

Macrobenthic communities

The Southern California Bight (SCB) benthos has long been considered a "patchy" habitat, with the distribution of species and communities varying in space and time. Barnard and Ziesenhenne described the SCB shelf as consisting of an *Amphiodia* "mega-community" with other sub-communities representing simple variations determined by differences in substrate type and microhabitat. Results of the 2005 and previous regional surveys off San Diego generally support this characterization. The 2005 benthic assemblages were very similar to those sampled at the same sites 10 years previously (1995) and segregated mostly due to differences in habitat type (e.g., depth and sediment grain size). There was little evidence of anthropogenic impact. Over 50% of the benthos off San Diego was characterized by one assemblage with the ophiuroid *Amphiodia urtica* representing the dominant species. Co-dominant species within this assemblage included other taxa common to the region such as the polychaetes *Myriochele striolata* and *Spiophanes duplex.* This group occurred along the mainland shelf at depths from 44 to 94 m, and in sediments composed of relatively fine particles (e.g., 40% fines).

The dominant species of the other assemblages occurring in the region varied according to the sediment type or depth. Shallow water assemblages (e.g., <30 m) were highly variable depending upon their sediment type, but these assemblages generally were similar to other shallow, sandy sediment communities in the SCB. At many of these stations, polychaete species such as *Spiophanes duplex* and *S. bombyx*, *Hesionura coineaui difficilis, Ampharete labrops,* and *Monticellina siblina* were numerically dominant. A deep water assemblage located at depths >180 m was dominated by the polychaetes *Aphelochaeta glandaria* and *Monticellina siblina,* and the mollusc *Huxleyia munita*. These sites had the highest percentage of fine particles with the lowest species richness, diversity and abundance.

Although there was a overall increase in the number of species and individuals as well as changes in community parameters between the 1995 and 2005 random surveys, the two surveys identified identical assemblages based on depth and sediment type. The influence of increased organic loading or metals contamination detected in the 2005 appears to have had little impact on overall structure of the benthos.

Chapter 1
General Introduction

Chapter 1. General Introduction

INTRODUCTION

The South Bay Ocean Outfall (SBOO) discharges treated effluent originating from two sources: the City of San Diego's South Bay Water Reclamation Plant (SBWRP), and the International Boundary and Water Commission's (IBWC) International Wastewater Treatment Plant (IWTP). Discharge from the SBWRP began on May 6, 2002 and is performed under NPDES Permit No. CA0109045, Order No. 2000–129. Discharge from the IWTP began on January 13, 1999 and is performed under the terms and conditions set forth in Order No. 96–50, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0108928 and Cease and Desist Order No. 96–52. These NPDES permits define the requirements for monitoring receiving waters around the SBOO, including the sampling plan, compliance criteria, laboratory analyses, statistical analyses and reporting guidelines.

Receiving waters monitoring for the South Bay region with respect to the above referenced permits is performed by the City of San Diego. Prior to the initiation of discharge through the SBOO, the City conducted a 3½-year baseline monitoring program in order to characterize background environmental conditions surrounding the discharge site (City of San Diego 2000a). The results of this baseline study provide background information against which the post-discharge data may be compared. In addition, the City has conducted annual region-wide surveys off the coast of San Diego since 1994 (see City of San Diego 1999, 2000b, 2001, 2002, 2003). Such regional surveys are useful in characterizing the ecological health of diverse coastal areas and may help to identify and distinguish reference sites from those impacted by wastewater discharge, stormwater input or other sources of contamination.

Finally, the City of San Diego and the IBWC also contract with Ocean Imaging Corporation (Solana Beach, CA) to conduct a remote sensing program for the San Diego/Tijuana region as part of the ocean monitoring programs for the Point Loma and South Bay areas. Imagery from satellite data and aerial sensors produces a synoptic look at surface water clarity that is not possible using shipboard sampling alone. The major limitation of aerial and satellite images, however, is that they only provide information about surface or near-surface waters (~0–15 m) without providing any direct information regarding the movement, color, or clarity of water in deeper layers. In spite of these limitations, one objective of this multi-year project is to ascertain relationships between the various types of imagery data and field-collected data. With public health issues 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 different oceanographic events (e.g., heavy rains) may have on shoreline water quality. In February 2005, Ocean Imaging Corporation and the City attempted a study designed to investigate the survival and dispersion characteristics of bacteria discharged through the SBOO. Unfortunately, poor weather conditions and turbid waters prevented a successful outcome. This bacteria dispersion study was rescheduled for winter 2006.

This report presents the results of monitoring conducted at fixed sites around the SBOO from January through December 2005. However, pursuant to an agreement with the Regional Board, offshore monthly water quality sampling was not conducted in February in exchange for participation in the above referenced bacteria dispersion study (see City of San Diego 2005b). Results of the 2005 remote sensing surveys have also been 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 during previous years in order to assess any outfall related changes that may have occurred. The major components of the monitoring program are covered in the following chapters: Oceanographic Conditions, Water Quality, Sediment Characteristics, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, amd Bioaccumulation of Contaminants in Fish Tissues. The results of the 2005 regional survey off San Diego are presented in two subsequent chapters describing sediment conditions and macrobenthic communities from a set of randomly selected stations. Detailed information concerning station locations, sampling equipment, analytical techniques, and quality assurance procedures are included in the Environmental Monitoring and Technical Services Division Laboratory Quality Assurance Project Plan for the City's Ocean Monitoring Program (City of San Diego in prep). General and more specific details of these monitoring programs and sampling designs are given below and in subsequent chapters and appendices.

SBOO MONITORING

The South Bay Ocean Outfall is located just north of the border between the United States and Mexico. It 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 SBOO pipeline begins as a tunnel on land and then continues under the seabed to a distance of about 4.3 km offshore. From there it connects to a vertical riser assembly that conveys effluent to a pipeline buried just beneath the surface of the seabed. This 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 designed to discharge and disperse effluent via a total of 165 diffuser risers. These include 1 riser located at the center of the outfall diffusers and 82 others spaced along each of the diffuser legs. However, low flow since outfall operation began has required closure of all ports along the northern diffuser leg as well as many of those along the southern diffuser leg. These closures are necessary to maintain sufficient back pressure within the drop shaft so that the outfall can operate in accordance with the theoretical model. Consequently, discharge during 2005 and previous years 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 sites are arranged in a grid spanning the terminus of the outfall, and are 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 centered 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 randomly selected each year by the United States Environmental Protection Agency (USEPA) using the USEPA 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 Colnett, Mexico to Point Conception, USA. These regional surveys were the Southern California Bight 1994 Pilot Project (SCBPP), the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight'98 and Bight'03, respectively). Results of the SCBPP and Bight'98 surveys are available in Bergen et al. (1998, 2001), Noblet et al. (2002), and Ranasinghe et al. (2003), while data from Bight'03 are currently being analyzed. A regional (random) survey was not conducted in 2004 in order to conduct a special strategic process study pursuant to an agreement with the SDRWQCB and USEPA (see City of San Diego 2005a,c). The results from Phase I of the San Diego Sediment Mapping Study are currently being analyzed (see Stebbins et al. 2004).

The 2005 survey of randomly selected sites off San Diego covered an area from Del Mar south to the United States/Mexico border and extending offshore from depths of 12 m to about 190 m. All sampling was conducted during the month of July. In order to compare conditions over a 10-year span, the 2005 survey revisited the 40 randomly selected sites sampled in 1995 (see City of San Diego 1999). Although 40 sites were initially selected, only 36 were successfully sampled for benthic infauna and sediments in 2005. Sampling at 4 sites was unsuccessful due to the presence of rocky reef, which made it impossible to collect samples.

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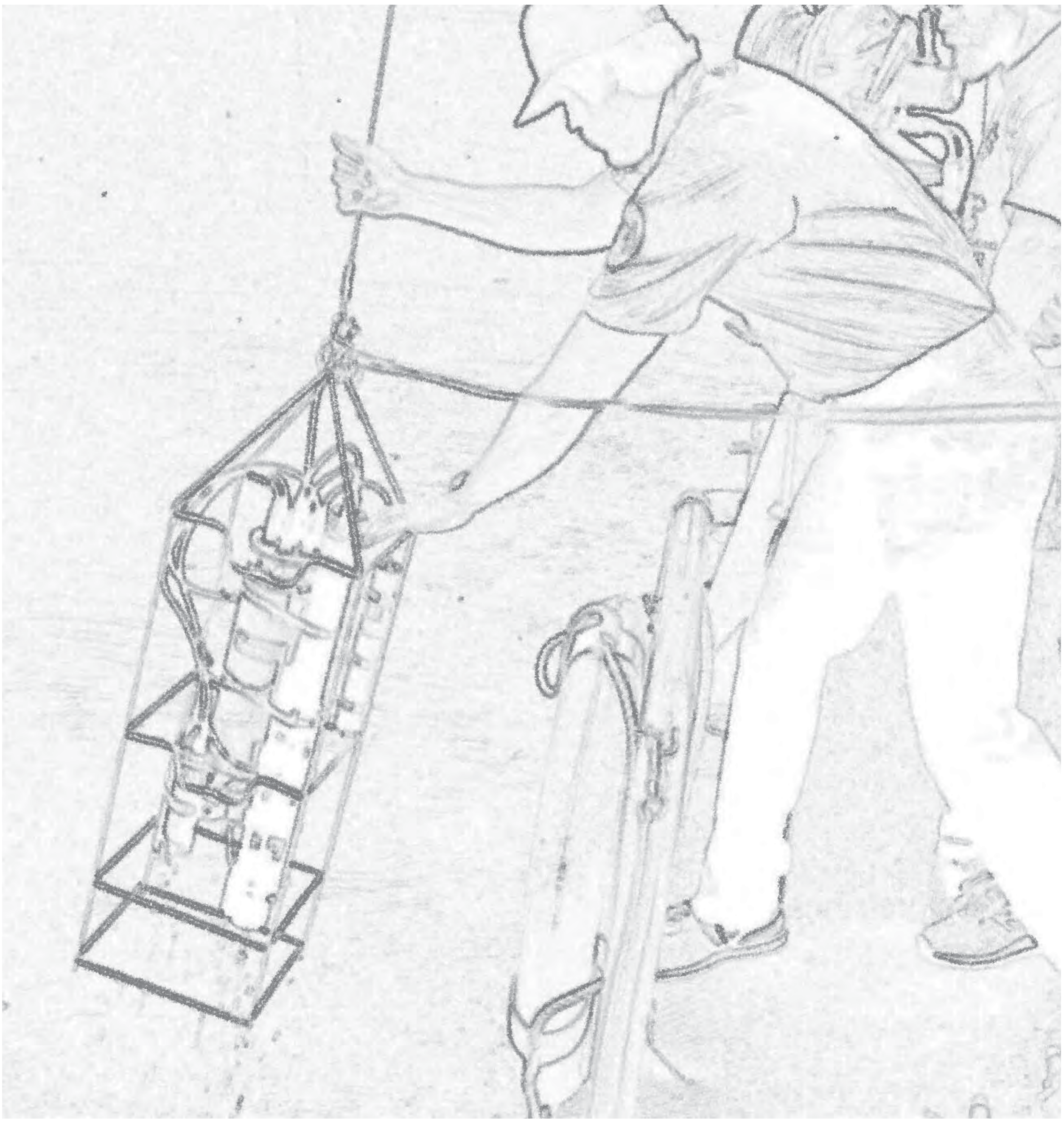
Chapter 2
Oceanographic Conditions



Chapter 2. Oceanographic Conditions

INTRODUCTION

The City of San Diego regularly monitors oceanographic conditions of the water column to assess possible impacts from the outfall discharge as well as the affects of the local oceanographic conditions on the fate of the discharge. Water quality in the South Bay region is naturally variable, but is also subject to various anthropogenic sources of contamination such as discharge from the South Bay Ocean Outfall (SBOO) and non-point source discharges such as San Diego Bay and the Tijuana River. These 2 non-point source discharges include 415 and 1731 square miles of watershed, respectively, and contribute significantly to nearshore turbidity, sedimentation, and bacteriological densities (Largier et al. 2004). The SBOO discharges treated wastewater approximately 5.6 km off shore at a depth of about 27 m, with an average daily flow rate of 24 mgd in 2005.

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

This chapter describes the oceanographic conditions that occurred during 2005 and is referenced in subsequent chapters to explain patterns of bacteriological occurrence (see Chapter 3) or other effects of the SBOO discharge on the marine environment (see Chapters 4–7).

MATERIALS AND METHODS

Field Sampling

Oceanographic measurements were collected at 40 fixed sampling sites located from 3.4 km to 14.6 km offshore (**Figure 2.1**). These stations form a grid encompassing an area of approximately 450 km^2 and were generally situated along 9, 19, 28, 38, and 55-m depth contours. Three of these

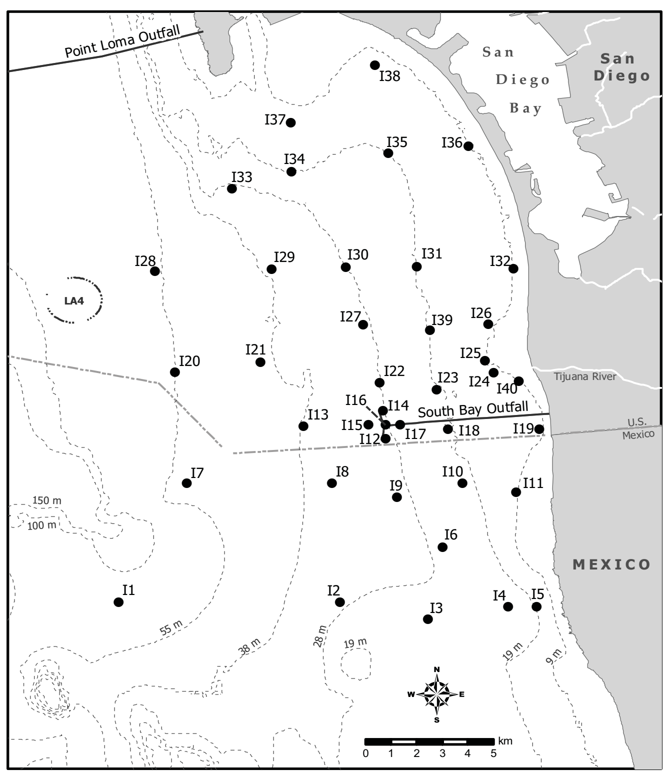


Figure 2.1
Water quality monitoring stations where CTD casts are taken, South Bay Ocean Outfall Monitoring Program.

stations (I25, I26, and I39) are considered kelp bed stations subject to California Ocean Plan (COP) water contact standards. These 3 stations were selected for their proximity to suitable substrates for the Imperial Beach kelp bed; however, this kelp bed has been historically transient and inconsistent in terms of size and density (North 1991, North et al. 1993). Thus, these stations are located in an area where kelp is only occasionally found.

Oceanographic measurements were collected at least once per month over a 3–5 day period. However, offshore monthly water quality sampling was not conducted in February 2005 pursuant to a resource exchange agreement between the City of San Diego and the Regional Water Quality Control Board (City of San Diego 2005b). Data for temperature, salinity, density, pH, transmissivity (water clarity), chlorophyll *a*, and dissolved oxygen were recorded by lowering a SeaBird conductivity, temperature and depth (CTD) instrument through the water column. Profiles of each parameter were constructed for each station by batch process averaging of the data values recorded over 1-m depth intervals. This ensured that physical measurements used in subsequent data analyses corresponded with bacterial sampling depths. Further details regarding CTD data processing are provided in the EMTS Division Laboratory Quality Assurance Plan (City of San Diego in prep.). To meet the COP sampling frequency requirements for kelp bed areas, CTD casts were conducted at the kelp stations an additional 4 times each month. Visual observations of weather and water conditions were recorded prior to each CTD sampling event.

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

RESULTS AND DISCUSSION

Expected Seasonal Patterns of Physical and Chemical Parameters

Southern California weather can be classified into 2 basic "seasons", wet (winter) and dry (spring through fall) (NOAA/NWS 2005), and certain patterns in oceanographic conditions track these "seasons." In the winter, water temperatures are cold and the water column is well-mixed resulting in similar properties throughout the water column. In contrast, dry summer weather warms the surface waters and introduces thermally-sustained stratification that is occasionally interrupted by upwelling events. Despite a sampling schedule that is spread out over several days during each month, historical analyses of oceanographic data collected from the South Bay region support this pattern (**Figure 2.2**).

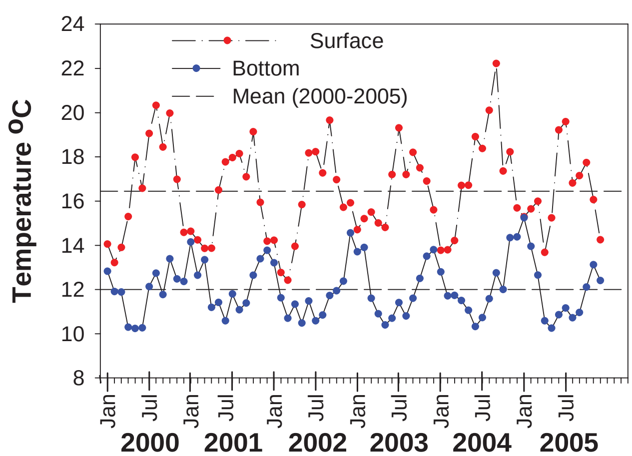


Figure 2.2
Average monthly surface and bottom temperatures (°C) for 2000–2005 compared to overall mean temperatures (+/-1 standard deviation).

Each year, typical winter conditions are present in January and February. A high degree of homogeneity within the water column is the normal winter signature for all physical parameters, although storm water runoff may intermittently influence density profiles by causing a freshwater lens within nearshore surface waters. The chance that the wastewater plume may surface is highest during these winter months when there is little, if any, stratification of the water column. These conditions often extend into March, when a decrease in the frequency of winter storms brings about the transition of seasons.

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

Observed Seasonal Patterns of Physical and Chemical Parameters

The record rainfall of October and December 2004 continued into early 2005, with above normal rain occurring during January and February (**Figure 2.3A**) (NOAA/NWS 2005). Normal conditions returned in March, continued through October, and were followed by drought conditions in November and December. Air temperatures were also extreme in 2005. Unseasonably warm air temperatures approaching the upper confidence limit for the historical average occurred in January–March, May, and November (Figure 2.3B). Despite these circumstances, thermal stratification of the water column followed normal seasonal patterns at the nearshore and offshore sampling areas, with local weather affecting an increase in surface water temperature and nearshore turbidity during the first part of the year.

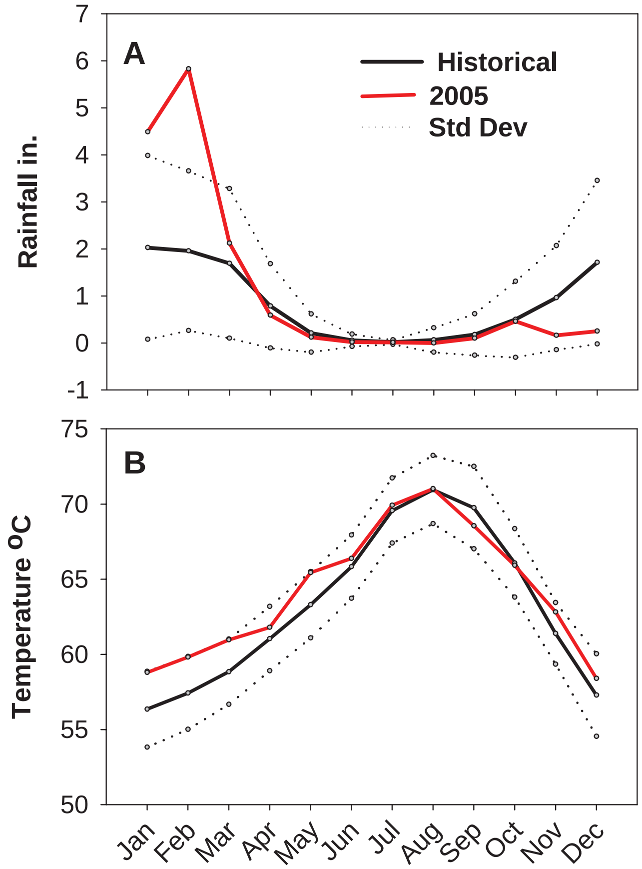


Figure 2.3
Total monthly rainfall (A) and monthly mean air temperature (B) at Lindbergh Field (San Diego, CA) for 2005 compared to monthly average rainfall and air temperature (+/-1 standard deviation) for the historical period 1914–2004.

Temperature is the main factor affecting water density and stratification of southern California ocean waters (Dailey et al. 1993, Largier et al. 2004) and provides the best indication of the surfacing potential of the wastewater plume. This is particularly true of the South Bay region where waters are shallow and salinity is relatively constant. During 2005, average surface water temperatures in January and March were unseasonably warm (15.3 and 16.0 °C, respectively), likely the result of the warmer than normal air temperatures (**Table 2.1**). Coincident with a subsequent decline in air temperature, surface water temperatures fell to 13.7 °C in

Table 2.1

Differences between the surface (≤2 m) and bottom (≥27 m) waters for mean values of temperature (°C), salinity (ppt), density (δ/θ),dissolved oxygen (mg/L), pH, chlorophyll *a* (µg/L), and transmissivity (%) at all SBOO monthly water quality stations during 2005. The greatest differences between surface and bottom values are highlighted and in bold bold type.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature	*Surface*	15.3	ns	16.0	13.7	15.2	19.2	19.6	16.8	17.1	17.7	16.1	14.2
	Bottom	15.2	ns	12.7	10.6	10.3	10.9	11.2	10.7	11.0	12.1	13.1	12.4
	Difference	0.04	ns	3.3	3.1	5.0	**8.3**	**8.4**	6.1	6.2	5.6	2.9	1.8
Density	*Surface*	24.23	ns	24.17	25.01	24.76	23.86	23.73	24.33	24.23	24.11	24.46	24.87
	Bottom	24.56	ns	25.16	25.87	25.90	25.77	25.57	25.66	25.70	25.40	25.15	25.31
	Difference	-0.33	ns	-0.99	-0.86	-1.13	**-1.91**	**-1.84**	-1.33	-1.47	-1.30	-0.69	-0.43
Salinity	*Surface*	32.82	ns	32.95	33.39	33.51	33.55	33.51	33.42	33.37	33.40	33.34	33.37
	Bottom	33.24	ns	33.33	33.74	33.70	33.68	33.49	33.51	33.61	33.50	33.43	33.45
	Difference	**-0.42**	ns	**-0.37**	**-0.35**	-0.19	-0.13	0.02	-0.08	-0.24	-0.10	-0.09	-0.08
DO	*Surface*	7.9	ns	8.1	9.2	7.1	8.5	9.5	9.4	9.4	8.6	8.6	8.0
	Bottom	7.7	ns	6.4	4.1	4.4	4.0	5.8	5.7	4.4	5.2	6.1	5.6
	Difference	0.1	ns	1.8	**5.1**	2.7	**4.6**	3.7	3.7	**5.0**	3.4	2.5	2.4
pH	*Surface*	8.1	ns	8.1	8.2	8.1	8.4	8.4	8.2	8.3	8.1	8.2	8.2
	Bottom	8.1	ns	7.9	7.8	7.9	7.8	7.9	7.9	7.8	7.8	8.0	8.0
	Difference	-0.0	ns	0.2	0.4	0.3	**0.6**	**0.5**	0.4	0.4	0.3	0.2	0.2
XMS	*Surface*	70	ns	71	62	76	72	71	78	72	79	85	84
	Bottom	88	ns	85	86	90	87	89	90	90	89	88	89
	Difference	**-18**	ns	-14	**-25**	-14	-15	**-18**	-13	**-17**	-10	-3	-5
Chl *a*	*Surface*	1.9	ns	2.0	16.8	2.3	10.0	18.3	6.5	12.0	4.3	2.9	3.7
	Bottom	1.7	ns	1.5	2.1	1.2	1.4	2.9	1.7	1.4	2.2	3.2	3.0
	Difference	0.2	ns	0.5	**14.7**	1.1	8.5	**15.4**	4.9	**10.6**	2.1	-0.3	0.7

April. This was followed by seasonal warming of the surface waters that began in May, progressed rapidly, and peaked in July with mean surface temperatures reaching 19.6 °C. A relatively rapid decline of about 3 °C occurred in August, followed by a slight increase during September and October. Thereafter, surface temperatures declined rapidly from 17.7 °C in October to 14.2 °C in December.

Bottom temperatures were also relatively high in January 2005, but fell back to normal in succeeding months (Table 2.1). Bottom water temperatures measured in January averaged 15.2 °C, over 1 °C higher than most other years (**Table 2.2**). They fell to about 12 °C by March, and ranged from 10.2 to 13.1 °C for the remainder of the year.

Although surface and bottom temperatures differed somewhat from previous years, thermal stratification of the water column followed normal seasonal patterns (**Figures 2.4, 2.5**, Table 2.2). Stratification of the water column was minimal or absent during January with the difference between average surface and bottom temperatures being only 0.04 °C. However, stratification started to develop in March and April with differences of >3 °C between surface and bottom temperatures. Thermoclines of ~1 °C over less than 1 meter of depth were present between 4 and 6 m during this period. Thermal stratification was strongest in June and July.

Table 2.2

Differences between the surface (≤2 m) and bottom (≥27 m) waters for mean values of temperature (°C) at all SBOO monthly water quality stations during 2000–2005. The highest annual temperatures for surface and bottom temperatures are in bold type. ns=not sampled (see text).

		2000		2001		2002		2003		2004		2005	
		Mean	**Δ**	**Mean**	**Δ**	**Mean**	**Δ**	**Mean**	**Δ**	**Mean**	**Δ**	**Mean**	**Δ**
Jan	*surface*	14.1		14.6		14.2		14.7		13.8		15.3	
	bottom	12.8	1.3	14.1	0.5	13.2	1.0	13.7	1.0	12.8	1.0	15.2	0.1
Feb	*surface*	13.2		14.2		12.8		15.2		13.8		ns	
	bottom	11.9	1.3	12.6	1.6	11.6	1.2	13.9	1.3	11.7	2.1	ns	
Mar	*surface*	13.9		13.9		12.4		15.5		14.2		16.0	
	bottom	11.9	2.0	13.4	0.5	10.7	1.7	11.6	3.9	11.7	2.5	12.7	3.3
Apr	*surface*	15.3		13.9		14.0		15.0		16.7		13.7	
	bottom	10.3	5.0	11.2	2.7	11.3	2.7	10.9	4.1	11.5	5.2	10.6	3.1
May	*surface*	18.0		16.5		15.8		14.8		16.7		15.2	
	bottom	**10.2**	7.8	11.4	5.1	**10.5**	5.3	**10.4**	4.4	11.1	5.6	**10.2**	5.0
Jun	*surface*	16.6		17.8		18.2		17.2		18.9		19.2	
	bottom	**10.3**	6.3	**10.6**	7.2	11.5	6.7	**10.7**	6.5	**10.3**	8.6	**10.9**	8.3
Jul	*surface*	19.1		18.0		18.2		**19.3**		18.4		**19.6**	
	bottom	12.1	7.0	11.8	6.2	**10.6**	7.6	11.4	7.9	**10.7**	7.7	11.2	8.4
Aug	*surface*	**20.3**		18.1		17.3		17.2		20.1		16.8	
	bottom	12.7	7.6	11.1	7.0	**10.8**	6.5	**10.8**	6.4	11.6	8.5	**10.7**	6.1
Sep	*surface*	18.4		17.1		**19.7**		18.2		**22.2**		17.1	
	bottom	11.8	6.6	11.4	5.7	11.7	8.0	11.6	6.6	12.7	9.5	11.0	6.1
Oct	*surface*	20.0		**19.1**		17.0		17.5		17.4		17.7	
	bottom	13.4	6.6	12.6	6.5	11.9	5.1	12.5	5.0	12.0	5.4	12.1	5.6
Nov	*surface*	17.0		15.9		15.7		16.9		18.2		16.1	
	bottom	12.5	4.5	13.4	2.5	12.4	3.3	13.5	3.4	14.3	3.9	13.1	3.0
Dec	*surface*	14.6		14.2		15.9		15.6		15.7		14.2	
	bottom	12.4	2.2	13.8	0.4	14.6	1.3	**13.8**	1.8	14.4	1.3	12.4	1.8

Temperature differences between surface and bottom waters were >8 °C with thermoclines of ~3 °C over 1 meter depth. A weaker shallow thermocline (~1 °C) persisted into October, but became undetectable in CTD profile data by November.

Deviations from this generally thermal-driven pattern occurred in April and August when surface and mid-level water temperatures dipped (Figures 2.4, 2.5 and Table 2.1). These cooling events are similar to those of previous years and may be the result of localized upwelling associated with the inshore movement of water from the California Current (see City of San Diego 2004, 2005a). A recent study of upwelling within the South Bay sampling region suggests that these events may not be primarily wind-driven, but rather due to topographic features that create a divergence of the prevailing southerly flow as it passes the Point Loma headland (Roughan et al. 2005).

Surface water salinity in 2005 displayed some seasonal patterns related to increasing air temperatures, rain runoff, and the April upwelling (see Figures 2.4, 2.5). Surface salinity at the monthly water quality stations ranged from 32.82 to 33.55 ppt (Table 2.1). Substantial freshwater inputs from winter storms during January–March resulted in average near-surface salinity values below 33 ppt. These conditions allowed for the development of salinity haloclines near the surface (1–5 m) during January–March. In contrast, warm air temperatures and the influx of cold, upwelled waters held surface, mid, and bottom water salinities to above 33.3 ppt for the remainder of the year.

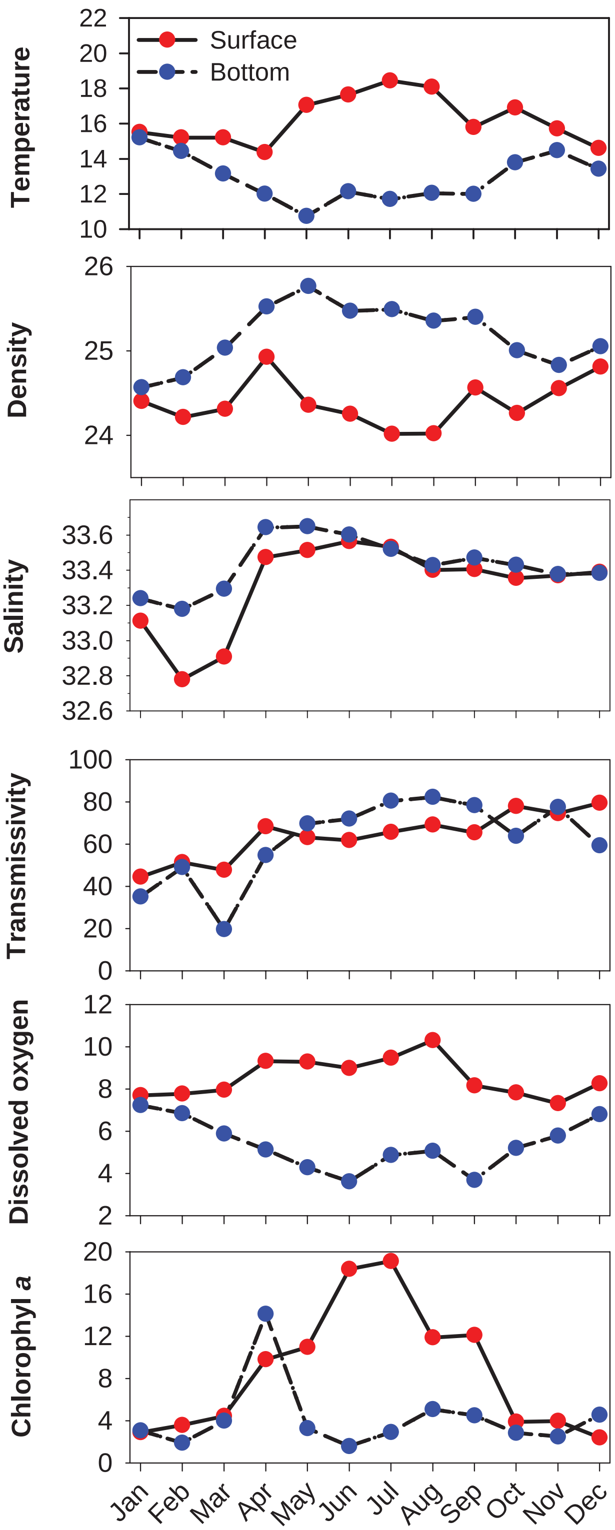


Figure 2.4

Monthly average temperature (°C), density (δ/θ), salinity (ppt), transmissivity (%), dissolved oxygen (mg/L), and chlorophyll a (µg/L) values for surface (<2m) and bottom (≥18m) waters at the three kelp water quality stations during 2005.

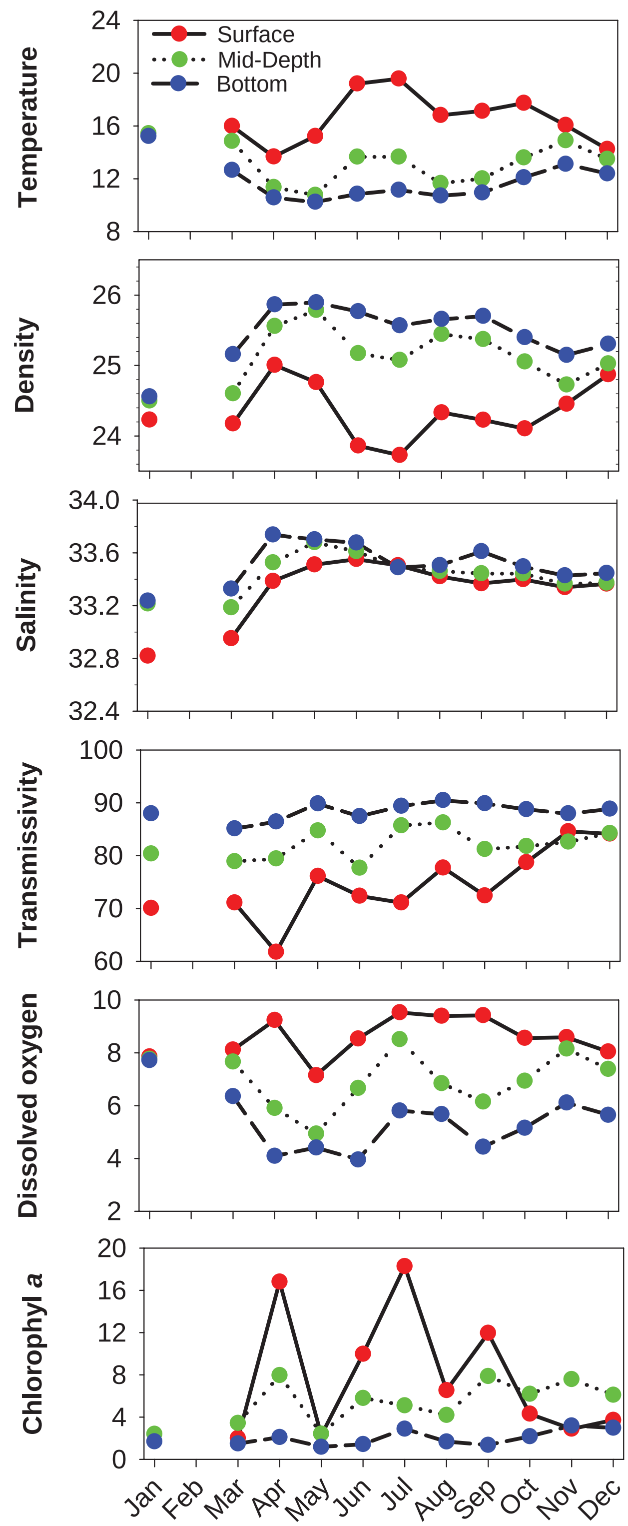


Figure 2.5

Monthly average temperature (°C), density (δ/θ), salinity (ppt), transmissivity (%), dissolved oxygen (mg/L), and chlorophyll a (µg/L) values for surface (<2m), mid-depth (10–20 m) and bottom (>27m) waters at the monthly water quality stations during 2005.

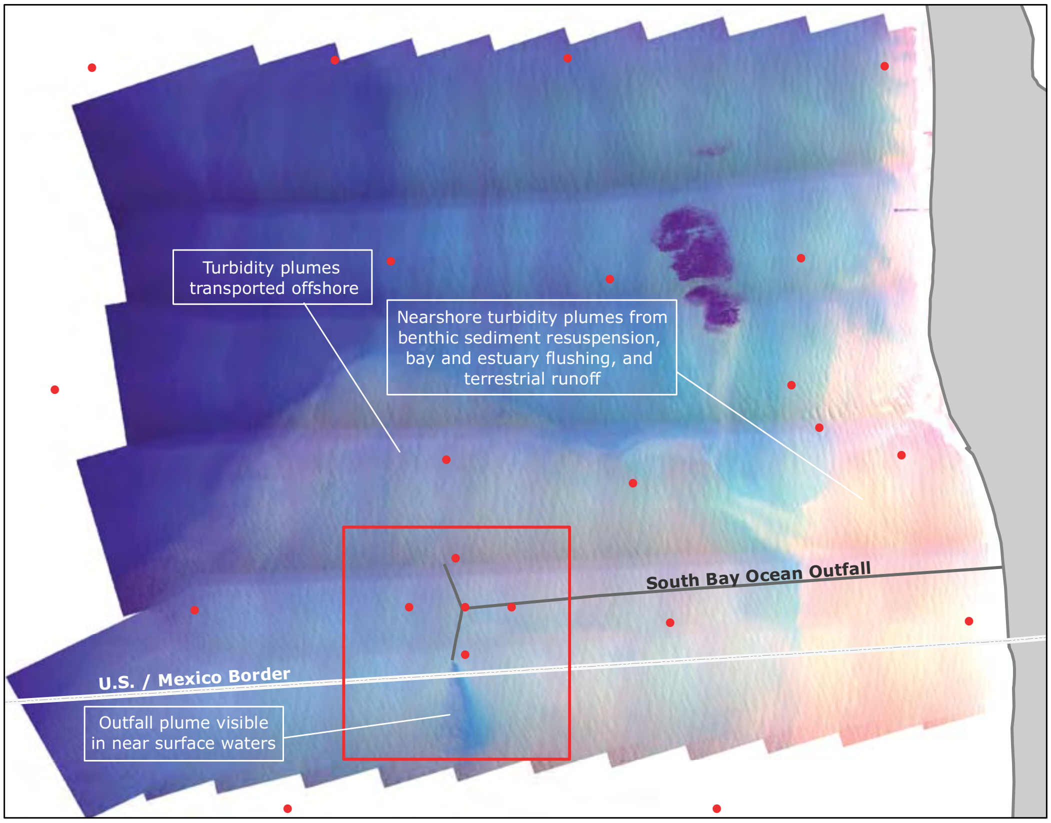


Figure 2.6
DMSC image composite acquired on January 12, 2005 showing the SBOO outfall and coastal region after heavy rains. The Tijuana River plume reached several kilometers west of the outfall wye. The outfall plume effluent displaced the shallow heavily turbid runoff layer and appears clearer.

Although density is a product of temperature, salinity and pressure, temperature is the principal component that drives density in the South Bay area because of the relatively shallow depths and the relative uniform salinity profiles. Therefore, changes in density typically mirror changes in temperature. This inverse relationship was true for the 2005 data collected by CTD at the South Bay kelp and offshore monthly water quality stations (see Figures 2.4, 2.5). Offshore surface water density was lowest in June and July, when surface waters were warmest. The difference between surface and bottom water densities was greatest from May through October, with the resulting pycnocline contributing to the stratification of the upper column at the time.

Remote sensing generally confirmed the above observations of water column stratification. For example, DMSC aerial imagery detected the outfall plume's near-surface signature in January and the latter part of February when the water column was well mixed (Ocean Imaging 2005a: **Figure 2.6**). Subsequent aerial imagery indicated that the outfall plume remained in the lower part of the water column from March through December (Ocean Imaging 2005a, b, 2006). Despite water column profile data from kelp and monthly water quality surveys suggesting an unstratified water column in November and December, the wastewater plume was not detected in surface waters by remote sensing until mid-December (Ocean Imaging 2006).

Observed Patterns in Turbidity and Plankton

The record rainfall in late 2004 through early 2005 caused large volumes of turbid runoff to exit from San Diego Bay, the San Diego and Tijuana Rivers, and Los Buenos Creek. The affects of this storm-driven surface turbidity were apparent in nearshore and offshore transmissivity measurements. For example, mean surface and bottom transmissivity measurements at the kelp bed stations were below 70% through May 2005 (Figure 2.4). Moreover, runoff containing agricultural and effluent materials from the Tijuana River during the heavy rains of January through March combined with cooler, nutrient-rich water upwelled near the Point Loma headland and created favorable conditions for plankton blooms.. The density of these blooms reduced offshore surface water clarity to near or below 75% for much of the year in the (Figure 2.5). Together, the storm and plankton-driven turbidity reduced surface water transmissivity values for 2005 by 7% compared to 2004 values (City of San Diego 2005a).

Patterns of turbidity caused by storm runoff, tidal flushing of the bay and rivers, and plankton acted as markers of water movement visible in the satellite imagery (see **Figure 2.7**). Although surface currents (0–15 m) typically flow southward in the Southern California Bight (Dailey et al 1993), analysis of MODIS imagery captured in 2005 shows intermittent northward flows in ~13% of the images. These northward flows were slightly more frequent from January through March and October through December (16%) than from April through September (11%). The highest frequency of northward flows occurred during the heavy rains of January–February (28%) and in August (40%), whereas the lowest frequency (0%) occurred in March and June. For example, record rainfall in February combined with relative strong northward current episodes to create turbidity plumes from the Tijuana River that extended to the northwest over the SBOO (Figure 2.7A). Later in the year, strong northward currents carried turbidity flows from San Diego Bay northwestward over the Point Loma outfall pipe (Figure 2.7D). In contrast, the typical southward flow was evident in patterns in nearshore turbidity and the movement of dense plankton blooms in April and June (Figures 2.7B, C).

Red tides present in the region from April through October were due to a bloom of the dinoflagellate *Lingulodinium polyedra*. This species has dominated the Southern California Bight since 1995. Gregorio and Pieper (2000) have found that the species persists at the Los Angeles River mouth from winter through summer and that river runoff during the rainy season provides significant amounts of nutrients that allow for rapid population increases. Runoff containing agricultural and effluent materials from the Tijuana River during the heavy rains of January through March most likely contributed to the widespread red tides observed in South Bay. In addition, cooler, nutrient-rich water upwelled near the Point Loma headland can drift south towards the Tijuana River mouth enriching conditions for plankton bloom development (Roughan et al. 2005).

Aerial imagery and chlorophyll *a* data indicated that the plankton bloom were strongest near Imperial Beach and the Tijuana River mouth (**Figure 2.8**). CTD profile data indicated that peak surface chlorophyll *a* concentrations occurred in April, June, July, and September. Corresponding declines in mean transmissivity values as well as increases in dissolved oxygen and pH indicate that this bloom persisted throughout the summer and fall and was strongest in April and July. The reduced oxygen values at mid and bottom depths during September were likely due to the biological and detrital oxidation associated with a fading plankton bloom (Pickard and Emery 1990).

SUMMARY AND CONCLUSIONS

Oceanographic conditions during 2005 were generally within expected seasonal variability. Rainfall was well above average during January and February, near average from March through October, and below average during November and December. The influx of freshwater during January through March contributed to shallow haloclines as well as large plumes of turbid water along shore that occasionally passed over the outfall. Surface temperatures differed from previous years as unseasonably high air temperatures in January–March contributed to warmer than normal winter surface waters. The maximum surface temperatures

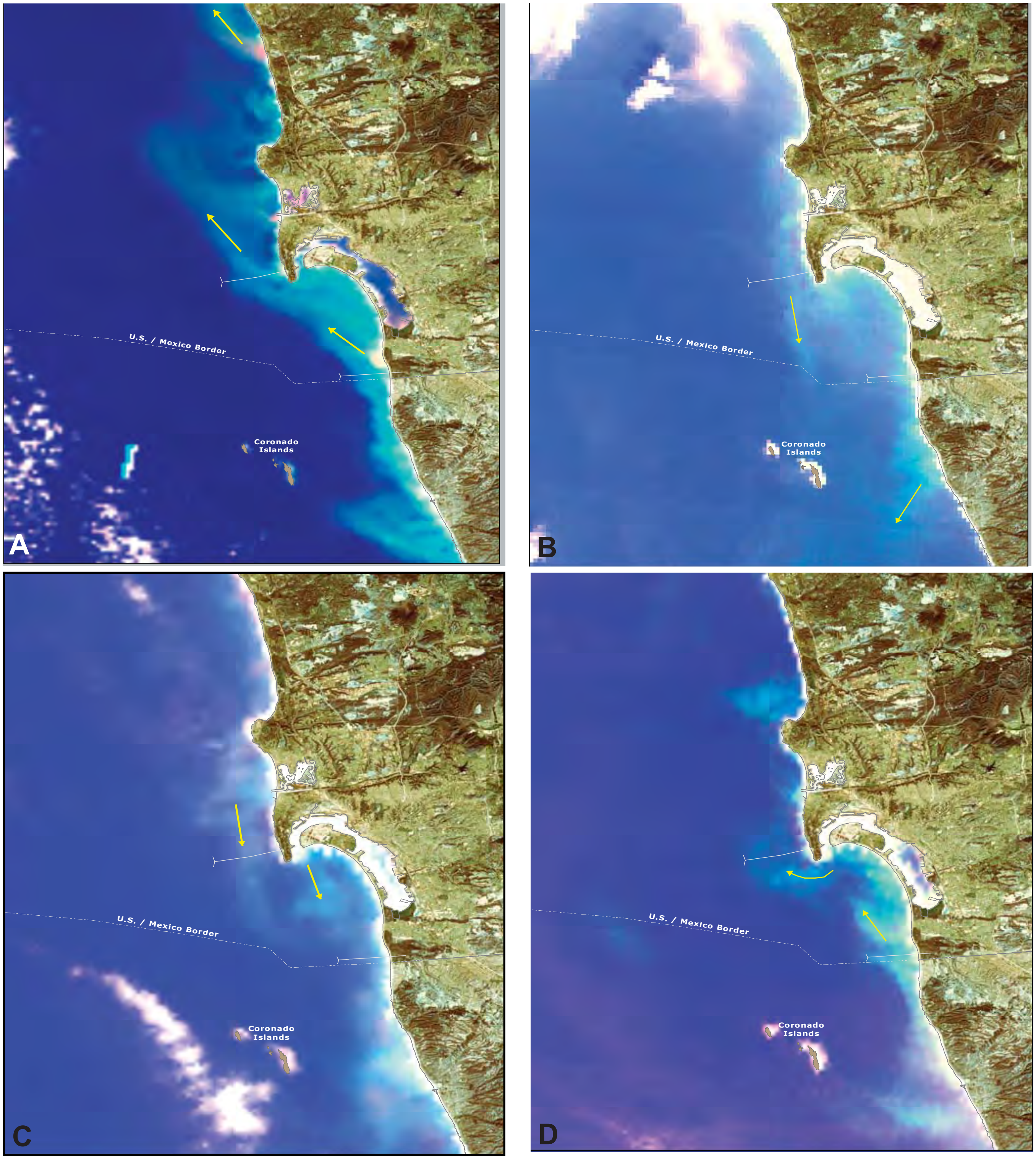


Figure 2.7

MODIS satellite image showing the San Diego region, captured during 2005 on (A) February 24, (B) April 15, (C) June 22, (D) October 10, and (E) December 9. White pixels offshore represent areas obscured by cloud cover. White pixels along the shoreline are due to "washout" or band saturation and to the histogram stretches used to enhance turbidity features in surface waters.

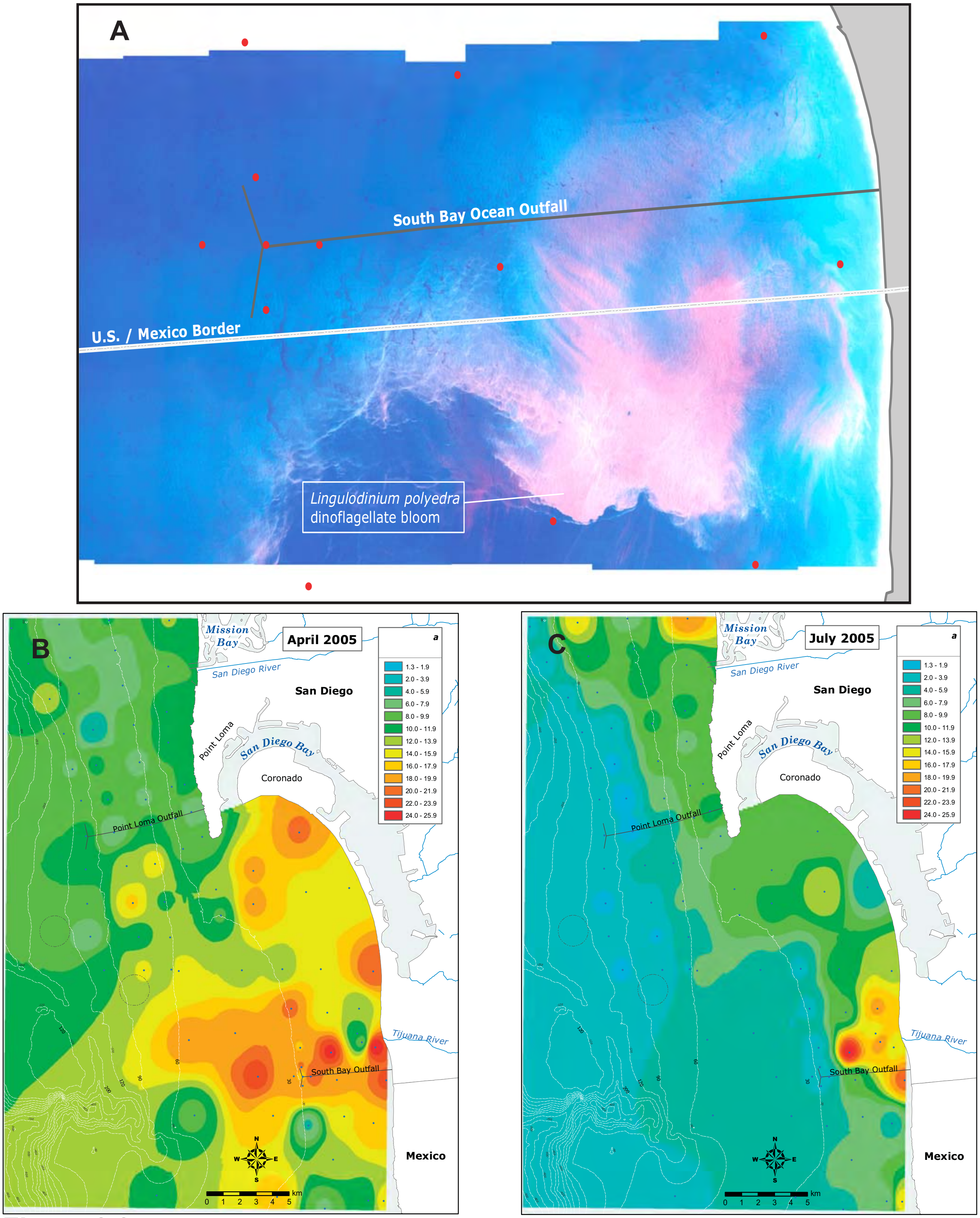


Figure 2.8

DMSC image composite acquired on August 26, 2005 showing (A) the SBOO outfall and coastal region during a red tide, and ArcView maps for (B) April and (C) July 2005 indicating surface chlorophyll *a* distribution (≤15m) along the San Diego coastline.

occurred in early summer (June and July) and declined in late summer (August and September) when mean air temperatures fell below a 90-year average. Bottom temperatures were also higher than normal in January 2005, but fell back to normal in succeeding months. Despite the minor deviations from expected surface and bottom temperatures, thermal stratification of the water column followed typical patterns. Water column stratification began to develop in March and persisted through October.

Record rains produced significant turbidity flows from San Diego Bay, the San Diego River, the Tijuana River, and Los Buenos Creek during the first few months of the year. Upwelling in April and August appeared to contribute to a massive red tide that was present from April through October, particularly along the shallower depth contours. Patterns in surface water turbidity resulting from these events revealed a predominantly northward current regime in the South Bay region from January through March, and a southerly flow thereafter.

Remote sensing observations generally confirmed the above pattern of water column stratification. The outfall plume's near-surface signature was detected by DMSC aerial imagery in January and the latter part of February when the water column was well mixed, but remained in the lower part of the water column from March through December (Ocean Imaging 2005a, b, 2006). Finally, aerial imagery indicated that runoff from the Tijuana River and occasionally San Diego Bay appeared to be significant factors in increasing turbidity and contamination to surface waters of the South Bay region, while the wastewater plume from the outfall tended to have a less significant effect. In general, data from water column measurements for the region, together with remote sensing data, revealed little evidence of impact from the SBOO.

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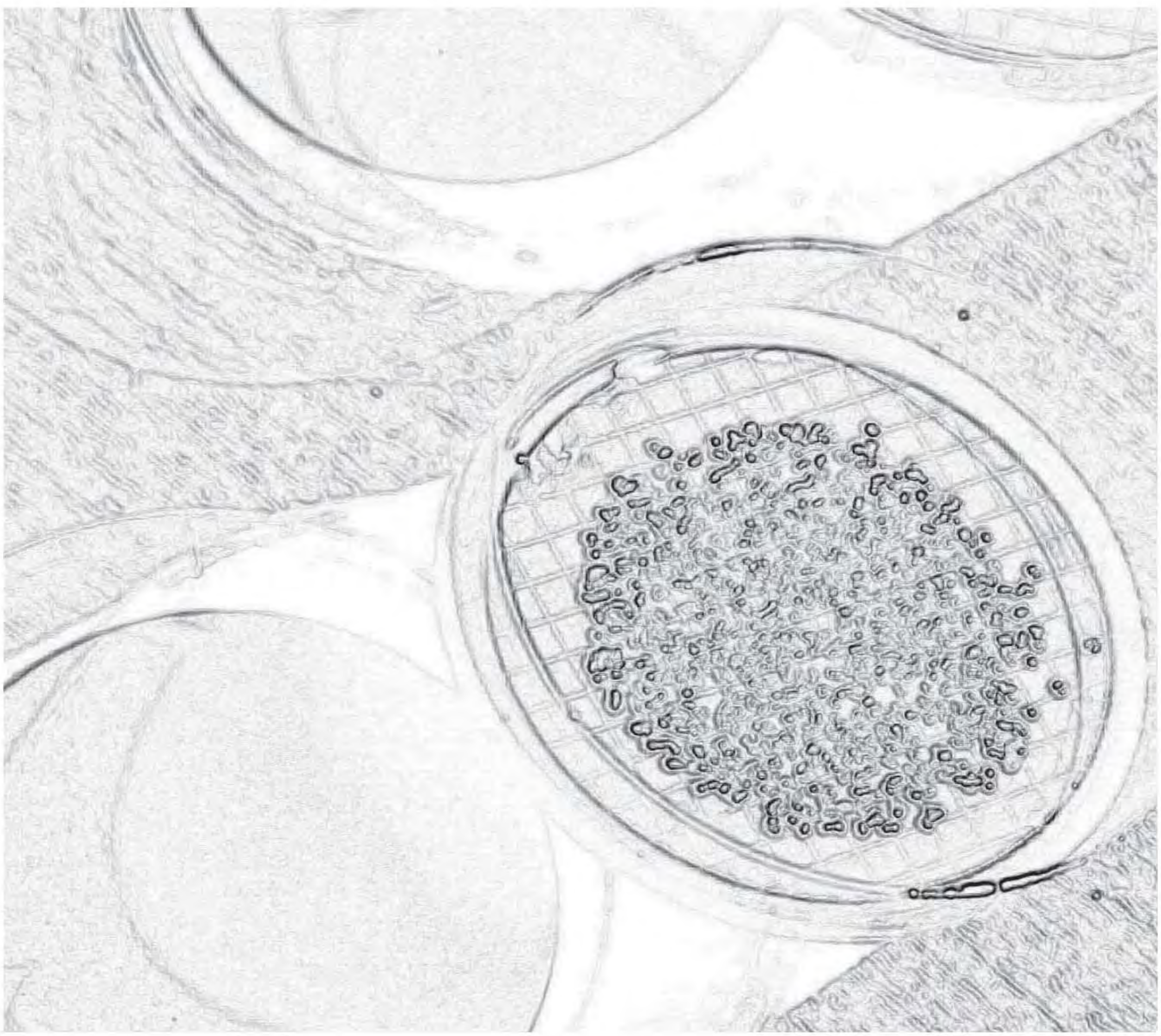
Chapter 3
Microbiology



Chapter 3. Microbiology

INTRODUCTION

The City of San Diego performs shoreline and water column bacterial monitoring in the region surrounding the South Bay Ocean Outfall (SBOO). The SBOO monitoring program is designed to assess general water quality, evaluate general patterns in movement and dispersal of the wastewater plume, and demonstrate a level of compliance with the 2001 California Ocean Plan (CSWRCB 2001) as required by the NPDES discharge permit. The final results of bacteriological and individual station compliance data are submitted to the International Boundary and Water Commission and San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Overall bacteriological densities, together with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged through the outfall. Analyses of these data may also implicate point or non-point sources other than the outfall as contributing to bacterial contamination events in the region. This chapter summarizes and interprets patterns in bacterial concentration data collected during 2005.

MATERIALS AND METHODS

Field Sampling

Water samples for bacteriological analyses were collected at fixed shore and offshore sampling sites during the year (**Figure 3.1**). Weekly sampling was performed at 11 shore stations to monitor bacteria levels along public beaches. Three shore stations (S0, S2, S3) located south of the US/Mexico border are not subject to 2001 California Ocean Plan (COP) water contact standards. Eight other shore stations (S4–S6, S8–S12) located within the United States between the border and Coronado are subject to the COP standards (see **Box 3.1**). In addition, 28 offshore stations were sampled monthly, usually over a 3-day period. However, this monthly sampling was not conducted in February pursuant to an agreement between the City and the Regional Water Quality Control Board (City of San Diego 2005b). These 28 offshore sites are located in a grid surrounding the outfall along the 9, 19, 28, 38, and 55-m depth contours. Three of these stations (I25, I26, I39) are considered kelp bed stations and are subject to the COP water contact standards. The kelp stations were sampled for bacterial analysis 5 times each month, such that each day of the week is represented over a 2-month period. The 3 kelp stations were selected because of their proximity to suitable substrates for the Imperial Beach kelp bed; however, this kelp bed is transient with variable size and density (North 1991, North et al. 1993). Thus,

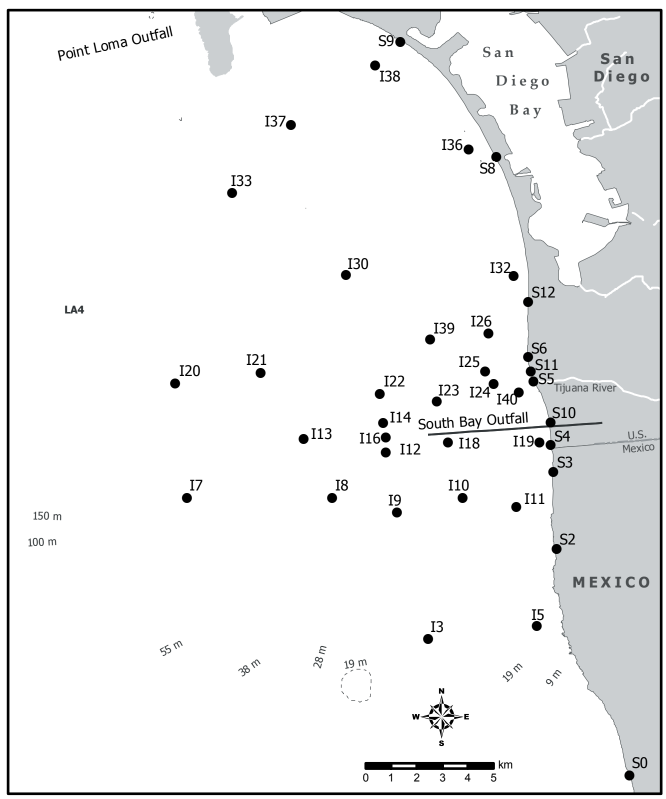


Figure 3.1
Water quality monitoring stations where bacteriological samples were collected, South Bay Ocean Outfall Monitoring Program.

Box 3.1

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

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

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

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

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

these 3 stations are located in an area where kelp is only occasionally found.

Seawater samples from the 11 shore stations were collected from the surf zone in sterile 250-mL bottles. In addition, visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were recorded at the time of collection. The seawater samples were then transported on ice to the City's Marine Microbiology Laboratory and analyzed to determine concentrations of total coliform, fecal coliform, and enterococcus bacteria.

Offshore seawater samples were collected at 3 discrete depths and analyzed for total coliform, fecal coliform, and enterococcus bacteria, as well as total suspended solids, and oil and grease. These samples were collected using either a series of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Specific field sampling procedures are outlined in the City's Quality Assurance Plan (City of San Diego in prep). Aliquots for each analysis were drawn into appropriate sample containers. The samples were refrigerated on board ship and then transported to either the City's Marine Microbiology Laboratory for bacterial analyses or to the City's Wastewater Chemistry Laboratory for analysis of oil and grease, and suspended solids. Visual observations of weather and sea state were also recorded at the time of sampling.

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

Laboratory Analyses and Data Treatment

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

Colony counting, calculation of results, data verification and reporting all follow guidelines established by the EPA (see Bordner et al. 1978). According to these guidelines, plates with bacterial counts above or below the ideal counting range were given greater than (>), less than (<), or estimated (e) qualifiers. However, these qualifiers were dropped and the counts treated as discrete values during the calculation of compliance with COP standards and mean values.

Shore and kelp bed station compliance with COP bacteriological standards were summarized according to the number of days that each station was out of compliance (see Box 3.1). Bacteriological data for offshore stations are not subject to COP standards, but were used to examine spatio-temporal patterns in the dispersion of the waste field. Spatial and temporal patterns in bacteriological contamination were determined from mean densities of total coliform, fecal coliform, and enterococcus bacteria. These data were calculated for each station by month, station, and depth. Monthly rainfall and climatological data (Lindbergh Field, San Diego, CA), oceanographic conditions (see Chapter 2), as well as other events (e.g., storm water flows, nearshore and surface water circulation patterns) identified through remote sensing data were evaluated relative to the bacterial data. COP and AB 411 (CDHS 2000) bacteriological benchmarks were used as reference points to distinguish elevated bacteriological values in receiving water samples discussed in this report. These were >1000 CFU/100 mL for total coliforms, >400 CFU/100 mL for fecal coliforms, and >104 CFU/100 mL for enterococcus bacteria. Furthermore, "contaminated" water samples were identified as samples containing total coliform concentrations ≥1000 CFU/mL and a fecal:total (F:T) ratio ≥0.1 (see CDHS 2000). Samples from offshore monthly water quality stations that met these criteria were used as indicators of the SBOO waste field.

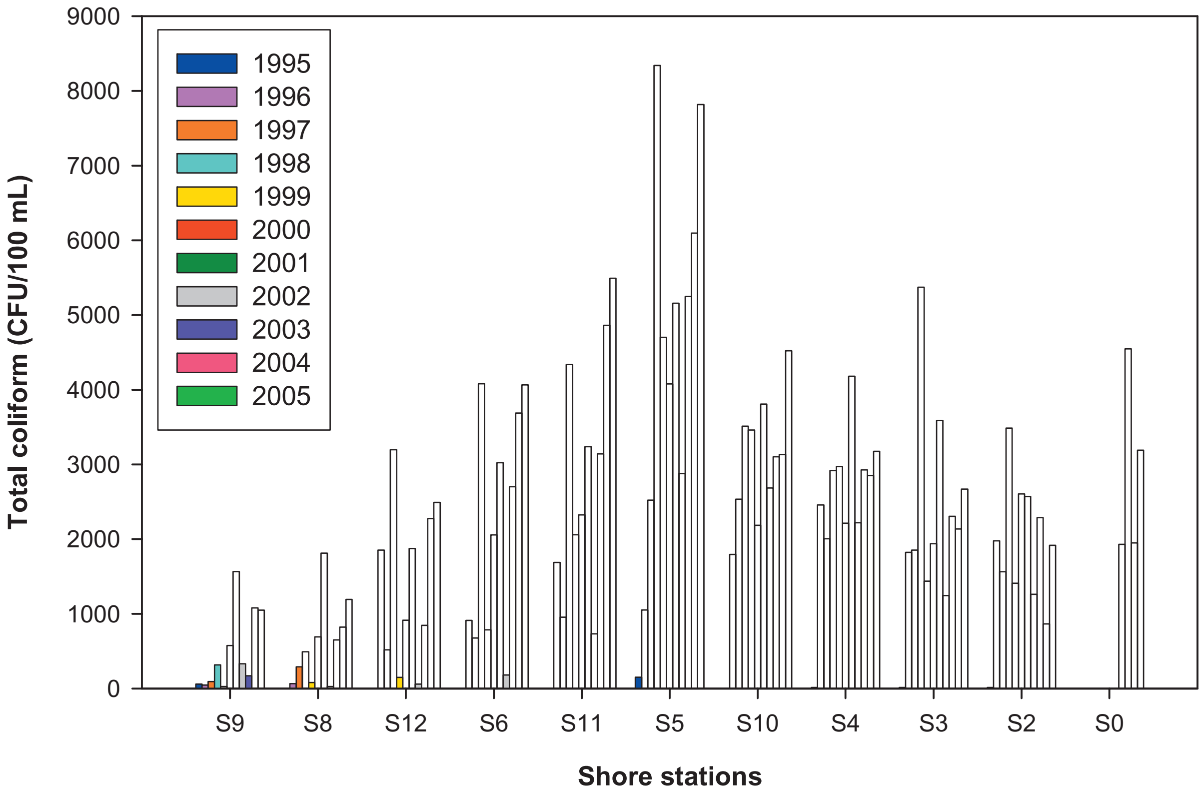
Quality assurance tests were performed routinely on water samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split field samples were collected according to method requirements and processed by laboratory personnel to measure intra-sample and inter-analyst variability,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

RESULTS AND DISCUSSION

Bacteriological densities in 2005 were generally high due to heavy rainfall from January and February (see Chapter 2). For example, annual mean concentrations of indicator bacteria along the shoreline (S5, S6, and S11) near the Tijuana River were similar to levels seen only during 1998 and 2004, 2 previous years with similarly heavy rainfall (**Figure 3.2**). Approximately 362 of the samples (18%) collected in 2005 had total coliform concentrations greater than or equal to the 1000 CFU/100 mL benchmark. Of these, 193 were collected at shore sites, 54 were collected at the kelp stations, and 114 were collected at the offshore sites. A total of 65 samples (11 kelp bed, 54 offshore) had F:T ratios ≥0.1 that indicated the presence of wastewater. These samples were further evaluated to assess possible patterns in plume movement.

Temporal Variability

January through March was the wettest period of the year and had the highest densities of indicator bacteria in shoreline samples (**Table 3.1**). Intermittent rainfall and continued stormwater discharges allowed high levels of indicator bacteria to persist through May. Most samples with total coliform concentrations exceeding 10,000 CFU/100 mL occurred during the wet months of January through May (n=112), compared to 7 instances during the remainder of the year. An unexpected increase in indicator bacteria at shore stations S0, S2, and S6 in August may be related to other non-point sources. Although there was no recorded rainfall in August, MODIS imagery



Mean annual total coliform densities for each SBOO shore station, 1995–2005. Stations are arranged from north to south on the x-axis. Stations S5, S6, and S11 are all within 1 km of the Tijuana River. Sampling for station S0 started in 2002.

taken on August 17 showed turbidity plumes from the Tijuana River and Los Buenos Creek, Mexico. Surface current data indicate a generally southern current regime through most of August (SDCOOS 2005), which may have driven materials from the Tijuana River southward. Bacteriological levels remained low at most of the shore stations from September to December, despite intermittent rains.

Similar to the shoreline results, the highest densities of indicator bacteria at the kelp bed stations occurred from January through March. Ninety-four percent of the samples with total coliform concentrations ≥1000 CFU/100 mL were collected from January through May (**Appendix A.1**). All of the samples collected in April and May had low fecal coliform densities and were probably not indicative of contaminated water from the outfall plume.

Monthly sampling at the offshore sites also showed distinct seasonal trends in indicator bacteria related to rainfall and storm discharge (**Figure 3.3**). Two-thirds of the 114 samples with total coliform concentrations ≥1000 CFU/100 mL occurred during January, March, April, and May (see **Appendices A.2, A.3**). Additionally, all but 2 of the 21 inshore (9 and 19-m contour) station samples representative of contaminated water occurred in January, March or April. Most, if not all, of these samples were likely related to discharge from the Tijuana River and Los Buenos Creek. During periods of northward current flows, discharge from the Tijuana River and Los Buenos Creek is carried up the coast towards Imperial Beach and may affect water quality at inshore stations (City of San Diego 2005a).

Seasonal trends related to water column stratification were also apparent in the offshore monthly water quality samples. The wastewater plume remained sub-surface most of the year, but was detected in surface waters at stations along the 28-m contour

Table 3.1

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

Month (Rainfall)		S9 (54)	S8 (54)	S12 (57)	S6 (59)	S11 (63)	S5 (70)	S10 (59)	S4 (55)	S3 (52)	S2 (52)	S0 (52)
Jan	*Total*	3909	5388	9964	10057	11370	14857	4140	1010	8115	8059	8063
(4.49)	*Fecal*	176	441	394	1100	2220	9234	211	30	3610	2003	3504
	Entero	448	632	973	1669	2965	6460	46	117	3840	6010	4911
Feb	*Total*	6812	7004	7156	10709	12170	13300	8762	9200	6425	4720	3709
(5.83)	*Fecal*	686	1980	1496	4228	5030	9079	433	563	719	334	158
	Entero	687	2207	3173	4364	4670	7956	1154	748	1446	1189	565
Mar	*Total*	18	10	4270	6500	10068	16000	10373	8750	6002	4622	1356
(2.12)	*Fecal*	4	2	1062	3030	4371	8556	803	1810	392	141	88
	Entero	4	3	60	270	1357	9185	181	164	66	42	56
Apr	*Total*	12	56	3452	6620	11591	13791	12817	4581	2223	824	934
(0.59)	*Fecal*	18	6	240	3282	4583	7832	3867	410	184	73	61
	Entero	5	4	4	161	332	5823	141	9	16	4	11
May	*Total*	20	33	992	5527	6114	9085	5478	5515	3273	85	1388
(0.12)	*Fecal*	8	4	124	1742	3618	3255	2031	2031	2404	4	108
	Entero	27	4	3	173	1201	1635	63	99	87	6	11
Jun	*Total*	20	16	97	95	85	85	380	480	600	120	4070
(0.02)	*Fecal*	4	2	17	13	9	13	24	12	32	11	1060
	Entero	6	2	24	3	8	9	14	8	34	7	31
Jul	*Total*	200	74	110	256	155	110	155	515	156	1045	4525
(0.01)	*Fecal*	17	7	11	17	7	8	5	38	31	257	549
	Entero	26	44	7	9	12	15	10	36	24	112	214
Aug	*Total*	128	52	844	1564	1814	1257	460	694	208	3214	6904
(0.00)	*Fecal*	3	2	150	178	86	46	22	77	14	602	158
	Entero	6	3	17	48	21	20	9	8	6	130	67
Sep	*Total*	11	16	14	66	21	61	29	53	126	62	764
(0.10)	*Fecal*	4	3	6	19	5	7	9	6	25	4	92
	Entero	7	5	4	6	10	3	5	7	7	4	15
Oct	*Total*	41	11	205	90	40	67	103	408	4096	134	532
(0.46)	*Fecal*	16	2	16	12	13	6	11	30	226	25	14
	Entero	4	4	16	6	17	14	15	34	203	49	11
Nov	*Total*	9	4	3	39	10	15	2	8	862	8	1213
(0.16)	*Fecal*	5	3	2	2	2	4	3	2	54	3	159
	Entero	3	2	4	2	2	4	3	2	6	4	11
Dec	*Total*	16	11	9	9	37	10	12	7	16	45	5280
(0.25)	*Fecal*	8	3	2	3	2	6	2	2	3	6	171
	Entero	3	2	12	3	3	4	2	2	15	21	18
Annual Means												
	Total	**1047**	**1191**	**2490**	**4067**	**5494**	**7819**	**4523**	**3175**	**2668**	**1917**	**3189**
	Fecal	**86**	**227**	**334**	**1325**	**2097**	**4344**	**827**	**555**	**647**	**281**	**481**
	Entero	**112**	**268**	**394**	**678**	**1053**	**3641**	**152**	**112**	**445**	**586**	**458**

in January and June (**Figure 3.4**). Prior to the development of seasonal stratification that began in March, an unstratified water column allowed the wastewater plume to surface in January (see Chapter 2). CODAR surface current data indicate that an upwelling or water shearing event occurred in June and was the likely cause of the plume surfacing at station I22 on June 14.

Spatial Variability

Elevated bacterial densities along the shoreline and in shallow, nearshore waters appeared to be related to sources other than the SBOO. Proximity to the Tijuana River and Los Buenos Creek discharges influenced bacteriological levels along the shoreline (Table 3.1). The highest densities of indicator bacteria occurred at the shore stations closest to the Tijuana River (S4, S5, S6, S10, S11), where contaminants from upstream sources (e.g., sod farms and runoff not captured by the canyon collector system) and the estuary (e.g., decaying plant material) are released during increased river flow and extreme tidal exchanges (Largier et al. 2004). For example, station S5, located next to the Tijuana

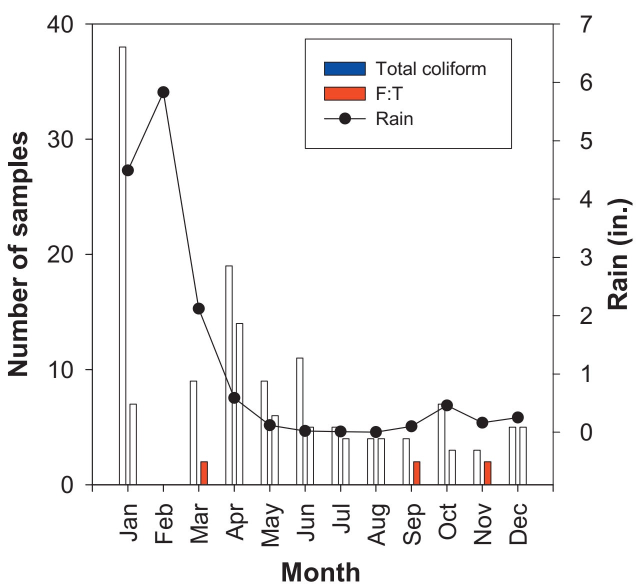


Figure 3.3
SBOO monthly water quality samples collected in 2005 with high bacteria densities. Total coliform=number of samples with total coliform densities ≥1000 CFU/100 mL; F:T=number of samples with total coliform densities ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥ 0.1 (indicative of wastewater). Mean rainfall is measured at Lindbergh Field, San Diego, CA.

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River mouth, had the highest bacteria levels of all of the shore stations sampled in 2005. Station S0, the southernmost shore station, was likely impacted by discharge from the nearby Los Buenos Creek and/or southerly alongshore flow carrying Tijuana River discharge. The 2 northern stations along the Coronado shore had the lowest overall bacteriological densities of all shore stations.

Discharge from the Tijuana River contained very high bacterial concentrations and affected water quality at the various nearshore stations (City of San Diego, unpublished data; Ocean Imaging 2005a, b). River discharge during January through May was likely responsible for the elevated bacterial densities in samples from inshore stations along the 9-m and 18-m contours. For example, there were 18 monthly inshore station water samples representative of stormwater (total coliforms ≥1000 CFU/100 mL and F:T ratios ≤0.1) taken in January (Appendix A.3). In addition, the samples from January with total coliforms ≥1000 CFU/100 mL and F:T ratios ≥0.1 came from inshore stations near the Tijuana River mouth, along the 9-m and 18-m contours (Appendix A.2).

Water samples considered indicative of the wastewater plume were detected most frequently at stations along the 28-m depth contour and from samples collected at depths ≥11 m (**Figure 3.5A**). Twenty-six of these samples occurred along the 28-m contour: 19 at the 3 outfall stations (I12, I14, I16), 6 at the northern stations I22 and I30, and 1 at the southern station I9. Six other samples were collected at deeper offshore stations (I8, I13, I20, I21) and 22 samples were collected at stations along the 9 and 19-m contours (I5, I10, I18, I19, I23, I24, I25, I39, I40).

There was limited bacteriological evidence that the wastewater plume reached surface waters in 2005. Only 9 of the 54 samples representative of contaminated water occurred in surface waters (2 m) (Figure 3.5B). These samples were collected in January (n=4), April (n=3), June (n=1), and October (n=1) (Appendix A.1). The January samples were collected from inshore stations after a 2-day storm dropped 1.7 inches of rain. The 3 April samples may have been affected by the Tijuana River turbidity plume, which was visible in MODIS imagery taken on April 6. Similarly, MODIS imagery taken on October 6 shows a turbidity plume emanating from Los Buenos Creek, Mexico that extended offshore to station I5. The San Antonio de los Buenos

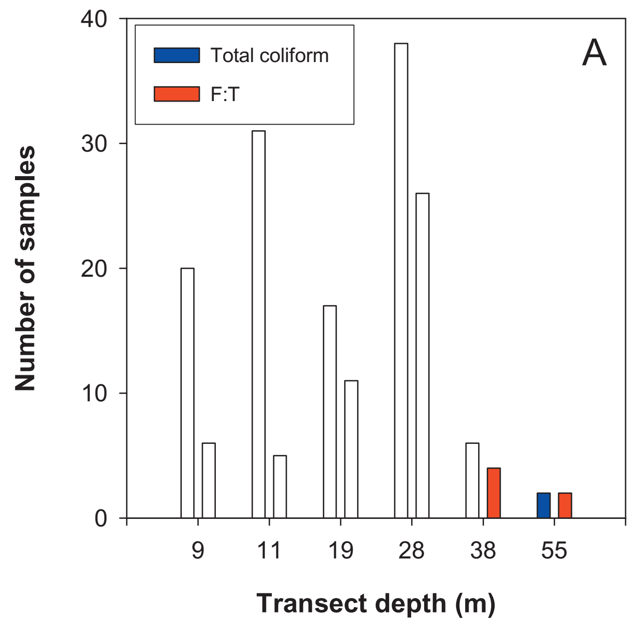

Figure 3.5

SBOO monthly water quality samples with high bacteria densities collected by (A) transect and (B) depth in 2005. Total coliform = number of samples with total coliform densities ≥1000 CFU/100 mL; F:T = number of samples with total coliform densities ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥0.1 (indicative of wastewater).

Table 3.2

Summary of compliance with 2001 California Ocean Plan water contact standards for SBOO shore and kelp bed stations during 2005. Values reflect the number of days that each station exceeded the 30-day and 10,000 total coliform standards (see Box 3.1). Shore stations are listed north to south in order from left to right.

30-day Total Coliform Standard						**Shore stations**				**Kelp stations**		
Month	**# days**	**S9**	**S8**	**S12**	**S6**	**S11**	**S5**	**S10**	**S4**	**I25**	**I26**	**I39**
January	31	26	31	31	31	31	31	31	31	31	31	19
February	28	21	21	28	28	28	28	28	28	15	27	4
March	31	23	23	31	31	31	31	31	31	31	31	28
April	30	0	0	17	17	30	30	30	30	18	12	12
May	31	0	0	30	31	31	31	31	31	5	0	0
June	30	0	0	0	6	2	15	9	9	0	0	0
July	31	0	0	0	0	0	0	19	29	0	0	0
August	31	0	0	10	10	10	10	10	16	0	0	0
September	30	0	0	10	10	10	10	10	10	0	0	0
October	31	0	0	0	0	0	0	0	10	0	0	0
November	30	0	0	0	0	0	0	0	10	0	0	0
December	31	0	0	0	0	0	0	0	0	0	0	0
Percent Compliance		**81%**	**79%**	**57%**	**55%**	**53%**	**49%**	**45%**	**36%**	**73%**	**72%**	**83%**
10,000 Total Coliform Standard												
January	31	0	0	1	1	2	3	0	0	0	0	0
February	28	1	1	1	2	2	3	0	1	1	0	0
March	31	0	0	0	1	2	5	2	0	0	1	0
April	30	0	0	0	1	2	3	2	0	0	0	0
May	31	0	0	0	1	1	1	1	1	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		**1**	**1**	**2**	**6**	**9**	**15**	**5**	**2**	**1**	**1**	**0**

Wastewater Treatment Plant releases its partially treated effluent through Los Buenos Creek (Ocean Imaging 2004) and this may have affected total and fecal coliform levels in the area. In contrast, samples indicative of wastewater were limited to waters 6 m and deeper during the rest of 2005.

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

Compliance with COP bacterial standards for U.S. shore and kelp bed stations in 2005 is summarized in **Tables 3.2** and **3.3**. As in the previous years, heavy rainfall caused some of the lowest compliance rates since 1999 when discharge began and compliance monitoring became required (see City of San Diego 2000–2005a). For example, compliance with the 30-day total coliform standard at the shore stations ranged from 36 to 81% in 2005 relative to 34 to 86% in 2004. However, the number of days that shore stations were out of compliance with the 10,000 total coliform standard increased from 31 in 2004 to 41 in 2005. The frequency of compliance with standards based on running means (i.e., the 30-day total, 60-day fecal, and geometric mean standards) was lowest during the rainy period of January through May.

Table 3.3

Summary of compliance with 2001 California Ocean Plan water contact standards for SBOO shore and kelp bed stations during 2005. Values reflect the number of days that each station exceeded the 60-day fecal coliform and geometric mean standards (see Box 3.1). Shore stations are listed north to south in order from left to right.

60-day Fecal Coliform Standard						**Shore stations**				**Kelp stations**		
Month	**# days**	**S9**	**S8**	**S12**	**S6**	**S11**	**S5**	**S10**	**S4**	**I25**	**I26**	**I39**
January	31	10	10	31	31	31	31	31	31	0	31	8
February	28	16	16	28	28	28	28	28	28	15	28	24
March	31	31	31	31	31	31	31	31	31	31	31	30
April	30	23	23	30	30	30	30	30	30	25	24	24
May	31	0	0	31	31	31	31	31	31	2	2	4
June	30	0	0	30	30	30	30	23	22	0	0	0
July	31	0	0	1	2	1	10	3	3	0	0	0
August	31	0	0	0	30	16	0	0	0	0	0	0
September	30	0	0	0	30	30	0	0	0	0	0	0
October	31	0	0	0	14	14	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		**78%**	**78%**	**50%**	**30%**	**34%**	**48%**	**52%**	**52%**	**80%**	**68%**	**75%**
Geometric Mean Standard												
January	31	0	0	22	28	10	31	0	0	0	0	0
February	28	0	0	0	6	14	28	0	0	0	0	0
March	31	0	0	9	28	31	31	14	7	0	0	0
April	30	0	0	0	3	30	30	26	18	0	0	0
May	31	0	0	0	26	26	31	18	0	0	0	0
June	30	0	0	0	0	0	1	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%**	**92%**	**75%**	**70%**	**58%**	**84%**	**93%**	**100%**	**100%**	**100%**

As in previous years, stations located near the Tijuana River mouth exceeded water quality standards more frequently than those farther northward. Only the 2 northernmost shore stations (S8 and S9) were compliant with COP standards ~80% of the time. In contrast, compliance at the more southern shore stations (S4, S5, S6, S10, S11, S12) was less than 60% for the 30-day total and 60-day fecal coliform standards. The proximity of these 6 stations to the Tijuana River may explain the frequency with which they were out of compliance. Excessive runoff volumes, tidal flushing, and frequent and persistent northward currents early in 2005 were probably responsible for the decreased compliance at stations north of the Tijuana River relative to previous years (City of San Diego 2005a, Ocean Imaging 2005a).

The 3 kelp stations were compliant with the COP standards over 68% of the time (Tables 3.2, 3.3). The lowest incidences of compliance occurred from January through April during periods of heavy rainfall. As with the shore stations, increased northward flow of surface waters in early 2005 affected compliance at stations northward of the Tijuana River (I26 and I39). Compliance with the 30-day total and 60-day fecal coliform standards ranged from 72% to 83% and 68% to 75%, respectively for these 2 sites. These values are similar to those reported in 2004. However, in years prior to 2004, the station farthest from shore (I39) was compliant with COP standards over 90% of the time. In general, it appears that shore and kelp station compliance with COP standards was affected most by shore-based discharges that increased during periods of record rainfall during the end of 2004 and early 2005.

Bacterial Patterns Compared to Other Wastewater Indicators

The monthly mean concentrations of oil and grease were <0.50 mg/L in 2005 (**Table 3.4**). Most individual samples had oil and grease concentrations of 0.20 mg/L throughout the year. The highest values (1.61–2.42 mg/L) occurred at 4 stations (I19, I23, I25, I26) in July, but the cause is uncertain. This level of oil and grease detection could indicate transport of the wastewater plume into nearshore surface waters, except that concentrations of indicator bacteria were low in these samples (<300 CFU/100 mL). Instead, July samples with high concentrations of bacteria indicative of the SBOO wastefield were found at depths of 12 m and below at stations I12, I16, and I23, suggesting a northeast transport below the thermocline.

Table 3.4
Means for total suspended solids (TSS; 3 depths) and oil and grease (O&G; 2 m depth) samples for each SBOO monthly water quality station during 2005. Ranges are given in parentheses. NS=not sampled (see text).

Month	O&G mg/L	TSS mg/L
January	0.20	9.2
	-	(0.2-57.0)
February	NS	NS
March	0.20	8.2
	-	(1.9-37.7)
April	0.20	6.3
	-	(0.2-27.7)
May	0.20	8.7
	-	(2.3-28.3)
June	0.20	7.8
	-	(2.1-38.5)
July	0.47	14.1
	(0.20-2.42)	(3.8-54.0)
August	0.20	10.7
	-	(1.7-32.8)
September	0.20	6.9
	-	(1.6-26.3)
October	0.20	4.4
	-	(1.6-10.4)
November	0.20	5.9
	-	(2.2-12.1)
December	0.20	4.1

Monthly mean concentrations of total suspended solids (TSS) ranged from 4.1 to 14.1 mg/L (Table 3.4). Individual values varied considerably, ranging between 0.2 and 57.0 mg/L, and did not correspond to bacterial concentrations. There were 194 TSS samples with concentrations ≥10.0 mg/L, but only 33 (17%) corresponded to samples where total coliform values were ≥1000 CFU/100 mL, and only 10 of these had F:T ratios ≥0.1. Instead, elevated TSS values corresponded primarily to stormwater discharges and plankton concentrations (see Chapter 2). The second highest TSS concentration was recorded in July during a red tide event at inshore station I25 (2 m sample). All corresponding bacteriological indicators were below 120 CFU/100 mL, while chlorophyll *a* was extremely elevated, dissolved oxygen values were relatively high, and transmissivity was low. Taken together, these results suggest a limited utility for high suspended solids or oil and grease concentrations as indicators of the waste field.

SUMMARY AND CONCLUSIONS

Record rainfall in 2005 strongly affected water quality conditions for the South Bay region. Bacterial concentrations in shore and kelp bed samples that exceeded COP standards appear to have been caused by contamination from river discharge and runoff during and after storm events. Bacterial concentration and visible satellite imagery data indicate that flows from the Tijuana River, Los Buenos Creek, and non-point source stormwater runoff are more likely to critically impact the water quality along the shore and at nearshore stations.

Data from the bacterial analyses for the South Bay region indicate that the wastewater plume from the SBOO rarely reached surface waters in 2005. Thermal stratification that began in March likely prevented the wastewater plume from surfacing through most of the year. Elevated bacterial counts evident near the surface in January, April, and October occurred during periods of heavy rainfall or when turbidity plumes from the Tijuana River or Los Buenos Creek reached the affected stations. Results indicative of wastewater reaching the surface occurred only in June. Remote sensing data suggests that frequent and persistent northward currents during the early part of 2005 affected the water quality at stations north of the Tijuana River. The majority of the subsurface (>2 m depth) monthly water quality samples indicative of the wastewater plume mostly occurred at depths of 18 m and below. These samples were collected predominantly near the outfall during the year.

In conclusion, although there were elevated bacterial densities detected at the nearshore and shore stations throughout the year, these data do not indicate a shoreward transport of the SBOO discharge plume. High amounts of rain, runoff from the Tijuana River and Los Buenos Creek, and northward currents appear to be the primary source of the nearshore bacteriological contamination. These conditions had the largest impact on water quality in the South Bay region during 2005.

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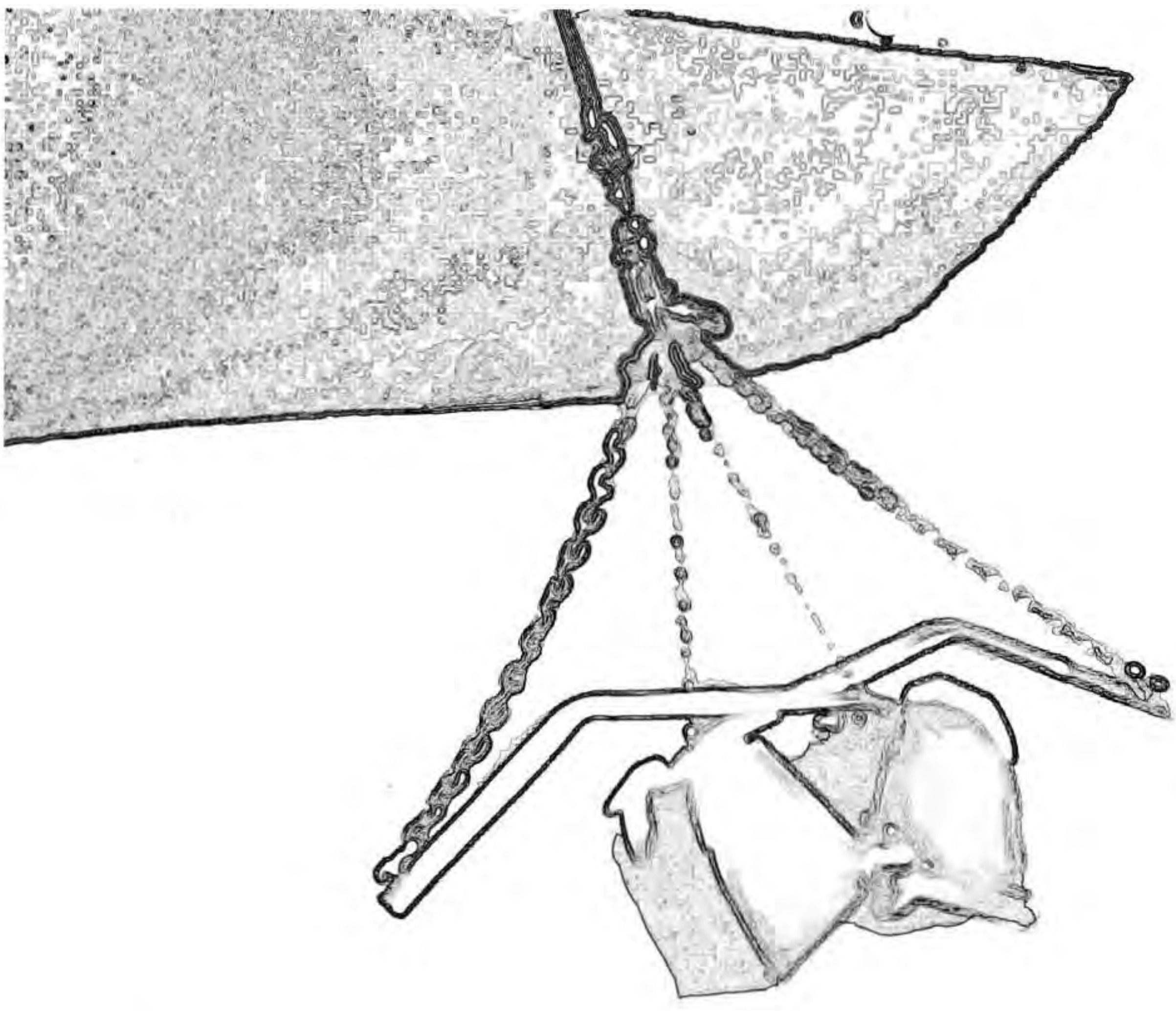
Chapter 4
Sediment Characteristics



Chapter 4. Sediment Characteristics

INTRODUCTION

Sediment conditions can influence the distribution of benthic invertebrates by affecting the ability of various species to burrow, build tubes or feed (Gray 1981, Snelgrove and Butman 1994). In addition, many demersal fishes are associated with specific sediment types that reflect the habitats of their preferred prey (Cross and Allen, 1993). Both natural and anthropogenic factors affect the distribution, stability and composition of sediments. Ocean outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of ocean sediments through the discharge of wastewater and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds discharged via outfalls are trace metals, pesticides and various organic compounds (e.g., organic carbon, nitrogen, sulfides) (Anderson et al. 1993). Moreover, the presence of large outfall pipes or associated structures can alter the hydrodynamic regime in the immediate area.

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

The chemical composition of sediments can also be affected by the geological history of an area. For example, sediment erosion from cliffs and shores, and the flushing of sediment particles and terrestrial debris from bays, rivers and streams, contribute to the composition of metals and organic content within an area. Additionally, nearshore primary productivity by marine plankton contributes to organic input in marine sediments (Mann 1982, Parsons et al. 1990). Concentrations of these materials within ocean sediments generally increase with increasing amounts of fine particles chiefly as a result of adsorption (Emery 1960).

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2005 in the vicinity of the South Bay Ocean Outfall. The primary goals are to: (1) assess possible impact of wastewater discharge on the benthic environment by analyzing spatial and temporal variability of the various sediment parameters, and (2) determine the presence or absence of sedimentary and chemical footprints near the discharge site.

MATERIALS AND METHODS

Field Sampling

Sediment samples were collected during January and July of 2005 at 27 stations surrounding the South Bay Ocean Outfall (SBOO) (**Figure 4.1**). These stations are located along the 19, 28, 38, and 55-m depth contours and form a grid surrounding the terminus of the outfall. A chain-rigged 0.1 m^2 double Van Veen grab was used to collect each sample. 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 Laboratory. Particle size analysis was performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., -1 to 11 phi). Coarser sediments (e.g., very coarse sand, gravel, shell hash) were removed prior to analysis by screening the samples through a 2.0 mm mesh sieve.

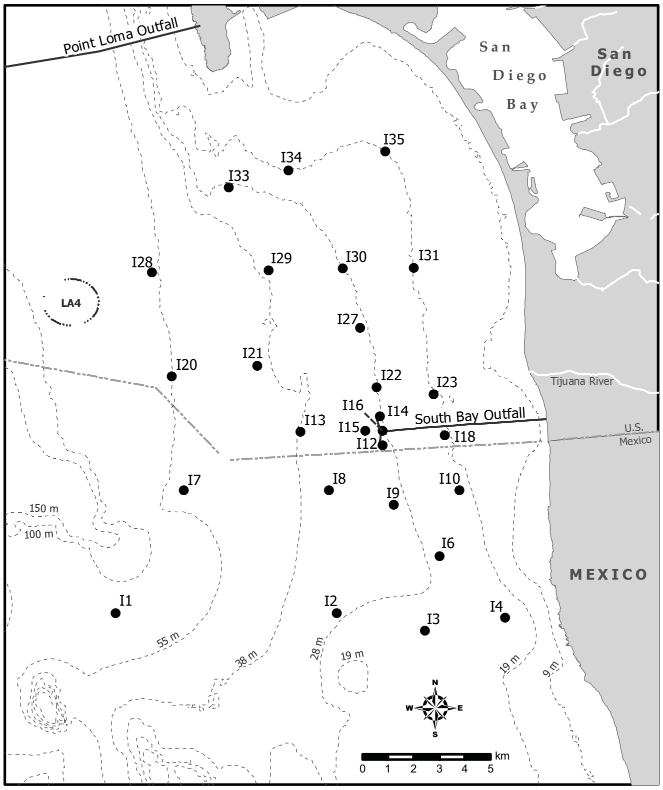


Figure 4.1
Benthic sediment station locations sampled for the South Bay Ocean Outfall Monitoring Program.

These data were expressed as the percent "Coarse" of the total sample sieved.

Data Analyses

Data output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles >0.0625 mm in size, silt as particles from <0.0625 to 0.0039 mm, and clay as particles <0.0039 mm (see **Table 4.1**). These data were standardized and incorporated with a sieved coarse fraction containing particles >2.0 mm in diameter to obtain a distribution of coarse, sand, silt, and clay totaling 100%. The coarse fraction was included with the $\geq$2.0 mm fraction in the calculation of various particle size parameters, which were determined using a normal probability scale (see Folk 1968). The parameters included mean and median particle size in millimeters and phi, standard deviation of phi size (sorting coefficient), skewness, kurtosis and percent sediment type (i.e., coarse, sand, silt, clay).

Chemical parameters analyzed were total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl compounds (PCBs) (see **Appendix B.1**). Generally, concentrations below method detection limits are treated as "not detected" (i.e., null). However, some parameters (e.g., PAH compounds) were determined to be present in a sample with high confidence (i.e., peaks are confirmed by mass-spectrometry) but at levels below the MDL. These values were included in the data as estimated values. Zeroes were substituted for null ("not detected") values when calculating mean values.

Concentrations of the sediment constituents that were detected in 2005 were compared to average results from previous years, including pre-discharge (1995–1998) and post-discharge (1999–2004) periods. In addition, values for metals, TOC, TN, and pesticides (i.e., DDT) were compared to median values for the Southern California Bight (SCB). These medians were based on the cumulative distribution function (CDF) calculated for each parameter using data from the SCB region-wide survey in 1994 (see Schiff and Gossett 1998). They are presented as the 50% CDF in the tables included herein. Levels of contamination were further evaluated by comparing the results of this study to the Effects Range Low (ERL) sediment quality guideline of Long et al. (1995). The ERL was originally calculated to provide a means for interpreting monitoring data by the National Status and Trends Program of the National Oceanic and Atmospheric Administration. The ERL represents chemical concentrations below which adverse biological effects were rarely observed.

RESULTS AND DISCUSSION

Particle Size Distribution

During 2005, overall composition of sediments surrounding the SBOO ranged from very fine to coarse sands (**Table 4.2**, **Figure 4.2**). Generally, stations located farther offshore and southward of

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	0.0020	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: $D(phi) = -3.3219\log_{10}D(mm)$

the SBOO had coarser sediments than those located inshore and to the north of the outfall (**Figure 4.3**). Most stations offshore and southward of the SBOO had sediments consisting of relatively coarse particles (≥0.3 mm or ≤2.0 phi). The remaining stations located along the shallower 19 and 28-m contours and towards the mouth of San Diego Bay typically had finer sediments (<0.2 mm or >2.0 phi) with samples collected at stations I23 and I34 being notable exceptions (see below). The higher silt content at these shallower, northern stations is probably due to sediment deposition from the Tijuana River and to a lesser extent from San Diego Bay (see City of San Diego 1988, 2003a). This pattern was evident even though the sediments at many sites varied in the proportion of shell hash, red relict sand, fine sand and silt.

There were few differences in particle size distribution between the January and July 2005 surveys (Figure 4.3). The greatest change in sediment particles occurred at stations I23, I4, and I34 where mean particle size differed by approximately 0.3– 0.6 mm (**Appendix B.2**). Station I34 is located just south of the channel that enters San Diego Bay, and may be occasionally affected by maintenance dredging of the harbor entrance channel. Stations I4 and I23 are located in shallow waters and experienced a substantial increase in coarse materials between surveys. Deposits of red relict sand of Pleistocene origin were also found at several stations greater than 38 m depth (e.g., I6, I7, I13, I20, I21). Most of these stations are located where such deposits have been collected consistently. The location of these relict sediments in probably related to decreased deposition of fine detrital sediments of terrestrial origin that would normally bury the Pleistocene sands (Emery 1960).

Sediment sorting or the sorting coefficient reflects the range of grain sizes comprising marine sediments. It is calculated as the standard deviation of the grain size in phi (see Table 4.1). Generally, areas with well-sorted sediments (SD ≤ 0.7 phi) are composed of mostly similarly sized particles, which are suggestive of strong wave and current activity within an area (see Gray 1981). In contrast, poorly sorted sediments (SD >1.0 phi) include particles of varied sizes and are indicative of low wave and current activity. Sorting coefficients in the area surrounding the SBOO ranged from 0.7–1.8 phi during 2005 indicating that sediments

Table 4.2

Summary of particle size parameters and organic loading indicators at SBOO stations during 2005. Data are expressed as annual means. CDF=cumulative distribution functions (see text); NA=not available. MDL=method detection limit. Area Mean=mean for 2005. Pre=pre-discharge mean values (1995–1998). Post = post discharge mean values (1999–2004).

	Particle Size						Organic Indicators		
	Mean (phi)	SD (phi)	Mean (mm)	Coarse (%)	Sand (%)	Fines (%)	Sulfides (ppm)	TN (wt%)	TOC (wt%)
CDF						38.5	NA	0.051	0.748
MDL							0.14	0.005	0.010
19 m stations									
I35	4.0	1.5	0.063	0.0	59.2	40.7	8.67	0.035	0.327
I34	1.0	1.1	0.496	20.3	78.6	1.0	0.48	0.028	0.318
I31	3.0	0.8	0.120	0.1	91.5	8.1	0.60	0.019	0.174
I23	1.7	0.9	0.432	10.9	83.4	5.5	0.80	0.014	0.168
I18	3.1	1.0	0.112	0.3	85.9	12.6	1.47	0.015	0.127
I10	3.0	0.9	0.123	0.3	90.9	8.6	1.22	0.034	0.144
I4	2.1	0.8	0.277	3.3	92.9	3.8	0.15	0.009	0.098
28 m stations									
I33	2.9	1.0	0.132	0.4	88.8	10.6	2.51	0.025	0.186
I30	3.2	1.1	0.103	0.6	83.7	15.6	1.56	0.043	0.200
I27	3.2	1.0	0.106	0.1	84.7	14.8	0.42	0.020	0.173
I22	3.2	1.3	0.109	0.5	82.1	16.9	1.89	0.025	0.215
I16	2.3	1.4	0.208	4.3	87.3	8.3	2.25	0.010	0.136
I15	1.7	1.2	0.298	4.3	89.4	4.8	0.12	0.019	0.075
I14	2.9	1.2	0.130	0.2	86.5	13.0	6.34	0.040	0.182
I12	1.6	1.0	0.325	4.6	92.6	2.7	0.21	0.011	0.087
I9	3.3	1.0	0.103	0.3	82.6	17.0	7.56	0.034	0.246
I6	0.9	0.7	0.528	8.2	91.7	0.0	0.00	0.015	0.072
I3	1.2	0.8	0.426	5.9	94.1	0.0	0.00	0.005	0.047
I2	1.6	0.9	0.328	4.1	93.4	0.4	0.10	0.010	0.070
38 m stations									
I29	3.6	1.4	0.083	0.0	71.5	27.5	0.73	0.041	0.605
I21	0.8	0.7	0.558	9.7	89.7	0.5	0.00	0.004	0.055
I13	1.3	1.0	0.393	5.5	90.6	3.8	0.00	0.038	0.122
I8	1.6	1.1	0.328	4.6	90.9	3.5	0.36	0.022	0.114
55 m stations									
I28	1.8	1.8	0.282	16.3	59.8	23.8	0.81	0.049	0.628
I20	1.0	1.5	0.498	15.0	73.8	11.1	0.17	0.008	0.056
I7	1.1	1.5	0.452	9.3	82.3	8.2	0.00	0.022	0.160
I1	2.9	1.0	0.134	0.0	89.7	10.2	0.21	0.021	0.233
Area Means									
2005	2.2	1.1	0.265	4.8	84.8	10.1	1.43	0.023	0.186
Post	2.4	0.9	0.245	2.2	88.6	8.9	2.20	0.018	0.141
Pre-	2.6	0.8	0.213	1.4	87.7	10.2	4.59	0.019	0.143

were moderately to poorly sorted as a result of either reduced wave and current velocity or some disturbance (Table 4.2). Twelve stations had poorly sorted sediments (i.e., SD >1.0 phi), including 4 sites along the 28-m contour near the SBOO (stations I14, I15, I16, I22), 1 site offshore of the SBOO along the 38-m contour (I8), 3 offshore sites along the 55-m contour (stations I7, I20, I28), and 4 sites north of the

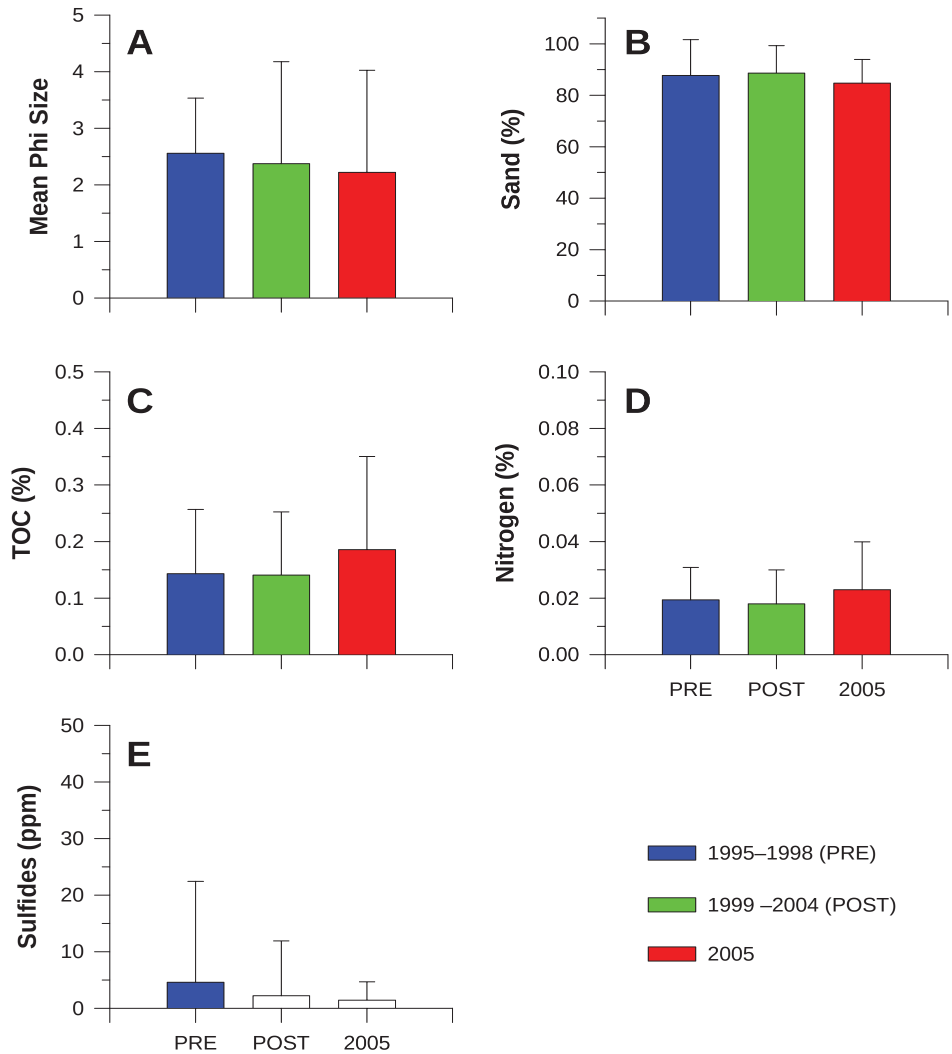


Figure 4.2

Comparison of values for several sediment quality parameters surrounding the SBOO in 2005 with values during previous post-discharge monitoring (1999–2004) and the pre-discharge period (1995–1998): (A) mean phi size; (B) percent sand; (C) percent total organic carbon (TOC); (D) percent total nitrogen; (E) sulfides (ppm). Data are expressed as area wide means for each survey period. Error bars represent one standard deviation.

SBOO (stations I29, I30, I34, I35) (see Figure 4.2). Station I35 near the mouth of San Diego Bay, and stations I7, I20, and I28 along the 55-m contour had the highest mean sorting coefficients (1.5–1.8 phi). The sorting coefficients for 2 of these sites (I28 and I35), along with station I29, have consistently been >1.0. Samples from these 3 stations comprise 56% of all poorly sorted sediment samples that have been collected since monitoring began in the South Bay region, which may reflect ongoing localized disturbance. For example, sediment observations at station I28 include the presence of materials of multiple origins (e.g., silt, coarse sand, and coarse black sand) with coarse black sands having been associated with disposal sites in the past (see City of San Diego 2003b). This site is located northeast of a dredge disposal site and appears to be affected by anthropogenic activities. Coarse black sand was also present at stations I29 and I35 and may indicate incidental deposition or the spreading of dredged materials. In addition, there has been an overall increase in the sorting coefficient in recent years.

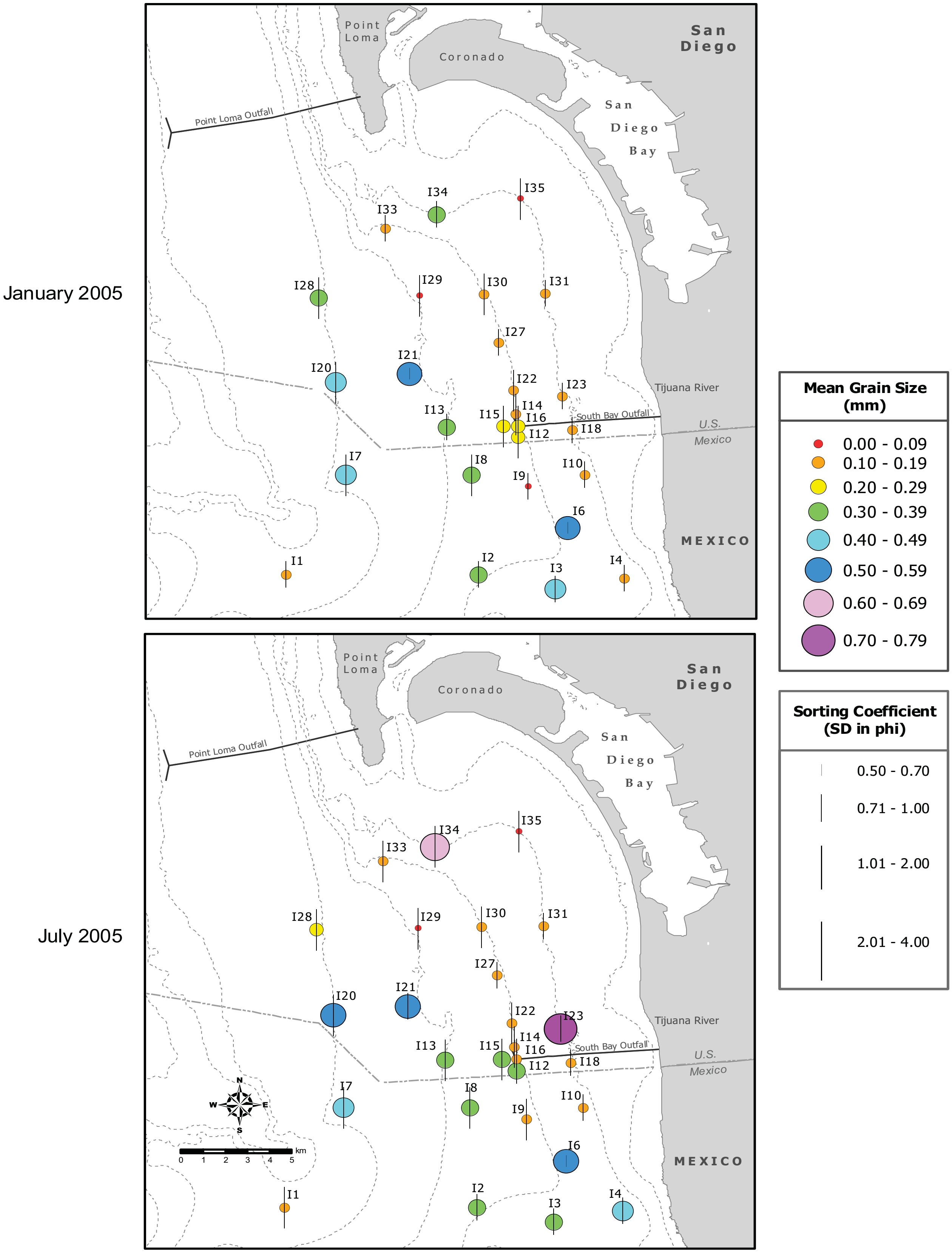


Figure 4.3

Comparison of January and July surveys for differences in sediment particle size distribution for SBOO sediment chemistry stations sampled during 2005. Mean particle size is based on diameter in millimeters, and sorting coefficient (standard deviation) is in phi units.

Thirty-eight percent of poorly sorted samples were collected from July 2004 to July 2005, coincident with the onset of record rains, and may be indicative of input from beach deposits (see below).

Mean particle size for the South Bay during the pre-discharge, post-discharge, and the 2005 surveys indicate that particle size has increased over time (see **Tables 4.2, 4.3, Figure 4.2**). Average particle size during the 1995–1998 period was 0.213 mm but has increased to 0.265 mm in 2005. Particle size began to increase after 1998 when El Niño conditions produced powerful storms and heavy surf that eroded beaches along the San Diego coastline (City of San Diego 2003c, U.S. Army Corp of Engineers 2002). Then drought conditions that persisted in San Diego from 1999 through early 2004 resulted in a reduction of runoff from rivers and bays that most likely caused a decrease in deposition of terrestrial fine particles onto the ocean shelf. In addition, record rainfall from October 2004 through February 2005 and associated heavy surf resulted in severe loss of beach sand from Imperial Beach as well as other beaches in San Diego County (Zúñiga 2005). In general, the increase in particle size in the South Bay appears to be in part the result of accretion of coarser sediments lost from the Silver Strand littoral cell.

Indicators of Organic Loading

The average concentrations of total organic carbon and total nitrogen in South Bay sediments in 2005 were slightly higher than those of previous surveys (see Tables 4.2, 4.3, Figure 4.2). Approximately two-thirds of the stations had mean TOC values that were 0.1–0.3% higher than in 2004. This change may be the result of persistent discharge from San Diego Bay and the Tijuana River during the winter of 2004–2005, which was laden with organic material and contributed to a lasting plankton bloom (see Chapter 2). However, concentrations of TN and TOC parameters at most sites were below SCB median values (Table 4.2). The single exception occurred at station I28 where total nitrogen was equal to the median value (0.05%). Higher concentrations of TOC and TN typically correspond to high concentrations of fine sediments (Emery 1960, Eganhouse and Venkatesan 1993), and this was generally true of the samples collected in 2005. The highest average values for TOC were found at stations I28 and I29 where relatively high concentrations of fine sediments also occurred.

Mean sulfide values ranged from non-detected to 8.7 ppm, however the mean at most stations was <1.0 ppm and only slightly higher than the MDL. Mean values in 2005 were lower than those collected in previous post-discharge years (1999–2004), which were lower than those prior to discharge (see Figure 4.2, Table 4.2). Overall, there was no pattern in concentrations of organic loading indicators relative to wastewater discharge.

Table 4.3

Summary of changes in particle size and organic indicators for 1995–2005. Data are expressed as annual means. Particle size is in phi and millimeters (mm). SD=standard deviation (phi) and is also the sorting coefficient. Coarse is the percent material greater than -1 phi or 2 mm. TN and TOC are in percent weight (wt %).

	Sediment Particle Size				Organic Indicators	
Year	phi	mm	SD	Coarse	TN	TOC
1995	2.6	0.21	0.8	2.6	0.019	0.148
1996	2.6	0.21	0.9	0.8	0.022	0.149
1997	2.5	0.22	0.7	0.7	0.019	0.147
1998	2.5	0.21	0.7	2.1	0.017	0.132
1999	2.5	0.24	0.7	0.9	0.017	0.129
2000	2.5	0.21	0.8	1.0	0.021	0.130
2001	2.3	0.25	0.8	1.5	0.015	0.149
2002	2.4	0.26	0.8	2.3	0.016	0.139
2003	2.3	0.24	0.9	3.3	0.016	0.119
2004	2.3	0.26	1.1	4.5	0.018	0.135
2005	2.2	0.27	1.1	4.8	0.023	0.186

Trace Metals

Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, nickel, tin, and zinc were detected at 100% of the South Bay area stations in 2005 (**Table 4.4**). In contrast, mercury, silver, thallium were detected less frequently (<55% of the stations), while selenium was not detected at all. The use of more sensitive instrumentation starting in late

2003 increased the detection frequency for several of these metals, specifically antimony, lead, and silver (see City of San Diego 2004).

Generally, there was no pattern in trace metal contamination related to proximity to the SBOO. Stations with sediments consisting of greater amounts of fine particles had higher concentrations of metals (see Table 4.3). For example, of the 12 stations with >10% fines, 9 had mean concentrations of aluminum and antimony above the 50% CDF, and 3 had concentrations of 3 or more metals above the CDF. Included among the latter group were stations I29 and I35, both of which also included the presence of coarse black sand indicative of dredged materials (see above). The highest concentrations of arsenic occurred where sediments consisted of very coarse red relict sand (i.e., stations I6, I7, I13 and I21).

Area means for aluminum, antimony, chromium, iron, lead, manganese, mercury, nickel, tin, and zinc have increased with respect to previous surveys (see Chapter 8). Of these, aluminum, iron, lead, and manganese have had large increases relative to previous years, particularly 2004. This is most likely the result of littoral sediment transport to the subtidal shelf during the heavy storm activity of 2004 and 2005 as described above. Despite a general increase in mean trace metal concentrations, SBOO sediments were generally below the median values for southern California. Moreover, all trace metal concentrations were below the ERL sediment quality thresholds for metals of concern (i.e., cadmium chromium, copper, lead, mercury, nickel, silver, zinc) with the exception of arsenic at station I21.

Pesticides

A single type of chlorinated pesticide was detected in sediment samples collected during 2005 (**Appendix B.3**). The DDT derivative, p,p-DDE, was found at stations I28 during January (740 ppt) and July (400 ppt), and at I29 (540 ppt) in July. These values were lower than the median CDF value of 1200 ppt for this pesticide, and significantly lower than the ERL of 2200 ppt. Station I28 has had elevated pesticide levels in the past, which are most likely related to contamination from dredge disposal materials (see City of San Diego 2001, 2003a).

PCBs and PAHs

PCBs were detected at 1 station (I33) during January 2005 with a total PCB concentration of 11,320 ppt. This value was below the median CDF and ERL levels of 26,000 and 22,700 ppt, respectively.

Low levels of 23 PAH compounds were detected at all stations (Appendix B.3). The PAH values were near or below MDL levels and should therefore be viewed with caution. The detection of low levels of PAHs at all stations appears to reflect a change in methodology where values below MDLs can be reliably estimated with qualitative identification via a mass spectrophotometer (see City of San Diego 2004). All of the values were well below the ERL of 4022 ppt for total PAH. The highest average PAH concentration (1036 ppb) was found at station I7, which is located in Mexican waters west of the Tijuana River at a depth of 55 m (see Figure 3.1). There did not appear to be a relationship of PAH or PCB concentrations relative to the outfall location.

SUMMARY AND CONCLUSIONS

Overall, a series of differences in sediment conditions surrounding the South Bay Ocean Outfall (SBOO) in 2005 relative to previous years seem to be related to the affects of a succession of record storms beginning in fall of 2004. These differences include the prevalence of poorly sorted sediments and slight increases in overall particle size, total organic carbon, and concentrations of certain trace metals. However, there was no indication of contamination attributable to the SBOO based on analyses of particle size or sediment chemistry data.

Sediments at the South Bay sampling sites consisted primarily of very fine to coarse sands in 2005. The average particle size was 0.265 mm (2.2 phi), which represents a continued increase in particle size from an

Table 4.4

Concentrations of trace metals (parts per million) detected at each station during 2005. CDF=cumulative distribution function (see text). MDL=method detection limit. ERL TV=Effects Range Low Threshold Value. NA=not available. Pre=pre-discharge values (1995–1998). Post=post discharge values (1999–2004). See Appendix A.1 for metal names represented by the periodic table symbols.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Ag	Tl	Sn	Zn
MDL	1.15	0.13	0.33	0.00	0.00	0.01	0.02	0.03	0.75	0.14	0.00	0.00	0.04	0.01	0.02	0.06	0.05
CDF	9400	0.20	4.80	na	0.26	0.29	34.0	12.0	16800	na	na	0.04	NA	0.17	na	na	56.0
ERL	na	na	8.20	na	na	1.2	81.0	34.0	na	46.7	na	0.20	20.9	1.00	na	na	150
19 m stations																	
I35	17250	1.0	2.82	56.20	0.28	0.15	20.4	8.2	17900	7.20	237	0.03	8.1	0.10	0.0	2.3	37.5
I34	3045	0.4	1.98	9.19	0.09	0.01	4.6	1.5	4830	2.80	96	0.00	1.0	0.10	0.0	1.0	8.4
I31	8710	0.3	1.37	22.05	0.15	0.09	14.0	2.1	14750	3.20	416	0.00	2.9	0.00	0.0	1.7	22.9
I23	7265	0.9	1.89	19.95	0.15	0.05	11.8	2.3	11850	3.30	315	0.00	2.4	0.10	0.0	1.2	20.9
I18	12650	0.9	1.66	48.30	0.21	0.09	21.4	3.9	19150	4.00	455	0.00	5.2	0.00	0.0	1.9	34.8
I10	10345	0.5	1.28	38.55	0.17	0.06	16.1	3.4	13500	3.10	266	0.00	4.1	0.10	0.0	1.6	25.4
I4	5200	0.3	1.49	13.29	0.09	0.03	10.6	1.8	8135	2.50	208	0.00	2.4	0.00	0.0	1.4	14.1
28 m stations																	
I33	9015	0.7	2.11	26.80	0.17	0.08	12.2	3.6	11950	4.80	254	0.01	3.5	0.10	0.0	2.0	22.4
I30	12800	0.6	2.01	38.45	0.20	0.08	15.4	4.6	11450	4.20	184	0.01	5.1	0.00	0.0	1.6	24.5
I27	12050	0.3	1.91	35.45	0.19	0.07	15.4	3.9	12100	4.10	225	0.00	4.6	0.00	0.0	1.6	24.7
I22	12450	0.8	1.74	38.70	0.19	0.07	17.9	4.4	14250	4.10	324	0.00	5.3	0.10	0.0	1.7	28.8
I16	7145	0.6	1.89	25.00	0.14	0.04	10.8	2.5	9865	2.40	223	0.00	2.7	0.00	0.0	1.2	19.5
I15	4460	0.3	2.86	12.55	0.10	0.04	11.0	1.4	7750	2.60	143	0.00	1.8	0.00	0.0	1.1	13.5
I14	11950	0.5	1.73	41.30	0.19	0.07	15.9	4.3	13100	3.80	266	0.00	4.6	0.00	0.0	1.7	27.2
I12	5300	0.3	1.73	17.00	0.11	0.02	9.5	1.5	8540	1.90	198	0.00	1.9	0.10	0.0	1.2	15.3
I9	14550	0.5	1.70	49.10	0.21	0.08	17.9	5.4	13350	3.80	218	0.00	6.0	0.00	0.0	1.7	30.0
I6	1765	0.2	4.88	3.47	0.06	0.02	8.4	0.7	4960	1.70	59	0.00	0.8	0.10	0.0	0.9	5.2
I3	2055	0.3	0.99	3.04	0.05	0.00	7.1	0.4	4565	1.40	148	0.00	0.8	0.00	0.0	1.1	6.5
I2	2250	0.3	0.61	3.40	0.06	0.01	6.2	0.5	2615	1.30	58	0.00	0.8	0.20	0.3	0.9	4.5
38 m stations																	
I29	14650	0.4	2.72	43.45	0.25	0.10	21.2	6.1	18100	6.50	359	0.01	7.0	0.00	0.0	2.0	31.5
I21	2390	0.8	9.73	3.62	0.10	0.04	12.0	0.8	9275	3.50	43	0.00	0.8	0.10	0.0	0.9	8.0
I13	3590	0.3	4.59	6.67	0.09	0.03	11.7	1.2	9060	3.20	177	0.00	1.4	0.00	0.1	1.1	11.4
I8	3965	0.6	2.55	7.75	0.10	0.04	10.9	1.1	6625	2.20	110	0.00	1.6	0.00	0.0	1.1	11.1
55 m stations																	
I28	10950	0.5	2.48	32.10	0.20	0.10	14.7	6.3	12550	5.50	201	0.01	6.6	0.00	0.0	1.8	26.3
I20	2765	0.6	3.60	5.13	0.09	0.02	6.2	1.0	5950	2.00	57	0.00	1.0	0.10	0.0	1.0	8.1
I7	3055	0.5	5.20	5.49	0.09	0.03	11.3	1.0	10180	2.80	163	0.02	1.4	0.10	0.0	1.2	11.5
I1	6040	0.5	1.22	14.50	0.13	0.09	10.4	1.9	9335	2.60	234	0.00	3.2	0.00	0.0	1.5	16.1
Area Means																	
2005	7691	0.5	2.55	22.98	0.14	0.06	12.8	2.8	10581	3.35	209	0.00	3.2	0.05	0.02	1.4	8.9
Post	4892	0.2	2.41	21.33	0.15	0.06	9.5	3.8	6330	0.59	68	0.00	1.6	0.13	0.36	0.3	13.2

average of 0.213 mm (2.6 phi) observed prior to wastewater discharge (1995–1998). This increase in coarser sediments may be partially attributed to the loss of littoral sands from the beaches in South Bay to deeper water. Since the 1940s, construction of dams and reservoirs on the Tijuana River has resulted in beach erosion along the Silver Strand littoral cell of approximately 76,000 cubic meters (100,000 cubic yards) per year (U.S. Army Corp of Engineers 2002). Additionally, drought conditions that persisted in San Diego from 1999 through early 2004 most likely resulted in a reduction of runoff from rivers and bays causing a decrease in deposition of terrestrial fine particles onto the ocean shelf. In February 2004 and from October 2004 through February 2005 record rainfall and heavy surf resulted in severe loss of beach sand from Imperial Beach as well as other beaches in San Diego County (Zúñiga 2005). The increase in overall mean particle size as well as the increase in sorting coefficients at several stations appears to be in part the result of accretion of coarser sediments lost from the Silver Strand littoral cell.

Spatial patterns in sediment composition within the SBOO region may be partially attributed to the multiple geological origins of red relict sands, shell hash, coarse sands, and other detrital sediments (Emery 1960). Stations located offshore and southward of the SBOO consisted of very coarse sediments. In contrast, stations located in shallower water and north of the outfall towards the mouth of San Diego Bay had finer sediments. Sediment deposition from the Tijuana River and to a lesser extent from San Diego Bay probably contributes to the higher content of silt at these stations (see City of San Diego 1988).

Concentrations of organic indicators and trace metals were relatively low in South Bay sediments compared to the entire southern California continental shelf (see Schiff and Gossett 1998). However, there was an overall increase in total organic carbon relative to previous years that was likely related to increased turbid discharge from San Diego Bay and the Tijuana River, and a strong and persistent plankton bloom that lasted from spring through fall of 2005.

The detection frequency of several trace metals increased in 2005 relative to previous surveys, but these changes are likely related to the use of a more sensitive instrument that began in late 2003. However, an increase in concentrations of several metals such as iron, aluminum, and manganese may be associated with the transport of littoral beach sands to deeper water during the storm activity of 2004 and 2005. Generally, trace metal concentrations in the SBOO sediments were low compared to median values for southern California, and all metals of concern were below ERL sediment quality thresholds with the exception of arsenic at 1 station. Higher concentrations of organic compounds and most trace metals were generally associated with finer sediments. This pattern is consistent with that found in other studies, in which the accumulation of fine particles has been shown to greatly influence the organic and metal content of sediments (e.g., Eganhouse and Venkatesan 1993).

Other sediment contaminants were rarely detected during 2005. For example, PCBs were detected at a single station, and only 1 derivative of the pesticide DDT was detected at 2 stations. PAHs were found at all stations but at low concentrations near or below their respective method detection limits. The increased frequency of detection was likely the result of a change in methodology and the increased reporting of estimated values. The highest concentration of total PAHs was still well below the 50% CDF and the ERL level. Overall, there was no pattern in sediment contaminant concentrations relative to the SBOO discharge.

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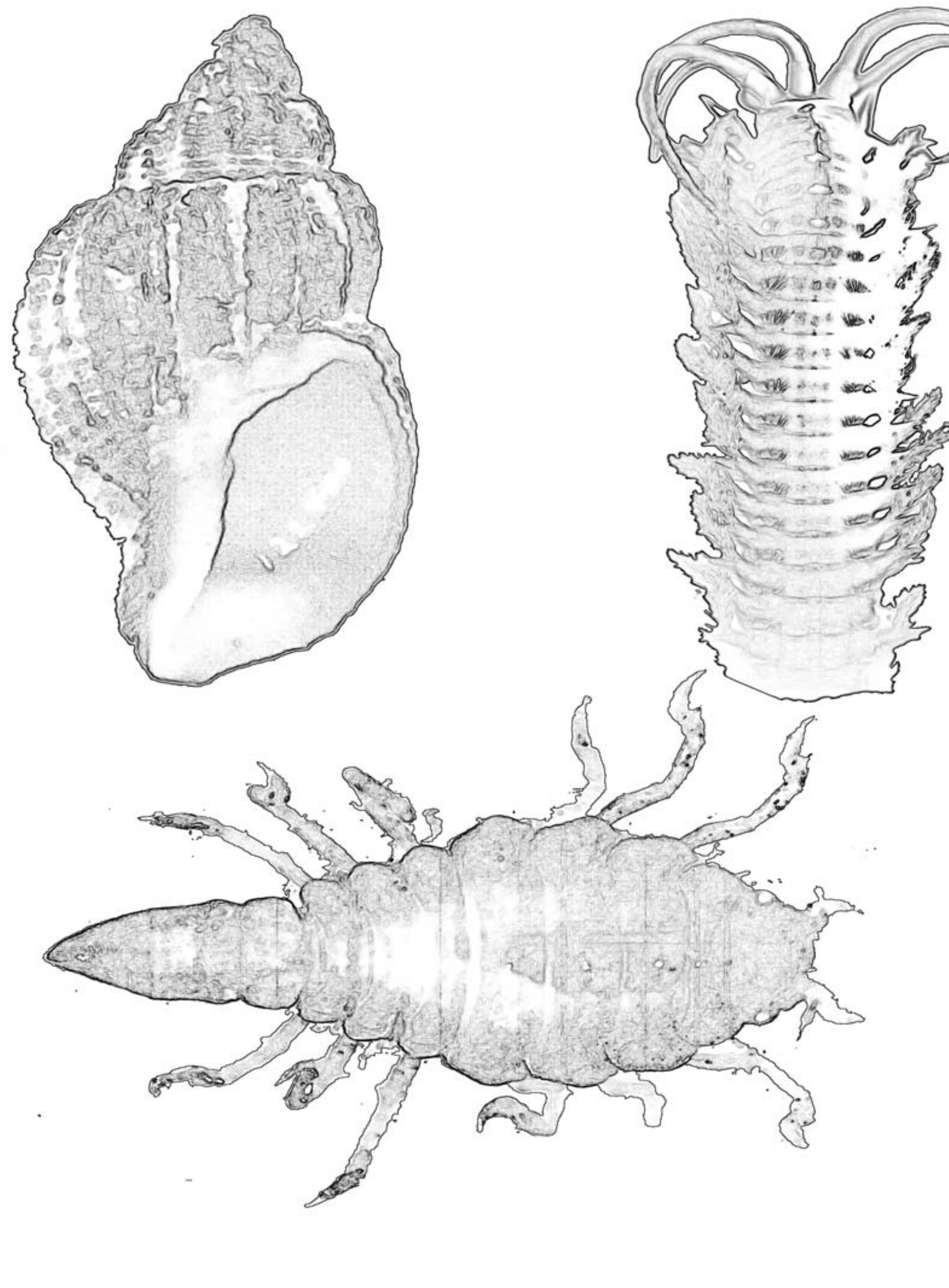
Chapter 5
Macrobenthic Communities



Chapter 5. Macrobenthic Communities

INTRODUCTION

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

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

The structure of benthic communities is influenced by many factors including sediment conditions (e.g., particle size and sediment chemistry), water conditions (e.g., temperature, salinity, dissolved oxygen, and current velocity), and biological factors (e.g., food availability, competition, and predation). For example, benthic assemblages on the coastal shelf off San Diego typically vary along gradients in sediment particle size and/or depth. However, both human activities and natural processes can influence the structure of invertebrate communities in marine sediments. Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have documentation of background or reference conditions for an area. Such information is available for the SBOO discharge area 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 2005. Included are descriptions and comparisons of soft-bottom macrofaunal assemblages in the area, and analysis of benthic community structure.

MATERIALS AND METHODS

Collection and Processing of Samples

Benthic samples were collected during January and July, 2005 at 27 stations surrounding the SBOO (**Figure 5.1**). These stations range in depth from 18 to 60 m and are distributed along 4 main depth contours. Listed from north to south along each contour, these stations include: 19-m contour: stations I35, I34, I31, I23, I18, I10, I4; 28-m contour: stations I33, I30, I27, I22, I14, I16, I15, I12, I9, I6, I2, I3; 38-m contour: stations I29, I21, I13, I8; 55-m contour: stations I28, I20, I7, I1.

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

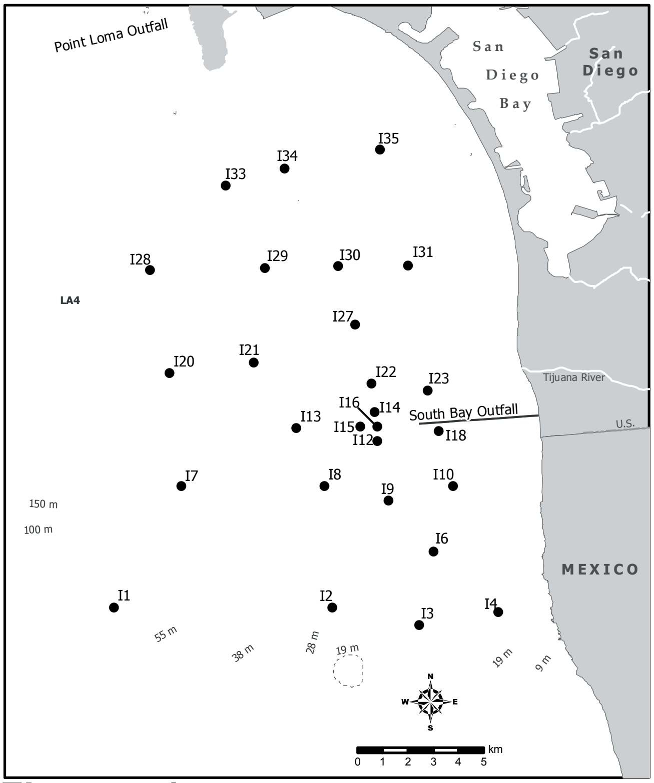


Figure 5.1
Macrobenthic station locations, South Bay Ocean Outfall Monitoring Program.

penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Organisms retained on the screen were relaxed for 30 minutes in a magnesium sulfate solution and then fixed in buffered formalin (see City of San Diego in prep.). After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All organisms were sorted from the debris into major taxonomic groups by a subcontractor. Biomass was measured as the wet weight in grams per sample for each of the following taxonomic categories: Annelida (mostly polychaetes), Arthropoda (mostly crustaceans), Mollusca, Ophiuroidea, non-ophiuroid Echinodermata, and other miscellaneous phyla combined (e.g. Chordata, Cnidaria, Nemertea, Platyhelminthes, Phoronida, Sipuncula). Values for ophiuroids and all other echinoderms were later combined to give a total echinoderm biomass. After biomassing, all animals were identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

Data Analyses

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

Multivariate analyses were performed using PRIMER v5 (Plymouth Routines in Multivariate Ecological Research) software to examine spatio-temporal patterns in the overall similarity of benthic assemblages in the region (see Clarke 1993, Warwick 1993). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). 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. Analyses were run on individual grab samples and on the mean of the 2 replicate grabs per station/survey. The results of these analyses showed negligible differences; thus for clarity and simplicity, results presented herein are for mean abundances of replicate grabs per station/survey. Patterns in the distribution of macrofaunal assemblages were compared to environmental variables by overlaying the physico-chemical data onto MDS plots based on the biotic data (see Field et al. 1982).

RESULTS AND DISCUSSION

Community Parameters

Number of Species
A total of 863 macrobenthic taxa were identified during 2005. Of these, 26% represented rare or

Table 5.1

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

	N	SR	Tot spp	Abun	Biomass	H'	J'	Dom	BRI	ITI
19 m stations										
I-35	4	79	115	250	4.6	3.9	0.90	30	28	80
I-34	4	68	97	747	5.1	2.9	0.70	12	13	64
I-31	4	51	74	133	2.0	3.4	0.88	22	19	78
I-23	4	71	123	408	3.4	3.4	0.84	22	20	73
I-18	4	55	77	124	4.5	3.6	0.91	25	20	76
I-10	4	63	94	140	4.4	3.9	0.94	30	16	80
I-4	4	42	68	124	2.8	3.2	0.86	17	8	75
28 m stations										
I-33	4	107	148	399	10.1	3.8	0.81	33	24	75
I-30	4	66	98	186	1.2	3.7	0.89	26	24	78
I-27	4	64	94	158	3.3	3.7	0.91	28	21	82
I-22	4	81	116	274	2.2	3.8	0.86	28	25	79
I-14	4	72	102	213	3.4	3.7	0.88	28	25	76
I-16	4	78	121	260	6.6	3.5	0.82	26	21	80
I-15	4	65	95	371	3.4	2.7	0.66	13	20	74
I-12	4	66	103	271	2.2	3.0	0.74	18	19	75
I-9	4	101	142	405	3.4	3.7	0.82	29	27	78
I-6	4	57	88	397	5.2	2.7	0.70	12	11	73
I-2	4	57	83	239	3.6	3.1	0.76	18	13	76
I-3	4	49	71	214	15.5	2.7	0.69	13	9	74
38 m stations										
I-29	4	121	168	478	3.5	4.1	0.85	38	18	82
I-21	4	62	87	366	5.4	2.7	0.66	11	9	86
I-13	4	85	131	400	4.6	3.3	0.75	21	16	83
I-8	4	65	93	327	37.8	3.3	0.79	17	17	81
55 m stations										
I-28	4	173	236	656	6.3	4.5	0.88	58	13	77
I-20	4	100	146	529	4.6	3.7	0.82	28	10	89
I-7	4	102	148	479	5.2	3.9	0.85	32	11	85
I-1	4	83	120	294	1.7	3.7	0.85	26	13	81
All stations										
Mean	108	77	112	327	5.8	3.5	0.81	24	17	78
Min	108	42	68	124	1.2	2.7	0.66	11	8	64
Max	108	173	236	747	37.8	4.5	0.94	58	28	89

unidentifiable taxa that were recorded only once. The average number of taxa per 0.1 m^2 grab ranged from 42 to 173, and the cumulative number of taxa per station ranged from 68 to 236 (**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 area (see City of San Diego 2004b). Higher numbers of species, for example, are common at stations such as I28 and I29 where sediments are finer than most other SBOO sites (see Chapter 4). In addition, species richness varied between surveys, averaging about 27% higher in July than in January (see **Figure 5.2**). Although species richness varied both spatially and temporally, there were no apparent patterns relative to distance from the outfall.

Polychaete worms made up the greatest proportion of species, accounting for 32–54% of the taxa per sites during 2005. Crustaceans composed 12–33% of the species, molluscs from 9 to 24%, echinoderms from 1 to 10%, and all other taxa combined about 7–23%. These percentages are generally similar to those observed during previous years, including prior to discharge (e.g., see City of San Diego 2000, 2004b).

Macrofaunal Abundance

Macrofaunal abundance ranged from a mean of 124 to 747 animals per grab in 2005 (Table 5.1). The greatest number of animals occurred at stations I7, I20, I28, I29, and I34, which averaged over 450 individuals per sample. Station I28 is typically characterized by high abundance, with a variety of different taxa accounting for the high numbers (see City of San Diego 2004). In contrast, high abundances at station I34 primarily were due to large numbers of nematodes and several species of polychaetes (i.e., *Polycirrus* sp SD 3, *Hesionura coineaui difficilis*, and *Protodorvillea gracilis*). Macrofaunal abundance varied between surveys, averaging about 66% higher in July than in January (Figure 5.2). Much of that increase is attributed to high abundance of polychaete worms as well as nematodes from the July survey of I34. Overall, abundance values were within the range of historical variation (Figure 5.2) and there were no clear spatial patterns relative to the outfall.

Similar to past years, polychaetes were the most abundant animals in the region, accounting for 36–78% of the different assemblages during 2005. Crustaceans averaged 2–47% of the animals at a station, molluscs from 3 to 23%, echinoderms from <1 to 10%, and all remaining taxa about 2–23% combined.

Biomass

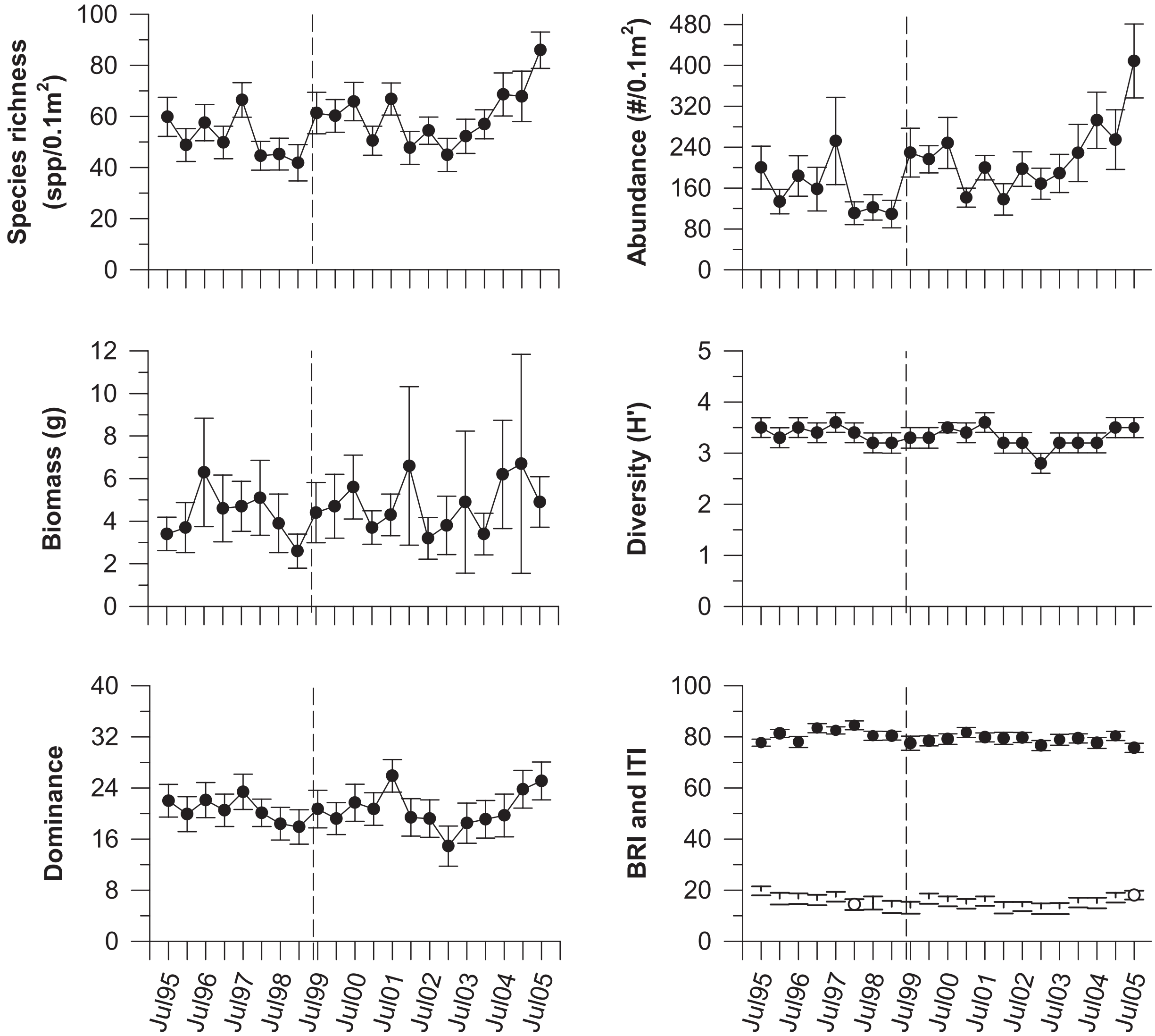
Total biomass averaged from 1.2 to 37.8 grams per 0.1 m^2 (Table 5.1). High biomass values are often due to the collection of large motile organisms such as sand dollars, sea stars, crabs, and snails. For example, during 2005 a single specimen of the mollusc *Crossata californica* weighed 140.5 grams, accounting for over 99% of the annual biomass at station I8, and over 37% of the biomass for all stations during the January survey. Although these large animals introduced considerable variability, overall biomass at the SBOO stations during the year was similar to historical values (Figure 5.2).

Overall, polychaetes accounted for 3–82% of the biomass at a station, crustaceans 1–81%, molluscs 3–93%, echinoderms <1–80%, and all other taxa combined 1–34%. In the absence of large individual molluscs or echinoderms, polychaetes dominated most stations in terms of biomass.

Species Diversity and Dominance

Species diversity (H') varied during 2005, ranging from 2.7 at several stations to 4.5 at I28 (Table 5.1). Average diversity in the region generally was similar to previous years (Figure 5.2), and no patterns relative to distance from the outfall were apparent. Also, the relatively wide range of evenness values (0.66–0.94) reflects the dominance of a few species at some of the SBOO stations. Most sites with evenness values below the mean (0.81) were dominated by polychaetes. The spatial patterns in evenness were similar to those for diversity.

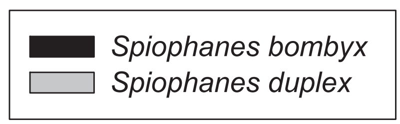
Species dominance was measured as the minimum number of species accounting for 75% of a community by abundance (see Swartz 1978). Consequently, dominance as discussed herein is inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species. Values at individual stations varied widely, averaging from 11 to 58 species per station during the year (Table 5.1). Dominance values for 2005 were similar to historical values (Figure 5.2). No clear patterns relative to the outfall were evident in dominance values.



Environmental Disturbance Indices

The benthic response index (BRI) during 2005 averaged from 8 to 28 at the various SBOO stations (Table 5.1). Index values below 25 (on a scale of 100) suggest undisturbed communities or "reference conditions," while those in the range of 25–33 represent "a minor deviation from reference condition," which may or may not reflect anthropogenic impact (Smith et al. 2001). Station I9 (27) and I35 (28) had the highest BRI, and were the only 2 stations above a value of 25, while stations I22 and I14 had BRI values at 25. There were no patterns in BRI relative to distance from the outfall, and index values at sites nearest the discharge did not suggest significant environmental disturbance.

The infaunal trophic index (ITI) averaged from 64 to 89 at the various sites in 2005 (Table 5.1). There were no patterns with respect to the outfall, and all values at sites near the discharge were characteristic of undisturbed sediments (i.e., ITI >60). In addition, average ITI over all sites has changed little since monitoring began (see Figure 5.2).



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 15 polychaetes, 3 crustaceans, 1 nemertean, and nematodes (not identified beyond phylum).

The spionid polychaete *Spiophanes bombyx* was the most numerous and the most ubiquitous species, averaging about 49 worms per sample and occurring in 100% of the samples. A closely related species, *S. duplex*, was third in total abundance. Together, these 2 species accounted for 18% of all individuals collected during 2005. Both were found in higher numbers than some past years, and the abundance of these taxa has increased substantially since January 2002 (**Figure 5.3**). The second most abundant taxa was the cirratulid polychaete *Monticellina siblina*.

Polychaetes comprised the top 10 most abundant species per occurrence. Several polychaete species were found in high numbers at only a few stations (e.g., *Polycirrus* sp SD 3, *Hesionura coineaui difficilis*, and *Pareuthoe californica*). Few macrobenthic species were widely distributed, and of these only *Spiophanes bombyx*, *S. duplex*, and *Mediomastus* sp occurred in more than 80% of the samples. Four of the most frequently collected species were also among the 10 taxa in terms of abundance (i.e., *S. bombyx*, *S. duplex*, *Mediomastus* sp, and *Ampelisca cristata cristata*).

Table 5.2

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

Species	Higher taxa	Abundance per sample	Abundance per occurence	Percent abundance	Percent occurence
Most Abundant					
1. *Spiophanes bombyx*	Polychaeta: Spionidae	49.0	49.0	15.0	100
2. *Monticellina siblina*	Polychaeta: Cirratulidae	10.8	16.7	3.3	65
3. *Spiophanes duplex*	Polychaeta: Spionidae	9.9	10.5	3.0	94
4. Nematoda	Nematoda	6.8	9.9	2.1	69
5. *Mediomastus* sp	Polychaeta: Capitellidae	5.8	7.2	1.8	81
6. *Mooreonuphis* sp SD 1	Polychaeta: Onuphidae	5.1	22.8	1.5	22
7. *Ampelisca cristata cristata*	Crustacea: Amphipoda	4.9	6.4	1.5	78
8. *Euphilomedes carcharodonta*	Crustacea: Ostracoda	4.5	6.0	1.4	74
9. *Lanassa venusta venusta*	Polychaeta: Terebellidae	4.2	20.6	1.3	20
10. *Protodorvillea gracilis*	Polychaeta: Dorvillidae	3.9	9.7	1.2	41
Most Abundant per Occurrence					
1. *Polycirrus* sp SD 3	Polychaeta: Terebellidae	3.8	103.3	1.2	4
2. *Spiophanes bombyx*	Polychaeta: Spionidae	49.0	49.0	15.0	100
3. *Hesionura coineaui difficilis*	Polychaeta: Phyllodocidae	3.6	39.3	1.1	9
4. *Pareurythoe californica*	Polychaeta: Amphinomidae	2.1	38.5	0.7	6
5. *Mooreonuphis* sp SD 1	Polychaeta: Onuphidae	5.1	22.8	1.5	22
6. *Lanassa venusta venusta*	Polychaeta: Terebellidae	4.2	20.6	1.3	20
7. *Pisione* sp	Polychaeta: Pisionidae	2.2	17.1	0.7	13
8. *Monticellina siblina*	Polychaeta: Cirratulidae	10.8	16.7	3.3	65
9. *Micropodarke dubia*	Polychaeta: Hesionidae	1.5	15.9	0.5	9
10. *Notomastus lineatus*	Polychaeta: Capitellidae	0.2	13.0	0.1	2
Most Frequently Collected					
1. *Spiophanes bombyx*	Polychaeta: Spionidae	49.0	49.0	15.0	100
2. *Spiophanes duplex*	Polychaeta: Spionidae	9.9	10.5	3.0	94
3. *Mediomastus* sp	Polychaeta: Capitellidae	5.8	7.2	1.8	81
4. *Spiochaetopterus costarum*	Polychaeta: Chaetopteridae	2.7	3.4	0.8	80
5. *Hemilamprops californicus*	Crustacea: Cumacea	2.3	2.8	0.7	80
6. *Ampelisca cristata cristata*	Crustacea: Amphipoda	4.9	6.4	1.5	78
7. Amphiuridae	Echinodermata: Amphiuridae	1.8	2.3	0.5	78
8. *Sigalion spinosus*	Polychaeta: Sigalionidae	1.6	2.0	0.5	78
9. *Leptochelia dubia*	Crustacea: Leptocheliidae	3.0	3.9	0.9	76
10. *Glycinde armigera*	Polychaeta: Goniadidae	1.6	2.1	0.5	76

A

Cluster Group	Species Richness	Abund.	% Fines	Top Three Taxa
A	101 (84-118)	1038 (504-1497)	2.3 (1.9-2.8)	Nematoda *Polycirrus* sp SD 3 *Hesionura coineaui difficilis*
B	89 (49-156)	433 (210-1176)	7.0 (0.0-13.6)	*Lanassa venusta venusta* *Moorenuphis* sp SD 1 *Euchone arenae*
C	64 (26-125)	323 (93-1050)	2.6 (0.0-8.8)	*Spiophanes bombyx* Euclymeninae *Lumbrinerides platypygos*
D	38 (27-54)	72 (56-92)	7.8 (7.0-8.6)	*Spiophanes bombyx* *Olivella baetica* *Ampharete labrops*
E	71 (33-142)	220 (52-738)	15.3 (2.7-44.8)	*Monticellina siblina* *Spiophanes bombyx* *Spiophanes duplex*
F	125 (64-192)	476 (195-798)	21.0 (10.1-30.5)	*Spiophanes bombyx* *Spiophanes duplex* *Ampelisca agassizi*

B

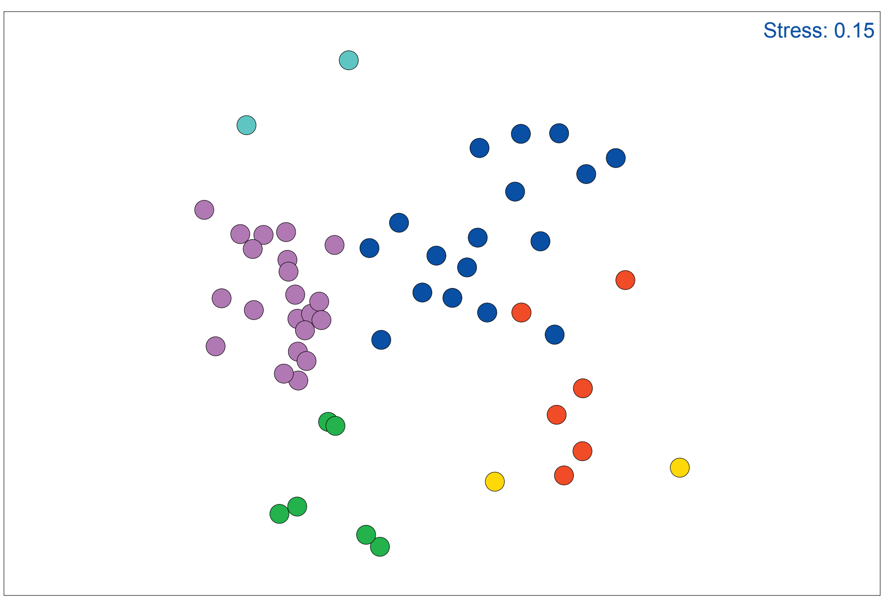


Figure 5.4
(A) Cluster results expressed as mean values per 0.1 m^2 grab over all stations in each group. Ranges in parentheses are for individual grab samples. **(B)** MDS ordination of SBOO benthic stations sampled during 2004. Plot based on square-root transformed macrofaunal abundance data for each station/survey entity. Cluster groups superimposed on station/surveys illustrate a clear distinction between faunal assemblages.

Multivariate Analyses

Classification analysis discriminated between 6 habitat-related benthic assemblages (cluster groups A–F) during 2005 (**Figure 5.4**). These assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances. The dominant species composing each group are listed in **Table 5.3**. An MDS ordination of the station/survey entities confirmed the validity of cluster groups A–F (Figure 5.4). These analyses identified no significant patterns regarding proximity to the discharge (**Figure 5.5**).

<u>Cluster group A</u> represented the July surveys from 2 stations, I23 and I34 located on the 19-m depth contour. Sediments at these sites were characterized by a relatively low percentage of fine particles. As in previous years (City of San Diego 2004, 2005) this assemblage was somewhat unique for the region; it had more than twice the mean abundance of any other assemblage and was dominated by nematode worms and several relatively uncommon polychaete species (e.g., *Hesionura coineaui difficilis*, *Polycirrus* sp SD 3, *Protodorvillea gracilis*, *Pareurythoe californica*, and *Pisione* sp).

<u>Cluster group B</u> comprised 2 stations characterized by coarse relict red sand sediments located along the 55-m depth contour and the January samples from 2 stations along the 38-m contour. In contrast to the other deeper-water assemblage described (see group F), this group had fewer taxa but about the same number of individual organisms per grab. Polychaetes numerically dominated this group including: *Lanassa venusta venusta* (Terebellidae), *Euchone arenae* (Sabellidae), and *Moorenuphis* sp SD1 (Onuphidae). Other species that were less abundant but more evenly distributed among stations within this group included the glycerid polychaete *Glycera oxycephala* and bodotriid crustacean *Cyclaspis nubila*.

<u>Cluster group C</u> comprised sites that were located on or near the 28-m depth contour, mostly south of the SBOO. These sites averaged a low percentage of fines, with some stations containing relict red sands and shell hash. The group C assemblage averaged 64 taxa and 323 individuals per grab. *Spiophanes bombyx* was numerically dominant in this group, followed by the polychaetes Euclymeninae (unidentified juveniles) and *Lumbrinerides platypygos*. Though present in lower abundances, the lampropid cumacean *Hemilamprops californicus* and Amphiuridae (unidentified juvenile ophiuroid echinoderms) were typically found across most samples within this cluster group.

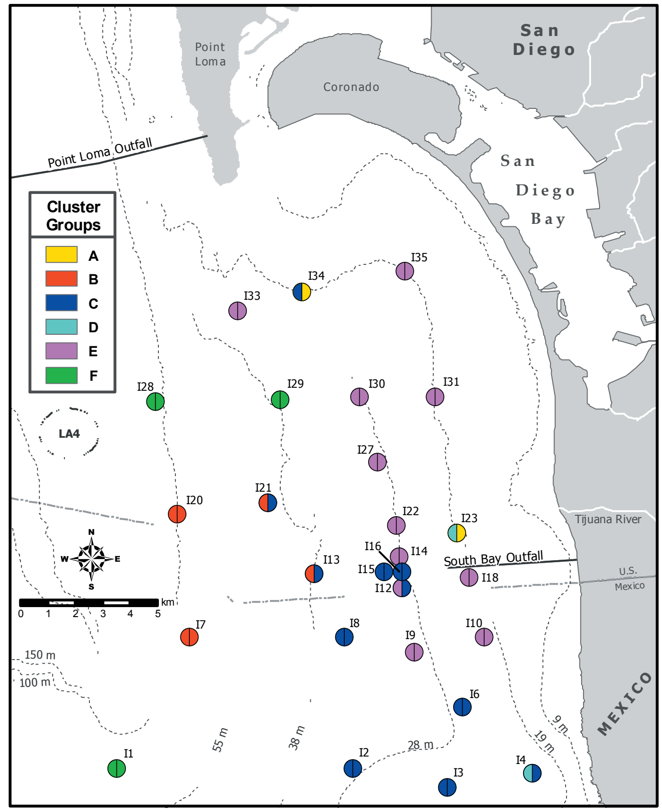


Figure 5.5
SBOO benthic stations sampled during January and July 2005, are color-coded to represent affiliation with benthic cluster groups. Left half of the circle represents cluster group affiliation for the January survey; the right half represents the July survey.

<u>Cluster group D</u> represented the January surveys for stations I4 and I23, both along the 19-m contour. The sediment habitat for this assemblage was relatively sandy. Group D contained the fewest number of species and the lowest densities among all the groups. *Spiophanes bombyx* was the most

Table 5.3

Summary of the most abundant taxa comprising cluster groups A–E from the 2005 survey of SBOO benthic stations. Data are expressed as mean abundance per sample (no./0.1m^2) and represent the 10 most abundant taxa in each group. Values for the 3 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 (n=2)	B (n=6)	C (n=17)	D (n=2)	E (n=21)	F (n=6)
Amaeana occidentalis	Polychaeta	—	—	0.16	2.75	0.30	0.25
Ampelisca agassizi	Crustacea	—	—	—	—	0.05	**16.00**
Ampelisca brachycladus	Crustacea	—	0.08	1.34	3.25	2.66	0.08
Ampelisca cristata cristata	Crustacea	0.25	17.58	5.41	0.50	2.75	2.17
Ampharete labrops	Polychaeta	2.50	0.08	1.78	**3.50**	1.66	1.33
Ampharetidae	Polychaeta	0.25	—	—	2.00	0.45	0.67
Amphiuridae	Echinodermata	—	0.25	3.56	—	1.02	2.67
Axiothella sp	Polychaeta	—	0.58	3.66	0.50	0.23	0.25
Cadulus aberrans	Mollusca	—	—	0.06	1.25	3.23	2.83
Carinoma mutabilis	Nemertea	8.00	0.42	1.09	1.50	1.34	1.17
Diastylopsis tenuis	Crustacea	—	—	—	1.75	0.18	—
Euchone arenae	Polychaeta	9.25	**25.50**	0.72	—	0.14	1.00
Euclymeninae	Polychaeta	—	0.08	**9.88**	—	0.45	0.50
Euclymeninae sp A	Polychaeta	1.75	1.50	0.50	0.25	5.41	2.75
Euphilomedes carcharodonta	Crustacea	0.25	0.83	2.78	0.75	5.86	10.08
Glycera oxycephala	Polychaeta	—	2.42	3.59	0.25	0.25	0.17
Hesionura coineaui difficilis	Polychaeta	**87.25**	3.58	0.03	—	—	—
Lanassa venusta venusta	Polychaeta	—	**36.25**	0.53	—	—	0.08
Laticorophium baconi	Crustacea	—	6.08	0.19	—	—	—
Leptochelia dubia	Crustacea	0.50	3.67	1.44	—	2.07	11.33
Lumbrinerides platypygos	Polychaeta	8.25	4.00	**6.84**	—	0.25	—
Mediomastus sp	Polychaeta	14.75	3.83	0.97	1.00	7.16	14.67
Micropodarke dubia	Polychaeta	38.75	0.17	—	—	0.02	0.08
Monticellina siblina	Polychaeta	0.75	—	2.50	0.25	**23.43**	4.42
Mooreonuphis sp	Polychaeta	0.25	21.92	3.25	—	0.25	0.42
Mooreonuphis sp SD1	Polychaeta	—	**30.58**	5.59	—	—	—
Myriochele gracilis	Polychaeta	—	0.08	0.13	—	—	8.00
Nematoda	Nematoda	**113.50**	9.92	1.19	0.75	1.16	5.75
Oligochaeta	Polychaeta	18.00	1.67	0.13	—	—	—
Olivella baetica	Mollusca	0.50	2.92	1.19	**3.75**	0.50	0.08
Onuphidae	Polychaeta	—	15.58	3.25	1.75	0.77	1.08
Pareurythoe californica	Polychaeta	57.50	—	—	—	0.02	—
Photis californica	Crustacea	—	5.00	—	—	0.02	9.50
Pisione sp	Polychaeta	54.50	1.75	0.03	—	—	—
Polycirrus sp SD 3	Polychaeta	**103.25**	—	—	—	—	—
Prionospio (*Prionospio*) *jubata*	Polychaeta	2.00	5.17	2.59	—	2.16	7.92
Protodorvillea gracilis	Polychaeta	81.75	2.92	1.78	0.25	0.11	0.08
Rhepoxynius menziesi	Crustacea	0.50	—	1.13	1.50	3.61	1.67
Sige sp A	Polychaeta	26.00	—	0.19	—	0.05	0.08
Siphonodentalium quadrifissatum	Mollusca	0.25	2.25	4.69	—	0.25	—
Spiochaetopterus costarum	Polychaeta	1.75	3.33	4.25	—	1.20	4.42
Spiophanes berkeleyorum	Polychaeta	0.25	0.92	2.97	—	4.55	6.75
Spiophanes bombyx	Polychaeta	25.25	18.50	**122.25**	**4.50**	**17.77**	**21.75**
Spiophanes duplex	Polychaeta	1.50	5.67	3.25	0.50	**9.57**	**39.00**
Sthenelanella uniformis	Polychaeta	—	0.42	0.03	—	0.25	7.42
Syllis (*Typosyllis*) sp SD1	Polychaeta	13.75	11.00	0.09	—	—	—
Tellina modesta	Mollusca	0.25	0.17	0.84	3.00	4.00	0.17

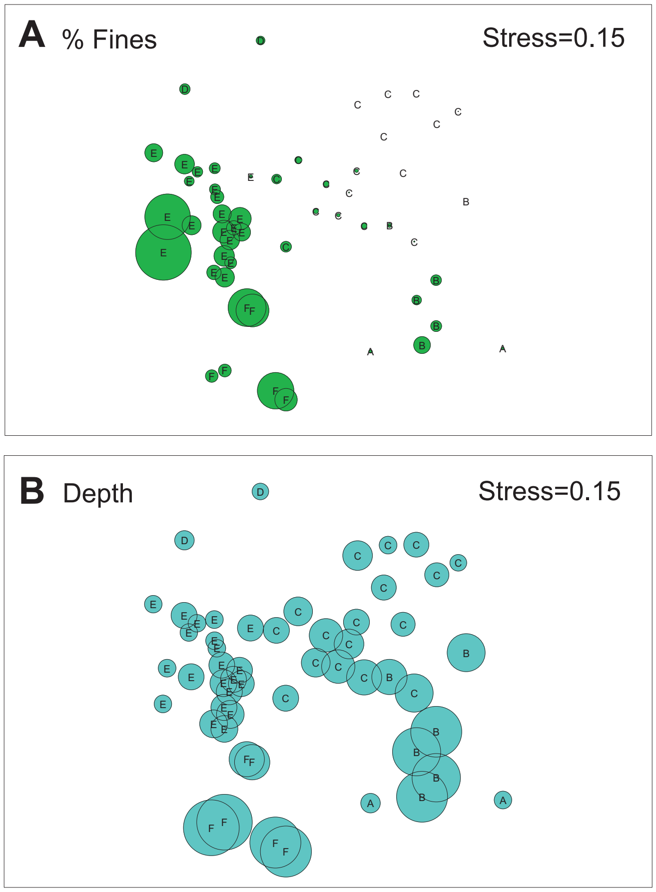


Figure 5.6
MDS ordination of SBOO benthic stations sampled during January and July 2005. Cluster groups A–F are superimposed on station/surveys. Percentage of fine particles in the sediments and station depth are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of benthic assemblages with habitats that differ in sediment grain size and depth.

abundant species in the group followed by *Olivella baetica*, the only mollusc within all the cluster groups defining an assemblage.

<u>Cluster group E</u> included sites primarily located along the 19 and 28-m depth contours, where sediments also contained the second highest amount of fine particles. This assemblage averaged 71 taxa and 220 individuals per 0.1 m^2. The numerically dominant species in this group were the cirratulid polychaete *Monticellina siblina, Spiophanes bombyx,* and *S. duplex*. The spionid *Paraprionospio pinnata* and the onuphid *Onuphis* sp A had relatively low average abundances per sample but were widespread among samples within this assemblage.

<u>Cluster group F</u> comprised 2 stations located along the 55-m depth contour and 1 at the 38-m contour. Sediments at these deepwater sites contained a relatively high percentage of fine particles (**Figure 5.6**). The group F assemblage was characterized by high species richness and abundance, averaging 125 taxa and 476 individuals per grab (Figure 5.4). The 3 most abundant species were *Spiophanes bombyx* and *S. duplex* and the amphipod crustacean *Ampelisca agassizi*. The following species were also characteristic of this assemblage, but relatively uncommon in other groups: the oweniid polychaete *Myriochele gracilis*, the ostracod crustacean *Euphilomedes carcharodonta*, the tanaid crustacean *Leptochelia dubia*, and the sigalionid polychaete *Sthenelanella uniformis* (Table 5.3).

SUMMARY AND CONCLUSIONS

Benthic macrofaunal assemblages surrounding the South Bay Ocean Outfall were similar in 2005 to those that occurred during previous years (City of San Diego 2000, 2005). In addition, these assemblages were generally typical of those occurring in other sandy, shallow-water habitats throughout the Southern California Bight (SCB) (e.g., Thompson et al. 1987, 1993b, City of San Diego 1999, Bergen et al. 2001). For example, the 2 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 2 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, such as the presence of a fine component (i.e., group E), or coarse, relict red sands (i.e., group C). Consistent with historical values, sediments in the shallow SBOO region generally were coarser south of the outfall relative to northern stations (see chapter 4). In contrast, the group F assemblage occurs in mid-depth shelf habitats that probably represent a transition between the shallow sandy sediments common in the area and the finer mid-depth sediments characteristic of much of the SCB mainland shelf (see Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, Thompson et al. 1987, 1993a, b, EcoAnalysis et al. 1993, Zmarzly et al. 1994, Diener and Fuller 1995, Bergen et al. 2001). A second deeper-water assemblage (group B) occurred where relict red sands were present. Polychaetes dominated group B, including the ubiquitous *S. bombyx*. Finally, the group A assemblage characteristic of station I23 and I34 during the July surveys was quite dissimilar from assemblages found at any other station. Nematode worms and several abundant polychaete species in these samples were not common elsewhere in the region. This assemblage is similar to that sampled previously at I23 during July 2003 and 2004. Analysis of the sediment chemistry data provided no evidence to explain the occurrence of this assemblage though mean sediments grain size were the highest measured among all stations for 2005 (see chapter 4). The presence of these animals may reflect the particular components of the sediments such as variation in microhabitats or types and amounts of shell hash or algal detritus.

Multivariate analyses revealed no clear spatial patterns relative to the outfall. Comparisons of the biotic data to the physico-chemical data indicated that macrofaunal distribution and abundance in the region varied primarily along gradients of sediment type and depth. Relatively high numbers of *S. bombyx* and *S. duplex* were collected during 2005 as in 2004. However, temporal fluctuations in the populations of these taxa are similar in magnitude to those that occur elsewhere in the region and that often correspond to large-scale oceanographic conditions (see Zmarzly et al. 1994). Overall, temporal patterns suggest that the benthic community has not been significantly impacted by wastewater discharge via the SBOO. For example, the range of values for species richness and abundance during 2005 was similar to that seen in previous years (see City of San Diego 2000, 2004b). In addition, environmental disturbance indices such as mean BRI and mean ITI generally were characteristic of assemblages from undisturbed sediments.

Anthropogenic impacts have spatial and temporal dimensions that can vary depending on a range of biological and physical factors. Such impacts can be difficult to detect, and specific effects of the SBOO discharge could not be identified during 2005. Furthermore, benthic invertebrate populations exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, b, Otway 1995). Although some changes likely have occurred near the SBOO, benthic assemblages in the area remain similar to those observed prior to discharge and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf.

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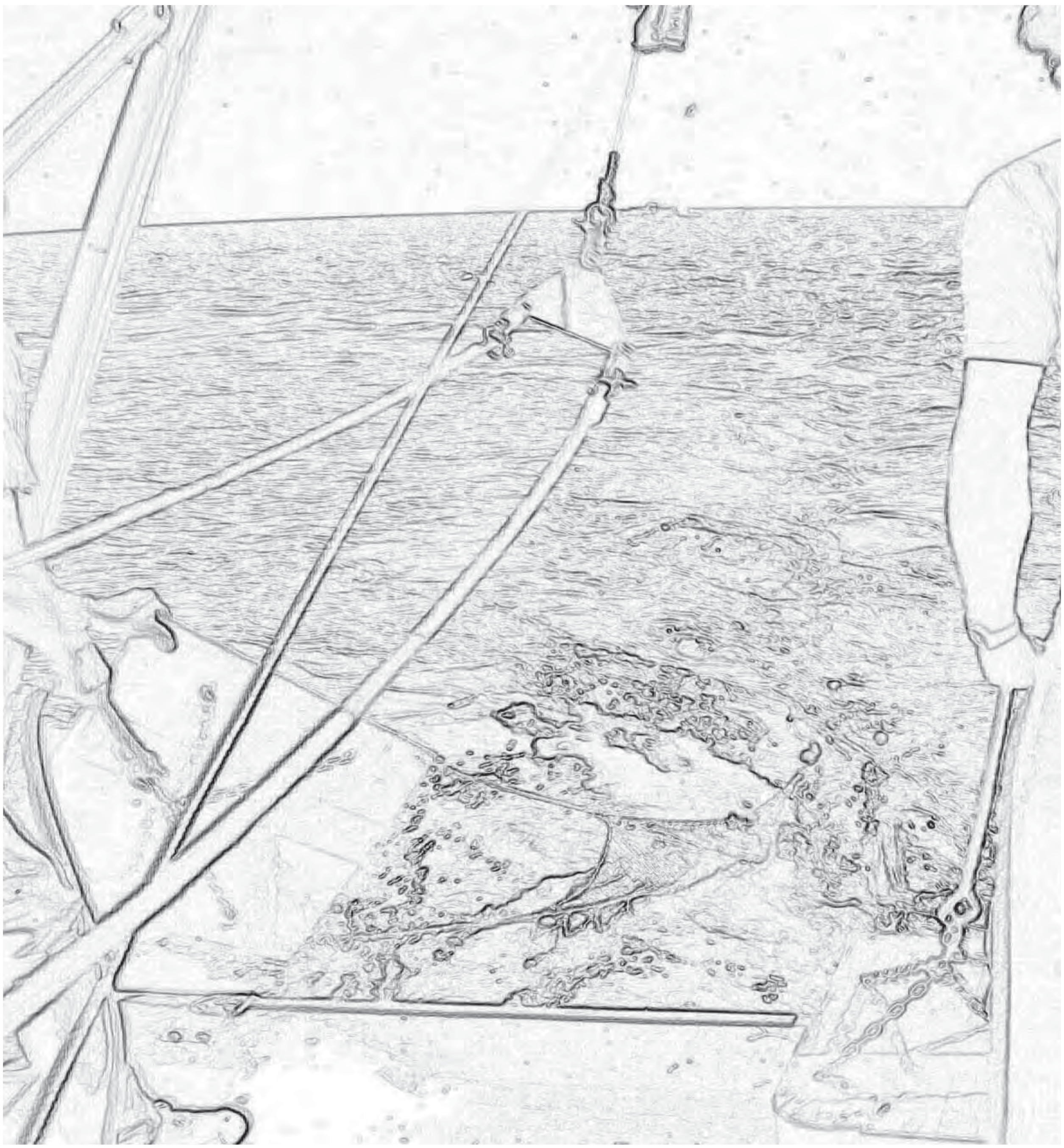
Chapter 6
Demersal Fishes and Megabenthic Invertebrates



Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Demersal fish and megabenthic invertebrate communities have become an important focus of ocean monitoring programs throughout the world. Fish and invertebrate assemblages of the Southern California Bight (SCB) mainland shelf have been sampled extensively for at least 30 years, primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of fish inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998). For the region surrounding the South Bay Ocean Outfall (SBOO), the most common trawl-caught fishes include speckled sanddab, longfin sanddab, hornyhead turbot, California halibut, California lizardfish and occasionally white croaker. The common trawl-caught invertebrates include relatively large species such as sea urchins and sand dollars.

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

The City of San Diego has been conducting trawl surveys in the area surrounding the SBOO since 1995. These surveys were designed to monitor the effects of wastewater discharge on the local marine biota by assessing the structure and stability of the demersal fish and megabenthic invertebrate communities. This chapter presents analyses and interpretations of data collected during the 2005 trawl surveys.

MATERIALS AND METHODS

Field Sampling

Trawl surveys were conducted in January, April, July, and October 2005 at 7 fixed sites around the SBOO (Figure 6.1). These stations, SD15–SD21, are located along the 28-m isobath, and encompass an area south of Point Loma, California, USA to Punta Bandera, Baja California, Mexico. During each survey a single trawl was performed at each

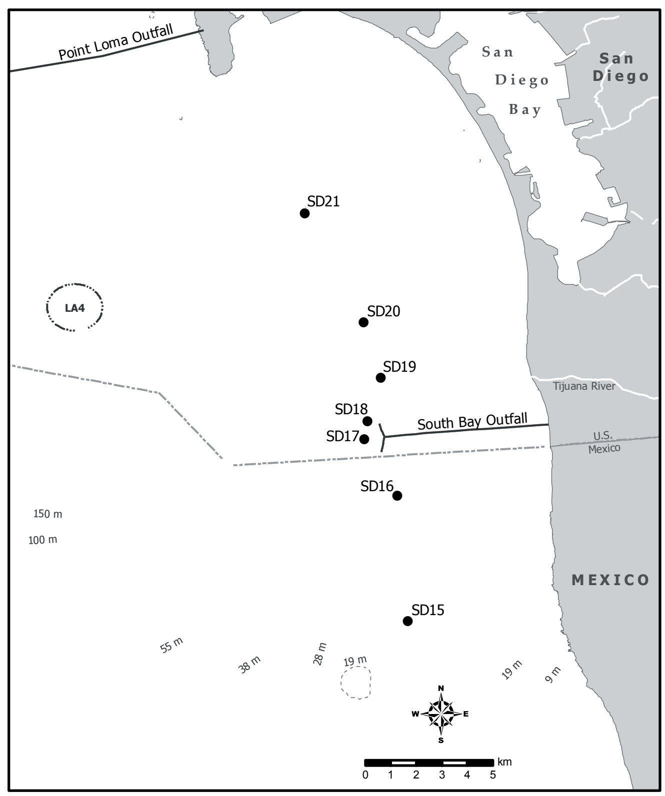


Figure 6.1
Otter trawl station locations, South Bay Ocean Outfall Monitoring Program (SD15–SD21).

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. Detailed methods for locating the stations and conducting trawls are described in the City of San Diego Quality Assurance Plan (City of San Diego in prep).

Trawl catches were brought on board for sorting and inspection. All organisms were identified to species or to the lowest taxon possible. If an animal could not be identified in the field, it was returned to the laboratory for further identification. For fishes, the total number of individuals and total biomass (wet weight, kg) were recorded for each species. Additionally, each individual fish was inspected for external parasites or physical anomalies (e.g., tumors, fin erosion, discoloration) and measured to the nearest centimeter in length according to standard protocols (see City of San Diego in prep). 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 by: frequency of occurrence (number of occurrences/total number of trawls x 100); percent abundance (number of individuals/total of all individuals caught x 100); mean abundance per haul (number of individuals/total number of trawls); mean abundance per occurrence (number of individuals/number of occurrences). In addition, the following parameters were calculated for both the fish and invertebrate assemblages at each station: species richness (number of species); total abundance; Shannon diversity index (H'); total biomass.

Multivariate analyses were performed on the seven stations using PRIMER (Plymouth Routines in Multivariate Ecological Research) software 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 square-root transformed and the Bray-Curtis measure of dissimilarity was used as the basis for both classification and ordination. The PRIMER SIMPER ("similarity percentages") routine was used to describe inter- and intra- group species differences.

RESULTS AND DISCUSSION

Fish Community

Thirty-five species of fish were collected in the area surrounding the SBOO during 2005 (Table 6.1). The total catch for the year was 4393 individuals, representing an average of about 157 fish per trawl. The speckled sanddab comprised 65% of the total catch. No other species contributed more than 8% of the total catch. Both the speckled sanddab and the hornyhead turbot were present in all of the hauls. Other frequently occurring fishes were yellowchin sculpin, California lizardfish, roughback sculpin, longfin sanddab, English sole, California tongue fish, and California scorpionfish. Most of these common fishes, as well as the majority of other species collected, tended to be relatively small (average length < 23 cm, see Appendix C.1). Larger species, such as the bat ray, thornback, round stingray and shovelnose guitarfish were relatively rare.

Fish abundance and biomass were highly variable during 2005. Abundance ranged from 37 to 331 fish per haul (Table 6.2). Hauls were generally much larger in the second half of the year than in the first half. Abundance per haul ranged from 37 to 176 during the January and April surveys and from 106 to 331 during the July and October surveys. These differences reflect larger catches of speckled sanddabs in July and October. The wide range in biomass values (1.1–7.1 kg per station) was generally attributable to variation in the size of the hauls or the occurrence of large individuals. For example, the heaviest catch occurred at station SD21 in October, and was due to several relatively large California scorpionfish with a combined weight of approximately 4.3 kg.

Table 6.1

Demersal fish species collected in 28 trawls in the SBOO region during 2005. Data for each species are expressed as: percent abundance (PA); frequency of occurrence (FO); mean abundance per haul (MAH).

Species	PA	FO	MAH	Species	PA	FO	MAH
Speckled sanddab	65	100	101	California skate	<1	14	<1
Yellowchin sculpin	8	68	12	Bat ray	<1	7	<1
California lizardfish	8	89	12	Pygmy poacher	<1	11	<1
Hornyhead turbot	5	100	7	Kelp bass	<1	4	<1
Roughback sculpin	4	82	6	Shovelnose guitarfish	<1	4	<1
Longfin sanddab	2	50	3	Barcheek pipefish	<1	4	<1
English sole	2	75	3	Barred sand bass	<1	4	<1
California tonguefish	1	57	2	Blackbelly eelpout	<1	4	<1
Longspine combfish	1	36	2	Diamond turbot	<1	4	<1
California scorpionfish	1	61	2	Giant kelpfish	<1	4	<1
Plainfin midshipman	1	36	2	Gulf sanddab	<1	4	<1
Specklefin midshipman	1	21	1	Northern anchovy	<1	4	<1
California halibut	1	36	1	Pink seaperch	<1	4	<1
Pacific sanddab	<1	11	1	Juvenile rockfish*	<1	4	<1
White croaker	<1	14	<1	Round stingray	<1	4	<1
Fantail sole	<1	25	<1	Shiner perch	<1	4	<1
Spotted turbot	<1	21	<1	Spotted cuskeel	<1	4	<1
Bigmouth sole	<1	14	<1	Thornback	<1	4	<1

* unidentified to species

Table 6.2

Summary of demersal fish community parameters for SBOO stations sampled during 2005. Data are expressed as the mean and standard deviation (SD) for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight).

Station	Jan	Apr	Jul	Oct	Mean	SD	Station	Jan	Apr	Jul	Oct	Mean	SD
Species richness							*Abundance*						
SD15	5	9	6	6	7	2	SD15	69	77	106	254	127	86
SD16	8	11	10	9	10	1	SD16	176	114	244	299	208	80
SD17	9	15	8	12	11	3	SD17	37	97	250	313	174	129
SD18	10	10	12	9	10	1	SD18	121	132	331	141	181	100
SD19	9	7	10	10	9	1	SD19	162	93	137	152	136	30
SD20	9	10	10	13	11	2	SD20	138	92	186	150	142	39
SD21	11	15	12	10	12	2	SD21	135	80	161	146	131	35
Mean	9	11	10	10			Mean	120	98	202	208		
SD	2	3	2	2			SD	50	19	78	78		
Diversity							*Biomass*						
SD15	1.1	1.3	0.3	0.3	0.7	0.5	SD15	1.5	4.3	1.1	2.8	2.4	1.4
SD16	1.2	1.4	0.7	1.0	1.1	0.3	SD16	2.0	1.9	5.2	5.0	3.5	1.8
SD17	1.5	1.9	1.2	1.5	1.5	0.3	SD17	1.4	4.5	3.4	6.9	4.1	2.3
SD18	1.3	1.0	1.2	1.5	1.3	0.2	SD18	5.8	3.4	3.4	3.1	3.9	1.3
SD19	1.0	1.0	1.4	1.4	1.2	0.2	SD19	2.5	1.4	3.3	4.4	2.9	1.3
SD20	1.3	1.5	1.3	1.5	1.4	0.1	SD20	2.4	3.2	3.6	3.2	3.1	0.5
SD21	1.1	1.9	1.6	1.8	1.6	0.4	SD21	3.4	3.6	3.3	7.1	4.4	1.8
Mean	1.2	1.4	1.1	1.3			Mean	2.7	3.2	3.3	4.6		
SD	0.2	0.4	0.4	0.5			SD	1.5	1.2	1.2	1.8		

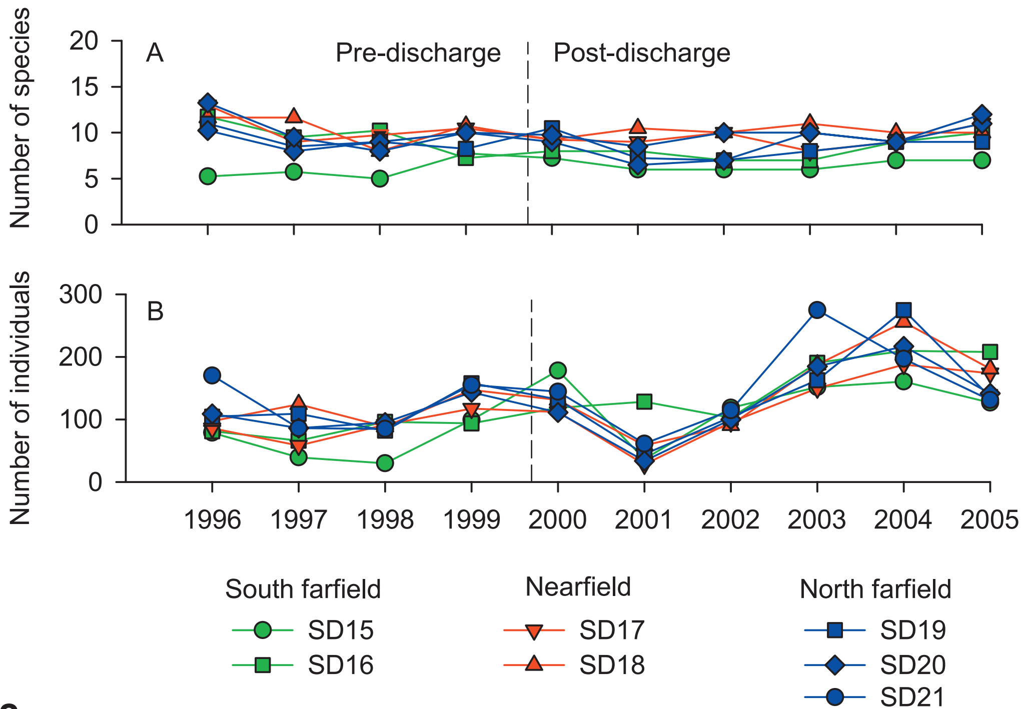


Figure 6.2
Number of species and number of individuals per SBOO station of demersal fishes collected from 1996 through 2005. Data are means averaged over the 4 surveys in each year.

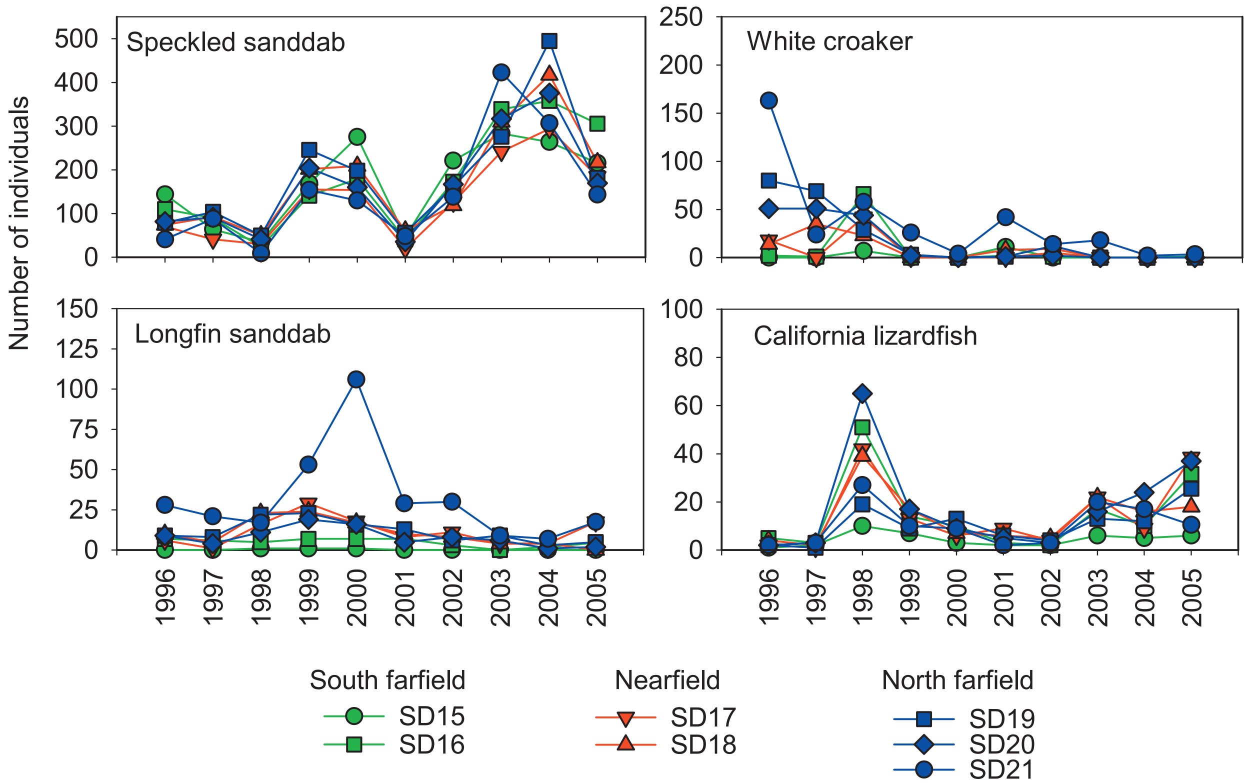


Figure 6.3
Number of individuals per SBOO station for the four most abundant fish species collected from 1996 through 2005. Data are means averaged over the 4 surveys in each year.

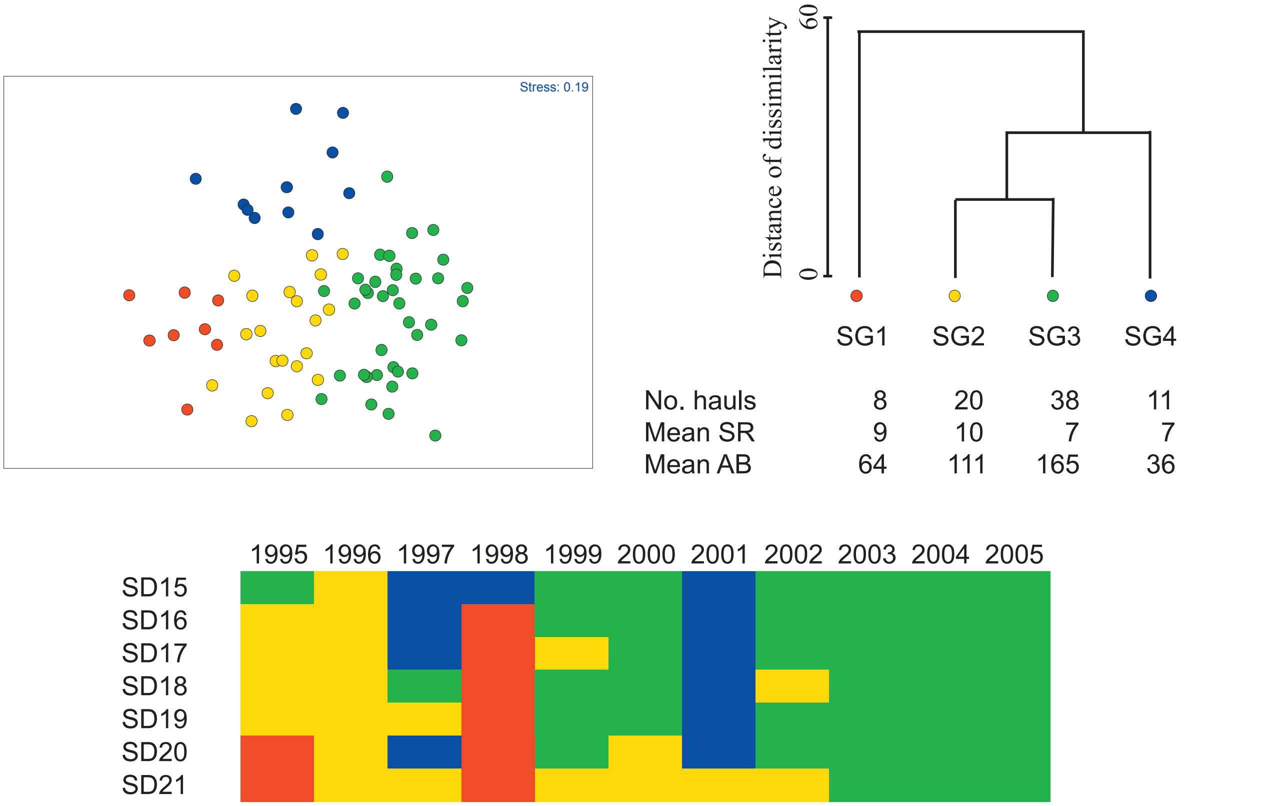


Figure 6.4
Results of classification analysis of demersal fish assemblages collected at SBOO stations SD15–SD21 between 1995 and 2005 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major station groups and (C) a matrix showing distribution over time. SR=species richness, AB=abundance.

In contrast to abundance and biomass, species richness and diversity (H') varied little with relatively low values in 2005 (Table 6.2). Twenty of the 28 samples had 10 or fewer species, with only 2 samples collected in April having as many as 15 species. Average diversity values were less than 2.0 at all stations. These relatively low values are typical of this area, and reflect the relatively low number of species that comprise this community.

Fish community structure in this region has varied in response to population fluctuations of a few dominant species since 1996 (Figures 6.2, 6.3). Although annual mean species richness has remained within a small range (between 5 and 14 species per station per year), mean abundances have fluctuated substantially over the years (between 28 and 275 individuals per station) (Figure 6.2). Inter-annual variability at individual stations is most often caused by large hauls of schooling species that occur infrequently. For example, large hauls of white croaker were responsible for the high abundance at SD21 in 1996, while a large haul of northern anchovy caused the high abundance at SD16 in 2001. In contrast, variability across stations primarily reflects changes in the populations of the dominant species (Figure 6.3). For example, the total catch for 2005 represents about a 27% decline from the 2004 total catch of 6010 individuals. This decline was due primarily to an approximately 45% drop in the total speckled sanddab catch from 2004 to 2005. Overall, none of the observed changes appear to be associated with the South Bay outfall.

Ordination and classification analyses of fish data from July surveys between 1991 and 2005 resulted in 4 major cluster groups (station groups 1–4) (see Figure 6.4). Table 6.3 summarizes the species that are primarily responsible for differences between the station groups. No patterns were evident that suggest changes in the fish assemblages were associated with the SBOO.

Table 6.3

Summary of the SIMPER procedure from PRIMER. Intra-group similarity: percent contribution that each species makes to the similarity within a station group. Values in bold type indicate the species that are most representative of a station group (i.e., similarity/SD ≥ 2). Inter-group dissimilarity: species that discriminate between groups are listed with the average dissimilarity between paired station groups (i.e., dissimilarity ≥ 1.5). SS=speckled sanddab, CT=California tonguefish, HT= hornyhead turbot, LS=longfin sanddab, ES=English sole.

Intra-group similarity

Species	SG1	SG2	SG3	SG4
Speckled sanddab	**21**	**45**	**72**	**54**
Longfin sanddab	**26**	15		
Hornyhead turbot	**11**	**13**	7	13
California lizardfish	18	6	7	5
Spotted turbot			4	12
English sole	9	6		
California scorpionfish		3		6
California tonguefish	5	5		
California halibut				4

Inter-group dissimilarities

	SG2	SG3	SG4
SG1	48	61	56
	CT, HT, SS	LS, SS	LS
SG2		47	52
		SS,ES	SS,ES,CT
SG3			55
			SS

Station group 1 comprised 2 stations sampled in 1995 and almost all of the stations sampled in 1998 during strong El Niño conditions (NOAA-CIRES 2003) (Figure 6.4). The assemblage averaged 9 species and 64 individuals per haul. The species that are characteristic of this group include longfin sanddabs, speckled sanddabs and hornyhead turbot (Table 6.3). This assemblage differed from the others in the relative contributions of California tonguefish, hornyhead turbot, speckled sanddabs, and longfin sanddabs.

Station group 2 comprised most stations sampled in 1995 and 1996, station SD21 (1996–1997, 1999–2002), and several other stations sampled in differing years (Figure 6.4). The assemblage averaged 10 species and 111 individuals per haul. This assemblage was dominated by speckled sanddabs and hornyhead turbot. It differed from the other assemblages in the relative contributions of California tonguefish and English sole, as well as hornyhead turbot, and speckled sanddabs (Table 6.3).

Station group 3 was the largest group with 38 hauls, and comprised most stations sampled after the 1998 El Niño (Figure 6.4). This station group averaged only 7 species per haul, but had the highest average abundance per haul (165). Speckled sanddabs were the dominant fish, responsible for 72% of the similarity among the included samples. Hornyhead turbot, California lizardfish, and spotted turbot contributed 7% or less to the overall similarity within this assemblage.

Station group 4 comprised several stations in 1997 and all but 1 station in 2001 (Figure 6.4). Like station group 3, station group 4 hauls were dominated almost exclusively by speckled sanddabs and lacked significant numbers of longfin sanddabs (Table 6.3). Longfins are typically associated with warmer ocean environments, and are near the northern extent of their geographic range in the South Bay. Consequently, their disappearance from the area, coincident with a shift in species composition (e.g., higher numbers of speckled sanddabs which prefer colder waters), likely reflects a change to colder oceanographic conditions during these years (see Figure 6.3). Station group 3 and 4 assemblages differed in the higher numbers of speckled sanddabs collected during the years encompassed by station group 3 (72% vs 54%).

Physical Abnormalities and Parasitism

The overall absence of fin rot or other physical abnormalities suggest that fish populations in the area continue to appear healthy. No physical abnormalities were found during 2005. In addition,

Table 6.4

Megabenthic invertebrate species collected in 28 trawls in the SBOO region during 2005. Data for each species are expressed as: percent abundance (PA); frequency of occurrence (FO); mean abundance per haul (MAH).

Species	PA	FO	MAH	Species	PA	FO	MAH
Astropecten verrilli	65	96	29	*Luidia armata*	<1	18	<1
Lytechinus pictus	5	43	2	*Loligo opalescens*	<1	11	<1
Dendraster terminalis	4	18	2	*Loxorhynchus grandis*	<1	11	<1
Philine auriformis	3	18	1	*Octopus rubescens*	<1	14	<1
Heterocrypta occidentalis	2	29	1	*Pleurobranchaea californica*	<1	7	<1
Kelletia kelletii	2	36	1	*Acanthodoris brunnea*	<1	11	<1
Hemisquilla ensigera californiensis	2	36	1	*Cancer anthonyi*	<1	7	<1
Heptacarpus stimpsoni	1	7	1	*Euspira lewisii*	<1	7	<1
Cancer sp	1	18	1	*Ophiothrix spiculata*	<1	11	<1
Pisaster brevispinus	1	46	1	*Platymera gaudichaudii*	<1	11	<1
Crangon nigromaculata	1	25	1	*Heptacarpus palpator*	<1	4	<1
Sicyonia ingentis	1	21	1	*Pteropurpura festiva*	<1	7	<1
Cancer gracilis	1	18	<1	*Thesea* sp B	<1	4	<1
Elthusa vulgaris	1	25	<1	*Astropecten armatus*	<1	4	<1
Portunus xantusii	1	14	<1	*Dendronotus iris*	<1	4	<1
Hamatoscalpellum californicum	1	11	<1	*Flabellina iodinea*	<1	4	<1
Pagurus spilocarpus	1	25	<1	Hirudinea	<1	4	<1
Crangon alba	1	11	<1	*Loxorhynchus* sp	<1	4	<1
Pyromaia tuberculata	1	14	<1	*Luidia foliolata*	<1	4	<1
Randallia ornata	1	14	<1	*Paguristes bakeri*	<1	4	<1
Acanthodoris rhodoceras	<1	7	<1	*Pandalus platyceros*	<1	4	<1
Crangon alaskensis	<1	7	<1	*Pugettia producta*	<1	4	<1
Crossata californica	<1	14	<1	*Stylatula elongata*	<1	4	<1

the overall rate of parasitism was very low (0.04%). External parasites were found on just 2 fish, including a single leech on a hornyhead turbot, as well as an eye parasite on a Pacific sanddab. In addition, the ectoparasitic isopod, Elthusa vulgaris, was observed in several trawls. This isopod becomes detached from its host during sorting, therefore it is unknown which fish were actually parasitized. Although E. vulgaris occurs on a wide variety of fish species in southern California, it is especially common on sanddabs and California lizardfish, where it may reach infestation rates of 3% and 80%, respectively (Brusca 1978, 1981).

Invertebrate Community

A total of 1238 megabenthic invertebrates (~21/trawl), representing 46 taxa, were collected during 2005 (Appendix C.2). The sea star Astropecten verrilli was the most abundant and most frequently captured species. This sea star was captured in almost all of the trawls and accounted for 65% of the total invertebrate catch (Table 6.4). The urchin Lytechinus pictus and the sea star Pisaster brevispinus occurred in at least 40% of the trawls. The remaining taxa occurred infrequently, with only 6 occurring in 25% or more of the hauls.

As with fish, invertebrate community parameters varied among stations and between surveys during the year (Table 6.5). Species richness ranged from 3 to 13 species per haul and abundance values ranged from 7 to 185 individuals per haul. The biggest hauls included large numbers of 3 echinoderms: A. verrilli, the sand dollar Dendraster terminalis, and L. pictus. Although biomass was also somewhat variable, high values generally corresponded to the collection of large species such as the sea star P. brevispinus and cancer or sheep crabs.

Variations in megabenthic invertebrate community structure in the South Bay area generally reflect changes in species abundance (Figures 6.5, 6.6). Although species richness has varied little (e.g., 4–14 species/station/year), annual

Table 6.5

Summary of megabenthic invertebrate community parameters for SBOO stations sampled during 2005. Data are expressed as mean and standard deviation (SD) for species richness (number of species), abundance (number of individuals), diversity (H') and biomass (kg, wet weight).

Station	Jan	Apr	Jul	Oct	Mean	SD
Species richness						
SD15	8	9	8	6	8	1
SD16	11	6	7	6	8	2
SD17	3	7	13	13	9	5
SD18	5	9	10	11	9	3
SD19	7	4	4	3	5	2
SD20	4	6	4	4	5	1
SD21	9	4	7	11	8	3
Mean	7	6	8	8		
SD	3	2	3	4		
Diversity						
SD15	1.4	1.2	1.1	0.6	1.1	0.3
SD16	2.3	0.6	1.6	0.6	1.3	0.8
SD17	0.8	0.7	2.2	1.7	1.3	0.7
SD18	1.5	1.0	2.0	1.8	1.6	0.5
SD19	1.3	0.4	0.9	0.4	0.7	0.4
SD20	1.0	1.4	0.7	0.5	0.9	0.4
SD21	2.0	1.3	1.5	1.9	1.7	0.3
Mean	1.5	0.9	1.4	1.1		
SD	0.5	0.4	0.6	0.7		

Station	Jan	Apr	Jul	Oct	Mean	SD
Abundance						
SD15	28	97	44	185	89	71
SD16	20	65	21	47	38	22
SD17	7	90	30	57	46	36
SD18	24	69	29	37	40	20
SD19	19	54	42	78	48	25
SD20	12	14	15	41	21	14
SD21	25	9	19	60	28	22
Mean	19	57	29	72		
SD	7	34	11	52		
Biomass						
SD15	0.1	0.6	0.7	0.4	0.5	0.3
SD16	0.4	0.8	0.8	0.5	0.6	0.2
SD17	0.1	0.8	1.3	0.6	0.7	0.5
SD18	0.5	0.3	1.6	0.3	0.7	0.6
SD19	1.9	0.3	0.4	0.1	0.7	0.8
SD20	1.1	0.4	0.8	0.3	0.7	0.4
SD21	1.8	0.4	1.3	1.4	1.2	0.6
Mean	0.8	0.5	1.0	0.5		
SD	0.8	0.2	0.4	0.4		

abundance values have averaged between 7 and 273 individuals per station. These wide ranging abundance values generally reflect fluctuations in the populations of the dominant species, especially the echinoderms A. verrilli, L. pictus, and D. terminalis, as well as the shrimp Crangon nigromaculata. For example, the high abundances recorded at SD17 in 1996 and SD15 in 1996 and 1997 were due to large hauls of A. verrilli and L. pictus. With the exception of a significant drop in D. terminalis and an increase of A. verrilli at SD15, there were no major changes in the populations of these 4 species during 2005. None of the observed variability in the invertebrate communities can be attributed to the South Bay outfall.

SUMMARY AND CONCLUSIONS

As in previous years, speckled sanddabs continued to dominate fish assemblages surrounding the South Bay Ocean Outfall during 2005. Although the numbers of speckled sanddabs declined markedly from the previous year, this species occurred at all stations and accounted for 65% of the total catch. Other characteristic, but less abundant species, included the yellowchin sculpin, California lizardfish, roughback sculpin, English sole, Californa scorpionfish and longfin sanddab. Most of these common fishes were relatively small, averaging less than 23 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 were similarly dominated by one prominent species, the sea star A. verrilli. Two other echinoderms, the white urchin L. pictus and the seastar P. brevispinus were also common. Although megabenthic community structure also varied between sites, these assemblages were generally characterized by low species richness, abundance, biomass, and diversity.

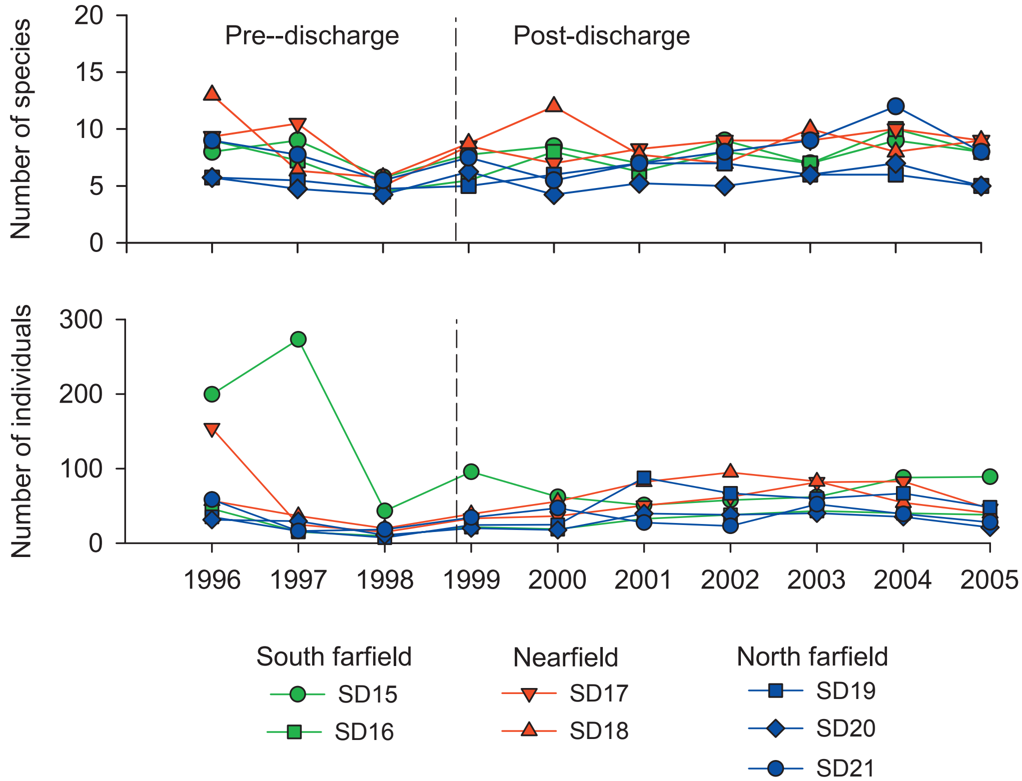


Figure 6.5
Number of species and number of individuals per SBOO station of megabenthic invertebrates collected from 1996 through 2005. Data are means averaged over the 4 surveys in each year.

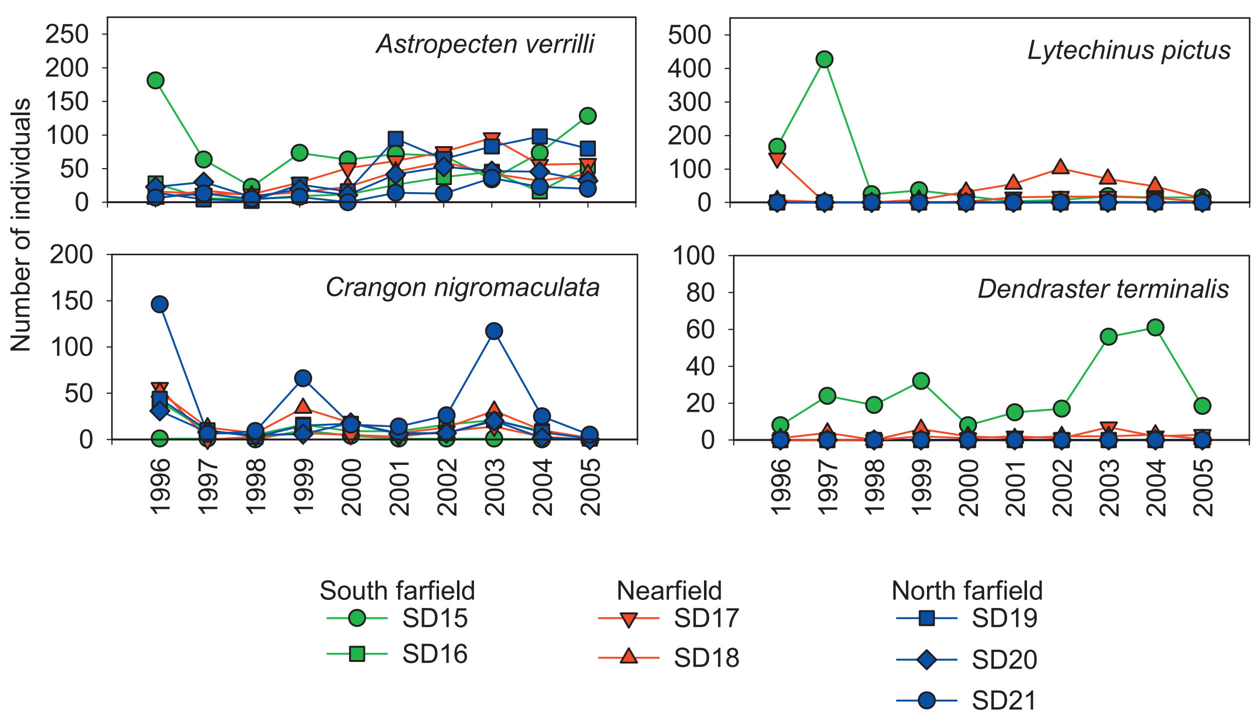


Figure 6.6
Number of individuals per SBOO station for the four most abundant megabenthic invertebrate species collected from 1996 through 2005. Data are means averaged over the 4 surveys in each year.

Overall, results of the 2005 trawl surveys provide no evidence that the discharge of wastewater from the South Bay Ocean Outfall has affected either the fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distrubtion of species were similar at stations located near the outfall and further away, indicating a lack of anthropogenic influence. Changes in the communities appeared to be more likely due to natural factors such as changes in water temperature associated with large scale oceanographic events (e.g., El Niño) and the mobile nature of many of the species collected. Finally, the absence of disease or other physical abnormalities in local fishes suggests that populations in the area continue to be healthy.

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Chapter 7
Bioaccumulation of Contaminants in Fish Tissues

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 adsorption or absorption of dissolved chemical constituents from the water and the ingestion and assimilation of pollutants from food sources. They also accumulate pollutants by ingesting pollutant-containing suspended particulate matter or sediment particles. Demersal fish are useful in biomonitoring programs because of their proximity to bottom sediments. For this reason, levels of contaminants in tissues of demersal fish are often related to those found in the environment (Schiff and Allen 1997).

The bioaccumulation portion of the SBOO monitoring program consists of 2 components: (1) liver tissues are analyzed from trawl-caught fishes; (2) muscle tissues are analyzed from fishes collected by rig fishing. Fishes collected from trawls are considered representative of the demersal fish community, and certain species are targeted based on their ecological significance (i.e., prevalence in the community). Chemical analyses are performed using livers of trawl-caught fishes because this is where contaminants typically concentrate due to the physiological role of this organ and the high lipid levels found there. In contrast, fishes targeted for collection by rig fishing represent 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 are directly pertinent to human health.

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

MATERIALS AND METHODS

Collection

Fishes were collected during the April and October surveys of 2005 at 7 trawl and 2 rig fishing stations (**Figure 7.1**). Trawl-caught fishes were collected, measured, and weighed following guidelines described in Chapter 6 of this report. Fishes targeted at the rig fishing sites were collected using rod and reel fishing tackle, and then measured and weighed

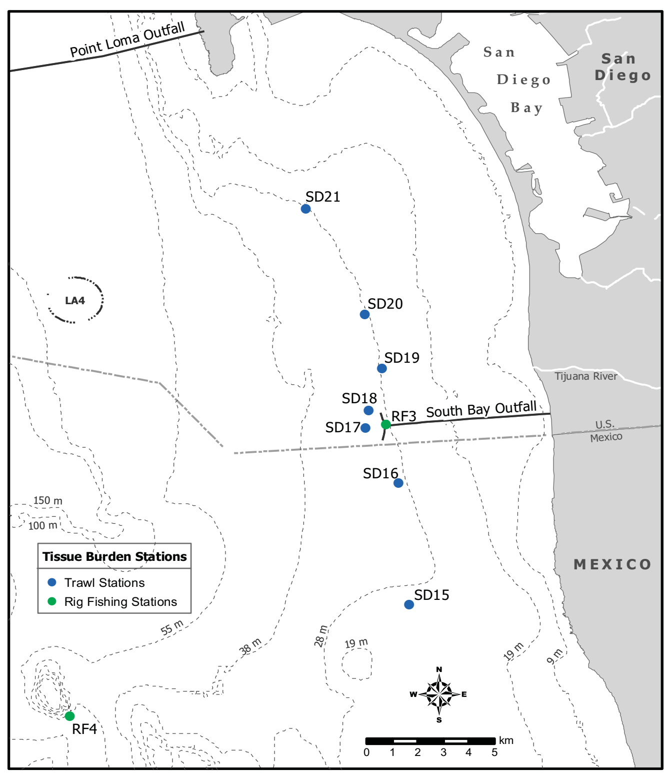

Figure 7.1
Otter trawl and rig fishing station locations for the South Bay Ocean Outfall Monitoring Program.

Table 7.1

Species collected at each SBOO trawl and rig fishing station during April and October 2005.

Station	Rep 1	Rep 2	Rep 3
April 2005			
SD15	English sole	Hornyhead turbot	California scorpionfish
SD16	Hornyhead turbot	California scorpionfish	English sole
SD17	English sole	Hornyhead turbot*	Longfin sanddab
SD18	Hornyhead turbot	California scorpionfish	English sole
SD19	Hornyhead turbot	English sole	Longfin sanddab
SD20	California scorpionfish	Hornyhead turbot	English sole
SD21	Longfin sanddab	Hornyhead turbot	English sole
RF3	Brown rockfish	Mixed rockfish	Brown rockfish
RF4	California scorpionfish	California scorpionfish	California scorpionfish
October 2005			
SD15	California scorpionfish	California scorpionfish	California scorpionfish
SD16	Hornyhead turbot	California scorpionfish	California scorpionfish
SD17	Hornyhead turbot	Hornyhead turbot	California scorpionfish
SD18	Hornyhead turbot	California scorpionfish	California scorpionfish
SD19	California scorpionfish	Hornyhead turbot	California scorpionfish
SD20	Hornyhead turbot	Hornyhead turbot	Hornyhead turbot
SD21	Hornyhead turbot	California scorpionfish	California scorpionfish
RF3	Brown rockfish	Vermilion rockfish	Vermilion rockfish
RF4	California scorpionfish	California scorpionfish	California scorpionfish

* missing all PAHs

following standard procedures (City of San Diego in prep). The species that were analyzed from each station are summarized in **Table 7.1**. The effort to collect targeted fishes at each trawl station was limited to five 10-minute trawls. Occasionally, insufficient numbers of target species were obtained despite this effort. Only fish >12 cm standard length were retained for tissue analyses. These fish were sorted into no more than 3 composite samples per station, each containing a minimum of 3 individuals. The fish were then wrapped in aluminum foil, labeled, put in ziplock bags, and placed on dry ice for transport to the Marine Biology laboratory freezer.

Tissue Processing and Chemical Analyses

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

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

RESULTS

Contaminants in Liver Tissues

Distribution among Species

Four species of fish comprised the 42 liver tissue samples collected in 2005. California scorpionfish and hornyhead turbot accounted for over 75% of the samples. Aluminum, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, selenium, silver, and zinc occurred frequently in the liver tissues of all 4 species sampled (**Table 7.2**). Each metal was detected in over 85% of the samples. Arsenic, copper, iron, and zinc occurred at concentrations above 20 ppm in at least 1 sample. Iron had the highest mean concentration (>100 ppm), and had maximum values above 200 ppm in 3 of the 4 species, California scorpionfish, English sole, and longfin sanddab. Antimony, lead, nickel, thallium, and tin were also detected, but less frequently. Although tin was detected in 100% of the samples collected in 2004, it was detected in only 50% of the samples this year.

Several chlorinated pesticides were also detected in liver tissues (**Table 7.3**). Total DDT (the sum of 7 metabolites, see Appendix D.2) was found in all samples, with concentrations ranging from 75.9 ppb in hornyhead turbot to 2214 ppb in California scorpionfish. Other pesticides included chlordane, hexachlorobenzene (HCB), and BHC (Lindane). Of these, HCB was the most common, occurring in 86% of the samples with values less than 5 ppb. Detected components of chlordane included alpha (*cis*) Chlordane, gamma (*trans*) Chlordane, *cis*-Nonachlor, and *trans*-Nonachlor, each with concentrations less than 20 ppb.

PAHs were not detected in any samples collected in 2005. However, PCBs occurred in all samples for each species. Concentrations for the individual PCB congeners are listed separately in Appendix D.3. Total PCB concentrations (i.e., the sum of all congeners detected in a sample) were variable, ranging from about 28 ppb in an English sole sample to 756 ppb in a longfin sanddab sample. Mean concentrations were highest among longfin sanddabs and California scorpionfish at 577 ppb and 235 ppb, respectively.

Distribution among Stations

Concentrations of the frequently detected metals in fish liver tissues were fairly even across all stations (**Figure 7.2**). Most contaminant concentrations were close to or below the maximum levels detected in the same species prior to discharge. Only 15 of the 42 samples samples occurred at concentrations above their respective pre-discharge maximum. These samples involved only 4 metals (arsenic, mercury, iron, and zinc) and there was no pattern to how the samples were distributed among the 7 stations. Intraspecific comparisons between the 2 stations closest to the discharge (SD17, SD18) and those located farther away (SD15–SD16, SD19–SD21) suggest that there was no clear relationship between contaminant loads and proximity to the outfall.

As with metals, there was no clear relationship between concentrations of the frequently occurring pesticides (i.e., DDT, HCB, *trans*-Nonachlor), PCBs and proximity to the outfall (**Figure 7.3**). All values were below the maximum concentrations detected in the same species prior to discharge.

Contaminants in Muscle Tissues

Twelve composite samples of muscle tissue were collected from various rockfish species (**Tables 7.4, 7.5**). Aluminum, arsenic, barium, chromium, copper, iron, manganese, mercury, selenium, and zinc occurred frequently in the liver tissues of the species sampled (Table 7.4). Each of these metals was detected in over 75% of the samples. Antimony, cadmium, lead, nickel, silver, thallium, and tin were also detected, but less frequently. The metals with the highest mean concentrations included aluminum, arsenic, iron, thallium, and zinc. Each exceeded 2.5 ppm

Table 7.2

Metals detected in liver tissues from fishes collected at SBOO trawl stations during 2005. Values are expressed as parts per million (ppm); n=number of detected values, nd=not detected.

	Al	Sb	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Califorina scorpionfish																	
N (out of 16)	13	9	16	16	15	12	16	16	11	16	15	5	16	13	12	4	16
Min	2.3	0.5	1.0	0.007	0.6	0.11	6.4	38	0.3	0.3	0.045	0.10	0.55	0.06	3.9	0.79	47
Max	18.0	1.0	3.8	0.316	3.4	0.47	25.7	239	0.9	0.6	0.440	0.21	1.00	0.99	5.3	1.09	158
Mean	8.5	0.8	2.7	0.041	1.6	0.24	13.9	138	0.6	0.4	0.146	0.14	0.73	0.31	4.7	0.96	84
Hornyhead turbot																	
N (out of 16)	15	3	16	14	16	15	16	16	9	16	16	5	16	13	9	7	16
Min	2.8	0.5	2.1	0.007	1.6	0.08	3.1	23	0.4	0.7	0.042	0.11	0.47	0.07	2.8	0.50	28
Max	11.8	0.6	4.7	0.042	6.2	1.23	8.2	84	0.8	2.0	0.145	0.31	1.07	0.31	3.8	0.69	66
Mean	7.5	0.5	3.4	0.026	3.6	0.31	5.6	44	0.6	1.3	0.085	0.22	0.67	0.17	3.4	0.57	40
English sole																	
N (out of 7)	7	nd	7	7	7	7	7	7	7	7	7	nd	7	7	nd	7	7
Min	8.6	—	9.5	0.029	0.8	0.16	3.9	132	0.4	0.9	0.018	—	1.09	0.16	—	0.46	28
Max	11.3	—	23.3	0.042	1.3	0.23	11.5	324	1.1	2.0	0.081	—	1.53	0.31	—	0.71	43
Mean	9.5	—	14.1	0.034	1.1	0.19	8.3	225	0.7	1.6	0.055	—	1.34	0.25	—	0.59	34
Longfin sanddab																	
N (out of 3)	3	nd	3	3	3	3	3	3	nd	3	3	nd	3	3	nd	3	3
Min	11.1	—	8.9	0.034	3.1	0.17	8.5	149	—	1.3	0.127	—	1.41	0.35	—	0.80	26
Max	16.2	—	22.0	0.054	5.8	0.27	13.0	213	—	2.1	0.195	—	1.63	0.59	—	0.95	28
Mean	14.2	—	17.2	0.047	4.4	0.22	10.5	182	—	1.6	0.161	—	1.54	0.44	—	0.87	27
ALL SPECIES																	
% Detected	90	29	100	95	98	88	100	100	64	100	98	24	100	86	50	50	100

Table 7.3

Chlorinated pesticides, total PCB, and lipids detected in liver tissues from fishes collected at SBOO trawl stations during 2005. A(C)C=alpha (*cis*) Chlordane, G(T)C=gamma (*trans*) Chlordane, CN=*cis*-nonachlor, TN=*trans*-Nonachlor, and HCB=hexachlorobenzene. 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.

	Chlorinated Pesticides								
				Chlordane				Total	
	DDT	HCB	BHC	A(C)C	G(T)C	CN	TN	PCB	Lipids
California scorpionfish									
N (out of 16)	16	16	nd	15	nd	12	16	16	16
Min	152.1	0.9	—	2.7	—	2.8	4.6	115.0	17.2
Max	2213.5	2.0	—	5.5	—	6.2	13.0	511.5	32.0
Mean	642.1	1.3	—	3.8	—	4.1	7.8	235.1	22.3
Hornyhead turbot									
N (out of 16)	16	12	1	2	1	1	7	16	16
Min	75.9	0.4	3.3	3.2	2.2	3.1	1.8	30.6	4.9
Max	339.4	4.8	3.3	3.3	2.2	3.1	7.3	101.6	16.1
Mean	171.8	1.1	3.3	3.3	2.2	3.1	3.3	59.8	9.0
English sole									
N (out of 7)	7	5	nd	nd	nd	nd	1	7	7
Min	92.5	0.7	—	—	—	—	3.5	27.6	4.6
Max	1902.1	1.6	—	—	—	—	3.5	239.6	9.2
Mean	472.6	1.1	—	—	—	—	3.5	96.3	5.9
Longfin sanddab									
N (out of 3)	3	3	nd	3	nd	2	3	3	3
Min	668.0	1.2	—	3.6	—	4.3	6.6	393.7	14.0
Max	1371.9	1.6	—	5.6	—	4.3	15.0	755.6	15.9
Mean	1115.3	1.4	—	4.8	—	4.3	10.1	577.4	14.8
ALL SPECIES									
% Detected	100	86	2	48	2	36	64	100	

for at least 1 species of fish sampled; however there was little difference between the species relative to the concentrations for these metals.

DDT and PCBs were detected in 100% of the muscle samples, but at concentrations substantially lower than values detected in the livers of trawled fishes (even for the same species). Additional pesticides, including BHC (Lindane), HCB, and *trans*-Nonachlor (a component of Chlordane), were found much less frequently, and also at very low levels relative to concentrations found in liver tissues.

To address human health concerns, concentrations of the constituents found in muscle tissue samples were compared to national and international limits and standards (Tables 7.4, 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 (Mearns et al. 1991). In addition, there are international standards for acceptable concentrations of various metals (Mearns et al. 1991). While many compounds were detected in the muscle tissues of fish collected as part of the SBOO monitoring program, only arsenic and mercury had

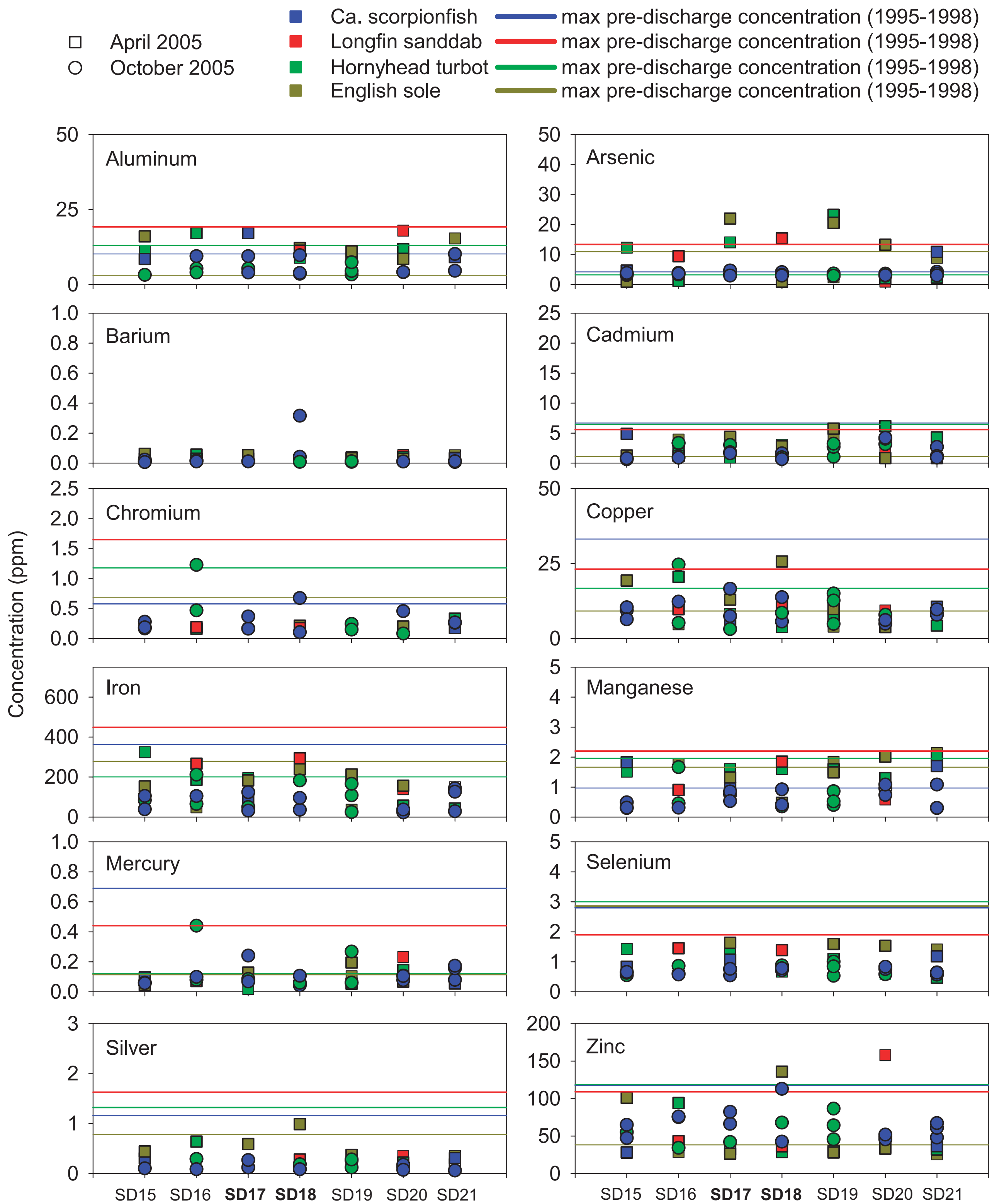

Figure 7.2
Concentrations of frequently detected metals in liver tissues of fishes collected from each SBOO trawl station during 2005. Reference lines are maximum values detected during the pre-discharge period (1995–1998). Stations closest to the discharge site are labeled in bold.

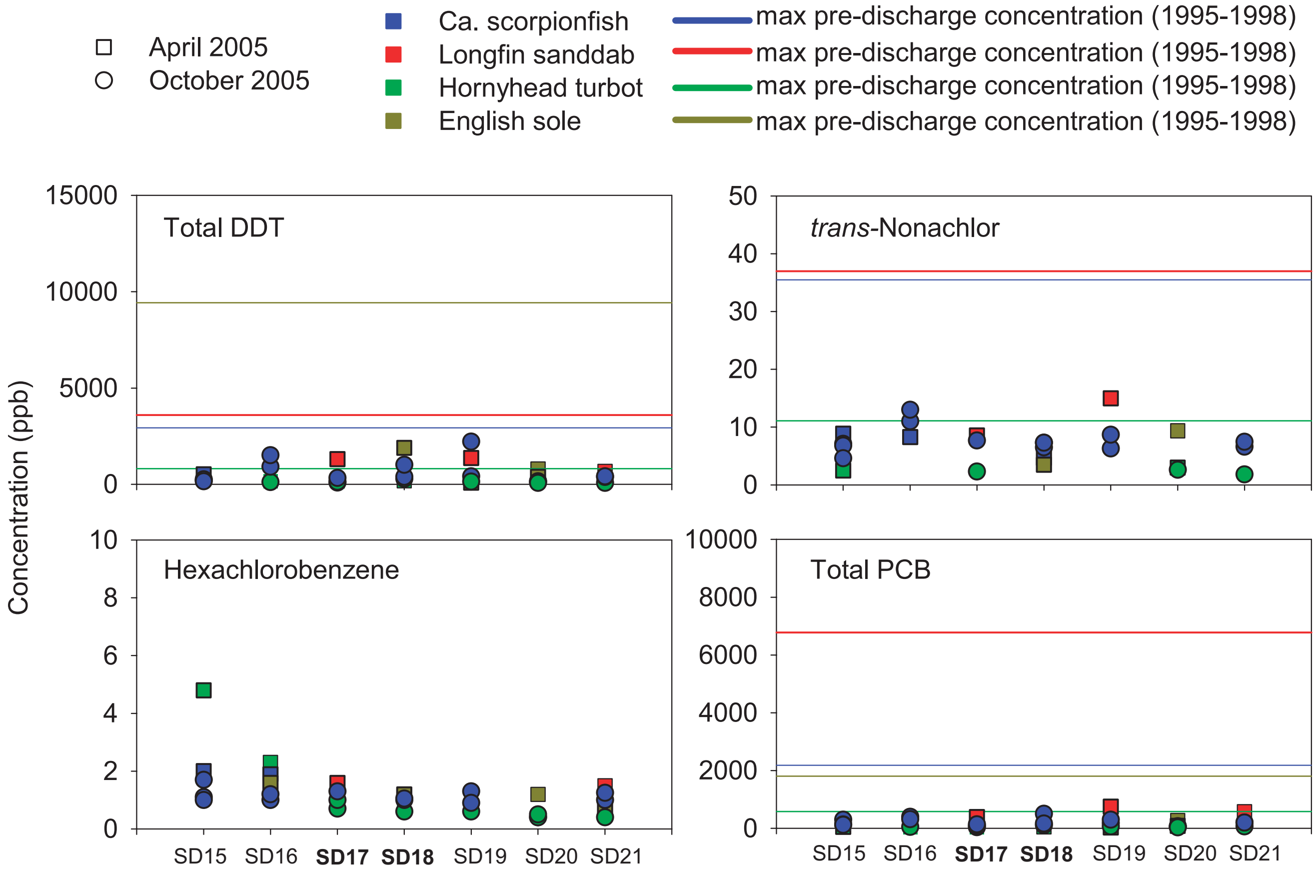

Figure 7.3
Concentrations of frequently detected chlorinated pesticides (total DDT, *trans*-Nonachlor, hexachlorobenzene) and total PCBs in liver tissues of fishes collected from each SBOO trawl station during 2005. Reference lines are maximum values detected during the pre-discharge period (1995–1998). Stations closest to the discharge site are labeled in bold.

concentrations that were higher than international standards.

In addition to addressing health concerns, spatial patterns were assessed for total DDT and total PCB, as well as all metals that occurred frequently in fish muscle tissue samples (**Figure 7.4**). Concentrations of metals, DDT, and PCB were variable in the muscle tissues of fishes from both rig fishing stations, and no clear relationship with proximity to the outfall was evident. Further, most samples had values close to or below the maximum concentrations detected in the same species prior to discharge. A notable exception is a high mercury value that exceeded the international standard, and was just below the US FDA action limit (see above). This sample came from California scorpionfish collected at station RF4 located near the Coronado Islands. California scorpionfish are known to travel over vast areas (Hartmann 1987, Love et al. 1987), so this high mercury level is most likely due to exposure from another area with higher levels of sediment contamination.

Comparison of contaminant loads between RF3 and RF4 should be considered with caution however, because different species of fish were collected at the 2 sites. Scorpionfish were collected at farfield station RF4 while rockfish were collected at nearfield station RF3. Both belong to the same family, Scorpaenidae, and have similar life histories (e.g., bottom dwelling tertiary carnivores), so they have similar mechanisms of exposure (e.g., exposure from direct contact with the sediments and through possibly similar food sources). These species are therefore comparable to a certain degree. However, since they are not the same species, differences in physiology and food choices may exist that could affect the accumulation of contaminants.

Table 7.4

Metals detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2005. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist. Bold values exceed these standards, n=number of detected values, nd=not detected.

	Al	Sb	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Brown rockfish																	
N (out of 3)	3	nd	3	2	nd	3	3	3	1	3	3	nd	3	2	1	2	3
Min	0.94	—	0.90	0.028	—	0.10	0.16	1.02	0.32	0.054	0.043	—	0.158	0.071	2.68	0.376	2.75
Max	6.99	—	**2.22**	0.033	—	0.14	1.40	2.36	0.32	0.071	0.209	—	0.245	0.083	2.68	0.549	3.60
Mean	4.87	—	1.35	0.030	—	0.12	0.59	1.78	0.32	0.060	0.128	—	0.204	0.077	2.68	0.463	3.16
California scorpionfish																	
N (out of 6)	5	nd	6	6	nd	4	6	6	3	6	6	1	6	3	3	3	6
Min	1.97	—	**1.77**	0.015	—	0.11	0.20	2.22	0.30	0.046	0.172	0.05	0.185	0.079	2.54	0.460	2.74
Max	9.13	—	**4.83**	0.047	—	0.13	1.39	3.88	0.38	0.080	**0.843**	0.05	0.257	0.089	2.74	0.602	3.98
Mean	5.90	—	**3.12**	0.029	—	0.12	0.62	2.92	0.35	0.063	0.295	0.05	0.227	0.083	2.66	0.539	3.38
Mixed rockfish																	
N (out of 1)	1	nd	1	1	nd	1	1	1	nd	1	1	nd	1	1	nd	1	1
Min	6.35	—	**1.93**	0.024	—	0.11	0.14	2.95	—	0.079	0.074	—	0.162	0.093	—	0.407	2.69
Max	6.35	—	**1.93**	0.024	—	0.11	0.14	2.95	—	0.079	0.074	—	0.162	0.093	—	0.407	2.69
Mean	6.35	—	**1.93**	0.024	—	0.11	0.14	2.95	—	0.079	0.074	—	0.162	0.093	—	0.407	2.69
Vermilion rockfish																	
N (out of 2)	1	1	2	2	nd	1	2	2	1	2	2	1	2	nd	2	nd	2
Min	4.17	0.49	**2.73**	0.004	—	0.81	0.27	1.21	0.44	0.101	0.054	0.73	0.275	—	2.87	—	3.01
Max	4.17	0.49	**2.88**	0.010	—	0.81	0.73	5.02	0.44	0.146	0.058	0.73	0.293	—	2.87	—	3.29
Mean	4.17	0.49	**2.81**	0.007	—	0.81	0.50	3.12	0.44	0.124	0.056	0.73	0.284	—	2.87	—	3.15
ALL SPECIES																	
% Detected	83	8	100	92	0	75	100	100	42	100	100	17	100	50	50	50	100
US FDA Action Limit*											1.0						
Median International Standard*			1.4		1.0	1.0	20		2.0		0.5		0.3			175	70.00

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

Table 7.5

Total PCB, chlorinated pesticides, and lipids detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2005. HCB=hexachlorobenzene and TN=*trans*-Nonachlor. Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt); n=number of detected values, nd=not detected. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist.

	Total	Pesticides				
	PCB	DDT	BHC	HCB	TN	Lipids
Brown rockfish						
N (out of 3)	3	3	1	nd	nd	3
Min	0.50	1.0	0.7	—	—	0.24
Max	2.40	4.3	0.7	—	—	0.35
Mean	1.27	2.6	0.7	—	—	0.28
California scorpionfish						
N (out of 6)	6	6	nd	nd	nd	6
Min	0.50	3.0	—	—	—	0.24
Max	2.25	8.9	—	—	—	0.85
Mean	1.37	5.8	—	—	—	0.54
Mixed rockfish						
N (out of 1)	1	1	nd	nd	nd	1
Min	0.90	2.6	—	—	—	0.32
Max	0.90	2.6	—	—	—	0.32
Mean	0.90	2.6	—	—	—	0.32
Vermilion rockfish						
N (out of 2)	2	2	nd	1	1	2
Min	0.40	1.3	—	0.1	0.2	0.47
Max	2.00	4.7	—	0.1	0.2	1.63
Mean	1.20	3.0	—	0.1	0.2	1.05
ALL SPECIES						
% Detected	100	100	8	8	8	
US FDA Action Limit*		5000			300	
Median International Standard*		5000			100	

* From Mearns et al. 1991. FDA action limits for total DDT and Chlordane (of which *trans*-Nonachlor is a component) are for fish muscle tissue and all international standards are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

SUMMARY AND CONCLUSIONS

Twelve trace metals, 2 pesticides, and a combination of PCBs were each detected in over 75% of the liver samples from 4 species of fish collected around the South Bay Ocean Outfall (SBOO) in 2005. 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 the concentrations of several trace metals from several individual samples exceeded pre-discharge maximum values, concentrations of most contaminants were not substantially different from pre-discharge data (City of San Diego 2000b). In addition, the few samples that did exceed these pre-discharge values were distributed widely among the sampled stations and showed no pattern relative to the SBOO discharge.

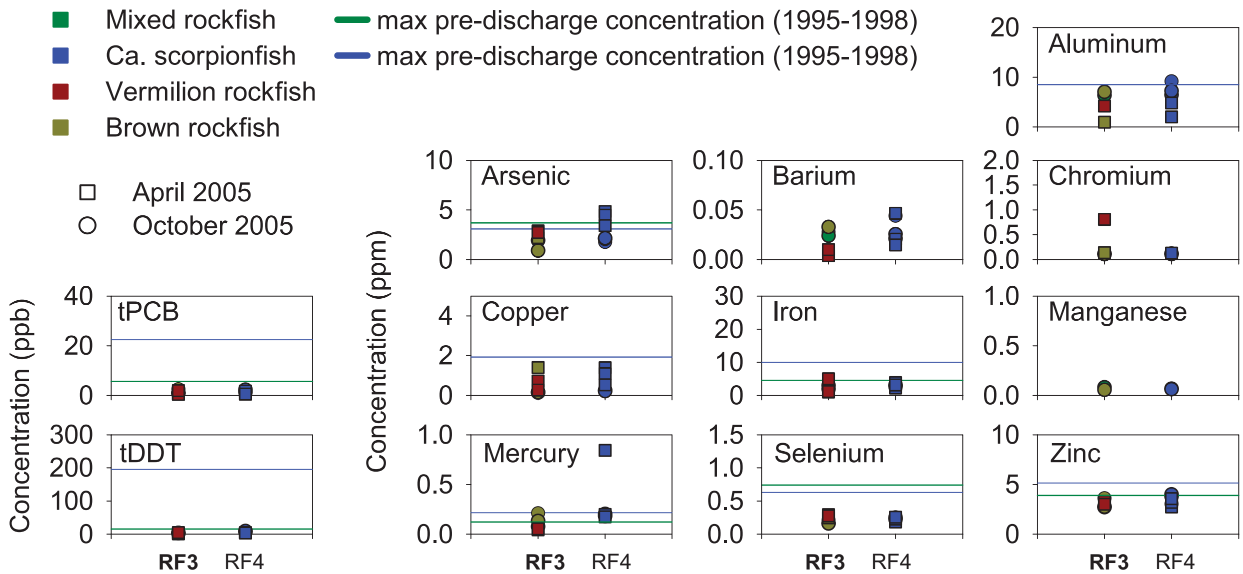

Figure 7.4

Concentrations of frequently detected metals, total DDT and total PCB in muscle tissues of fishes collected from each SBOO rig fishing station during 2005. Missing data represent concentrations below detection limits. Reference lines are maximum values detected during the pre-discharge period (1995-1998) for California scorpionfish and mixed rockfish. No vermilion or brown rockfish were collected during that period. Station RF3 is the station closest to the discharge site.

The frequent occurrence of metals and chlorinated hydrocarbons in SBOO fish tissues may be due to many factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB. In fact, many metals occur naturally in the environment, although little information is available on their background levels in fish tissues. Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998). The lack of contaminant-free reference areas in the SCB clearly pertains to the South Bay region, as demonstrated by the presence of many contaminants in fish tissues prior to wastewater discharge (City of San Diego 2000b).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. For example, exposure to contaminants can vary greatly between species and among individuals of the same species depending on migration habits (Otway 1991). Fish may be exposed to contaminants in one highly contaminated area and then move into an area that is less contaminated. This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many point and non-point sources that may contribute to contamination in the region. For example, some monitoring stations are located near the Tijuana River, San Diego Bay, and dredged materials disposal sites, and input from these sources may affect fish in nearby areas.

Overall, there was no evidence that fishes collected in 2005 were contaminated by the discharge of waste water from the SBOO. While some muscle tissue samples from sport fish collected in the area had concentrations of arsenic and mercury above the median international standard for shellfish, concentrations of mercury and DDT were below FDA human consumption limits. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot or other physical anomalies (see Chapter 6).

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Chapter 8
San Diego Regional Survey
Sediment Characteristics

Chapter 8. Regional Survey off San Diego Sediment Characteristics

INTRODUCTION

The City of San Diego has conducted summer regional surveys of sediment conditions on the mainland shelf off San Diego since 1994 in order to evaluate physical and chemical patterns and trends over a large geographic area. Such region-wide monitoring is designed to assess the quality and characteristics of sediments, as well as provide additional information that may help to differentiate reference areas from sites impacted by wastewater and stormwater discharge. These annual surveys are based on an array of stations randomly selected for each year by the United States Environmental Protection Agency (USEPA) using the USEPA probability-based EMAP design. The 1994, 1998, and 2003 surveys were conducted as part of the Southern California Bight 1994 Pilot Project (SCBPP), and the Southern California Bight 1998 and 2003 Regional Monitoring Programs (Bight′98 and Bight′03, respectively). These large-scale surveys included other major southern California dischargers, and included sampling sites representing the entire Southern California Bight (i.e., Cabo Colnett, Mexico to Point Conception, U.S.A.). The same randomized sampling design was used for the random sampling surveys limited to the San Diego region (1995–1997, 1999–2002). A regional (random) survey was not conducted in 2004 in order to conduct a special strategic process study pursuant to an agreement with the SDRWQCB and USEPA (see City of San Diego 2005). The results from Phase I of the San Diego Sediment Mapping Study are currently being analyzed (see Stebbins et al. 2004). In July 2005, the City revisited the 1995 survey sites in order to compare conditions 10 years later.

This chapter presents analyses of sediment particle size and chemistry data collected during the San Diego regional survey of 2005. Descriptions and comparisons of the sediment conditions present in 2005 are included with analyses of levels and patterns of contamination relative to known and presumed sources. Results from the 2005 survey are compared to those of the 1995 survey.

MATERIALS AND METHODS

The July 2005 survey of randomly selected sites off San Diego covered an area from Del Mar south to the United States/Mexico border (**Figure 8.1**). This survey revisited the sites selected for the 1995 regional survey, which was based on the USEPA probability-based EMAP sampling design. Site selection involved a hexagonal grid that was randomly placed over a map of the region. One sample site was then randomly selected from within each grid cell. This randomization helps to ensure an unbiased estimate of ecological condition. The area sampled included the section of the mainland shelf from nearshore to shallow slope depths (12–202 m). Although 40 sites were initially selected for the 1995 and 2005 surveys, sampling at 3 sites in 1995 and 4 sites in 2005 was unsuccessful due to the presence of a rocky reefs.

Benthic sediment samples were collected using a modified 0.1-m^2 chain-rigged van Veen grab. Sub-samples were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (USEPA 1987). All sediment analyses were performed at the City of San Diego Wastewater Chemistry Laboratory. Particle size analyses were performed using a Horiba LA-920 laser analyzer, which measures particles ranging in size from 0.00049–2.0 mm (i.e., -1 to 11 phi). Sand was defined as particles ranging in size >0.0625 mm, silt as particles from <0.0625 to 0.0039 mm, and clay as particles <0.0039 phi (**Table 8.1**). Coarse sediments (e.g., gravel, pebble, shell hash) were removed from each sample prior to analysis by screening the samples through a 2.0 mm mesh sieve. The retained material was weighed and expressed as the percent coarse of the total sample sieved. All of these data were standardized to obtain a distribution of coarse, sand, silt, and clay totaling 100%. The clay and silt

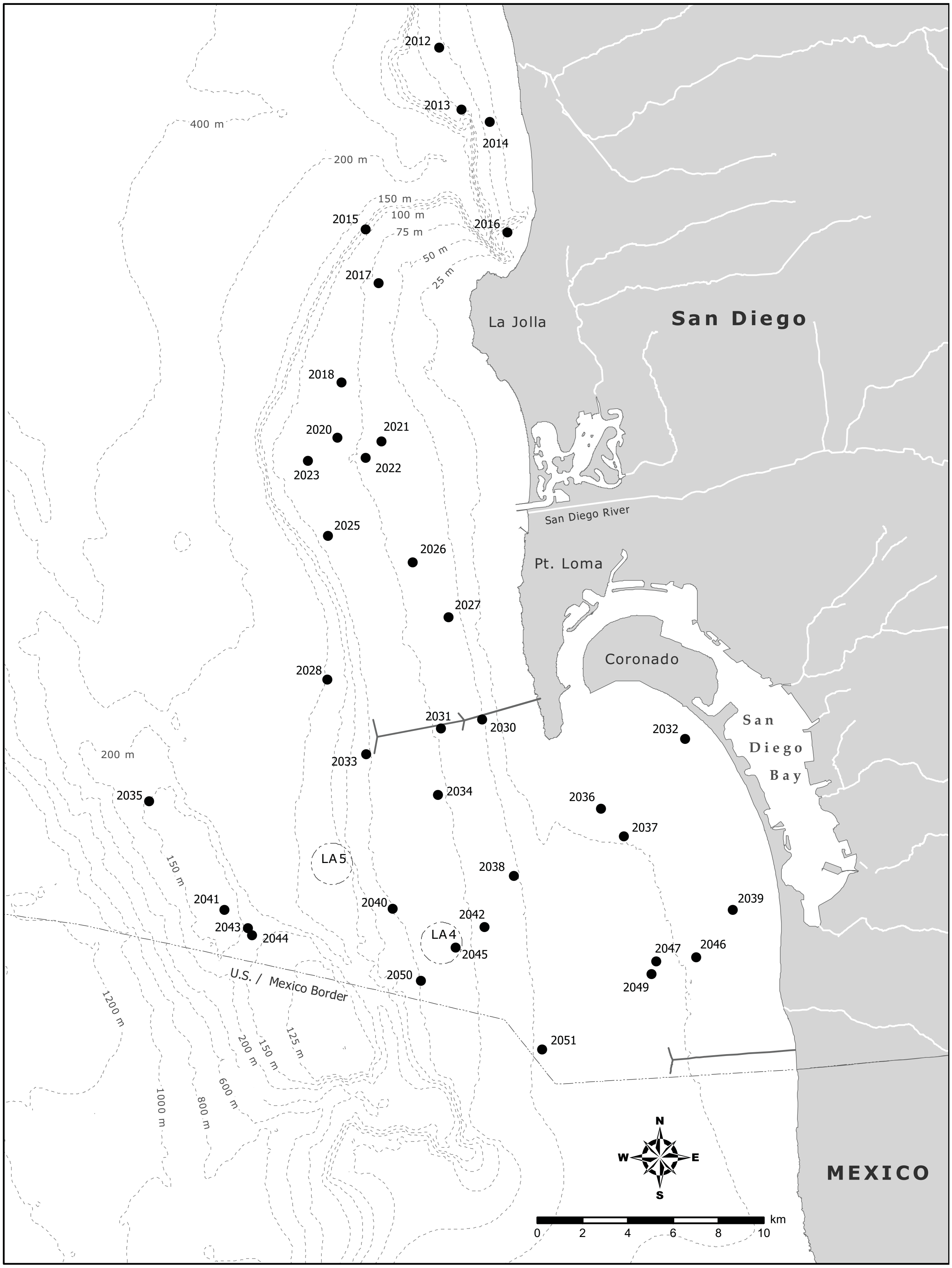

Figure 8.1
Randomly selected regional sediment quality stations (numbered stations) sampled off San Diego, CA (July 1995, 2005), including the semi-annual sampling grid for the South Bay Ocean Outfall (I stations).

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	0.0020	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)

fractions were then combined to yield the percent "fines". Sediment particle size parameters were summarized according to calculations based on a normal probability scale with the sieved coarse fraction included with the >2 mm fraction (see Folk 1968). The calculated parameters include median and mean particle size in millimeters and phi, sorting coefficient (standard deviation), skewness, kurtosis and percent sediment type (i.e., coarse particles, sand, silt, clay).

The following sediment chemical parameters were analyzed: total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyl compounds (PCBs). These data generally were limited to values above method detection limits (MDLs). However, the presence of some parameters (e.g., PAH compounds) detected at concentrations below their MDL were confirmed with high confidence by mass-spectrometry (i.e., peaks are confirmed by MS). These data were included as estimated values. Null (i.e., zero) values represent instances where the substance was either not detected, or detected below the MDL but not be confirmed by MS. Zeros were substituted for null values when estimating mean values. The data are summarized by depth strata used in the Bight'98 and Bight'03 regional surveys of the entire Southern California Bight (SCB): shallow shelf, 5–30 m; mid-shelf, 30–120 m; deep shelf, 120–200 m.

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

RESULTS AND DISCUSSION

Particle Size Analysis

With few exceptions, the overall composition of sediments off San Diego in 2005 consisted of fine sands and silts (**Figure 8.2, Table 8.2**). The general distribution of sediment particles was similar to that of the previous years: higher sand content in shallow nearshore areas, decreasing to a mixture of mostly coarse silt and very fine sand at the mid-shelf region and deeper offshore sites (see City of San Diego 1998, 2000, 2001, 2002, 2003). However, coarse sediments (~85% sand) occurred in 2 distinct locations: (1) in shallow waters, particularly in the South Bay area, and (2) along the Coronado Bank, a southern rocky ridge located offshore of Point Loma.

Stations along the mid-shelf depth strata (30–120 m) represented most of the shelf region off San Diego (n=24). Sediments at these sites averaged ~61% sand, with a mean particle size of 0.096 mm, and the highest amount of fines (~37%). By comparison, the 7 sites occurring at in shallow water (≤30 m) had coarser sediments with only 8.5% fines and particles with a mean diameter of ~0.262 mm. Sand content at these shallow sites was nearly 83%. Station 2036, with the coarsest sediments (0.987 mm), was among these sites. This station was located near the mouth of San Diego Bay and contained primarily coarse sediments (55%), including coarse sand, relict sands, and shell hash. Five deep water sites (120–200 m) contained sediments of 0.206 mm average particle size, including 73% sand. The deep water strata included 1 fine and 4 coarse sediment stations. The fine sediment site (2028) was located near the shelf-slope interface northwest of the Point Loma Ocean Outfall. It was the deepest station sampled, had the smallest average sediments (0.037 mm), and consisted of 61% fines. The coarse sites (2035, 2041, 2043, 2044) were located along the rocky Coronado Bank.

Exceptions to the above general pattern occurred primarily at several shallow water sites located southward of the entrance to San Diego Bay (stations 2032, 2039, 2046, 2047). These sites were composed of very fine sands composed of more fine materials (~10% fines) relative to other shallow sites in the surrounding area (i.e., stations 2036, 2037). Additionally, 3 mid-shelf stations consisted of primarily coarse sands. Station 2040 was between the EPA designated dredge spoils disposal sites (LA-4 and LA-5), and station 2051 was offshore of the SBOO where relict sands are known to occur. One site north of Point Loma (station 2023) contained over 25% coarse materials including gravel and rock (see **Appendix D.1**). The patchy nature of sediments in these areas has been well documented during previous surveys (see City of San Diego 1998, 2000, 2001, 2002, 2003).

Generally, sediment particle size composition along the San Diego shelf in 2005 was little different than at the same sites sampled in 1995 (Figures 8.2A, B). Only 8 of the 36 stations sampled in 2005 were different by more than 0.05 mm (mean particle size) from the 1995 samples. These sites include 1 shallow water station (2036), 4 mid-shelf stations (2023, 2031, 2040, 2051), and 3 deep water stations (2035, 2041, 2044).

Organic Indicators

As in previous regional surveys, concentrations of TOC and TN tended to increase with depth and decreasing grain size, and were highest at sites along the Coronado Bank and northward where finer sediments were common (**Table 8.2, Figure 8.2**). Mean TOC values were 0.35% at the shallow water stations, but increased to 0.73% at the mid-shelf stations, and 3.87% at the deep shelf sites. The deepest station sampled (2028), had the highest amount of TN, the third highest concentration of sulfides, and fourth highest percent TOC. Stations 2035 and 2041, located along the Coronado Bank, had relatively coarse sediments but the highest levels

Table 8.2

Summary of particle size parameters and organic loading indicators for the 2005 regional survey stations. Data are expressed as station means. MDL=method detection limit. CDF=median cumulative distribution functions (see text); Bolded values exceed the median CDF. Area Mean=mean across all stations.

Station	Depth (m)	Mean (mm)	Fines (%)	Sulfides (ppm)	TN (%)	TOC (%)
Shallow shelf						
2032	12	0.129	11.8	1.8	0.019	0.166
2036	16	0.987	0.0	0.0	0.015	**1.480**
2039	16	0.104	12.7	0.9	0.013	0.127
2046	22	0.122	9.8	0.2	0.012	0.142
2037	24	0.232	5.6	1.1	0.016	0.187
2016	25	0.158	5.0	14.3	0.019	0.179
2047	29	0.101	14.7	0.9	0.016	0.167
Mean	21	0.262	8.5	2.7	0.016	0.350
Mid-shelf						
2049	31	0.099	15.4	1.2	0.015	0.170
2014	38	0.080	28.8	2.0	0.046	0.494
2030	47	0.052	41.7	9.8	**0.068**	**0.835**
2051	49	0.549	2.3	4.4	0.008	0.084
2038	52	0.055	40.0	0.7	**0.056**	0.617
2027	58	0.054	43.2	7.1	**0.067**	0.746
2012	59	0.059	36.0	1.5	**0.053**	0.533
2021	67	0.051	44.9	2.8	**0.072**	**1.050**
2026	68	0.045	54.0	1.0	**0.080**	**0.827**
2042	68	0.090	30.9	1.1	0.047	0.697
2017	69	0.052	41.6	2.6	**0.067**	**0.815**
2022	72	0.051	44.8	1.0	0.066	0.676
2013	73	0.071	29.7	1.4	**0.052**	0.525
2031	74	0.048	49.0	6.4	**0.079**	**0.850**
2034	81	0.044	53.9	1.8	**0.089**	**0.970**
2020	82	0.045	52.3	0.6	**0.094**	**1.500**
2045	84	0.053	39.7	0.8	**0.058**	**0.760**
2018	85	0.044	54.3	1.9	**0.058**	0.733
2023	90	0.210	33.7	1.0	**0.081**	**1.250**
2025	95	0.058	39.9	2.2	**0.071**	**0.783**
2050	101	0.092	22.8	3.8	0.026	0.334
2040	102	0.272	11.3	6.3	**0.065**	**0.808**
2033	104	0.068	31.4	1.1	0.051	**0.834**
2015	108	0.057	38.6	2.7	**0.058**	0.724
Mean	73	0.096	36.7	2.7	0.059	0.734
Deep shelf						
2041	137	0.321	8.5	0.5	**0.065**	**9.020**
2035	152	0.248	13.9	1.5	**0.061**	**5.250**
2043	171	0.273	13.3	1.6	0.044	**1.660**
2044	179	0.151	21.4	0.3	**0.054**	**1.740**
2028	190	0.037	61.4	8.1	**0.121**	**1.660**
Mean	166	0.206	23.7	2.4	0.069	3.866
Area Mean	76	0.143	29.0	2.7	0.052	1.094
MDL				0.14	0.005	0.010
50% CDF					0.051	0.748

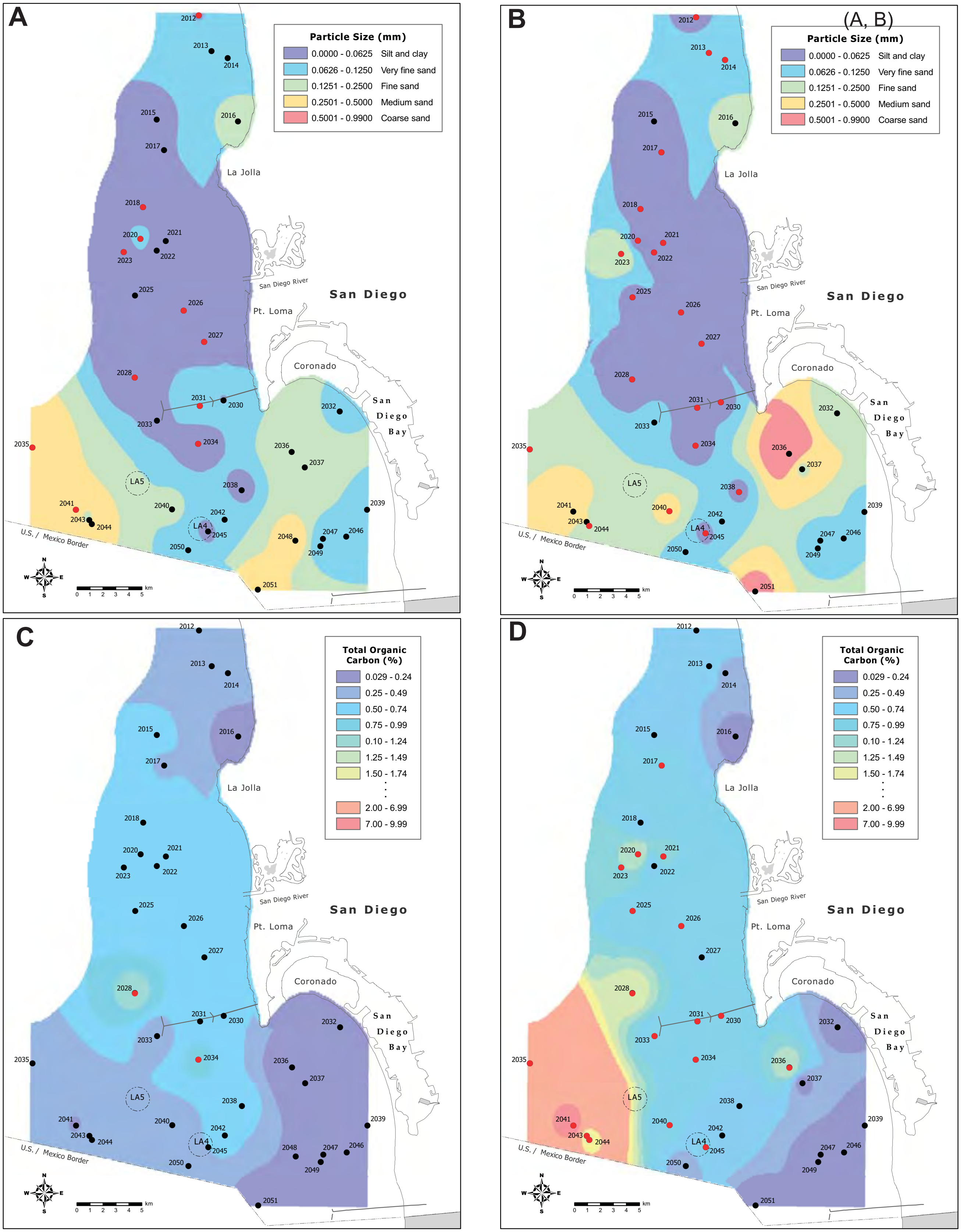

Figure 8.2

Interpolated mean particle size (mm) and TOC (%) data from the regional sediment quality stations sampled off San Diego, CA in July 1995 (A, C) and 2005 (B, D). Sites shown in red include those with concentrations of 3 or more metals (A, B) above the median CDF and individual TOC concentrations (C, D) exceeding the median CDF value.

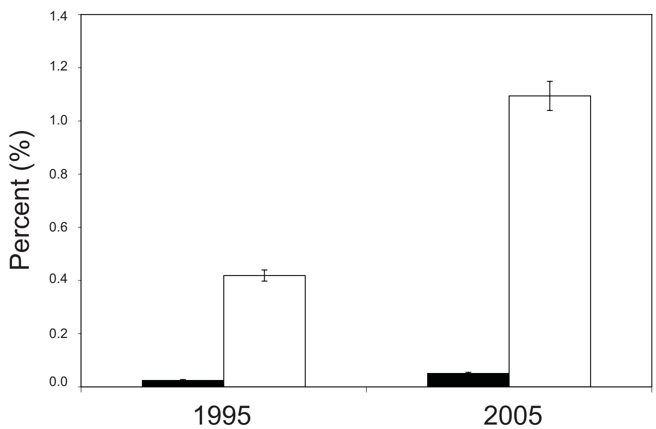

Figure 8.3
Mean concentraion of TOC (white) and TN (black) for the regional survey stations sampled in 1995 versus 2005.

of TOC. The sediments at station 2041 exceeded 6% TOC, an amount associated with severely impacted areas (see Zeng et al. 1995). Both sites had low organic loads in 1995. In contrast, the shallow shelf station 2016 was composed of sediments the greatest amount of sands (94%) with relatively low concentrations of TN and TOC, but the highest concentration of sulfides (14.3 ppm).

In general, concentrations of total organic carbon (TOC) and total nitrogen (TN) in sediment samples collected during 2005 were relatively high compared to prior years (see City of San Diego 1998, 2000, 2001, 2002, 2003). For example, TOC and TN values were over twice as high in 2005 relative to 1995 (**Figure 8.3**). In 2005, approximately 50% of the stations had TOC values that exceeded the median CDF levels, compared to just 5% in 1995 (see Figures 8.2C, D). Similarly, 64% of the TN samples exceeded the median in 2005 relative to 8% in 1995. The cause of the increased organic load is unclear, but may be related to sedimentation resulting from record high rainfall that began in October 2004 and continued through February 2005 (see Chapter 2). For example, there was a large increase in TOC at stations off shore of the Point Loma Ocean Outfall between 2004 and 2005 (see City of San Diego 2006). The resultant storm runoff created large turbidity plumes bearing terrestrial detritus that spread over much of the sampling area. In addition, these circumstances created optimal conditions for the development of large plankton blooms that blanketed the region from April through October 2005. Decaying plankton and terrestrial detritus may have contributed to increased organic content along the shelf (see Mann 1982, Parsons et al. 1990).

Trace Metals

Fourteen trace metals (i.e., aluminum, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc) were detected at almost all 36 survey stations in 2005 (**Table 8.3**). Four metals (i.e., antimony, silver, selenium, and thallium) were detected in one-third or less of the samples. The most widely distributed trace metals appeared to co-vary with iron, a pattern common among many metals found in marine sediments (see Schiff and Gossett 1998). Metal concentrations were generally highest along gradients of increasing depth and decreasing particle size, or near anthropogenic inputs (e.g., ocean outfalls and dredge spoils disposal sites) (**Figure 8.4**). For example, average concentrations for 11 trace metals in the sediments from the mid-shelf strata were higher than either the shallow or deep water strata. Station 2040, located between LA-4 and LA-5 disposal sites, had the highest concentrations of 8 different metals (i.e., arsenic, cadmium, copper, manganese, mercury, silver, tin, and zinc). This is similar to the general pattern of metals contamination that has been found for the SCB (Schiff and Gossett 1998) and in previous regional surveys (see City of San Diego 1998, 2000, 2001, 2002, 2003).

As with organics, concentrations of trace metals in sediments increased between 1995 and 2005 (see Figure 8.4). The sediments at 21 stations sampled in 2005 had 3 or more metals whose concentrations exceeded the median values, which is nearly twice as many as were found in 1995 (see Figure 8.2A, B). Aluminum, beryllium, and iron were the most common trace metals exceeding median CDF values in 2005 (see Table 8.3). However, sediments from several sites contained relatively high amounts of metals associated with industrial (e.g., antimony, beryllium, cadmium, selenium), or that occurred in high concentrations in San Diego Bay (e.g., copper and lead) (City of San Diego 2003b).

Table 8.3

Concentrations of trace metals (parts per million) detected at each 2005 regional survey station. MDL=method detection limit. CDF=median cumulative distribution function (see text). Area Mean=mean across all stations. Values that exceed the median CDF are indicated in bold type. See Appendix A.1 for the names of each metal represented by the periodic table symbol.

Station	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe
Shallow shelf									
2032	8050	**0.24**	2.04	24.2	0.139	0.05	10.7	2.44	9040
2036	2760	**1.08**	3.47	8.1	0.148	nd	4.3	3.61	4680
2039	8600	nd	1.75	26.4	0.162	0.07	14.6	2.42	13400
2046	**10000**	**0.89**	1.48	29.4	0.180	0.05	14.9	2.43	13300
2037	7720	**0.31**	2.76	31.3	0.134	0.04	10.0	3.20	9590
2016	9090	nd	1.34	31.0	0.155	0.09	16.2	2.48	11500
2047	**11700**	nd	1.99	37.5	0.193	0.10	14.3	3.84	10700
Mean	8274	0.36	2.12	26.8	0.159	0.06	12.1	2.92	10316
Mid-shelf									
2049	**9540**	nd	2.04	37.5	0.157	0.06	12.6	4.02	8430
2014	**19200**	nd	3.94	77.1	**0.361**	0.18	24.7	7.95	**19400**
2030	**20000**	nd	3.69	69.1	**0.359**	0.26	25.0	11.40	**19400**
2051	2710	**0.45**	**9.85**	4.6	0.098	0.03	10.4	1.35	8610
2038	**17400**	**0.87**	3.59	52.2	**0.301**	0.15	22.3	8.86	**18400**
2027	**15700**	nd	4.15	58.7	**0.294**	0.26	22.8	10.40	16700
2012	**17100**	**0.25**	4.01	64.0	**0.354**	0.13	24.2	7.11	**19500**
2021	**18000**	nd	3.38	59.9	**0.345**	0.11	24.5	9.19	**19500**
2026	**23600**	nd	**5.01**	76.8	**0.405**	0.17	31.1	11.80	**23400**
2042	8790	nd	2.10	24.5	0.184	0.07	11.4	5.11	9470
2017	**16100**	nd	3.35	62.3	**0.315**	0.13	22.9	7.60	**17800**
2022	**17000**	nd	3.81	50.7	**0.307**	0.09	23.1	8.47	**18300**
2013	**17300**	nd	4.20	62.5	**0.371**	0.16	24.7	7.43	**20200**
2031	**24300**	nd	4.23	81.6	**0.404**	0.19	30.5	11.90	**22700**
2034	**24400**	**0.28**	**4.81**	84.4	**0.409**	0.17	31.1	**15.10**	**24800**
2020	**20900**	nd	4.48	63.5	**0.434**	0.05	30.8	11.40	**23900**
2045	**17400**	**1.27**	3.97	53.5	**0.320**	0.05	23.6	10.40	**18800**
2018	**22200**	**0.46**	4.30	67.7	**0.395**	0.14	30.0	10.70	**22700**
2023	**20900**	nd	**7.69**	142.0	**0.693**	0.20	**39.4**	10.90	**37700**
2025	**18100**	nd	4.02	49.0	**0.329**	0.14	24.4	8.10	**19400**
2050	8480	**0.96**	1.63	24.5	0.186	0.02	13.5	5.14	10400
2040	**24300**	0.15	**26.70**	83.3	**0.441**	**0.90**	**37.2**	**172.00**	**25500**
2033	**11200**	nd	3.44	31.2	**0.269**	0.07	17.1	7.08	13500
2015	**13800**	nd	3.09	185.0	**0.287**	0.17	20.2	7.06	15600
Mean	17018	0.20	5.06	65.2	0.334	0.16	24.1	15.44	18921
Deep shelf									
2041	4980	nd	3.82	14.5	**0.465**	0.18	24.6	7.01	**19300**
2035	7170	nd	**5.38**	20.9	**0.485**	0.07	27.6	4.96	**18200**
2043	4740	nd	2.57	16.8	**0.265**	0.03	14.5	3.20	8110
2044	8640	nd	**7.81**	41.2	**0.586**	**0.34**	**39.7**	5.95	**21200**
2028	**25500**	nd	3.06	75.7	**0.464**	**0.31**	**35.5**	**15.40**	**23600**
Mean	10206	0.00	4.53	33.8	0.453	0.19	28.4	7.30	18082
Area Mean	14281	0.20	4.37	53.0	0.313	0.14	22.1	11.73	16999
MDL	1.15	0.13	0.33	0.002	0.001	0.01	0.016	0.028	0.76
50% CDF	9400	0.2	4.8	na	0.26	0.29	34	12	16800

Table 8.3 continued

Concentrations of trace metals (parts per million) detected at each 2005 regional survey station. MDL=method detection limit. CDF=median cumulative distribution function (see text). Area Mean=mean across all stations. Values that exceed the median CDF are indicated in bold type. See Appendix A.1 for the names of each metal represented by the periodic table symbol.

Station	Pb	Mn	Hg	Ni	Se	Ag	Ti	Sn	Zn
Shallow shelf									
2032	2.93	178	0.005	2.89	nd	0.054	nd	1.56	19.1
2036	3.08	80	0.007	0.73	nd	**0.403**	nd	1.00	7.4
2039	3.39	348	0.005	3.28	nd	nd	nd	1.58	23.9
2046	2.62	350	0.003	3.37	nd	0.135	nd	1.61	25.5
2037	6.33	145	0.009	2.84	nd	0.094	0.32	1.46	20.6
2016	2.69	322	0.003	3.79	nd	nd	nd	1.19	22.5
2047	3.36	177	0.007	4.70	nd	nd	nd	1.21	23.8
Mean	3.49	229	0.006	3.09	0.00	0.098	0.05	1.37	20.4
Mid-shelf									
2049	2.62	105	0.005	4.29	nd	nd	nd	1.20	19.9
2014	6.93	313	0.008	7.91	nd	nd	nd	2.23	46.3
2030	10.00	286	**0.053**	10.80	nd	nd	nd	2.88	50.6
2051	3.59	57	nd	0.98	nd	0.084	nd	0.93	8.4
2038	7.03	263	0.037	9.41	nd	0.145	nd	2.56	39.3
2027	8.48	219	**0.071**	9.49	nd	0.024	nd	2.62	42.1
2012	7.96	279	0.015	7.66	nd	nd	nd	2.49	41.7
2021	8.12	290	0.035	9.32	nd	nd	nd	2.31	44.9
2026	10.90	335	**0.064**	12.20	**0.316**	nd	nd	3.42	52.9
2042	4.33	152	0.022	5.05	nd	nd	nd	1.64	21.3
2017	7.84	279	0.027	8.27	nd	nd	nd	2.34	40.7
2022	8.37	267	0.033	8.64	nd	nd	nd	2.09	53.4
2013	7.77	260	0.014	7.77	nd	nd	nd	2.07	44.6
2031	11.60	336	**0.048**	12.40	nd	nd	nd	3.28	54.2
2034	10.10	307	**0.142**	13.50	nd	0.066	nd	2.93	**56.9**
2020	9.31	283	**0.046**	11.70	0.122	nd	nd	2.82	52.8
2045	7.48	269	**0.052**	10.40	nd	**0.190**	nd	2.52	41.7
2018	11.10	325	**0.043**	11.20	nd	nd	nd	2.66	50.4
2023	9.66	258	**0.040**	12.20	nd	nd	nd	2.58	**61.3**
2025	7.18	318	0.035	9.53	nd	nd	nd	2.68	40.9
2050	4.04	200	**0.077**	5.80	nd	0.143	nd	1.74	23.2
2040	154.00	290	**16.800**	11.30	0.215	**1.200**	nd	6.93	**180.0**
2033	4.83	164	0.024	7.01	nd	nd	nd	1.63	29.7
2015	6.03	214	0.031	7.63	nd	nd	nd	1.76	34.9
Mean	13.72	253	0.738	8.94	0.03	0.08	0.00	2.51	47.2
Deep shelf									
2041	8.48	32	0.015	5.38	0.277	nd	nd	0.75	34.2
2035	6.16	86	0.016	5.77	0.282	nd	nd	1.38	31.3
2043	4.07	47	0.016	3.87	**0.346**	nd	nd	1.29	14.1
2044	7.50	78	**0.052**	7.51	0.00	nd	nd	3.32	26.4
2028	9.28	310	**0.057**	16.90	**0.374**	nd	n	3.51	**57.8**
Mean	7.10	111	0.031	7.89	0.26	0.00	0.00	2.05	32.8
Area Mean	10.69	229	0.491	7.57	0.05	0.07	0.01	2.21	39.6
MDL	0.14	0.004	0.003	0.036	0.24	0.013	0.22	0.06	0.05
50% CDF	na	na	0.04	na	0.29	0.17	na	na	56

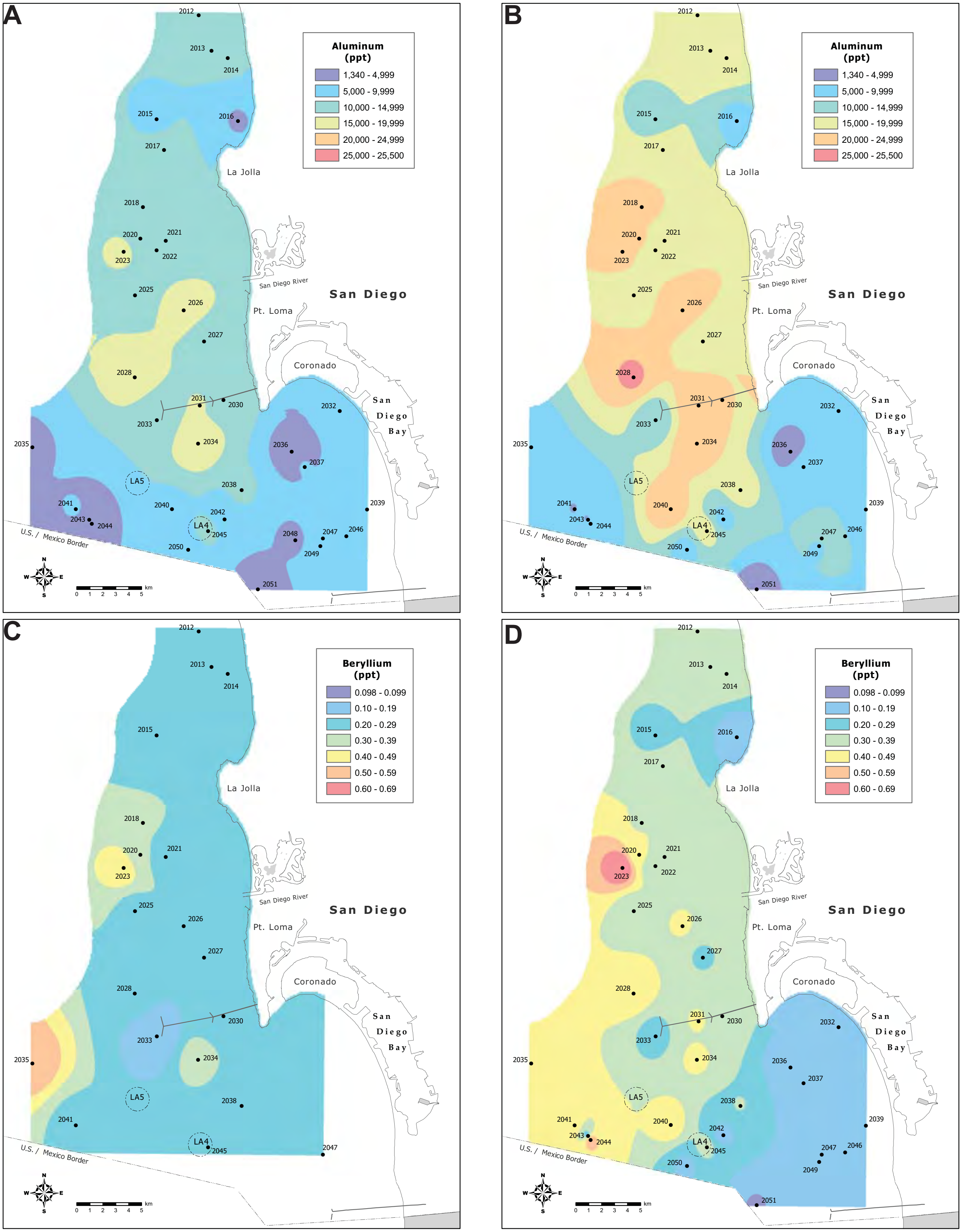

Figure 8.4

Interpolated aluminum and beryllium concentrations (ppt) from the regional sediment quality stations sampled off San Diego, CA in July 1995 (A, C) and 2005 (B, D).

Beryllium was the most widespread of these metals. It exceeded the median CDF at 25 stations in 2005, primarily at mid-shelf and deep water sites. However, 4 of the 10 sites with 2 or more of these industrial-use metals above the median were located near or around LA-4 and LA-5 dredge spoils sites (2034, 2038, 2040, 2045). Two others occurred farther offshore along the Coronado Bank (stations 2043, 2044). Sediments at 5 stations included concentrations of several metals above the TEL: station 2023 (arsenic), station 2028 (nickel), station 2034 (mercury), station 2040 (arsenic and mercury), and station 2044 (arsenic).

Other Contaminants: Pesticides, PCBs and PAHs

Pesticides and PCBs were detected rarely during 2005, while PAHs occurred at every station in low concentrations (Table 8.4). No sample exceeded the 50% CDF for either contaminant. Total DDT (the sum of several metabolites) was detected at 3 sites located near the head of La Jolla Canyon (i.e., stations 2013, 2015, 2016) and 1 site near the LA-4 disposal site (i.e., 2045). PCBs were detected at station 2023, a northern site located near the continental shelf-slope interface. The two stations with the PAH highest concentrations and relatively high numbers of PAH compounds included the deepest site (2028) and the one station (2040) located between the two dredge spoils disposal area (LA-4 and LA-5). The increased frequency of detection in PAHs was due to a change in methodology and instrumentation, not to an increase in sediment load. In general, PAH, PCB, and pesticide concentrations have been relatively low in the sediments along the mainland shelf off San Diego compared to other sites in the SCB (see City of San Diego 1998, 2000, 2001, 2002, 2003).

SUMMARY AND CONCLUSIONS

Although the presence of canyons, peninsulas, bays, and alluvial fans from rivers contribute to

Table 8.4
Mean concentrations for total DDT, total PCBs, and total PAHs, including the number of PAH compounds detected at each 2005 regional survey station. CDF=median cumulative distribution function (see text). Undetected values are indicated by "nd."

Station	Total DDT (ppt)	Total PCBs (ppt)	Total PAH (ppt)	Total PAH Number
Shallow shelf				
2032	nd	nd	133	8
2036	nd	nd	159	11
2039	nd	nd	188	15
2046	nd	nd	126	6
2037	nd	nd	153	8
2016	630	nd	128	8
2047	nd	nd	142	6
Mid-shelf				
2049	nd	nd	150	7
2014	nd	nd	167	6
2030	nd	nd	320	11
2051	nd	nd	131	8
2038	nd	nd	199	9
2027	nd	nd	185	6
2012	nd	nd	185	6
2021	nd	nd	67	6
2026	nd	nd	173	6
2042	nd	nd	132	9
2017	nd	nd	368	11
2022	nd	nd	267	9
2013	350	nd	219	9
2031	nd	nd	339	12
2034	nd	nd	309	9
2020	nd	nd	346	11
2045	400	nd	301	11
2018	nd	nd	295	9
2023	nd	1380	149	7
2025	nd	nd	178	7
2050	nd	nd	143	7
2040	nd	nd	946	14
2033	nd	nd	227	8
2015	700	nd	199	9
Deep shelf				
2041	nd	nd	250	8
2035	nd	nd	158	7
2043	nd	nd	120	5
2044	nd	nd	141	7
2028	nd	nd	521	13
50%CDF	1200	2600	—	—

the complexity of sediment composition and origin along the San Diego shelf (see Emery 1960), the distribution of sediment particles off San Diego in 2005 was similar to that of previous years and to the Southern California Bight (SCB) in general. There was a trend towards higher sand content in shallow nearshore areas and increased fine sand and silt at the deeper offshore sites. For example, stations ≤30 m in depth averaged the most amount of sand (83%), while stations along the mid-shelf (30–120 m) averaged the least sand (61%) and the highest fines (37%). The deep shelf stations (120–200 m) included 4 coarse sediment stations located along the Coronado Bank and 1 soft sediment station northwest of the Point Loma Ocean Outfall. Collectively, these sites averaged 73% sand and 24% fines; however, the deepest site had the most fines of any station sampled (61%). Exceptions to the general pattern occurred at several shallow water sites located southward of the entrance to San Diego Bay. These sites contained more fine materials relative to other shallow sites in the surrounding area. Additionally, 3 mid-shelf stations contained coarse sediments relative to the other mid-shelf stations: 1 site located between the EPA designated dredge spoils disposal sites (LA-4 and LA-5); 1 offshore of the South Bay Ocean Outfall (SBOO) where relict sediments are typical; and 1 northern site near the shelf-slope interface.

Overall, the majority of the San Diego mainland shelf consists of predominantly fine sediments, with coarse sediments occurred in shallow waters, particularly in the South Bay area, and along the Coronado Bank, a southern rocky ridge located offshore of Point Loma. There has been little change in sediment composition or average particle size since 1995 when these sites were first sampled. Only 8 of the 36 revisited sites changed in mean particle size between the two surveys. Although several sights contained coarse sands and gravel, there was little evidence of anthropogenic impacts in sediment particle size data collected during the 2005 regional survey.

Patterns in sediment chemistries followed the expected relationship of rising concentrations with decreasing particle size and increasing depth (see Emery 1960, Anderson et al. 1993, Schiff and Gossett 1998). However, in contrast to particle size, sediment chemistries did show evidence of natural and anthropogenic impacts in the region. For example, 5 sites had metals concentration above TEL sediment quality guideline, and one site contained TOC load high enough to be considered severely impacted (see Zeng, et al. 1995). In addition, the concentrations of various constituents (e.g., TOC, TN, trace metals) were substantially higher in 2005 relative to 1995. Only a few stations had sediments with concentrations of TN or TOC above Bight-wide median CDF values in 1995, while over 60% of the stations exceeded these benchmark values in 2005. Similarly, 11 stations had concentrations of 3 or more metals that exceeded the median CDF in 1995, while 21 stations did so in 2005. Some of this increase may be related to record rainfall, storm water runoff, and turbidity plumes that spread over much of the sampling area in late 2004 and early 2005. Discharges from the San Diego and Tijuana Rivers as well as Mission Bay and San Diego Bay could have contributed to the observed increases in organic and trace metal contamination. In addition, some naturally occurring and prevalent trace metals, such as aluminum and iron, are also used in the wastewater treatment process. One station located between LA-4 and LA-5 dredge spoils disposal sites had the highest concentration of 8 different metals, several of which (arsenic, copper, manganese, and zinc) were also found in high concentrations within San Diego Bay (City of San Diego 2003b). While the source of the increased organic and trace metals concentrations is unknown, it may well be a combination of natural and anthropogenic affects.

Although contamination of other types (e.g., pesticides, PCBs, PAHs) was generally low in 2005, the pattern of detection was similar to that seen previously. PCBs were detected a northern site located near the continental shelf-slope interface and derivatives of DDT were detected at several northern stations near the head of La Jolla Canyon and 1 site near LA-4. Similarly, PAH contamination was more common near the dredged materials disposal sites, as has been the case in past surveys.

Finally, the regional survey data did not show any pattern of contamination relative to wastewater discharge from the SBOO. Contaminant levels at the shallow stations included in the SBOO sampling grid were similar to the shallow regional survey samples, whereas sediments at the 38 and 55 m stations had lower levels of organics or trace metals than comparable mid-shelf stations.

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Chapter 9
San Diego Regional Survey
Macrobenthic Communities

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 for 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 and natural events. These annual surveys are based on an array of stations randomly selected each year by the United States Environmental Protection Agency (USEPA) using the USEPA probability-based EMAP design. The 1994, 1998, and 2003 surveys off San Diego were conducted as part of the Southern California Bight 1994 Pilot Project (SCBPP) and the Southern California Bight 1998 and 2003 Regional Monitoring Project (Bight '98, Bight '03). These large-scale surveys included other major southern California dischargers, and included sampling sites representing the entire Southern California Bight (i.e., Cabo Colnett, Mexico to Point Conception, U.S.A.). The same randomized sampling design was used in the surveys limited to the San Diego region (1995–1997 and 1999–2002). A regional (random) survey was not conducted in 2004 in order to conduct a special strategic process study pursuant to an agreement with the SDRWQCB and USEPA (see City of San Diego 2005a,b). The results from Phase I of the San Diego Sediment Mapping Study are currently being analyzed (see Stebbins et al. 2004). In July 2005, the City revisited the 1995 survey sites in order to compare conditions 10 years later.

This chapter presents an analysis and interpretation of the benthic macrofaunal data collected during the San Diego 2005 regional survey with a comparison to those data from the 1995 survey. Included are descriptions and comparisons of the region's soft-bottom macrobenthic assemblages, and analysis of benthic community structure. Results of the sediment quality analyses for this survey are provided in Chapter 8 of this report.

MATERIALS AND METHODS

Collection and Processing of Benthic Samples

The July 2005 survey covered an area off San Diego, CA from Del Mar south to the United States/Mexico border (**Figure 9.1**). This survey revisited the sites sampled during the1995 regional survey. Site selection was based on the USEPA probability-based EMAP sampling design. A hexagonal grid was randomly placed over a map of the region and one sample site was then randomly selected from within each grid cell. This randomization helps to ensure an unbiased estimate of ecological condition. The area sampled included the section of the mainland shelf from nearshore to shallow slope depths (12–202 m). Although 40 sites were initially selected for the 1995 and 2005 survey, sampling at 3 sites in 1995 and 4 sites in 2005 were unsuccessful due to the presence of rocky substrata.

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

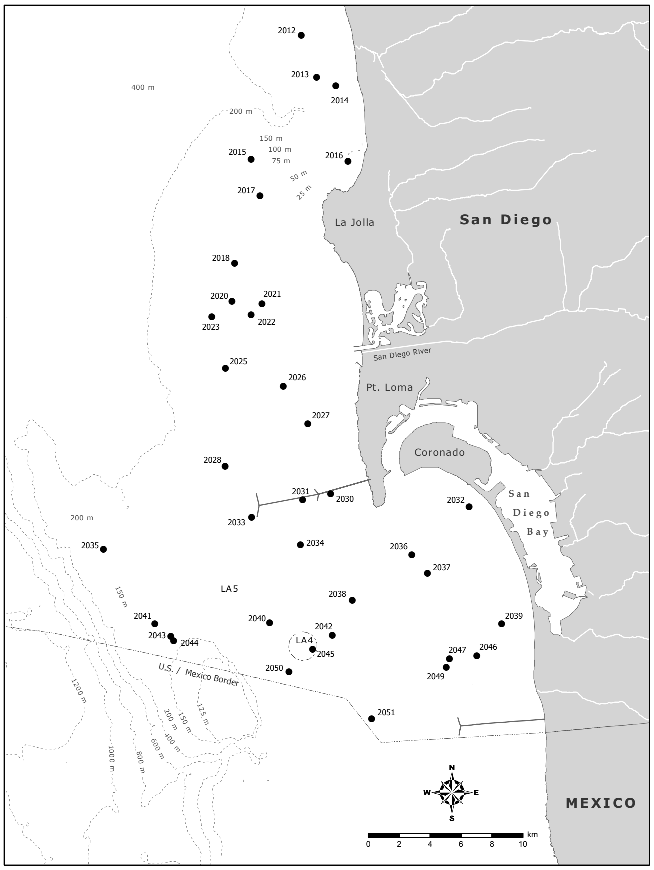


Figure 9.1
2005 regional macrobenthic station locations.

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

Multivariate analyses were performed using PRIMER v5 (Plymouth Routines in Multivariate Ecological Research) software to examine spatio-temporal patterns in the overall similarity of benthic assemblages in the region (see Clarke 1993, Warwick 1993). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (MDS). 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. Analyses were run on mean abundances of replicate grabs per station/survey. 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). Univariate and multivariate data collected from both the 1995 and 2005 surveys were analyzed and compared to evaluate any changes in infaunal community structure over a 10-year period. Classification analysis was first run on the 1995 and 2005 surveys independently. The resulting cluster patterns from 1995 and 2005 were nearly identical. In the absence of any obvious temporal differences data from the two surveys were combined and analyzed together.

RESULTS AND DISCUSSION

Community Parameters

Number of Species

A total of 856 macrobenthic taxa were identified during 2005. Of these, 28% represented rare or unidentifiable taxa that were recorded only once. The average number of taxa per 0.1 m^2 grab ranged from 41 to 163, and the cumulative number of taxa per station ranged from 60 to 234 (**Table 9.1**). This wide variation in species richness generally is consistent with recent years, but represents a 24–29% increase relative to 1995. For example, mean species richness among all stations was~83 species in 1995 versus 120 in 2005. Although the varied habitat types in the area contribute to a diverse community, some of the

Table 9.1

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

Station	Depth (m)	SR	Tot spp	Abun	H'	J'	Dom	BRI	ITI
Inner shelf									
2032	12	41	60	120	3.3	0.9	17	23	86
2036	16	62	97	881	3.1	0.8	12	13	60
2039	16	47	77	194	3.2	0.8	16	21	78
2046	22	72	108	143	4.0	0.9	37	19	77
2037	24	74	111	429	2.7	0.6	12	22	71
2016	25	142	218	727	3.8	0.8	35	20	73
2047	29	73	109	218	3.6	0.8	25	23	76
Mean		73	111	387	3.4	0.8	22	20	74
Mid shelf									
2049	31	81	116	253	3.7	0.8	30	21	77
2014	38	119	168	397	4.2	0.9	44	15	79
2030	47	163	234	587	4.4	0.9	55	20	78
2051	49	110	155	398	3.9	0.8	36	14	74
2038	52	155	222	526	4.3	0.9	53	16	83
2027	58	115	174	453	3.9	0.8	34	12	83
2012	59	111	157	424	3.9	0.8	33	6	80
2021	67	159	229	859	3.7	0.7	36	8	76
2026	68	98	137	443	3.5	0.8	26	3	91
2042	68	157	213	587	4.5	0.9	56	12	79
2017	68	111	150	434	3.9	0.8	32	7	80
2022	72	105	146	746	2.8	0.6	14	5	74
2013	73	102	141	393	3.8	0.8	29	2	84
2031	74	93	132	484	3.4	0.8	21	10	90
2034	81	81	111	469	3.2	0.7	18	5	92
2020	82	112	163	368	4.0	0.9	38	3	83
2045	84	116	171	415	4.0	0.8	36	6	85
2018	84	84	119	306	3.7	0.8	27	4	82
2023	90	119	165	427	4.2	0.9	41	5	78
2025	95	119	161	422	4.2	0.9	41	6	77
2050	101	98	132	315	4.0	0.9	37	5	76
2040	102	116	167	380	4.3	0.9	47	6	80
2033	104	116	158	450	4.2	0.9	39	7	79
2015	108	90	130	298	4.1	0.9	37	8	76
Mean		114	160	451	3.9	0.8	36	9	81
Outer shelf									
2041	136	72	102	286	3.5	0.8	22	4	71
2035	152	82	127	228	3.9	0.9	32	-6	77
2043	171	79	114	254	3.7	0.9	26	-0	76
2044	179	43	63	138	2.8	0.7	13	3	74
2028	190	72	104	202	3.7	0.9	29	16	79
Mean		70	102	222	3.5	0.8	24	3	75
All stations									
Mean		99	143	407	3.7	0.8	31	10	78
Min		41	60	120	2.7	0.6	12	-6	60
Max		163	234	881	4.5	0.9	56	23	92

change in species richness between 1995 and 2005 can be attributed to increased taxonomic resolution of certain taxa. One example is that polynoid polychaetes recorded as *Malmgreniella* sp in 1995 were split into 4 separate taxa by 2005.

Polychaete worms made up the greatest proportion of species, accounting for 37–59% of the taxa per sites during 2005. Crustaceans composed 13–37% of the species, molluscs from 6 to 31%, echinoderms from 1 to 9%, and all other taxa combined about 1–20%. These percentages are generally similar to those observed during previous years (e.g., see City of San Diego 2002, 2004).

Macrofaunal Abundance

Macrofaunal abundance ranged from a mean of 120 to 881 animals per grab in 2005 (Table 9.1). The greatest number of animals occurred at stations 2036, 2021, 2022, and 2016 all of which averaged over 700 individuals per sample. In contrast to 1995, high abundances at station 2036 in 2005 primarily were due to large numbers of nematodes and several species of polychaetes (i.e., *Polycirrus* sp, *Hesionura coineaui difficilis*, and *Spiophanes bombyx*). Overall, average abundance among all stations in 2005 was about 15% higher than in 1995.

Polychaetes were the most abundant animals in the region, accounting for 33–73% of the different assemblages during 2005. Crustaceans averaged 6–46% of the animals at a station, molluscs from 1 to 32%, echinoderms from <1 to 46%, and all remaining taxa about <1–19% combined. These values remained similar to those in previous years and to those in 1995.

Species Diversity and Dominance

Species diversity (H') varied among stations, and ranged from 2.7 to 4.5 (Table 9.1). Although most of the stations had values between 3.0 and 4.0, stations with the highest diversity (i.e., $\geq$4.0) were found along the mainland shelf. The lowest values (<3.0) occurred at 3 disjointed stations, one each from the deep, mid-shelf, and shallow water strata. Station 2044, a deepwater site, along the Coronado Bank, was dominated by the bivalve mollusc *Huxleyia munita* and the polychaete *Aphelochaeta glandaria*. Station 2022, a mid-shelf station northwest of Mission Bay was dominated by *Myriochele striolata*, an owenid polychaete that accounted for over 44% of the total abundance. Finally, station 2037, a shallow, sandy station south of Coronado, was dominated by the polychaete *Spiophanes bombyx*, which accounted for approximately 42% of this station's total abundance. Two of theses sites (2022 and 2037), along with 5 others (2018, 2021, 2026, 2036, 2039) also had low diversity values (<3.0) in 1995.

Dominance, measured as the minimum number of species comprising 75% of a community by abundance (see Swartz 1978), is inversely proportional to numerical dominance. These values varied widely throughout the region, averaging from 12 to 56 species per station. The pattern of dominance across depth strata was similar to that of diversity. Dominance (i.e., low values for Swartz dominance) was highest among those stations with low diversity values, such as those mentioned above.

Environmental Disturbance Indices: ITI and BRI

Average Infaunal Trophic Index (ITI) values generally were similar to those of recent years and, with one exception (station 2036), averaged between 71 to 92 throughout the San Diego region (Table 9.1). The lowest value occurred at station 2036 (ITI=60) and is likely due to the high abundance of oligochaetes and the dorvilleid polychaete *Protodorvillea gracilis*. All other stations, as well as every station sampled in 1995, had mean ITI values >70. ITI values >60 are generally considered characteristic of "normal" benthic conditions (Bascom et al. 1979, Word 1980).

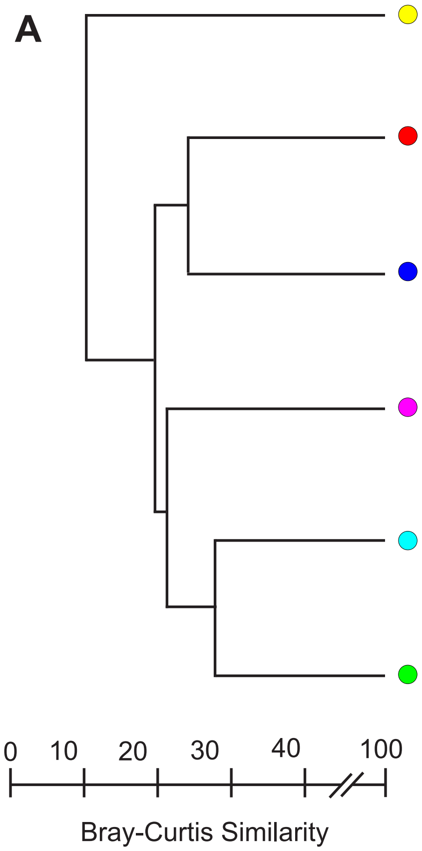
Similarly, Benthic Response Index (BRI) values at most stations were indicative of undisturbed communities or "reference conditions." Index values below 25 (on a scale of 100) suggest undisturbed communities or "reference conditions," and those in the range of 25–33 only represent "a minor deviation from reference condition," which may or may not reflect anthropogenic impact (Smith et al. 2001). Values greater than 44 indicate a loss of community function. No stations sampled in

Table 9.2

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

Species	Higher taxa	Abundance per sample	Abundance per occurence	Percent abundance	Percent occurence
Most Abundant					
1. *Amphiodia urtica*	Echinodermata: Amphiuridae	49.0	41.5	6.5	64
2. *Spiophanes duplex*	Polychaeta: Spionidae	10.8	22.3	5.3	97
3. *Myriochele striolata*	Polychaeta: Oweniidae	9.9	45.6	6.5	39
4. *Amphiodia* sp	Echinodermata: Ophiuroidea	6.8	18.7	5.3	67
5. Spiophanes bombyx	Polychaeta: Spionidae	5.8	22.9	4.4	50
6. *Prionospio* (*Prionospio*) *jubata*	Polychaeta: Spionidae	5.1	8.5	3.1	92
7. *Spiophanes berkeleyorum*	Polychaeta: Spionidae	4.9	8.3	2.8	89
8. *Monticellina siblina*	Polychaeta: Cirratulidae	4.5	11.6	1.9	58
9. *Paraprionospio pinnata*	Polychaeta: Spionidae	4.2	6.1	1.8	94
10. *Euphilomedes carcharodonta*	Crustacea: Ostracoda	3.9	8.3	1.7	69
Most Abundant per Occurrence					
1. *Hesionura coineaui difficilis*	Polychaeta: Phyllodocidae	4.1	73.0	1.0	6
2. *Pareurythoe californica*	Polychaeta: Amphinomidae	1.7	61.0	0.4	3
3. *Myriochele striolata*	Polychaeta: Oweniidae	17.7	45.6	4.4	39
4. *Amphiodia urtica*	Echinodermata: Ophiuroidea	26.5	41.5	6.5	64
5. *Pisione* sp	Polychaeta: Pisionidae	1.7	29.8	0.4	6
6. *Polycirrus* sp SD3	Polychaeta: Terebellidae	0.8	29.5	0.2	3
7. *Anchicolurus occidentalis*	Crustacea: Camacea	0.8	27.5	0.2	3
8. *Cnemidocarpa rhizopus*	Chordata: Styelidae	1.4	25.8	0.4	6
9. *Spiophanes bombyx*	Polychaeta: Spionidae	11.5	22.9	2.8	50
10. *Spiophanes duplex*	Polychaeta: Spionidae	21.7	22.3	5.3	97
Most Frequently Collected					
1. *Spiophanes duplex*	Polychaeta: Spionidae	21.7	22.3	5.3	97
2. *Paraprionospio pinnata*	Polychaeta: Spionidae	5.8	6.1	1.4	94
3. *Mediomastus* sp	Polychaeta: Capitellidae	5.1	5.4	1.2	94
4. *Prionospio* (*Prionospio*) *jubata*	Polychaeta: Spionidae	7.8	8.5	1.9	92
5. *Spiochaetopterus costarum*	Polychaeta: Chaetopteridae	2.0	2.2	0.5	92
6. *Spiophanes berkeleyorum*	Polychaeta: Spionidae	7.4	8.3	1.8	89
7. Amphiuridae	Echinodermata: Ophiuroidea	5.5	6.2	1.4	89
8. *Paradiopatra parva*	Polychaeta: Onuphidae	3.5	4.2	0.9	83
9. *Ampelisca careyi*	Crustacea: Amphipoda	2.2	2.6	0.5	83
10. Lineidae	Nermertea: Lineidae	0.9	1.1	0.2	83

A



Cluster group	Species richness	Abund.	% Fines	Top three taxa
A	86 (53–114)	640 (358–1404)	1.2 (0.0–2.3)	*Hesionura coineaui difficilis* Nematoda *Spiophanes bombyx*
B	44 (40–51)	157 (86–302)	12.3 (11.8–12.7)	*Ampharete labrops* *Scoletoma tetraura* *Carinoma mutabilis*
C	88 (65–174)	354 (142–887)	10.1 (5.0–15.4)	*Spiophanes bombyx* *Monticellina siblina* *Edwardsia* sp G (MEC)
D	69 (38–89)	226 (129–358)	14.3 (8.5–21.4)	*Aphelochaeta glandaria* *Monticellina siblina* *Huxleyia munita*
E	72 (60–84)	203 (183–222)	61.4 (61.4)	*Spiophanes berkeleyorum* *Spiophanes kimballi* *Paradiopatra parva*
F	115 (74–191)	463 (251–947)	39.2 (11.3–54.3)	*Amphiodia urtica* *Spiophanes duplex* *Myriochele striolata*

B

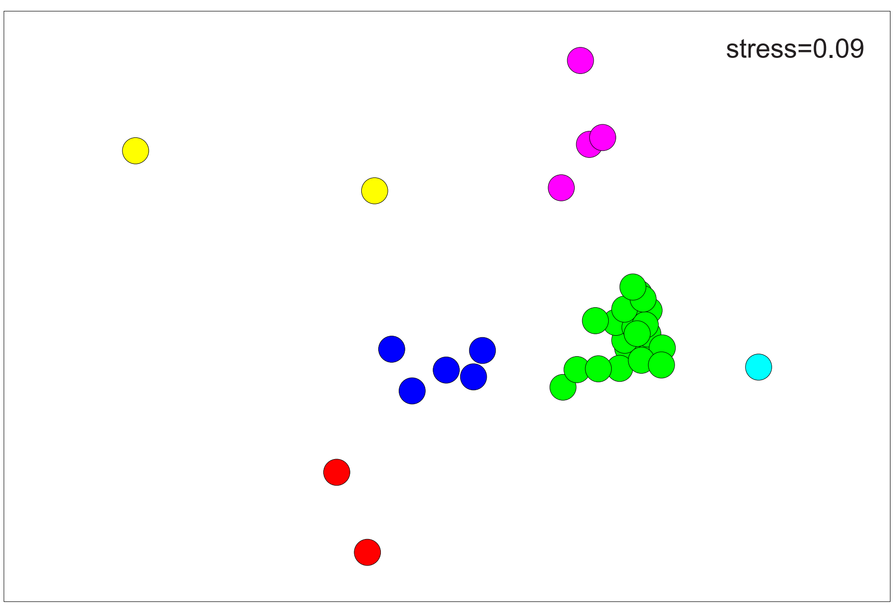


Figure 9.2

(A) Cluster results of the macrofaunal abundance data for the regional benthic stations sampled during July 2005. Data are expressed as mean values per 0.1 m^2 grab over all stations in each group. Ranges in parentheses are for individual grab samples. **(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 macrofaunal assemblages.

2005 had a BRI that exceeded the threshold of 25. However, Stations 2047 and 2049 had values of about 30 in 1995.

Dominant Species

Most assemblages in the San Diego region were dominated by polychaete worms and brittlestars. For example, the list of dominant fauna in **Table 9.2** includes 14 polychaetes, 3 echinoderms, 3 crustaceans, a single chordate and a single nemertean.

The ophiuroid *Amphiodia urtica* was the most numerous ubiquitous species, averaging about 49 individuals per sample. The second most abundant taxa was the spionid polychaete *Spiophanes duplex*. The oweniid polychaete, *Myriochele striolata,* was third in total abundance.

Polychaetes comprised 7 of the top 10 most abundant species per occurrence. Several polychaete species were found in high numbers at only a few stations (e.g. *Hesionura coineaui difficilis*, *Pareurythoe californica, Polycirrus* sp SD3). Several macrobenthic species were widely distributed, and the top three, *Spiophanes bombyx*, *Paraprionospio pinnata* and *Mediomastus* sp, occurred in more than 93% of the samples.

Classification of Assemblages and Dominant Macrofauna

Classification analysis discriminated between six habitat-related benthic assemblages (cluster groups A–F) during 2005 (**Figures 9.2, 9.3**). These assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances. The dominant species composing each group are listed in **Table 9.3**. An MDS ordination of the station/survey entities confirmed the validity of cluster groups A–F (Figure 9.2). Similar to previous random sample surveys of the region, depth and sediment composition were the primary factors affecting the distribution of assemblages (see **Figure 9.4**, e.g., Bergen et

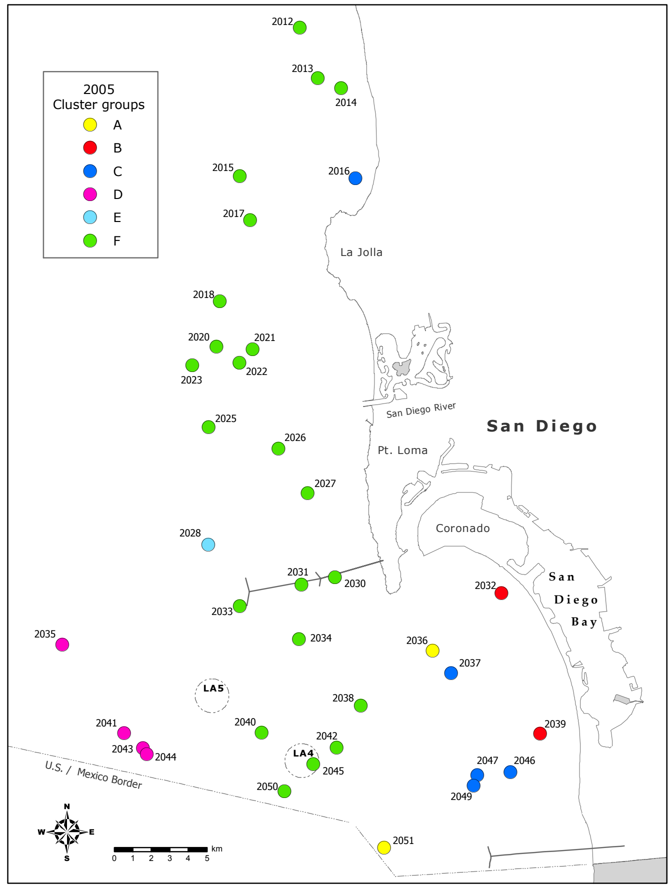


Figure 9.3
Regional benthic stations sampled during July 2005, color-coded to represent affiliation with benthic cluster groups.

al. 1998, City of San Diego 1999a, 2000a, 2001, 2002, 2003, 2005).

<u>Cluster group A</u> consisted of 2 stations (2036, 2051) made up of sediments with few fine particles (i.e.,1.2% fines). This assemblage was quite different from the others and was dominated by nematode worms and polychaetes. Of the top dominant species, the polychaete, *Hesionura coineaui difficilis* was unique to these stations. Two other polychaetes, *Pisione* sp and *Polycirrus californicus,* were also limited to this station group.

<u>Cluster group B</u> comprised the 2 shallowest stations 2039 (16 m) and 2032 (12 m). The sediments at these sites were generally fine sands (~12% fines). Dominate species included the polychaetes *Ampharete labrops* and *Scoletoma tetraura* (=spp complex), and the nemertean *Carinoma mutabilis*.

Table 9.3

Summary of the most abundant taxa composing cluster groups A–F from the 2005 regional benthic station survey. Data are expressed as mean abundance per sample (no./0.1m^2) and represent the ten 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					
Species/Taxa	Taxa	A (n=2)	B (n=2)	C (n=5)	D (n=4)	E (n=1)	F (n=22)
Adontorhina cyclia	Mollusca	—	—	—	—	5.5	1.2
Amaeana occidentalis	Polychaeta	—	5.0	0.2	—	—	0.2
Ampelisca careyi	Crustacea	—		1.2	6.6	2.5	2.0
Ampharete labrops	Polychaeta	0.5	23.8	0.6	0.3	—	0.1
Amphiodia sp	Echinodermata	—	0.3	0.1	0.5	0.5	20.2
Amphiodia urtica	Echinodermata	—	—	0.1	—	—	43.4
Amphiuridae	Echinodermata	0.3	0.8	1.6	3.0	—	8.0
Aoroides sp A	Crustacea	—	—		4.6	—	0.1
Aphelochaeta glandaria	Polychaeta	0.3	—	0.3	20.4	—	1.0
Axinopsida serricata	Mollusca	—	—	—	—	1.0	8.6
Caecum crebricinctum	Mollusca	1.0	—	—	13.1	—	0.0
Carinoma mutabilis	Nemertea	—	9.3	8.9	0.3	—	0.3
Chaetozone sp SD3	Polychaeta	—	—	—	6.6	—	0.2
Cnemidocarpa rhizopus	Chordata	25.8	—	—	—	—	—
Compressidens stearnsii	Mollusca	—	—	—	0.6	4.0	0.1
Diastylopsis tenuis	Crustacea	—	5.8	0.1	—	—	—
Edwardsia sp G (MEC)	Cnidaria	—	0.3	23.1	—	—	0.0
Euphilomedes carcharodonta	Crustacea	—	3.0	5.3	—	—	8.0
Glycera oxycephala	Polychaeta	0.3	—	6.2	2.6	—	—
Hemilamprops californicus	Crustacea	0.5	—	4.6	—	—	0.4
Hesionura coineaui difficilis	Polychaeta	73.0	—	—	—	—	—
Huxleyia munita	Mollusca	—	—	—	13.4	—	0.0
Leptochelia dubia	Crustacea	0.5	0.3	1.8	6.3	—	3.5
Mediomastus sp	Polychaeta	3.0	3.3	8.9	0.8	4.5	5.4
Melinna heterodonta	Polychaeta	—	—	—	—	5.0	—
Monticellina siblina	Polychaeta	—	—	23.5	14.9	—	3.0
Myriochele striolata	Polychaeta	—	—	0.3	8.5	—	27.4
Nematoda	Nematoda	51.5	0.5	0.4	0.3	—	0.4
Oligochaeta	Annelida	31.5	—	—	0.1	—	0.0
Olivella baetica	Mollusca	2.3	8.5	0.2	—	—	—
Paradiopatra parva	Polychaeta	—	—	0.9	0.6	16.0	4.6
Paraprionospio pinnata	Polychaeta	—	1.0	1.6	2.6	8.0	8.2
Pareurythoe californica	Polychaeta	30.5	—	—	—	—	—
Petaloclymene pacifica	Polychaeta	—	—	—	—	4.5	0.6
Phyllochaetopterus limicolus	Polychaeta	—	—	0.1	—	10.5	0.1
Pisione sp	Polychaeta	29.8	—	—	—	—	—
Polycirrus californicus	Polychaeta	20.3	—	—	—	—	0.0
Polycirrus sp	Polychaeta	39.8	—	0.3	0.9	—	1.0
Prionospio (*Prionospio*) *jubata*	Polychaeta	1.3	—	9.8	6.3	0.5	9.3
Protodorvillea gracilis	Polychaeta	29.8	—	—	0.6	—	—
Rhepoxynius menziesi	Crustacea	—	7.5	3.5	—	—	0.7
Scoletoma tetraura (=spp complex)	Polychaeta	—	13.3	1.8	—	2.0	1.0
Spiophanes berkeleyorum	Polychaeta	0.3	0.3	3.4	0.4	25.0	10.1
Spiophanes bombyx	Polychaeta	43.0	2.8	60.4	—	—	0.9
Spiophanes duplex	Polychaeta	1.5	4.0	18.8	4.5	3.0	29.7
Spiophanes kimballi	Polychaeta	—	—	0.1	2.5	21.5	7.9
Tellina modesta	Mollusca	—	8.8	2.9	—	—	—

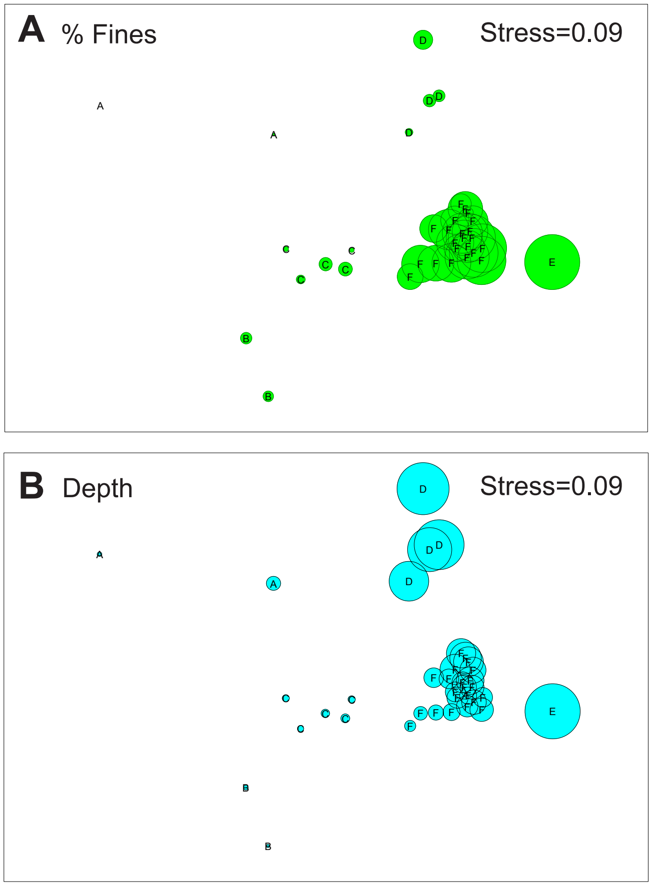


Figure 9.4
MDS ordination of regional benthic stations sampled July 2005. Cluster groups A–F are superimposed on station/surveys. Percentage of fine particles in the sediments and station depth are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of macrobenthic assemblages with habitats that differ in sediment grain size and depth.

Cluster group C consisted of 5 nearshore stations ranging in depth from 22 to 31 m. Four were located in the South Bay gyre area, north of the Tijuana River and SBOO, and 1 north of La Jolla. Sediments at stations within this group averaged approximately 10% fines (i.e., similar to cluster group B). Overall, the benthic assemblage at these stations was typical of the shallow water sites in the region the region (e.g., see Chapter 4 in City of San Diego 2001, 2002, 2003, 2005). The dominant species included the polychaetes *Spiophanes bombyx* and *Monticellina siblina* an the cnidarian *Edwardsia* sp G.

Cluster group D consisted of 4 stations along the Coronado bank (i.e., 136–179 m). Sediments at this group were relatively coarse (2.1 phi) and contained pea gravel, rock, and shell hash. These sites averaged about 14% fines and had the highest organic load (e.g. TOC=4.4%, see Chapter 8). The dominant species included two polychaetes, *Aphelochaeta glandaria* and *Monticellina siblin*a, as well as two molluscs, *Huxleyia munita* and *Caecum crebricinctum* (Table 9.3).

Cluster group E consisted of the deepest station (2028, 190m) by itself, which contained over 60% fines along with some of the highest concentrations of associated contaminants (e.g., organics and trace metals). Many of the most abundant and frequently occurring species were polychaetes, including *Spiophanes berkrleyorum*, *S. kimballi*, *Paradiopatra parva,* and *Phyllochaetopterus limicolus*. Most other included taxa were poorly represented at this site.

Cluster group F comprised most of the mid-shelf sites ranging in depth from 38 to 108 m. This cluster group, characterized by mixed sediments averaging 39% fines (11–54%), had the highest average species richness, and second highest values for abundance, diversity, and dominance. This main assemblage type is typical of the ophiuroid dominated community that occurs along the mainland shelf off southern California (City of San Diego 2001, 2002, 2003, 2004). The most abundant species representing this mid-shelf group were the ophiuroid *Amphiodia urtica,* and the polychaetes *Spiophanes bombyx* and *Myriochele striolata*. *Myriochele striolata* is an opportunistic species whose populations vary spatially and temporally (see City of San Diego 2002). *Amphiodia urtica,* a dominant species along the mainland shelf of southern California, averaged about 43 animals per 0.1 m^2 (Table 9.2). However, since juvenile ophiuroids usually cannot be identified to species and are recorded at the generic or familial level (i.e., *Amphiodia* sp or Amphiuridae, respectively), this number underestimates actual populations of *A. urtica*. The only other species of *Amphiodia* that occurred in 2005 was *A. digitata*, which accounted for about 6% of ophiuroids in the genus *Amphiodia* that could be identified to species (i.e., *A. urtica* = about 94%). If the values for these taxa are adjusted accordingly, then the estimated population size for *A. urtica* off Point Loma becomes about 60 animals per 0.1 m^2.

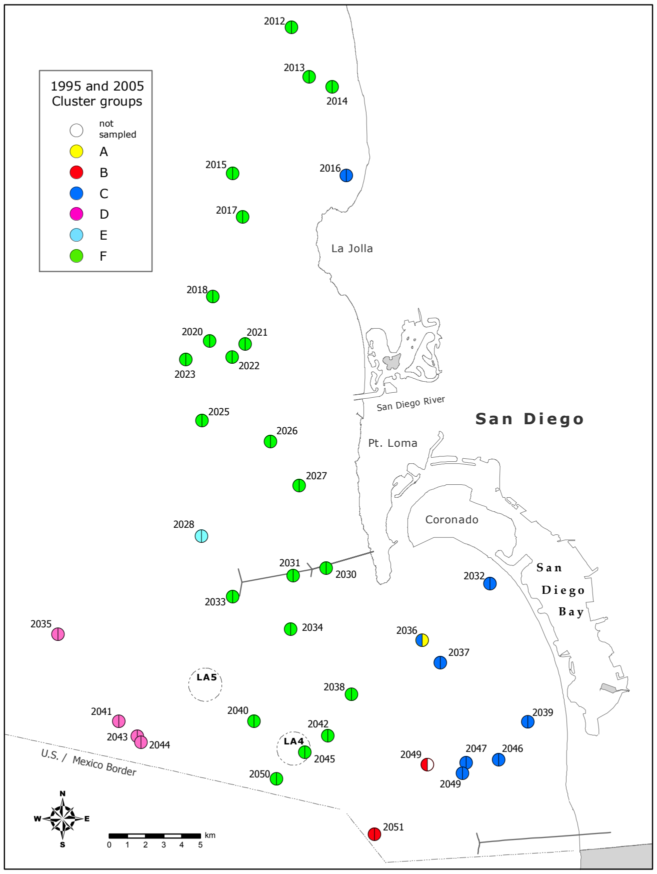


Figure 9.5
Results of ordination and classification analyses of macrofaunal abundance data from 1995 (left half) and 2005 (right half). Cluster groups are color-coded on the map to reveal spatial patterns in the distribution of

Classification analysis of the 1995 and 2005 surveys also combined discriminated between 6 habitat-related benthic assemblages (cluster groups A–F) that closely resembled the results of the 2005 analysis (**Figure 9.5**). With 1 exception (station 2036) all sites surveyed in 1995 clustered with its 2005 counterpart. Station 2048 in cluster group B of the combined analysis was sampled in 1995 but not 2005.

SUMMARY AND CONCLUSIONS

The Southern California Bight (SCB) benthos has long been considered a "patchy" habitat, with the distribution of species and communities varying in space and time. Barnard and Ziesenhenne (1961) described the SCB shelf as consisting of an *Amphiodia* "mega-community" with other sub-communities representing simple variations determined by differences in substrate type and microhabitat. Results of the 2005 and previous regional surveys off San Diego generally support this characterization. The 2005 benthic assemblages segregated mostly due to differences in habitat (e.g., depth and sediment grain size) and were very similar to those sampled 10 years earlier. The biological data provide little evidence of anthropogenic impact in the region despite apparent changes in sediment chemistry (see chapter 8). Over 50% of the benthos off San Diego was characterized by an assemblage dominated by the ophiuroid *Amphiodia urtica* (Station group F). The co-dominant species within this assemblage included other taxa common to the region such as the polychaetes *Myriochele striolata*, and *Spiophanes duplex*. This group occurred at depths from 44 to 94 m in sediments composed of relatively fine particles (e.g., ~40% fines).

In contrast, the dominant species of other assemblages occurring in the region varied according to sediment type or depth. Shallow water assemblages (e.g., <30 m) were highly variable depending upon their sediment type and station depths. For example, these assemblages generally were similar to other shallow, sandy sediment communities in the SCB. At many of these stations, polychaete species such as *Spiophanes duplex* and *S. bombyx*, *Hesionura coineaui difficilis, Ampharete labrops,* and *Monticellina siblina* were numerically dominant. A deep water assemblage (group E), located at a depth >180 m, was dominated by the polychaetes *Aphelochaeta glandaria* and *Monticellina siblina,* and the mollusc *Huxleyia munita*. This site had the highest percentage of fine particles with the lowest species richness, diversity, and abundance. Overall, the influence of increased organic loading or metals contamination detected in 2005 (see chapter 8) appears to have had little impact on overall structure of the benthos, though the higher organic load may be a factor contributing to an increase in the number of individuals.

There was a general increase in the number of species and individuals as well as changes in community parameters between the 1995 and 2005 random surveys. Over the 10 year period, changes in taxonomic resolution created some disparity in nomenclature among select species. For example, certain species complexes (e.g., *Americhelidium*, *Chaetozone*) have been further resolved into individual species. These types of changes can account for some of the differences in species richness and the associated diversity indexes; however, the two surveys identified identical assemblages based on depth and sediment type. SIMPER analysis confirmed that the major species driving the discrimination between groups were ones with taxonomic integrity. A single exception, the polychaete *Aphelochaeta glandaria*, contributed ~1% of the difference between cluster groups C and D. Overall, the similarities between macrofaunal communities from 1995 and 2005 suggest that benthic assemblages have not changed substantially in recent years.

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Glossary

GLOSSARY

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

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

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

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

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

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

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

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

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

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

Biota The living organisms within a habitat or region.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Epifauna Animals living on the surface of sea bottom sediments.

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

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

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

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

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

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

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

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

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

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

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

Motile Self-propelled or actively moving.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Rosette sampler
A device consisting of a round metal frame housing a CTD in the center and multiple bottles (see Niskin bottle) arrayed about the perimeter. As the instrument is lowered through the water column, continuous measurements of various physical and chemical parameters are recorded by the CTD. Discrete water samples are captured at desired depths by the bottles.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Appendices

Appendix A

Supporting Data

2005 SBOO Stations

Microbiology

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Appendix A.1

Bacteriological densities for SBOO kelp station water quality samples with total coliform concentrations ≥1000 CFU/100 mL collected during 2005. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Fecal to total coliform ratio = F:T. Sample depth is in meters.

Station	Month	Sample depth	Total	Fecal	Entero	F:T
I39	Feb	18	2600	520	52	**0.20**
I25		2	11000	1100	2400	**0.10**
I25		9	16000	2400	3200	**0.15**
I39		2	16000	1600	2200	**0.10**
I25		6	16000	1800	2800	**0.11**
I25	Mar	2	16000	2200	820	**0.14**
I26		2	16000	2400	600	**0.15**
I26		2	16000	3000	90	**0.19**
I39		12	2000	960	76	**0.48**
I25	Apr	2	2000	220	2	**0.11**
I39	May	12	1600	260	10	**0.16**
I25	Jan	2	13000	200	420	0.02
I25		6	1100	44	110	0.04
I25		9	3800	58	120	0.02
I26		2	2600	38	92	0.01
I26		9	3000	32	260	0.01
I25		2	7600	260	220	0.03
I25		2	2400	100	6	0.04
I26		2	16000	1200	160	0.08
I26		6	1200	72	4	0.06
I39		2	3400	300	12	0.09
I26		2	1500	130	2	0.09
I25	Feb	6	11000	640	1200	0.06
I26		2	16000	1000	2000	0.06
I26		6	3400	220	480	0.06
I26		9	16000	1400	1600	0.09
I39		18	1100	32	48	0.03
I25		9	13000	480	1400	0.04
I26		9	7600	160	580	0.02
I25		9	1200	32	130	0.03
I26		9	1400	50	140	0.04
I25	Mar	6	2600	50	42	0.02
I39		12	1600	110	90	0.07
I25		2	2600	10	20	0.00
I25		6	4800	74	40	0.02
I25		9	7600	180	100	0.02
I26		6	4400	120	86	0.03
I26		9	7400	80	220	0.01
I39		2	1800	40	18	0.02
I39		12	8400	760	62	0.09
I39		18	8600	200	140	0.02

Appendix A.1 continued

Bacteriological densities for SBOO kelp station water quality samples with total coliform concentrations ≥1000 CFU/100 mL collected during 2005. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Fecal to total coliform ratio = F:T. Sample depth is in meters.

Station	Month	Sample depth	Total	Fecal	Entero	F:T
I25	Mar	2	3200	120	12	0.04
I25		6	2000	130	52	0.07
I25		9	1100	70	10	0.06
I26		6	1600	94	6	0.06
I39		2	1700	74	8	0.04
I26		2	17000	320	42	0.02
I26	Apr	2	17000	1600	44	0.09
I26		6	1000	68	2	0.07
I26		9	1500	92	2	0.06
I25	May	2	2600	220	2	0.08
I25	Jun	2	3200	2	52	0.00
I39		12	16000	2	1000	0.00
I25	Aug	2	2400	56	46	0.02

Appendix A.2

Bacteriological densities for SBOO offshore and kelp station water quality samples with total coliform concentrations ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥ 0.1 collected during 2005. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Individual values for corresponding total suspended solids (SuSo) and oil and grease (O&G; 2 m depth) samples are listed. Sample depth is in meters.

	Station	Month	Sample depth	Total	Fecal	Entero	F:T	O&G	SuSo
Inshore									
	I24	Jan	2	16000	3400	7000	0.21	0.20	8.8
	I24		6	16000	3600	6000	0.23		8.9
	I25		2	16000	3200	4800	0.20	0.20	9.8
	I39		2	16000	1600	4800	0.10	0.20	6.7
	I40		2	16000	10000	12000	0.63	0.20	57.0
	I40		6	16000	5400	12000	0.34		51.3
	I40		9	16000	6400	12000	0.40		32.1
	I10	Mar	12	1600	320	86	0.20		11.2
	I18	Apr	12	9000	3600	200	0.40		16.2
	I18		18	1600	800	44	0.50		7.2
	I18		2	1800	320	18	0.18	0.20	11.5
	I19		11	1100	420	10	0.38		16.6
	I23		2	7600	780	4	0.10	0.20	8.1
	I23		12	4200	940	120	0.22		4.1
	I23		18	3600	1000	82	0.28		2.0
	I24		2	1200	460	38	0.38	0.20	8.5
	I25		6	1000	100	14	0.10		8.8
	I25		9	3000	660	50	0.22		4.2
	I39		12	4800	840	74	0.18		3.3
	I23	Jul	12	1500	660	160	0.44		12.7
	I23		18	1400	400	72	0.29		7.7
Offshore									
	I13	May	37	2600	360	100	0.14		5.4
	I20		55	2000	420	130	0.21		2.3
	I21		37	4200	1100	220	0.26		3.2
	I8		37	3600	560	78	0.16		3.9
	I20	Aug	55	1000	440	34	0.44		5.3
	I21	Dec	18	1700	300	38	0.18		3.6
North									
	I30	Jun	18	16000	2800	300	0.18		12.0
	I22		2	16000	2200	360	0.14	0.20	7.7
	I22	Aug	18	1600	340	54	0.21		6.0
	I30	Nov	18	6200	2000	60	0.32		5.5
	I30	Dec	18	1400	300	10	0.21		5.2
	I22		18	4000	1100	40	0.28		2.5
South									
	I9	May	27	2400	460	28	0.19		17.4
	I5	Oct	2	2800	540	340	0.19	0.20	9.9

Appendix A.2 continued

Bacteriological densities for SBOO offshore and kelp station water quality samples with total coliform concentrations ≥1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥ 0.1 collected during 2005. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Individual values for corresponding total suspended solids (SuSo) and oil and grease (O&G; 2 m depth) samples are listed. Sample depth is in meters.

	Station	Month	Sample depth	Total	Fecal	Entero	F:T	O&G	SuSo
Outfall									
	I16	Mar	18	16000	2000	320	0.13		5.6
	I12	Apr	18	9000	1200	100	0.13		2.5
	I14		18	4800	580	22	0.12		3.3
	I16		27	10000	1400	40	0.14		5.3
	I16	May	18	2400	380	110	0.16		6.1
	I12	Jun	18	16000	12000	7200	0.75		4.0
	I14		18	16000	9600	1000	0.60		5.3
	I16		18	16000	12000	3800	0.75		4.1
	I12	Jul	18	16000	12000	4200	0.75		6.3
	I16		27	3800	780	86	0.21		8.1
	I16	Aug	18	2400	420	88	0.18		4.2
	I16		27	1100	200	38	0.18		6.2
	I14	Sep	18	5600	580	32	0.10		3.1
	I16		18	16000	12000	2600	0.75		3.4
	I12	Oct	18	16000	16000	3600	1.00		2.2
	I14		18	1100	280	50	0.25		2.9
	I14	Nov	18	2800	580	140	0.21		5.0
	I14	Dec	18	5600	1200	34	0.21		3.1
	I16		18	1800	620	22	0.34		6.3

Appendix A.3

Bacteriological densities for SBOO offshore and kelp station water quality samples with total coliform concentrations <1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≥ 0.1 collected during 2005. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Individual values for corresponding total suspended solids (SuSo) and oil and grease (O&G; 2 m depth) samples are listed. Sample depth is in meters.

	Station	Month	Sample depth	Total	Fecal	Entero	F:T	O&G	SuSo
Inshore									
	I11	Jan	6	3600	64	100	0.02		12.6
	I11		11	12000	300	400	0.03		15.4
	I18		2	5400	420	840	0.08	0.20	9.1
	I18		12	1100	46	54	0.04		9.6
	I19		2	12000	740	3200	0.06	0.20	23.2
	I19		6	7400	300	500	0.04		9.0
	I19		11	16000	480	2800	0.03		27.1
	I23		2	8600	420	460	0.05	0.20	5.2
	I23		18	7400	340	60	0.05		7.0
	I24		11	14000	340	880	0.02		10.7
	I25		6	16000	1100	2400	0.07		10.1
	I25		9	16000	620	2400	0.04		14.2
	I26		2	16000	900	1000	0.06	0.20	8.1
	I26		6	16000	820	1200	0.05		7.1
	I26		9	3400	110	260	0.03		9.0
	I32		6	1500	24	64	0.02		5.7
	I32		9	2000	58	180	0.03		19.4
	I36		11	1300	36	80	0.03		5.7
	I19	Mar	6	1100	60	74	0.05		20.2
	I24		11	2400	40	300	0.02		37.7
	I40		2	5200	180	78	0.03	0.20	16.6
	I40		6	1600	20	160	0.01		16.2
	I40		9	1100	44	140	0.04		19.5
	I19	Apr	2	5800	440	2	0.08	0.20	7.0
	I24		6	9200	80	2	0.01		3.8
	I25		2	16000	1200	50	0.08	0.20	4.0
	I40		2	16000	960	14	0.06	0.20	5.7
	I19	May	2	16000	120	4	0.01	0.20	11.6
	I19		6	1100	2	2	0.00		11.5
	I32		6	1300	70	2	0.05		18.6
	I11	Jun	2	2000	100	6	0.05	0.20	8.0
	I32		9	1300	60	2	0.05		15.5
	I36		11	1100	2	2	0.00		32.5
	I38		11	2000	2	2	0.00		13.7
	I11	Oct	2	8000	180	72	0.02	0.20	5.6
	I11		6	16000	1000	100	0.06		3.4
	I11		11	15000	580	72	0.04		5.7
Offshore									
	I13	Jan	2	1300	72	440	0.06	0.20	11.2
	I21		2	1400	110	740	0.08	0.20	5.6

Appendix A.3 continued

Bacteriological densities for SBOO offshore and kelp station water quality samples with total coliform concentrations <1000 CFU/100 mL and fecal to total coliform ratio (F:T) ≤ 0.1 collected during 2005. Total coliform (Total), fecal coliform (Fecal), and enterococcus (Entero) bacteriological densities are expressed as CFU/100 mL. Individual values for corresponding total suspended solids (SuSo) and oil and grease (O&G; 2 m depth) samples are listed. Sample depth is in meters.

	Station	Month	Sample depth	Total	Fecal	Entero	F:T	O&G	SuSo
North									
	I22	Jan	2	2400	10	340	0.00	0.20	5.2
	I22		18	1300	6	12	0.00		6.0
	I22		27	3800	74	28	0.02		4.0
	I30		27	1600	36	260	0.02		11.7
	I33	Jun	27	1400	2	2	0.00		6.0
South									
	I5	Jan	11	2000	80	320	0.04		18.1
	I9		18	2200	2	4	0.00		4.3
	I10		12	1300	16	42	0.01		8.2
	I10		18	2800	36	140	0.01		7.7
	I5	Apr	2	8400	620	2	0.07	0.20	4.7
	I5	Jun	11	1600	50	2	0.03		5.5
	I9	Jul	18	4000	200	48	0.05		23.0
	I5	Sep	6	1200	50	10	0.04		8.8
	I5		11	2600	120	10	0.05		6.1
	I5	Oct	11	3800	140	24	0.04		7.4
	I5	Nov	11	1200	46	6	0.04		4.6
Outfall									
	I12	Jan	2	6400	6	8	0.00	0.20	3.1
	I14		2	4800	120	380	0.03	0.20	2.5
	I16		2	2200	2	12	0.00	0.20	8.9
	I12	Mar	18	5400	100	28	0.02		3.6
	I14		27	1200	60	4	0.05		3.8

Appendix B

Supporting Data

2005 SBOO Stations

Sediment Characteristics

Appendix B.1

Sediment chemistry constituents analyzed for South Bay Ocean Outfall sampling during 2005.

Cholorinated Pesticides

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

Polycylic Aromatic Hydrocarbons

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

Metals

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

PCB Congeners

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

Appendix B.2

SBOO sediment statistics January 2005.

Station	Mean (phi)	Std Dev. (phi)	Median (phi)	Mean (mm)	Skewness	Kurtosis	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
19 m stations											
I35	3.9	1.4	3.6	0.069	0.4	1.2	0.0	63.2	34.5	2.3	Coarse black sand, fine sand, silt, organic debris
I34	1.5	0.9	1.6	0.353	-0.2	0.8	5.3	94.6	0.1	0.0	Sand, shell hash
I31	3.1	0.8	3.1	0.121	0.1	1.4	0.3	91.8	7.7	0.2	Fine sand, silt
I23	3.0	0.9	3.0	0.122	-0.1	6.3	0.9	90.5	8.5	0.1	Fine sand, shell hash
I18	3.2	1.0	3.2	0.111	0.1	1.5	0.3	85.1	14.1	0.5	Fine sand, silt
I10	3.1	0.7	3.0	0.117	0.2	4.1	0.5	90.9	8.6	0.1	Fine sand, silt
I4	2.9	0.8	2.9	0.136	-0.2	1.6	0.0	93.0	7.0	0.0	Sand, silt, shell hash
28 m stations											
I33	3.1	0.9	2.9	0.120	0.3	3.2	0.0	90.3	9.3	0.4	Fine sand, silt, shell hash
I30	3.3	1.1	3.0	0.101	0.4	3.7	1.0	83.6	14.7	0.8	Fine sand, silt
I27	3.2	1.0	3.1	0.109	0.3	2.0	0.3	83.9	14.7	1.1	Fine sand
I22	3.2	1.3	3.0	0.106	0.3	3.3	0.8	81.1	16.8	1.3	Fine sand, silt
I16	2.2	1.3	2.4	0.219	-0.1	1.1	4.7	87.4	7.8	0.1	Sand, shell hash
I15	1.9	1.2	2.0	0.266	0.0	1.0	4.0	90.3	5.7	0.0	Fine sand
I14	3.2	1.1	3.2	0.109	0.0	1.8	0.3	84.9	14.0	0.7	Fine sand, silt
I12	1.8	1.1	1.8	0.295	-0.0	1.0	4.4	92.9	2.7	0.0	Fine sand
I9	3.4	0.9	3.3	0.094	0.4	1.8	0.0	81.7	17.4	0.9	Fine sand, silt
I6	1.0	0.7	0.9	0.502	0.2	1.0	7.3	92.6	0.0	0.0	Fine red relic sand, sand, shell hash
I3	1.1	0.8	1.1	0.458	0.1	0.9	6.7	93.3	0.0	0.0	Sand
I2	1.6	0.8	1.7	0.325	-0.2	0.9	3.9	96.1	0.0	0.0	Fine Sand
38 m stations											
I29	3.6	1.5	3.4	0.082	0.2	1.6	0.0	69.5	28.5	2.0	Coarse black sand, fine sand, silt
I21	0.7	0.7	0.7	0.595	0.1	1.1	10.7	89.3	0.0	0.0	Red relict sand, coarse sand, shell hash
I13	1.3	0.9	1.3	0.396	0.1	1.0	5.4	91.3	3.3	0.0	Fine red relict sand, shell hash
I8	1.7	1.1	1.7	0.306	0.0	1.1	4.1	91.4	4.5	0.0	Sand
55 m stations											
I28	1.7	1.7	1.0	0.301	0.4	0.7	13.7	68.1	18.2	0.0	Coarse sand, coarse black sand, silt
I20	1.2	1.7	0.7	0.435	0.6	1.9	15.5	70.9	12.6	1.0	Red relict sand, coarse sand, silt
I7	1.1	1.5	0.9	0.458	0.5	2.1	9.3	81.8	8.4	0.5	Red relict sand
I1	3.0	1.0	2.9	0.127	0.2	2.5	0.0	89.9	9.6	0.5	Fine Sand

Appendix B.2 continued

SBOO sediment statistics July 2005.

Station	Mean (phi)	Std Dev. (phi)	Median (phi)	Mean (mm)	Skewness	Kurtosis	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment Observations
19 m stations											
I35	4.2	1.6	3.8	0.056	0.3	1.1	0.0	55.2	41.7	3.1	Fine sand, silt,worm tubes
I34	0.6	1.4	0.9	0.640	-0.2	0.6	35.3	62.6	1.9	0.0	Coarse sand, red relict sand, shell hash
I31	3.1	0.6	3.1	0.114	0.3	6.3	0.0	91.2	8.5	0.3	Fine sand, silt
I23	0.4	0.8	0.4	0.738	0.1	2.0	21.0	76.3	2.8	0.0	Coarse and fine sand. shell hash
I18	3.1	0.9	3.1	0.116	-0.0	1.4	0.3	88.9	10.7	0.1	Fine sand, silt
I10	3.0	0.9	3.0	0.122	0.0	1.4	0.2	91.0	8.7	0.1	Fine sand, silt
I4	1.2	0.9	1.2	0.427	0.1	0.9	6.7	92.8	0.5	0.0	Sand, shell hash
28 m stations											
I33	2.9	1.1	3.0	0.131	0.0	22.0	0.9	87.5	10.9	0.8	Fine sand, silt
I30	3.2	1.1	3.3	0.105	0.0	1.8	0.3	83.9	14.9	0.8	Fine sand, silt
I27	3.2	1.0	3.2	0.107	0.1	1.7	0.0	85.6	13.6	0.7	Fine sand
I22	3.3	1.1	3.1	0.103	0.4	3.2	0.3	83.2	15.6	0.9	Fine sand, silt
I16	2.3	1.2	2.7	0.197	-0.2	1.2	4.0	87.3	8.4	0.3	Fine sand, silt
I15	1.5	1.0	1.5	0.349	0.1	1.1	4.7	91.3	4.0	0.0	Sand
I14	2.7	1.3	2.8	0.153	-0.0	2.1	0.2	88.2	10.9	0.7	Fine sand, silt
I12	1.5	1.0	1.5	0.355	0.0	1.0	4.8	92.4	2.8	0.0	Sand, shell hash
I9	3.2	1.1	3.1	0.112	0.2	2.1	0.7	83.6	15.2	0.5	Fine sand, silt
I6	0.9	0.7	0.8	0.554	0.2	1.0	9.1	90.8	0.0	0.0	Coarse red relict sand, shell hash
I3	1.3	0.8	1.4	0.395	-0.1	0.9	5.1	94.9	0.0	0.0	Sand
I2	1.6	0.8	1.6	0.337	-0.1	0.9	4.3	94.9	0.8	0.0	Fine sand, sand
38 m stations											
I29	3.5	1.3	3.3	0.090	0.3	1.5	0.0	73.5	24.9	1.6	Black sand, fine sand, silt
I21	0.9	0.8	0.9	0.543	0.1	1.8	8.8	90.1	1.1	0.0	Red relict sand
I13	1.3	1.0	1.3	0.411	0.2	1.1	5.7	89.9	4.4	0.1	Coarse red relict sand, sand, silt, shell hash
I8	1.5	0.9	1.5	0.365	-0.1	1.0	5.1	92.2	2.8	0.0	Sand
55 m stations											
I28	1.9	1.9	1.8	0.264	0.0	0.6	19.0	51.5	29.5	0.0	Coarse sand, black sand, silt
I20	0.8	1.4	0.6	0.561	0.6	3.0	14.6	76.8	8.2	0.4	Coarse sand, red relict sand
I7	1.1	1.5	0.8	0.480	0.5	1.7	9.3	82.9	7.4	0.4	Fine red relict sand
I1	2.8	1.1	2.7	0.142	0.3	2.0	0.1	89.6	9.6	0.7	Fine sand, silt

Appendix B.3

Mean concentrations of pesticides and total PAH found at each station during 2005.

Station	Total DDT (ppt)	p,p-DDE (ppt)	Total PAH (ppt)
19 m stations			
I35	nd	nd	303
I34	nd	nd	115
I31	nd	nd	123
I23	nd	nd	161
I18	nd	nd	152
I10	nd	nd	194
I4	nd	nd	169
28 m stations			
I33	nd	nd	153
I30	nd	nd	151
I27	nd	nd	148
I22	nd	nd	161
I16	nd	nd	106
I15	nd	nd	125
I14	nd	nd	121
I12	nd	nd	310
I9	nd	nd	208
I6	nd	nd	154
I3	nd	nd	132
I2	nd	nd	169
38m stations			
I29	270	270	168
I21	nd	nd	138
I13	nd	nd	129
I8	nd	nd	154
55 m stations			
I28	570	570	168
I20	nd	nd	95
I7	nd	nd	1036
I1	nd	nd	172
CDF	10,000	1200	
ERL	1580	2200	4022

Appendix C

Supporting Data

2005 SBOO Stations

Demersal Fishes and Megabenthic Invertebrates

Appendix C.1

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

				LENGTH		
Taxon/Species	**Common Name**	**N**	**BM**	**Min**	**Max**	**Mean**
RAJIFORMES						
Rhinobatidae						
Platyrhinoidis triseriata	thornback	1	0.7	50	50	50
Rhinobatos productus	shovelnose guitarfish	2	0.6	36	49	43
Rajidae						
Raja inornata	California skate	4	1.9	17	37	29
MYLOBATIFORMIS						
Urolophidae						
Urobatis haller	round stingray	1	1.2	35	35	35
Myliobatitidae						
Myliobatis californica	bat ray	3	1.5	45	53	49
CLUPEIFORMES						
Engraulidae						
Engraulis mordax	northern anchovy	1	0.1	13	13	13
AULOPIFORMES						
Synodontidae						
Synodus lucioceps	California lizardfish	334	5.0	7	25	13
OPHIDIIFORMES						
Ophidiidae						
Chilara taylori	spotted cusk-eel	1	0.1	17	17	17
BATRACHOIDIFORMES						
Batrachoididae						
Porichthys myriaster	specklefin midshipman	40	1.5	4	28	12
Porichthys notatus	plainfin midshipman	44	1.0	5	20	10
GASTEROSTEIFORMES						
Syngnathidae						
Synathus exilis	barcheek pipefish	1	0.1	22	22	22
SCORPAENIFORMES						
Scorpaenidae	(juv. rockfish unid.)	1	0.1	3	3	3
Scorpaena guttata	California scorpionfish	48	18.6	15	31	22
Hexagrammidae						
Zaniolepis latipinnis	longspine combfish	49	1.5	13	15	14
Cottidae						
Chitonotus pugetensis	roughback sculpin	166	2.5	4	11	8
Icelinus quadriseriatus	yellowchin sculpin	341	2.5	4	9	6
Agonidae						
Odontopyxis trispinosa	pygmy poacher	3	0.3	5	8	7

Appendix C.1 continued

Taxon/Species	Common Name	N	BM	LENGTH Min	Max	Mean
PERCIFORMES						
Serranidae						
Paralabrax clathratus	kelp bass	2	0.1	8	10	9
Paralabrax nebulifer	barred sand bass	1	0.5	30	30	30
Sciaenidae						
Genyonemus lineatus	white croaker	11	1.2	13	21	19
Embiotocidae						
Cymatogaster aggregata	shiner perch	1	0.1	11	11	11
Zalembius rosaceus	pink seaperch	1	0.1	6	6	6
Zoarcidea						
Lycodes pacificus	blackbelly eelpout	1	0.1	18	18	18
Clinidae						
Heterostichus rostratus	giant kelpfish	1	0.1	15	15	15
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	gulf sanddab	1	0.1	7	7	7
Citharichthys sordidus	Pacific sanddab	18	0.9	5	20	13
Citharichthys stigmaeus	speckled sanddab	2835	19.7	3	14	7
Citharichthys xanthostigma	longfin sanddab	93	4.2	5	21	12
Hippoglossina stomata	bigmouth sole	5	0.4	11	18	14
Paralichthys californicus	California halibut	24	9.2	4	57	23
Xystreurys liolepis	fantail sole	9	2.0	12	31	20
Pleuronectidae						
Parophrys vetulus	English sole	86	6.1	7	25	15
Pleuronichthys guttulatus	diamond turbot	1	0.2	24	24	24
Pleuronichthys ritteri	spotted turbot	8	1.1	15	23	17
Pleuronichthys verticalis	hornyhead turbot	199	10.1	4	20	11
Cynoglossidae						
Symphurus atricauda	California tonguefish	56	1.7	6	18	10

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

Appendix C.2

List of megabenthic invertebrate taxa collected at SBOO stations SD15–SD21 during 2005 surveys. (N) = total number of individuals collected. Taxonomic arrangement from SCAMIT 2001.*

TAXON/SPECIES	N
CINDARIA	
ANTHOZOA	
ALCYONACEA	
Muriceidae	
Thesea sp B	2
PENNATULACEA	
Virgulariidae	
Stylatula elongata	1
MOLLUSCA	
GASTROPODA	
NEOTAENIOGLOSSA	
Naticidae	
Euspira lewisii	3
Bursidae	
Crossata californica	5
NEOGASTROPODA	
Muricidae	
Pteropurpura festiva	2
Buccinidae	
Kelletia kelletii	22
CEPHALASPIDEA	
Philinidae	
Philine auriformis	33
NOTASPIDEA	
Pleurobranchaeidae	
Pleurobranchaea californica	4
NUDIBRANCHIA	
Onchidorididae	
Acanthodoris brunnea	3
Acanthodoris rhodoceras	5
DENDRONOTIDAE	
Dendronotus iris	1
Flabellinidae	
Flabellina iodinea	1
CEPHALOPODA	
TEUTHIDA	
Loliginidae	
Loligo opalescens	4
OCTOPODA	
Octopodidae	
Octopus rubescens	4

Appendix C.2 continued

Taxon/ Species	N
ANNELIDA	
HIRUDINEA	1
ARTHROPODA	
CIRRIPEDIA	
THORACICA	
Scalpellidae	
Hamatoscalpellum californicum	11
MALACOSTRACA	
STOMATOPODA	
Hemisquillidae	
Hemisquilla ensigera californiensis	21
ISOPODA	
Cymothoidae	
Elthusa vulgaris	13
DECAPODA	
Sicyoniidae	
Sicyonia ingentis	15
Pandalidae	
Pandalus platyceros	1
Hippolytidae	
Heptacarpus palpator	2
Heptacarpus stimpsoni	18
Crangonidae	
Crangon alaskensis	5
Crangon alba	8
Crangon nigromaculata	15
Diogenidae	
Paguristes bakeri	1
Paguridae	
Pagurus spilocarpus	9
Calappidae	
Platymera gaudichaudii	3
Leucosiidae	
Randallia ornata	7
Majidae	
Loxorhynchus grandis	4
Loxorhynchus sp	1
Pugettia producta	1
Pyromaia tuberculata	7
Parthenopidae	
Heterocrypta occidentalis	22
Cancridae	
Cancer anthonyi	3
Cancer gracilis	13
Cancer sp (juvenile)	17
Portunidae	
Portunus xantusii	12

Appendix C.2 continued

Taxon/ Species	N
ECHINODERMATA	
ASTEROIDEA	
PAXILLOSIDA	
Luidiidae	
Luidia armata	5
Luidia foliolata	1
Astropectinidae	
Astropecten armatus	1
Astropecten verrilli	808
FORCIPULATIDA	
Asteriidae	
Pisaster brevispinus	16
OPHIUROIDEA	
OPHIURIDA	
Ophiotricidae	
Ophiothrix spiculata	3
ECHINOIDEA	
TEMNOPLEUROIDA	
Toxopneustidae	
Lytechinus pictus	60
CLYPEASTEROIDA	
Dendrasteridae	
Dendraster terminalis	44

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

Appendix D

Supporting Data

2005 SBOO Stations

Bioaccumulation of Contaminants in Fish Tissues

Appendix D.1

Lengths (L, cm) and weights (WT, g) of fishes used for each composite sample for the SBOO monitoring program during April and October 2005.

Station	Rep	Species	N	min L	max L	avg L	min WT	max WT	avg WT
April 2005									
RF3	1	Brown rockfish	3	24	28	26	377	600	489
RF3	2	Mixed rockfish	3	21	28	25	260	566	414
RF3	3	Brown rockfish	3	21	27	23	255	535	372
RF4	1	California scorpionfish	3	26	28	27	510	600	545
RF4	2	California scorpionfish	3	24	26	25	493	590	535
RF4	3	California scorpionfish	3	26	28	27	572	700	624
SD15	1	English sole	4	15	21	19	52	123	92
SD15	2	Hornyhead turbot	4	15	24	19	80	356	181
SD15	3	California scorpionfish	3	24	28	26	484	800	608
SD16	1	Hornyhead turbot	9	15	19	17	86	165	119
SD16	2	California scorpionfish	3	18	25	21	180	486	301
SD16	3	English sole	10	16	25	19	47	235	103
SD17	1	English sole	8	17	21	20	69	149	106
SD17	2	Hornyhead turbot	8	14	18	16	69	138	95
SD17	3	Longfin sanddab	5	14	21	16	47	160	90
SD18	1	Hornyhead turbot	10	14	18	16	60	142	97
SD18	2	California scorpionfish	3	18	23	21	187	401	286
SD18	3	English sole	5	23	27	25	143	291	205
SD19	1	Hornyhead turbot	7	15	20	17	79	212	118
SD19	2	English sole	8	16	28	20	46	309	111
SD19	3	Longfin sanddab	7	14	21	17	57	185	104
SD20	1	California scorpionfish	3	21	25	23	246	538	368
SD20	2	Hornyhead turbot	9	14	19	15	65	191	102
SD20	3	English sole	5	15	20	19	49	105	86
SD21	1	Longfin sanddab	9	13	18	15	40	139	74
SD21	2	Hornyhead turbot	8	15	19	17	73	202	119
SD21	3	English sole	5	17	26	20	66	231	124
October 2005									
RF3	1	Brown rockfish	3	14	19	17	85	187	147
RF3	2	Vermilion rockfish	3	20	25	23	259	466	396
RF3	3	Vermilion rockfish	3	15	35	28	94	1500	931
RF4	1	California scorpionfish	3	26	28	27	556	800	719
RF4	2	California scorpionfish	3	21	25	23	354	700	551
RF4	3	California scorpionfish	3	24	27	26	478	606	548
SD15	1	California scorpionfish	3	22	25	23	325	435	362
SD15	2	California scorpionfish	3	16	20	19	145	253	216
SD15	3	California scorpionfish	3	14	19	17	130	349	254
SD16	1	Hornyhead turbot	4	18	21	19	145	229	195
SD16	2	California scorpionfish	3	20	24	22	216	416	343
SD16	3	California scorpionfish	3	20	24	23	266	516	413
SD17	1	Hornyhead turbot	7	14	17	16	80	141	107
SD17	2	Hornyhead turbot	4	17	19	18	130	183	152
SD17	3	California scorpionfish	4	20	23	22	224	379	307
SD18	1	Hornyhead turbot	6	15	18	16	83	172	116
SD18	2	California scorpionfish	3	19	22	20	194	353	265
SD18	3	California scorpionfish	3	17	22	19	183	345	243
SD19	1	California scorpionfish	3	18	20	19	215	253	234
SD19	2	Hornyhead turbot	4	15	21	18	97	244	159
SD19	3	California scorpionfish	3	20	28	23	264	700	428
SD20	1	Hornyhead turbot	3	19	21	20	164	272	207
SD20	2	Hornyhead turbot	7	14	18	16	81	173	108
SD20	3	Hornyhead turbot	7	14	18	16	75	152	110
SD21	1	Hornyhead turbot	6	13	18	16	64	170	111
SD21	2	California scorpionfish	3	19	23	21	238	349	287
SD21	3	California scorpionfish	3	24	30	26	388	1000	624

Appendix D.2

Analyzed constituents for fish tissue samples analyzed for the SBOO monitoring program during April and October 2005.

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

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

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

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

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Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF3	1	Brown rockfish	Muscle	Aluminum		6.69	mg/kg	0.583
RF3	1	Brown rockfish	Muscle	Arsenic		0.939	mg/kg	0.375
RF3	1	Brown rockfish	Muscle	Barium		0.0277	mg/kg	0.0066
RF3	1	Brown rockfish	Muscle	Chromium		0.103	mg/kg	0.0804
RF3	1	Brown rockfish	Muscle	Copper		0.21	mg/kg	0.0684
RF3	1	Brown rockfish	Muscle	Iron		2.36	mg/kg	0.0958
RF3	1	Brown rockfish	Muscle	Lipids		0.35	%wt	0.005
RF3	1	Brown rockfish	Muscle	Manganese		0.0558	mg/kg	0.0071
RF3	1	Brown rockfish	Muscle	Mercury		0.209	mg/kg	0.03
RF3	1	Brown rockfish	Muscle	p,p-DDE		4.3	ug/kg	1.33
RF3	1	Brown rockfish	Muscle	PCB 101	E	0.2	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 118	E	0.3	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 128	E	0.1	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 138	E	0.4	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 153/168	E	0.6	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 180	E	0.3	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 187	E	0.3	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 99	E	0.2	ug/kg	
RF3	1	Brown rockfish	Muscle	Selenium		0.21	mg/kg	0.06
RF3	1	Brown rockfish	Muscle	Silver		0.0826	mg/kg	0.0568
RF3	1	Brown rockfish	Muscle	Tin		0.376	mg/kg	0.24
RF3	1	Brown rockfish	Muscle	Total DDT		4.3	ug/kg	
RF3	1	Brown rockfish	Muscle	Total PCB		2.4	ug/kg	
RF3	1	Brown rockfish	Muscle	Total Solids		20.1	%wt	0.4
RF3	1	Brown rockfish	Muscle	Zinc		3.6	mg/kg	0.0487
RF3	2	Mixed rockfish	Muscle	Aluminum		6.35	mg/kg	0.583
RF3	2	Mixed rockfish	Muscle	Arsenic		1.93	mg/kg	0.375
RF3	2	Mixed rockfish	Muscle	Barium		0.0239	mg/kg	0.0066
RF3	2	Mixed rockfish	Muscle	Chromium		0.106	mg/kg	0.0804
RF3	2	Mixed rockfish	Muscle	Copper		0.144	mg/kg	0.0684
RF3	2	Mixed rockfish	Muscle	Iron		2.95	mg/kg	0.0958
RF3	2	Mixed rockfish	Muscle	Lipids		0.32	%wt	0.005
RF3	2	Mixed rockfish	Muscle	Manganese		0.0792	mg/kg	0.0071
RF3	2	Mixed rockfish	Muscle	Mercury		0.074	mg/kg	0.03
RF3	2	Mixed rockfish	Muscle	p,p-DDE		2.6	ug/kg	1.33
RF3	2	Mixed rockfish	Muscle	PCB 118	E	0.2	ug/kg	
RF3	2	Mixed rockfish	Muscle	PCB 153/168	E	0.3	ug/kg	
RF3	2	Mixed rockfish	Muscle	PCB 180	E	0.2	ug/kg	
RF3	2	Mixed rockfish	Muscle	PCB 187	E	0.1	ug/kg	
RF3	2	Mixed rockfish	Muscle	PCB 99	E	0.1	ug/kg	
RF3	2	Mixed rockfish	Muscle	Selenium		0.162	mg/kg	0.06
RF3	2	Mixed rockfish	Muscle	Silver		0.0929	mg/kg	0.0568
RF3	2	Mixed rockfish	Muscle	Tin		0.407	mg/kg	0.24
RF3	2	Mixed rockfish	Muscle	Total DDT		2.6	ug/kg	
RF3	2	Mixed rockfish	Muscle	Total PCB		0.9	ug/kg	
RF3	2	Mixed rockfish	Muscle	Total Solids		20	%wt	0.4

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF3	2	Mixed rockfish	Muscle	Zinc		2.69	mg/kg	0.0487
RF3	3	Brown rockfish	Muscle	Aluminum		6.99	mg/kg	0.583
RF3	3	Brown rockfish	Muscle	Arsenic		0.898	mg/kg	0.375
RF3	3	Brown rockfish	Muscle	Barium		0.0328	mg/kg	0.0066
RF3	3	Brown rockfish	Muscle	Chromium		0.112	mg/kg	0.0804
RF3	3	Brown rockfish	Muscle	Copper		0.158	mg/kg	0.0684
RF3	3	Brown rockfish	Muscle	Iron		1.95	mg/kg	0.0958
RF3	3	Brown rockfish	Muscle	Lipids		0.25	%wt	0.005
RF3	3	Brown rockfish	Muscle	Manganese		0.0542	mg/kg	0.0071
RF3	3	Brown rockfish	Muscle	Mercury		0.133	mg/kg	0.03
RF3	3	Brown rockfish	Muscle	p,p-DDE		2.4	ug/kg	1.33
RF3	3	Brown rockfish	Muscle	p,-p-DDMU	E	0.1	ug/kg	
RF3	3	Brown rockfish	Muscle	PCB 101	E	0.1	ug/kg	
RF3	3	Brown rockfish	Muscle	PCB 118	E	0.1	ug/kg	
RF3	3	Brown rockfish	Muscle	PCB 138	E	0.2	ug/kg	
RF3	3	Brown rockfish	Muscle	PCB 153/168	E	0.3	ug/kg	
RF3	3	Brown rockfish	Muscle	PCB 187	E	0.1	ug/kg	
RF3	3	Brown rockfish	Muscle	PCB 99	E	0.1	ug/kg	
RF3	3	Brown rockfish	Muscle	Selenium		0.158	mg/kg	0.06
RF3	3	Brown rockfish	Muscle	Silver		0.0708	mg/kg	0.0568
RF3	3	Brown rockfish	Muscle	Tin		0.549	mg/kg	0.24
RF3	3	Brown rockfish	Muscle	Total DDT		2.5	ug/kg	
RF3	3	Brown rockfish	Muscle	Total PCB		0.9	ug/kg	
RF3	3	Brown rockfish	Muscle	Total Solids		19.8	%wt	0.4
RF3	3	Brown rockfish	Muscle	Zinc		2.75	mg/kg	0.0487
RF4	1	California scorpionfish	Muscle	Aluminum		9.13	mg/kg	0.583
RF4	1	California scorpionfish	Muscle	Arsenic		1.77	mg/kg	0.375
RF4	1	California scorpionfish	Muscle	Barium		0.044	mg/kg	0.0066
RF4	1	California scorpionfish	Muscle	Chromium		0.111	mg/kg	0.0804
RF4	1	California scorpionfish	Muscle	Copper		0.203	mg/kg	0.0684
RF4	1	California scorpionfish	Muscle	Iron		2.42	mg/kg	0.0958
RF4	1	California scorpionfish	Muscle	Lipids		0.59	%wt	0.005
RF4	1	California scorpionfish	Muscle	Manganese		0.0633	mg/kg	0.0071
RF4	1	California scorpionfish	Muscle	Mercury		0.176	mg/kg	0.03
RF4	1	California scorpionfish	Muscle	p,p-DDD	E	0.2	ug/kg	
RF4	1	California scorpionfish	Muscle	p,p-DDE		8	ug/kg	1.33
RF4	1	California scorpionfish	Muscle	p,-p-DDMU	E	0.2	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 101	E	0.2	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 118	E	0.3	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 138	E	0.3	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 153/168	E	0.6	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 180	E	0.2	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 187	E	0.2	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 99	E	0.1	ug/kg	
RF4	1	California scorpionfish	Muscle	Selenium		0.221	mg/kg	0.06
RF4	1	California scorpionfish	Muscle	Silver		0.0817	mg/kg	0.0568

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF4	1	California scorpionfish	Muscle	Tin		0.555	mg/kg	0.24
RF4	1	California scorpionfish	Muscle	Total DDT		8.4	ug/kg	
RF4	1	California scorpionfish	Muscle	Total PCB		1.9	ug/kg	
RF4	1	California scorpionfish	Muscle	Total Solids		21.1	%wt	0.4
RF4	1	California scorpionfish	Muscle	Zinc		3.02	mg/kg	0.0487
RF4	2	California scorpionfish	Muscle	Aluminum		6.43	mg/kg	0.583
RF4	2	California scorpionfish	Muscle	Arsenic		2.08	mg/kg	0.375
RF4	2	California scorpionfish	Muscle	Barium		0.0211	mg/kg	0.0066
RF4	2	California scorpionfish	Muscle	Chromium		0.108	mg/kg	0.0804
RF4	2	California scorpionfish	Muscle	Copper		0.256	mg/kg	0.0684
RF4	2	California scorpionfish	Muscle	Iron		3.1	mg/kg	0.0958
RF4	2	California scorpionfish	Muscle	Lipids		0.85	%wt	0.005
RF4	2	California scorpionfish	Muscle	Manganese		0.0675	mg/kg	0.0071
RF4	2	California scorpionfish	Muscle	Mercury		0.202	mg/kg	0.03
RF4	2	California scorpionfish	Muscle	p,p-DDE		5.9	ug/kg	1.33
RF4	2	California scorpionfish	Muscle	PCB 101	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 118	E	0.2	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 153/168	E	0.5	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 180	E	0.2	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 187	E	0.2	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 99	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	Selenium		0.225	mg/kg	0.06
RF4	2	California scorpionfish	Muscle	Silver		0.0789	mg/kg	0.0568
RF4	2	California scorpionfish	Muscle	Tin		0.46	mg/kg	0.24
RF4	2	California scorpionfish	Muscle	Total DDT		5.9	ug/kg	
RF4	2	California scorpionfish	Muscle	Total PCB		1.3	ug/kg	
RF4	2	California scorpionfish	Muscle	Total Solids		21.1	%wt	0.4
RF4	2	California scorpionfish	Muscle	Zinc		3.79	mg/kg	0.0487
RF4	3	California scorpionfish	Muscle	Aluminum		7.2	mg/kg	0.583
RF4	3	California scorpionfish	Muscle	Arsenic		2.16	mg/kg	0.375
RF4	3	California scorpionfish	Muscle	Barium		0.0255	mg/kg	0.0066
RF4	3	California scorpionfish	Muscle	Chromium		0.116	mg/kg	0.0804
RF4	3	California scorpionfish	Muscle	Copper		0.211	mg/kg	0.0684
RF4	3	California scorpionfish	Muscle	Iron		2.74	mg/kg	0.0958
RF4	3	California scorpionfish	Muscle	Lipids		0.61	%wt	0.005
RF4	3	California scorpionfish	Muscle	Manganese		0.0611	mg/kg	0.0071
RF4	3	California scorpionfish	Muscle	Mercury		0.181	mg/kg	0.03
RF4	3	California scorpionfish	Muscle	p,p-DDD		0.25	ug/kg	
RF4	3	California scorpionfish	Muscle	p,p-DDE		8.5	ug/kg	1.33
RF4	3	California scorpionfish	Muscle	p,-p-DDMU		0.15	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 101		0.15	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 118	E	0.4	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 138	E	0.4	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 153/168		0.7	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 180	E	0.2	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 187	E	0.2	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF4	3	California scorpionfish	Muscle	PCB 99	E	0.2	ug/kg	
RF4	3	California scorpionfish	Muscle	Selenium		0.247	mg/kg	0.06
RF4	3	California scorpionfish	Muscle	Silver		0.0892	mg/kg	0.0568
RF4	3	California scorpionfish	Muscle	Tin		0.602	mg/kg	0.24
RF4	3	California scorpionfish	Muscle	Total DDT		8.9	ug/kg	
RF4	3	California scorpionfish	Muscle	Total PCB		2.25	ug/kg	
RF4	3	California scorpionfish	Muscle	Total Solids		23.1	%wt	0.4
RF4	3	California scorpionfish	Muscle	Zinc		3.98	mg/kg	0.0487
SD15	1	English sole	Liver	Aluminum		11.3	mg/kg	0.583
SD15	1	English sole	Liver	Arsenic		12.3	mg/kg	0.375
SD15	1	English sole	Liver	Barium		0.042	mg/kg	0.0066
SD15	1	English sole	Liver	Cadmium		1	mg/kg	0.0288
SD15	1	English sole	Liver	Chromium		0.208	mg/kg	0.0804
SD15	1	English sole	Liver	Copper		7.15	mg/kg	0.0684
SD15	1	English sole	Liver	Hexachlorobenzene	E	1	ug/kg	
SD15	1	English sole	Liver	Iron		324	mg/kg	0.0958
SD15	1	English sole	Liver	Lead		1.08	mg/kg	0.3
SD15	1	English sole	Liver	Lipids		5.37	%wt	0.005
SD15	1	English sole	Liver	Manganese		1.51	mg/kg	0.0071
SD15	1	English sole	Liver	Mercury		0.039	mg/kg	0.03
SD15	1	English sole	Liver	o,p-DDE	E	6.4	ug/kg	
SD15	1	English sole	Liver	p,p-DDD	E	2.8	ug/kg	
SD15	1	English sole	Liver	p,p-DDE		160	ug/kg	13.3
SD15	1	English sole	Liver	p,-p-DDMU	E	6.3	ug/kg	
SD15	1	English sole	Liver	PCB 101	E	2.7	ug/kg	
SD15	1	English sole	Liver	PCB 110	E	1.9	ug/kg	
SD15	1	English sole	Liver	PCB 118	E	3.6	ug/kg	
SD15	1	English sole	Liver	PCB 128	E	1.1	ug/kg	
SD15	1	English sole	Liver	PCB 138	E	4.9	ug/kg	
SD15	1	English sole	Liver	PCB 149	E	2.6	ug/kg	
SD15	1	English sole	Liver	PCB 151	E	1	ug/kg	
SD15	1	English sole	Liver	PCB 153/168	E	8.1	ug/kg	
SD15	1	English sole	Liver	PCB 170	E	1.8	ug/kg	
SD15	1	English sole	Liver	PCB 180	E	3.7	ug/kg	
SD15	1	English sole	Liver	PCB 183	E	1.1	ug/kg	
SD15	1	English sole	Liver	PCB 187	E	4.2	ug/kg	
SD15	1	English sole	Liver	PCB 194	E	1.6	ug/kg	
SD15	1	English sole	Liver	PCB 201	E	1.8	ug/kg	
SD15	1	English sole	Liver	PCB 206	E	1.1	ug/kg	
SD15	1	English sole	Liver	PCB 66	E	1.1	ug/kg	
SD15	1	English sole	Liver	PCB 99	E	2.1	ug/kg	
SD15	1	English sole	Liver	Selenium		1.43	mg/kg	0.06
SD15	1	English sole	Liver	Silver		0.303	mg/kg	0.0568
SD15	1	English sole	Liver	Tin		0.711	mg/kg	0.24
SD15	1	English sole	Liver	Total DDT		175.5	ug/kg	
SD15	1	English sole	Liver	Total PCB		44.4	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD15	1	English sole	Liver	Total Solids		24.1	%wt	0.4
SD15	1	English sole	Liver	Zinc		27.6	mg/kg	0.0487
SD15	2	Hornyhead turbot	Liver	Alpha (cis) Chlordane	E	3.2	ug/kg	
SD15	2	Hornyhead turbot	Liver	Aluminum		8.56	mg/kg	0.583
SD15	2	Hornyhead turbot	Liver	Arsenic		4.66	mg/kg	0.375
SD15	2	Hornyhead turbot	Liver	Barium		0.0311	mg/kg	0.0066
SD15	2	Hornyhead turbot	Liver	BHC, Beta isomer	E	3.3	ug/kg	
SD15	2	Hornyhead turbot	Liver	Cadmium		4.88	mg/kg	0.0288
SD15	2	Hornyhead turbot	Liver	Chromium		0.184	mg/kg	0.0804
SD15	2	Hornyhead turbot	Liver	Copper		7.87	mg/kg	0.0684
SD15	2	Hornyhead turbot	Liver	Gamma (trans) Chlordane	E	2.2	ug/kg	
SD15	2	Hornyhead turbot	Liver	Hexachlorobenzene	E	4.8	ug/kg	
SD15	2	Hornyhead turbot	Liver	Iron		64.8	mg/kg	0.0958
SD15	2	Hornyhead turbot	Liver	Lipids		8.81	%wt	0.005
SD15	2	Hornyhead turbot	Liver	Manganese		1.83	mg/kg	0.0071
SD15	2	Hornyhead turbot	Liver	Mercury		0.096	mg/kg	0.03
SD15	2	Hornyhead turbot	Liver	o,p-DDE	E	1.8	ug/kg	
SD15	2	Hornyhead turbot	Liver	p,p-DDD		26	ug/kg	13.3
SD15	2	Hornyhead turbot	Liver	p,p-DDE		150	ug/kg	13.3
SD15	2	Hornyhead turbot	Liver	p,-p-DDMU	E	6.7	ug/kg	
SD15	2	Hornyhead turbot	Liver	p,p-DDT		31	ug/kg	13.3
SD15	2	Hornyhead turbot	Liver	PCB 101	E	2.6	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 110	E	1.2	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 118	E	3.8	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 138	E	6	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 149	E	2.9	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 153/168	E	11	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 170	E	2.1	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 180	E	5.6	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 183	E	1.2	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 187	E	4.5	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 194	E	1.4	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 201	E	1.4	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 206	E	0.9	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 49	E	0.9	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 52	E	1.5	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 66	E	1	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 70	E	0.8	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 74	E	0.7	ug/kg	
SD15	2	Hornyhead turbot	Liver	PCB 99	E	2.6	ug/kg	
SD15	2	Hornyhead turbot	Liver	Selenium		0.83	mg/kg	0.06
SD15	2	Hornyhead turbot	Liver	Silver		0.306	mg/kg	0.0568
SD15	2	Hornyhead turbot	Liver	Tin		0.529	mg/kg	0.24
SD15	2	Hornyhead turbot	Liver	Total DDT		215.5	ug/kg	
SD15	2	Hornyhead turbot	Liver	Total PCB		52.1	ug/kg	
SD15	2	Hornyhead turbot	Liver	Total Solids		24.8	%wt	0.4

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD15	2	Hornyhead turbot	Liver	Trans Nonachlor	E	2.5	ug/kg	
SD15	2	Hornyhead turbot	Liver	Zinc		28.2	mg/kg	0.0487
SD15	3	California scorpionfish	Liver	Alpha (cis) Chlordane		5.5	ug/kg	
SD15	3	California scorpionfish	Liver	Aluminum		16.1	mg/kg	0.583
SD15	3	California scorpionfish	Liver	Arsenic		0.96	mg/kg	0.375
SD15	3	California scorpionfish	Liver	Barium		0.0619	mg/kg	0.0066
SD15	3	California scorpionfish	Liver	Cadmium		1.28	mg/kg	0.0288
SD15	3	California scorpionfish	Liver	Chromium		0.18	mg/kg	0.0804
SD15	3	California scorpionfish	Liver	Cis Nonachlor		3.75	ug/kg	
SD15	3	California scorpionfish	Liver	Copper		19.4	mg/kg	0.0684
SD15	3	California scorpionfish	Liver	Hexachlorobenzene		2	ug/kg	
SD15	3	California scorpionfish	Liver	Iron		153	mg/kg	0.0958
SD15	3	California scorpionfish	Liver	Lipids		32	%wt	0.005
SD15	3	California scorpionfish	Liver	Manganese		0.436	mg/kg	0.0071
SD15	3	California scorpionfish	Liver	Mercury		0.045	mg/kg	0.03
SD15	3	California scorpionfish	Liver	o,p-DDE		2.35	ug/kg	
SD15	3	California scorpionfish	Liver	p,p-DDD		12.5	ug/kg	
SD15	3	California scorpionfish	Liver	p,p-DDE		490	ug/kg	13.3
SD15	3	California scorpionfish	Liver	p,-p-DDMU		12.5	ug/kg	
SD15	3	California scorpionfish	Liver	p,p-DDT		5.75	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 101		8.7	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 105	E	5.1	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 110		5.5	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 118		15.5	ug/kg	13.3
SD15	3	California scorpionfish	Liver	PCB 123		2.1	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 128		3.85	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 138		19	ug/kg	13.3
SD15	3	California scorpionfish	Liver	PCB 149		6.6	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 151		4.35	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 153/168		35	ug/kg	13.3
SD15	3	California scorpionfish	Liver	PCB 158		1.65	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 167	E	1.4	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 170		6.85	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 177		4.05	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 180		16	ug/kg	13.3
SD15	3	California scorpionfish	Liver	PCB 183		3.8	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 187		14	ug/kg	13.3
SD15	3	California scorpionfish	Liver	PCB 194		3.6	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 201		3.75	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 206	E	1.8	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 28	E	1.6	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 49		1.9	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 52		3.65	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 66		3.3	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 70		1.15	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 74		1.65	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD15	3	California scorpionfish	Liver	PCB 87		2.1	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 99		7.35	ug/kg	
SD15	3	California scorpionfish	Liver	Selenium		0.571	mg/kg	0.06
SD15	3	California scorpionfish	Liver	Silver		0.441	mg/kg	0.0568
SD15	3	California scorpionfish	Liver	Tin		0.991	mg/kg	0.24
SD15	3	California scorpionfish	Liver	Total DDT		523.1	ug/kg	
SD15	3	California scorpionfish	Liver	Total PCB		185.3	ug/kg	
SD15	3	California scorpionfish	Liver	Total Solids		48.6	%wt	0.4
SD15	3	California scorpionfish	Liver	Trans Nonachlor		8.9	ug/kg	
SD15	3	California scorpionfish	Liver	Zinc		101	mg/kg	0.0487
SD16	1	Hornyhead turbot	Liver	Aluminum		9.26	mg/kg	0.583
SD16	1	Hornyhead turbot	Liver	Arsenic		2.47	mg/kg	0.375
SD16	1	Hornyhead turbot	Liver	Barium		0.0356	mg/kg	0.0066
SD16	1	Hornyhead turbot	Liver	Cadmium		3.94	mg/kg	0.0288
SD16	1	Hornyhead turbot	Liver	Chromium		0.187	mg/kg	0.0804
SD16	1	Hornyhead turbot	Liver	Copper		4.76	mg/kg	0.0684
SD16	1	Hornyhead turbot	Liver	Hexachlorobenzene	E	2.3	ug/kg	
SD16	1	Hornyhead turbot	Liver	Iron		48	mg/kg	0.0958
SD16	1	Hornyhead turbot	Liver	Lipids		4.91	%wt	0.005
SD16	1	Hornyhead turbot	Liver	Manganese		1.76	mg/kg	0.0071
SD16	1	Hornyhead turbot	Liver	Mercury		0.071	mg/kg	0.03
SD16	1	Hornyhead turbot	Liver	p,p-DDD	E	3.7	ug/kg	
SD16	1	Hornyhead turbot	Liver	p,p-DDE		150	ug/kg	13.3
SD16	1	Hornyhead turbot	Liver	p,-p-DDMU	E	6.1	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 101	E	1.3	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 118	E	3.8	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 138	E	6	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 149	E	1.5	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 153/168	E	9.1	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 170	E	2	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 180	E	5.2	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 183	E	1.5	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 187	E	4.3	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 194	E	1.6	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 99	E	1.6	ug/kg	
SD16	1	Hornyhead turbot	Liver	Selenium		0.578	mg/kg	0.06
SD16	1	Hornyhead turbot	Liver	Silver		0.208	mg/kg	0.0568
SD16	1	Hornyhead turbot	Liver	Tin		0.689	mg/kg	0.24
SD16	1	Hornyhead turbot	Liver	Total DDT		159.8	ug/kg	
SD16	1	Hornyhead turbot	Liver	Total PCB		37.9	ug/kg	
SD16	1	Hornyhead turbot	Liver	Total Solids		23.2	%wt	0.4
SD16	1	Hornyhead turbot	Liver	Zinc		28.9	mg/kg	0.0487
SD16	2	California scorpionfish	Liver	Alpha (cis) Chlordane	E	4.9	ug/kg	
SD16	2	California scorpionfish	Liver	Aluminum		17.2	mg/kg	0.583
SD16	2	California scorpionfish	Liver	Arsenic		1.25	mg/kg	0.375
SD16	2	California scorpionfish	Liver	Barium		0.0571	mg/kg	0.0066

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD16	2	California scorpionfish	Liver	Cadmium		2.26	mg/kg	0.0288
SD16	2	California scorpionfish	Liver	Chromium		0.164	mg/kg	0.0804
SD16	2	California scorpionfish	Liver	Cis Nonachlor	E	3.8	ug/kg	
SD16	2	California scorpionfish	Liver	Copper		20.6	mg/kg	0.0684
SD16	2	California scorpionfish	Liver	Hexachlorobenzene	E	1.9	ug/kg	
SD16	2	California scorpionfish	Liver	Iron		186	mg/kg	0.0958
SD16	2	California scorpionfish	Liver	Lipids		24.4	%wt	0.005
SD16	2	California scorpionfish	Liver	Manganese		0.433	mg/kg	0.0071
SD16	2	California scorpionfish	Liver	Mercury		0.099	mg/kg	0.03
SD16	2	California scorpionfish	Liver	o,p-DDE	E	3	ug/kg	
SD16	2	California scorpionfish	Liver	p,p-DDD	E	10	ug/kg	
SD16	2	California scorpionfish	Liver	p,p-DDE		410	ug/kg	13.3
SD16	2	California scorpionfish	Liver	p,p-DDT	E	6	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 105	E	4.8	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 110	E	5.3	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 118		15	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 123	E	1.9	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 128	E	4.1	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 138		22	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 149	E	7	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 151	E	4	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 153/168		38	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 158	E	2	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 170	E	7.9	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 177	E	4.1	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 180		19	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 183	E	4	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 187		16	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 194	E	4.3	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 201	E	5.3	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 206	E	2.3	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 49	E	2	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 52	E	3.2	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 66	E	2.6	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 70	E	1.1	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 74	E	1.2	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 87	E	1.9	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 99	E	7.7	ug/kg	
SD16	2	California scorpionfish	Liver	Selenium		0.747	mg/kg	0.06
SD16	2	California scorpionfish	Liver	Silver		0.641	mg/kg	0.0568
SD16	2	California scorpionfish	Liver	Tin		0.952	mg/kg	0.24
SD16	2	California scorpionfish	Liver	Total DDT		429	ug/kg	
SD16	2	California scorpionfish	Liver	Total PCB		186.7	ug/kg	
SD16	2	California scorpionfish	Liver	Total Solids		41.7	%wt	0.4
SD16	2	California scorpionfish	Liver	Trans Nonachlor	E	8.3	ug/kg	
SD16	2	California scorpionfish	Liver	Zinc		94.2	mg/kg	0.0487

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD16	3	English sole	Liver	Aluminum		8.62	mg/kg	0.583
SD16	3	English sole	Liver	Arsenic		9.49	mg/kg	0.375
SD16	3	English sole	Liver	Barium		0.0305	mg/kg	0.0066
SD16	3	English sole	Liver	Cadmium		1.17	mg/kg	0.0288
SD16	3	English sole	Liver	Chromium		0.193	mg/kg	0.0804
SD16	3	English sole	Liver	Copper		9.79	mg/kg	0.0684
SD16	3	English sole	Liver	Hexachlorobenzene	E	1.6	ug/kg	
SD16	3	English sole	Liver	Iron		267	mg/kg	0.0958
SD16	3	English sole	Liver	Lead		0.547	mg/kg	0.3
SD16	3	English sole	Liver	Lipids		9.2	%wt	0.005
SD16	3	English sole	Liver	Manganese		0.904	mg/kg	0.0071
SD16	3	English sole	Liver	Mercury		0.071	mg/kg	0.03
SD16	3	English sole	Liver	o,p-DDE		28	ug/kg	13.3
SD16	3	English sole	Liver	p,p-DDD	E	8.4	ug/kg	
SD16	3	English sole	Liver	p,p-DDE		460	ug/kg	13.3
SD16	3	English sole	Liver	p,-p-DDMU		37	ug/kg	13.3
SD16	3	English sole	Liver	p,p-DDT	E	3.8	ug/kg	
SD16	3	English sole	Liver	PCB 101	E	7	ug/kg	
SD16	3	English sole	Liver	PCB 105	E	3.5	ug/kg	
SD16	3	English sole	Liver	PCB 110	E	5.9	ug/kg	
SD16	3	English sole	Liver	PCB 118	E	12	ug/kg	
SD16	3	English sole	Liver	PCB 123	E	1.6	ug/kg	
SD16	3	English sole	Liver	PCB 128	E	2.6	ug/kg	
SD16	3	English sole	Liver	PCB 138	E	13	ug/kg	
SD16	3	English sole	Liver	PCB 149	E	6.6	ug/kg	
SD16	3	English sole	Liver	PCB 151	E	2.4	ug/kg	
SD16	3	English sole	Liver	PCB 153/168		21	ug/kg	13.3
SD16	3	English sole	Liver	PCB 158	E	1.3	ug/kg	
SD16	3	English sole	Liver	PCB 170	E	4.2	ug/kg	
SD16	3	English sole	Liver	PCB 177	E	2.6	ug/kg	
SD16	3	English sole	Liver	PCB 180	E	7.7	ug/kg	
SD16	3	English sole	Liver	PCB 183	E	2.2	ug/kg	
SD16	3	English sole	Liver	PCB 187	E	9.2	ug/kg	
SD16	3	English sole	Liver	PCB 194	E	2.1	ug/kg	
SD16	3	English sole	Liver	PCB 201	E	2.5	ug/kg	
SD16	3	English sole	Liver	PCB 206	E	1.6	ug/kg	
SD16	3	English sole	Liver	PCB 49	E	2.1	ug/kg	
SD16	3	English sole	Liver	PCB 52	E	2	ug/kg	
SD16	3	English sole	Liver	PCB 66	E	3.6	ug/kg	
SD16	3	English sole	Liver	PCB 70	E	1.9	ug/kg	
SD16	3	English sole	Liver	PCB 74	E	1.3	ug/kg	
SD16	3	English sole	Liver	PCB 87	E	1.8	ug/kg	
SD16	3	English sole	Liver	PCB 99	E	6.6	ug/kg	
SD16	3	English sole	Liver	Selenium		1.45	mg/kg	0.06
SD16	3	English sole	Liver	Silver		0.261	mg/kg	0.0568
SD16	3	English sole	Liver	Tin		0.62	mg/kg	0.24

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD16	3	English sole	Liver	Total DDT		537.2	ug/kg	
SD16	3	English sole	Liver	Total PCB		128.3	ug/kg	
SD16	3	English sole	Liver	Total Solids		24	%wt	0.4
SD16	3	English sole	Liver	Zinc		43	mg/kg	0.0487
SD17	1	English sole	Liver	Aluminum		8.7	mg/kg	0.583
SD17	1	English sole	Liver	Arsenic		14.1	mg/kg	0.375
SD17	1	English sole	Liver	Barium		0.0289	mg/kg	0.0066
SD17	1	English sole	Liver	Cadmium		0.938	mg/kg	0.0288
SD17	1	English sole	Liver	Chromium		0.23	mg/kg	0.0804
SD17	1	English sole	Liver	Copper		8.24	mg/kg	0.0684
SD17	1	English sole	Liver	Hexachlorobenzene	E	0.9	ug/kg	
SD17	1	English sole	Liver	Iron		195	mg/kg	0.0958
SD17	1	English sole	Liver	Lead		0.903	mg/kg	0.3
SD17	1	English sole	Liver	Lipids		4.63	%wt	0.005
SD17	1	English sole	Liver	Manganese		1.6	mg/kg	0.0071
SD17	1	English sole	Liver	Mercury		0.0175	mg/kg	0.03
SD17	1	English sole	Liver	o,p-DDE	E	2.7	ug/kg	
SD17	1	English sole	Liver	p,p-DDD	E	1.7	ug/kg	
SD17	1	English sole	Liver	p,p-DDE		84	ug/kg	13.3
SD17	1	English sole	Liver	p,-p-DDMU	E	4.1	ug/kg	
SD17	1	English sole	Liver	PCB 101	E	3.7	ug/kg	
SD17	1	English sole	Liver	PCB 105	E	1.5	ug/kg	
SD17	1	English sole	Liver	PCB 110	E	2.8	ug/kg	
SD17	1	English sole	Liver	PCB 118	E	4.7	ug/kg	
SD17	1	English sole	Liver	PCB 128	E	1.3	ug/kg	
SD17	1	English sole	Liver	PCB 138	E	6.5	ug/kg	
SD17	1	English sole	Liver	PCB 149	E	4.1	ug/kg	
SD17	1	English sole	Liver	PCB 153/168	E	11	ug/kg	
SD17	1	English sole	Liver	PCB 158	E	0.8	ug/kg	
SD17	1	English sole	Liver	PCB 170	E	2.7	ug/kg	
SD17	1	English sole	Liver	PCB 180	E	5.6	ug/kg	
SD17	1	English sole	Liver	PCB 183	E	1.8	ug/kg	
SD17	1	English sole	Liver	PCB 187	E	6.2	ug/kg	
SD17	1	English sole	Liver	PCB 201	E	1.9	ug/kg	
SD17	1	English sole	Liver	PCB 99	E	3.2	ug/kg	
SD17	1	English sole	Liver	Selenium		1.31	mg/kg	0.06
SD17	1	English sole	Liver	Silver		0.228	mg/kg	0.0568
SD17	1	English sole	Liver	Tin		0.554	mg/kg	0.24
SD17	1	English sole	Liver	Total DDT		92.5	ug/kg	
SD17	1	English sole	Liver	Total PCB		57.8	ug/kg	
SD17	1	English sole	Liver	Total Solids		22.3	%wt	0.4
SD17	1	English sole	Liver	Zinc		28.3	mg/kg	0.0487
SD17	2	Hornyhead turbot	Liver	Aluminum		9.18	mg/kg	0.583
SD17	2	Hornyhead turbot	Liver	Arsenic		3.57	mg/kg	0.375
SD17	2	Hornyhead turbot	Liver	Barium		0.031	mg/kg	0.0066
SD17	2	Hornyhead turbot	Liver	Cadmium		4.28	mg/kg	0.0288

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD17	2	Hornyhead turbot	Liver	Chromium		0.176	mg/kg	0.0804
SD17	2	Hornyhead turbot	Liver	Copper		5.3	mg/kg	0.0684
SD17	2	Hornyhead turbot	Liver	Iron		84	mg/kg	0.0958
SD17	2	Hornyhead turbot	Liver	Lipids		5.4	%wt	0.005
SD17	2	Hornyhead turbot	Liver	Manganese		0.984	mg/kg	0.0071
SD17	2	Hornyhead turbot	Liver	Mercury		0.079	mg/kg	0.03
SD17	2	Hornyhead turbot	Liver	o,p-DDE	E	2.3	ug/kg	
SD17	2	Hornyhead turbot	Liver	p,p-DDD	E	3.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	p,p-DDE		160	ug/kg	13.3
SD17	2	Hornyhead turbot	Liver	p,-p-DDMU	E	4.6	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 101	E	1.9	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 118	E	3.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 138	E	5.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 153/168	E	10	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 170	E	2.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 180	E	6.3	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 183	E	1.8	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 187	E	4.5	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 194	E	2.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 201	E	1.8	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 99	E	2.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	Selenium		1.07	mg/kg	0.06
SD17	2	Hornyhead turbot	Liver	Silver		0.219	mg/kg	0.0568
SD17	2	Hornyhead turbot	Liver	Tin		0.585	mg/kg	0.24
SD17	2	Hornyhead turbot	Liver	Total DDT		170	ug/kg	
SD17	2	Hornyhead turbot	Liver	Total PCB		41	ug/kg	
SD17	2	Hornyhead turbot	Liver	Total Solids		24.5	%wt	0.4
SD17	2	Hornyhead turbot	Liver	Zinc		31.7	mg/kg	0.0487
SD17	3	Longfin sanddab	Liver	Alpha (cis) Chlordane	E	5.6	ug/kg	
SD17	3	Longfin sanddab	Liver	Aluminum		16.2	mg/kg	0.583
SD17	3	Longfin sanddab	Liver	Arsenic		22	mg/kg	0.375
SD17	3	Longfin sanddab	Liver	Barium		0.0537	mg/kg	0.0066
SD17	3	Longfin sanddab	Liver	Cadmium		4.39	mg/kg	0.0288
SD17	3	Longfin sanddab	Liver	Chromium		0.235	mg/kg	0.0804
SD17	3	Longfin sanddab	Liver	Cis Nonachlor	E	4.3	ug/kg	
SD17	3	Longfin sanddab	Liver	Copper		13	mg/kg	0.0684
SD17	3	Longfin sanddab	Liver	Hexachlorobenzene	E	1.6	ug/kg	
SD17	3	Longfin sanddab	Liver	Iron		183	mg/kg	0.0958
SD17	3	Longfin sanddab	Liver	Lipids		14.6	%wt	0.005
SD17	3	Longfin sanddab	Liver	Manganese		1.32	mg/kg	0.0071
SD17	3	Longfin sanddab	Liver	Mercury		0.127	mg/kg	0.03
SD17	3	Longfin sanddab	Liver	o,p-DDD	E	2.2	ug/kg	
SD17	3	Longfin sanddab	Liver	o,p-DDE		21	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	o,p-DDT	E	4.8	ug/kg	
SD17	3	Longfin sanddab	Liver	p,p-DDD		21	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	p,p-DDE		1220	ug/kg	13.3

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD17	3	Longfin sanddab	Liver	p,-p-DDMU		19	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	p,p-DDT		18	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	PCB 101	E	9.2	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 105	E	8.2	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 110	E	5.8	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 118		27	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	PCB 123	E	2.8	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 128	E	8.4	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 138		47	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	PCB 149	E	11	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 151	E	8.6	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 153/168		85	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	PCB 156	E	4.6	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 157	E	1.1	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 158	E	3.7	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 167	E	2.9	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 170		16	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	PCB 177	E	8.3	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 180		40	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	PCB 183	E	11	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 187		36	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	PCB 194	E	11	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 201	E	12	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 206	E	4.6	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 49	E	1.3	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 52	E	3.9	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 66	E	3.1	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 70	E	1	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 74	E	2.2	ug/kg	
SD17	3	Longfin sanddab	Liver	PCB 99		18	ug/kg	13.3
SD17	3	Longfin sanddab	Liver	Selenium		1.63	mg/kg	0.06
SD17	3	Longfin sanddab	Liver	Silver		0.591	mg/kg	0.0568
SD17	3	Longfin sanddab	Liver	Tin		0.945	mg/kg	0.24
SD17	3	Longfin sanddab	Liver	Total DDT		1306	ug/kg	
SD17	3	Longfin sanddab	Liver	Total PCB		393.7	ug/kg	
SD17	3	Longfin sanddab	Liver	Total Solids		38.4	%wt	0.4
SD17	3	Longfin sanddab	Liver	Trans Nonachlor	E	8.6	ug/kg	
SD17	3	Longfin sanddab	Liver	Zinc		26.4	mg/kg	0.0487
SD18	1	Hornyhead turbot	Liver	Aluminum		8.94	mg/kg	0.583
SD18	1	Hornyhead turbot	Liver	Arsenic		2.41	mg/kg	0.375
SD18	1	Hornyhead turbot	Liver	Barium		0.0294	mg/kg	0.0066
SD18	1	Hornyhead turbot	Liver	Cadmium		3.08	mg/kg	0.0288
SD18	1	Hornyhead turbot	Liver	Chromium		0.195	mg/kg	0.0804
SD18	1	Hornyhead turbot	Liver	Copper		3.88	mg/kg	0.0684
SD18	1	Hornyhead turbot	Liver	Hexachlorobenzene	E	0.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	Iron		50.6	mg/kg	0.0958

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD18	1	Hornyhead turbot	Liver	Lipids		5.9	%wt	0.005
SD18	1	Hornyhead turbot	Liver	Manganese		1.6	mg/kg	0.0071
SD18	1	Hornyhead turbot	Liver	Mercury		0.042	mg/kg	0.03
SD18	1	Hornyhead turbot	Liver	o,p-DDE	E	3.2	ug/kg	
SD18	1	Hornyhead turbot	Liver	p,p-DDD	E	5.1	ug/kg	
SD18	1	Hornyhead turbot	Liver	p,p-DDE		180	ug/kg	13.3
SD18	1	Hornyhead turbot	Liver	p,-p-DDMU	E	6.4	ug/kg	
SD18	1	Hornyhead turbot	Liver	p,p-DDT	E	3.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 101	E	2.2	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 110	E	1.4	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 118	E	4.3	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 138	E	6.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 149	E	2.4	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 153/168	E	11	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 170	E	2.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 180	E	7	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 187	E	5.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 194	E	1.9	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 201	E	1.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 206	E	1.1	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 66	E	0.8	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 99	E	2.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	Selenium		0.67	mg/kg	0.06
SD18	1	Hornyhead turbot	Liver	Silver		0.2	mg/kg	0.0568
SD18	1	Hornyhead turbot	Liver	Tin		0.57	mg/kg	0.24
SD18	1	Hornyhead turbot	Liver	Total DDT		198.4	ug/kg	
SD18	1	Hornyhead turbot	Liver	Total PCB		51.3	ug/kg	
SD18	1	Hornyhead turbot	Liver	Total Solids		24.5	%wt	0.4
SD18	1	Hornyhead turbot	Liver	Trans Nonachlor	E	3.5	ug/kg	
SD18	1	Hornyhead turbot	Liver	Zinc		28.5	mg/kg	0.0487
SD18	2	California scorpionfish	Liver	Aluminum		12.2	mg/kg	0.583
SD18	2	California scorpionfish	Liver	Arsenic		0.978	mg/kg	0.375
SD18	2	California scorpionfish	Liver	Barium		0.0388	mg/kg	0.0066
SD18	2	California scorpionfish	Liver	Cadmium		2.81	mg/kg	0.0288
SD18	2	California scorpionfish	Liver	Chromium		0.217	mg/kg	0.0804
SD18	2	California scorpionfish	Liver	Copper		25.7	mg/kg	0.0684
SD18	2	California scorpionfish	Liver	Hexachlorobenzene	E	1.2	ug/kg	
SD18	2	California scorpionfish	Liver	Iron		239	mg/kg	0.0958
SD18	2	California scorpionfish	Liver	Lipids		17.5	%wt	0.005
SD18	2	California scorpionfish	Liver	Manganese		0.471	mg/kg	0.0071
SD18	2	California scorpionfish	Liver	Mercury		0.105	mg/kg	0.03
SD18	2	California scorpionfish	Liver	o,p-DDE	E	1.3	ug/kg	
SD18	2	California scorpionfish	Liver	p,p-DDD	E	7.1	ug/kg	
SD18	2	California scorpionfish	Liver	p,p-DDE		310	ug/kg	13.3
SD18	2	California scorpionfish	Liver	p,-p-DDMU	E	3	ug/kg	
SD18	2	California scorpionfish	Liver	p,p-DDT	E	4	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD18	2	California scorpionfish	Liver	PCB 101	E	5.2	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 105	E	4	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 110	E	3.3	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 118	E	12	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 128	E	3.5	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 138		18	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 149	E	4.5	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 151	E	2.9	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 153/168		31	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 158	E	1.4	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 170	E	5.7	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 177	E	3.6	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 180		14	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 183	E	3.7	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 187	E	13	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 194	E	3.6	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 201	E	4.2	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 206	E	2	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 28	E	0.9	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 49	E	1.2	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 52	E	2	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 66	E	1.7	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 74	E	1.1	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 87	E	1.2	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 99	E	6	ug/kg	
SD18	2	California scorpionfish	Liver	Selenium		0.847	mg/kg	0.06
SD18	2	California scorpionfish	Liver	Silver		0.989	mg/kg	0.0568
SD18	2	California scorpionfish	Liver	Tin		0.792	mg/kg	0.24
SD18	2	California scorpionfish	Liver	Total DDT		325.4	ug/kg	
SD18	2	California scorpionfish	Liver	Total PCB		149.7	ug/kg	
SD18	2	California scorpionfish	Liver	Total Solids		34.2	%wt	0.4
SD18	2	California scorpionfish	Liver	Trans Nonachlor	E	4.7	ug/kg	
SD18	2	California scorpionfish	Liver	Zinc		136	mg/kg	0.0487
SD18	3	English sole	Liver	Aluminum		11.3	mg/kg	0.583
SD18	3	English sole	Liver	Arsenic		15.4	mg/kg	0.375
SD18	3	English sole	Liver	Barium		0.0387	mg/kg	0.0066
SD18	3	English sole	Liver	Cadmium		1.21	mg/kg	0.0288
SD18	3	English sole	Liver	Chromium		0.178	mg/kg	0.0804
SD18	3	English sole	Liver	Copper		11.5	mg/kg	0.0684
SD18	3	English sole	Liver	Hexachlorobenzene	E	1.2	ug/kg	
SD18	3	English sole	Liver	Iron		294	mg/kg	0.0958
SD18	3	English sole	Liver	Lead		0.54	mg/kg	0.3
SD18	3	English sole	Liver	Lipids		6.76	%wt	0.005
SD18	3	English sole	Liver	Manganese		1.85	mg/kg	0.0071
SD18	3	English sole	Liver	Mercury		0.081	mg/kg	0.03
SD18	3	English sole	Liver	o,p-DDE		45	ug/kg	13.3

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD18	3	English sole	Liver	p,p-DDD		14	ug/kg	13.3
SD18	3	English sole	Liver	p,p-DDE		1770	ug/kg	13.3
SD18	3	English sole	Liver	p,-p-DDMU		66	ug/kg	13.3
SD18	3	English sole	Liver	p,p-DDT	E	7.1	ug/kg	
SD18	3	English sole	Liver	PCB 101		15	ug/kg	13.3
SD18	3	English sole	Liver	PCB 105	E	7.4	ug/kg	
SD18	3	English sole	Liver	PCB 110	E	8.9	ug/kg	
SD18	3	English sole	Liver	PCB 118		25	ug/kg	13.3
SD18	3	English sole	Liver	PCB 123	E	2.7	ug/kg	
SD18	3	English sole	Liver	PCB 128	E	5.1	ug/kg	
SD18	3	English sole	Liver	PCB 138		26	ug/kg	13.3
SD18	3	English sole	Liver	PCB 149	E	11	ug/kg	
SD18	3	English sole	Liver	PCB 151	E	4.4	ug/kg	
SD18	3	English sole	Liver	PCB 153/168		37	ug/kg	13.3
SD18	3	English sole	Liver	PCB 156	E	4	ug/kg	
SD18	3	English sole	Liver	PCB 158	E	2.7	ug/kg	
SD18	3	English sole	Liver	PCB 170	E	6.6	ug/kg	
SD18	3	English sole	Liver	PCB 177	E	4.3	ug/kg	
SD18	3	English sole	Liver	PCB 180		15	ug/kg	13.3
SD18	3	English sole	Liver	PCB 183	E	3.8	ug/kg	
SD18	3	English sole	Liver	PCB 187		14	ug/kg	13.3
SD18	3	English sole	Liver	PCB 194	E	4.2	ug/kg	
SD18	3	English sole	Liver	PCB 201	E	5	ug/kg	
SD18	3	English sole	Liver	PCB 206	E	2.3	ug/kg	
SD18	3	English sole	Liver	PCB 49	E	3.4	ug/kg	
SD18	3	English sole	Liver	PCB 52	E	2	ug/kg	
SD18	3	English sole	Liver	PCB 66	E	6.3	ug/kg	
SD18	3	English sole	Liver	PCB 70	E	2.7	ug/kg	
SD18	3	English sole	Liver	PCB 74	E	3.5	ug/kg	
SD18	3	English sole	Liver	PCB 87	E	4.3	ug/kg	
SD18	3	English sole	Liver	PCB 99	E	13	ug/kg	
SD18	3	English sole	Liver	Selenium		1.39	mg/kg	0.06
SD18	3	English sole	Liver	Silver		0.28	mg/kg	0.0568
SD18	3	English sole	Liver	Tin		0.66	mg/kg	0.24
SD18	3	English sole	Liver	Total DDT		1902.1	ug/kg	
SD18	3	English sole	Liver	Total PCB		239.6	ug/kg	
SD18	3	English sole	Liver	Total Solids		24.4	%wt	0.4
SD18	3	English sole	Liver	Trans Nonachlor	E	3.5	ug/kg	
SD18	3	English sole	Liver	Zinc		36.4	mg/kg	0.0487
SD19	1	Hornyhead turbot	Liver	Aluminum		10.6	mg/kg	0.583
SD19	1	Hornyhead turbot	Liver	Arsenic		2.41	mg/kg	0.375
SD19	1	Hornyhead turbot	Liver	Barium		0.042	mg/kg	0.0066
SD19	1	Hornyhead turbot	Liver	Cadmium		4.56	mg/kg	0.0288
SD19	1	Hornyhead turbot	Liver	Chromium		0.155	mg/kg	0.0804
SD19	1	Hornyhead turbot	Liver	Copper		3.99	mg/kg	0.0684
SD19	1	Hornyhead turbot	Liver	Hexachlorobenzene	E	0.9	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD19	1	Hornyhead turbot	Liver	Iron		36.8	mg/kg	0.0958
SD19	1	Hornyhead turbot	Liver	Lipids		6.96	%wt	0.005
SD19	1	Hornyhead turbot	Liver	Manganese		1.84	mg/kg	0.0071
SD19	1	Hornyhead turbot	Liver	Mercury		0.103	mg/kg	0.03
SD19	1	Hornyhead turbot	Liver	o,p-DDE	E	3.9	ug/kg	
SD19	1	Hornyhead turbot	Liver	p,p-DDD	E	6	ug/kg	
SD19	1	Hornyhead turbot	Liver	p,p-DDE		250	ug/kg	13.3
SD19	1	Hornyhead turbot	Liver	p,-p-DDMU	E	10	ug/kg	
SD19	1	Hornyhead turbot	Liver	p,p-DDT	E	5.4	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 101	E	2.4	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 118	E	6.6	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 128	E	1.5	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 138	E	11	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 149	E	2.3	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 153/168		19	ug/kg	13.3
SD19	1	Hornyhead turbot	Liver	PCB 158	E	1.4	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 170	E	4.3	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 180	E	10	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 183	E	2.6	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 187	E	7.7	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 194	E	2.9	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 201	E	1.8	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 28	E	1	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 49	E	0.9	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 52	E	1	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 66	E	1.4	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 74	E	1	ug/kg	
SD19	1	Hornyhead turbot	Liver	PCB 99	E	3.9	ug/kg	
SD19	1	Hornyhead turbot	Liver	Selenium		0.676	mg/kg	0.06
SD19	1	Hornyhead turbot	Liver	Silver		0.18	mg/kg	0.0568
SD19	1	Hornyhead turbot	Liver	Tin		0.495	mg/kg	0.24
SD19	1	Hornyhead turbot	Liver	Total DDT		275.3	ug/kg	
SD19	1	Hornyhead turbot	Liver	Total PCB		82.7	ug/kg	
SD19	1	Hornyhead turbot	Liver	Total Solids		24.2	%wt	0.4
SD19	1	Hornyhead turbot	Liver	Zinc		28	mg/kg	0.0487
SD19	2	English sole	Liver	Aluminum		8.85	mg/kg	0.583
SD19	2	English sole	Liver	Arsenic		23.3	mg/kg	0.375
SD19	2	English sole	Liver	Barium		0.0325	mg/kg	0.0066
SD19	2	English sole	Liver	Cadmium		1.32	mg/kg	0.0288
SD19	2	English sole	Liver	Chromium		0.156	mg/kg	0.0804
SD19	2	English sole	Liver	Copper		7.05	mg/kg	0.0684
SD19	2	English sole	Liver	Iron		204	mg/kg	0.0958
SD19	2	English sole	Liver	Lead		0.569	mg/kg	0.3
SD19	2	English sole	Liver	Lipids		5.03	%wt	0.005
SD19	2	English sole	Liver	Manganese		1.59	mg/kg	0.0071
SD19	2	English sole	Liver	Mercury		0.054	mg/kg	0.03

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD19	2	English sole	Liver	o,p-DDE	E	4.4	ug/kg	
SD19	2	English sole	Liver	p,p-DDD	E	1.9	ug/kg	
SD19	2	English sole	Liver	p,p-DDE		83	ug/kg	13.3
SD19	2	English sole	Liver	p,-p-DDMU	E	4.1	ug/kg	
SD19	2	English sole	Liver	PCB 101	E	2	ug/kg	
SD19	2	English sole	Liver	PCB 110	E	1.5	ug/kg	
SD19	2	English sole	Liver	PCB 118	E	3.1	ug/kg	
SD19	2	English sole	Liver	PCB 138	E	3.8	ug/kg	
SD19	2	English sole	Liver	PCB 149	E	2.5	ug/kg	
SD19	2	English sole	Liver	PCB 153/168	E	6.4	ug/kg	
SD19	2	English sole	Liver	PCB 180	E	3.1	ug/kg	
SD19	2	English sole	Liver	PCB 187	E	3.3	ug/kg	
SD19	2	English sole	Liver	PCB 99	E	1.9	ug/kg	
SD19	2	English sole	Liver	Selenium		1.09	mg/kg	0.06
SD19	2	English sole	Liver	Silver		0.197	mg/kg	0.0568
SD19	2	English sole	Liver	Tin		0.565	mg/kg	0.24
SD19	2	English sole	Liver	Total DDT		93.4	ug/kg	
SD19	2	English sole	Liver	Total PCB		27.6	ug/kg	
SD19	2	English sole	Liver	Total Solids		21.7	%wt	0.4
SD19	2	English sole	Liver	Zinc		30	mg/kg	0.0487
SD19	3	Longfin sanddab	Liver	Alpha (cis) Chlordane	E	3.6	ug/kg	
SD19	3	Longfin sanddab	Liver	Aluminum		11.1	mg/kg	0.583
SD19	3	Longfin sanddab	Liver	Arsenic		20.6	mg/kg	0.375
SD19	3	Longfin sanddab	Liver	Barium		0.0336	mg/kg	0.0066
SD19	3	Longfin sanddab	Liver	Cadmium		5.75	mg/kg	0.0288
SD19	3	Longfin sanddab	Liver	Chromium		0.167	mg/kg	0.0804
SD19	3	Longfin sanddab	Liver	Copper		9.87	mg/kg	0.0684
SD19	3	Longfin sanddab	Liver	Hexachlorobenzene	E	1.2	ug/kg	
SD19	3	Longfin sanddab	Liver	Iron		213	mg/kg	0.0958
SD19	3	Longfin sanddab	Liver	Lipids		14	%wt	0.005
SD19	3	Longfin sanddab	Liver	Manganese		1.49	mg/kg	0.0071
SD19	3	Longfin sanddab	Liver	Mercury		0.195	mg/kg	0.03
SD19	3	Longfin sanddab	Liver	o,p-DDE	E	9	ug/kg	
SD19	3	Longfin sanddab	Liver	p,p-DDD	E	6.9	ug/kg	
SD19	3	Longfin sanddab	Liver	p,p-DDE		1330	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	p,-p-DDMU	E	12	ug/kg	
SD19	3	Longfin sanddab	Liver	p,p-DDT		14	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 101		15	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 105		16	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 110	E	11	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 118		67	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 123	E	6	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 128		19	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 138		100	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 149		14	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 151		14	ug/kg	13.3

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD19	3	Longfin sanddab	Liver	PCB 153/168		180	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 156	E	8.7	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 157	E	2.4	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 158	E	8.4	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 167	E	5.1	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 170		29	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 177	E	13	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 180		73	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 183		19	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 187		56	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 194		18	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 201		20	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	PCB 206	E	7.8	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 52	E	5.3	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 66	E	3.9	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 74	E	2.9	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 87	E	3.1	ug/kg	
SD19	3	Longfin sanddab	Liver	PCB 99		38	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	Selenium		1.59	mg/kg	0.06
SD19	3	Longfin sanddab	Liver	Silver		0.372	mg/kg	0.0568
SD19	3	Longfin sanddab	Liver	Tin		0.795	mg/kg	0.24
SD19	3	Longfin sanddab	Liver	Total DDT		1371.9	ug/kg	
SD19	3	Longfin sanddab	Liver	Total PCB		755.6	ug/kg	
SD19	3	Longfin sanddab	Liver	Total Solids		29.7	%wt	0.4
SD19	3	Longfin sanddab	Liver	Trans Nonachlor		15	ug/kg	13.3
SD19	3	Longfin sanddab	Liver	Zinc		28.1	mg/kg	0.0487
SD20	1	California scorpionfish	Liver	Alpha (cis) Chlordane	E	4.7	ug/kg	
SD20	1	California scorpionfish	Liver	Aluminum		18	mg/kg	0.583
SD20	1	California scorpionfish	Liver	Arsenic		1.02	mg/kg	0.375
SD20	1	California scorpionfish	Liver	Barium		0.0539	mg/kg	0.0066
SD20	1	California scorpionfish	Liver	Cadmium		2.3	mg/kg	0.0288
SD20	1	California scorpionfish	Liver	Chromium		0.206	mg/kg	0.0804
SD20	1	California scorpionfish	Liver	Cis Nonachlor	E	6.2	ug/kg	
SD20	1	California scorpionfish	Liver	Copper		9.37	mg/kg	0.0684
SD20	1	California scorpionfish	Liver	Hexachlorobenzene	E	1.2	ug/kg	
SD20	1	California scorpionfish	Liver	Iron		139	mg/kg	0.0958
SD20	1	California scorpionfish	Liver	Lipids		22.3	%wt	0.005
SD20	1	California scorpionfish	Liver	Manganese		0.587	mg/kg	0.0071
SD20	1	California scorpionfish	Liver	Mercury		0.231	mg/kg	0.03
SD20	1	California scorpionfish	Liver	o,p-DDE	E	3.5	ug/kg	
SD20	1	California scorpionfish	Liver	p,p-DDD		15	ug/kg	13.3
SD20	1	California scorpionfish	Liver	p,p-DDE		760	ug/kg	13.3
SD20	1	California scorpionfish	Liver	p,-p-DDMU		19	ug/kg	13.3
SD20	1	California scorpionfish	Liver	p,p-DDT	E	4.7	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 101	E	12	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 105	E	6.8	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD20	1	California scorpionfish	Liver	PCB 110	E	8.1	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 118		24	ug/kg	13.3
SD20	1	California scorpionfish	Liver	PCB 123	E	2.6	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 128	E	6.6	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 138		31	ug/kg	13.3
SD20	1	California scorpionfish	Liver	PCB 149	E	10	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 151	E	6.2	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 153/168		51	ug/kg	13.3
SD20	1	California scorpionfish	Liver	PCB 156	E	4.2	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 158	E	2.7	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 167	E	2	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 170	E	8.7	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 177	E	5.9	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 180		25	ug/kg	13.3
SD20	1	California scorpionfish	Liver	PCB 183	E	6.5	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 187		22	ug/kg	13.3
SD20	1	California scorpionfish	Liver	PCB 194	E	5.6	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 201	E	6.9	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 206	E	3	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 49	E	1.9	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 52	E	3.3	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 66	E	3.9	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 70	E	1.1	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 74	E	2	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 87	E	3.5	ug/kg	
SD20	1	California scorpionfish	Liver	PCB 99	E	12	ug/kg	
SD20	1	California scorpionfish	Liver	Selenium		0.687	mg/kg	0.06
SD20	1	California scorpionfish	Liver	Silver		0.354	mg/kg	0.0568
SD20	1	California scorpionfish	Liver	Tin		1.09	mg/kg	0.24
SD20	1	California scorpionfish	Liver	Total DDT		802.2	ug/kg	
SD20	1	California scorpionfish	Liver	Total PCB		278.5	ug/kg	
SD20	1	California scorpionfish	Liver	Total Solids		41.3	%wt	0.4
SD20	1	California scorpionfish	Liver	Trans Nonachlor	E	9.4	ug/kg	
SD20	1	California scorpionfish	Liver	Zinc		158	mg/kg	0.0487
SD20	2	Hornyhead turbot	Liver	Aluminum		11.8	mg/kg	0.583
SD20	2	Hornyhead turbot	Liver	Arsenic		2.12	mg/kg	0.375
SD20	2	Hornyhead turbot	Liver	Barium		0.0418	mg/kg	0.0066
SD20	2	Hornyhead turbot	Liver	Cadmium		6.18	mg/kg	0.0288
SD20	2	Hornyhead turbot	Liver	Chromium		0.184	mg/kg	0.0804
SD20	2	Hornyhead turbot	Liver	Copper		5.1	mg/kg	0.0684
SD20	2	Hornyhead turbot	Liver	Iron		56.6	mg/kg	0.0958
SD20	2	Hornyhead turbot	Liver	Lipids		6.23	%wt	0.005
SD20	2	Hornyhead turbot	Liver	Manganese		1.3	mg/kg	0.0071
SD20	2	Hornyhead turbot	Liver	Mercury		0.145	mg/kg	0.03
SD20	2	Hornyhead turbot	Liver	o,p-DDE	E	3	ug/kg	
SD20	2	Hornyhead turbot	Liver	p,p-DDD	E	4.3	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD20	2	Hornyhead turbot	Liver	p,p-DDE		150	ug/kg	13.3
SD20	2	Hornyhead turbot	Liver	p,-p-DDMU	E	5.3	ug/kg	
SD20	2	Hornyhead turbot	Liver	p,p-DDT	E	4.1	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 101	E	3.3	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 105	E	1.4	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 110	E	2.2	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 118	E	6.2	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 128	E	1.8	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 138	E	8.5	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 149	E	3	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 153/168		15	ug/kg	13.3
SD20	2	Hornyhead turbot	Liver	PCB 170	E	3.1	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 177	E	1.1	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 180	E	8.2	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 183	E	2.5	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 187	E	7.4	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 194	E	2.4	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 201	E	2.2	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 206	E	1.6	ug/kg	13.3
SD20	2	Hornyhead turbot	Liver	PCB 66	E	1	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 74	E	0.7	ug/kg	
SD20	2	Hornyhead turbot	Liver	PCB 99	E	3.3	ug/kg	
SD20	2	Hornyhead turbot	Liver	Selenium		0.578	mg/kg	0.06
SD20	2	Hornyhead turbot	Liver	Silver		0.22	mg/kg	0.0568
SD20	2	Hornyhead turbot	Liver	Tin		0.523	mg/kg	0.24
SD20	2	Hornyhead turbot	Liver	Total DDT		166.7	ug/kg	
SD20	2	Hornyhead turbot	Liver	Total PCB		74.9	ug/kg	
SD20	2	Hornyhead turbot	Liver	Total Solids		24.1	%wt	0.4
SD20	2	Hornyhead turbot	Liver	Trans Nonachlor	E	3	ug/kg	
SD20	2	Hornyhead turbot	Liver	Zinc		34.7	mg/kg	0.0487
SD20	3	English sole	Liver	Aluminum		8.57	mg/kg	0.583
SD20	3	English sole	Liver	Arsenic		13.3	mg/kg	0.375
SD20	3	English sole	Liver	Barium		0.0299	mg/kg	0.0066
SD20	3	English sole	Liver	Cadmium		0.846	mg/kg	0.0288
SD20	3	English sole	Liver	Chromium		0.202	mg/kg	0.0804
SD20	3	English sole	Liver	Copper		3.86	mg/kg	0.0684
SD20	3	English sole	Liver	Iron		156	mg/kg	0.0958
SD20	3	English sole	Liver	Lead		0.944	mg/kg	0.3
SD20	3	English sole	Liver	Lipids		4.61	%wt	0.005
SD20	3	English sole	Liver	Manganese		2.01	mg/kg	0.0071
SD20	3	English sole	Liver	Mercury		0.067	mg/kg	0.03
SD20	3	English sole	Liver	o,p-DDE		19	ug/kg	13.3
SD20	3	English sole	Liver	p,p-DDD	E	6.5	ug/kg	
SD20	3	English sole	Liver	p,p-DDE		350	ug/kg	13.3
SD20	3	English sole	Liver	p,-p-DDMU		22	ug/kg	13.3
SD20	3	English sole	Liver	PCB 101	E	4.8	ug/kg	

Appendix D.3
Summary of all parameters detected in each sample collected as part of the SBOO monitoring program during April 2005.

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD20	3	English sole	Liver	PCB 105	E	1.9	ug/kg	
SD20	3	English sole	Liver	PCB 110	E	3.6	ug/kg	
SD20	3	English sole	Liver	PCB 118	E	8.7	ug/kg	
SD20	3	English sole	Liver	PCB 128	E	1.2	ug/kg	
SD20	3	English sole	Liver	PCB 138	E	9.5	ug/kg	
SD20	3	English sole	Liver	PCB 149	E	5.2	ug/kg	
SD20	3	English sole	Liver	PCB 153/168		16	ug/kg	13.3
SD20	3	English sole	Liver	PCB 156	E	1.5	ug/kg	
SD20	3	English sole	Liver	PCB 170	E	2.5	ug/kg	
SD20	3	English sole	Liver	PCB 180	E	6.6	ug/kg	
SD20	3	English sole	Liver	PCB 183	E	1.9	ug/kg	
SD20	3	English sole	Liver	PCB 187	E	7.8	ug/kg	
SD20	3	English sole	Liver	PCB 194	E	2.2	ug/kg	
SD20	3	English sole	Liver	PCB 201	E	2.8	ug/kg	
SD20	3	English sole	Liver	PCB 206	E	1.4	ug/kg	
SD20	3	English sole	Liver	PCB 66	E	2	ug/kg	
SD20	3	English sole	Liver	PCB 70	E	1.1	ug/kg	
SD20	3	English sole	Liver	PCB 74	E	0.9	ug/kg	
SD20	3	English sole	Liver	PCB 99	E	4.5	ug/kg	
SD20	3	English sole	Liver	Selenium		1.53	mg/kg	0.06
SD20	3	English sole	Liver	Silver		0.163	mg/kg	0.0568
SD20	3	English sole	Liver	Tin		0.533	mg/kg	0.24
SD20	3	English sole	Liver	Total DDT		397.5	ug/kg	
SD20	3	English sole	Liver	Total PCB		86.1	ug/kg	
SD20	3	English sole	Liver	Total Solids		21.2	%wt	0.4
SD20	3	English sole	Liver	Zinc		33.2	mg/kg	0.0487
SD21	1	Longfin sanddab	Liver	Alpha (cis) Chlordane		5.15	ug/kg	
SD21	1	Longfin sanddab	Liver	Aluminum		15.4	mg/kg	0.583
SD21	1	Longfin sanddab	Liver	Arsenic		8.92	mg/kg	0.375
SD21	1	Longfin sanddab	Liver	Barium		0.053	mg/kg	0.0066
SD21	1	Longfin sanddab	Liver	Cadmium		3.07	mg/kg	0.0288
SD21	1	Longfin sanddab	Liver	Chromium		0.269	mg/kg	0.0804
SD21	1	Longfin sanddab	Liver	Cis Nonachlor	E	4.3	ug/kg	
SD21	1	Longfin sanddab	Liver	Copper		8.49	mg/kg	0.0684
SD21	1	Longfin sanddab	Liver	Hexachlorobenzene		1.5	ug/kg	
SD21	1	Longfin sanddab	Liver	Iron		149	mg/kg	0.0958
SD21	1	Longfin sanddab	Liver	Lipids		15.9	%wt	0.005
SD21	1	Longfin sanddab	Liver	Manganese		2.13	mg/kg	0.0071
SD21	1	Longfin sanddab	Liver	Mercury		0.161	mg/kg	0.03
SD21	1	Longfin sanddab	Liver	o,p-DDD		1.35	ug/kg	
SD21	1	Longfin sanddab	Liver	o,p-DDE		9.25	ug/kg	
SD21	1	Longfin sanddab	Liver	p,p-DDD		7.85	ug/kg	
SD21	1	Longfin sanddab	Liver	p,p-DDE		605	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	p,-p-DDMU		13.5	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	p,p-DDT		31	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 101		10.5	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD21	1	Longfin sanddab	Liver	PCB 105	E	11	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 110		9.6	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 118		47	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 123		4.75	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 128		13.5	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 138		74.5	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 149		12.5	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 151		9.75	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 153/168		125	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 156	E	7	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 157		1.9	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 158		6.1	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 167		4.5	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 170		23.5	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 177	E	11	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 180		56	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 183		16	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 187		50	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 194		16.5	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 201		18.5	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	PCB 206		8.9	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 28		1.55	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 49		1.55	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 52		4.2	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 66		4.6	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 70		1.05	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 74		3.05	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 87	E	2.4	ug/kg	
SD21	1	Longfin sanddab	Liver	PCB 99		26.5	ug/kg	13.3
SD21	1	Longfin sanddab	Liver	Selenium		1.41	mg/kg	0.06
SD21	1	Longfin sanddab	Liver	Silver		0.349	mg/kg	0.0568
SD21	1	Longfin sanddab	Liver	Tin		0.867	mg/kg	0.24
SD21	1	Longfin sanddab	Liver	Total DDT		667.95	ug/kg	
SD21	1	Longfin sanddab	Liver	Total PCB		582.9	ug/kg	
SD21	1	Longfin sanddab	Liver	Total Solids		32.8	%wt	0.4
SD21	1	Longfin sanddab	Liver	Trans Nonachlor		6.55	ug/kg	
SD21	1	Longfin sanddab	Liver	Zinc		25.7	mg/kg	0.0487
SD21	2	Hornyhead turbot	Liver	Aluminum		10.2	mg/kg	0.583
SD21	2	Hornyhead turbot	Liver	Arsenic		2.35	mg/kg	0.375
SD21	2	Hornyhead turbot	Liver	Barium		0.0356	mg/kg	0.0066
SD21	2	Hornyhead turbot	Liver	Cadmium		4.3	mg/kg	0.0288
SD21	2	Hornyhead turbot	Liver	Chromium		0.332	mg/kg	0.0804
SD21	2	Hornyhead turbot	Liver	Copper		4.34	mg/kg	0.0684
SD21	2	Hornyhead turbot	Liver	Iron		42.5	mg/kg	0.0958
SD21	2	Hornyhead turbot	Liver	Lipids		6.34	%wt	0.005
SD21	2	Hornyhead turbot	Liver	Manganese		2.02	mg/kg	0.0071

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD21	2	Hornyhead turbot	Liver	Mercury		0.127	mg/kg	0.03
SD21	2	Hornyhead turbot	Liver	Nickel		0.132	mg/kg	0.0939
SD21	2	Hornyhead turbot	Liver	o,p-DDE	E	9.3	ug/kg	
SD21	2	Hornyhead turbot	Liver	p,p-DDD	E	6.5	ug/kg	
SD21	2	Hornyhead turbot	Liver	p,p-DDE		310	ug/kg	13.3
SD21	2	Hornyhead turbot	Liver	p,-p-DDMU	E	8	ug/kg	
SD21	2	Hornyhead turbot	Liver	p,p-DDT	E	5.6	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 101	E	2.7	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 105	E	1.7	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 110	E	1.6	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 118	E	7.7	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 128	E	1.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 138	E	11	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 149	E	3.7	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 153/168		20	ug/kg	13.3
SD21	2	Hornyhead turbot	Liver	PCB 156	E	1.3	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 170	E	3.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 177	E	1.3	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 180	E	8.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 183	E	3.5	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 187	E	10	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 194	E	2.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 201	E	2.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 206	E	1.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 66	E	1.2	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 74	E	0.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	PCB 99	E	4.5	ug/kg	
SD21	2	Hornyhead turbot	Liver	Selenium		0.47	mg/kg	0.06
SD21	2	Hornyhead turbot	Liver	Silver		0.186	mg/kg	0.0568
SD21	2	Hornyhead turbot	Liver	Tin		0.576	mg/kg	0.24
SD21	2	Hornyhead turbot	Liver	Total DDT		339.4	ug/kg	
SD21	2	Hornyhead turbot	Liver	Total PCB		92.8	ug/kg	
SD21	2	Hornyhead turbot	Liver	Total Solids		23.4	%wt	0.4
SD21	2	Hornyhead turbot	Liver	Zinc		31.9	mg/kg	0.0487
SD21	3	English sole	Liver	Aluminum		9.18	mg/kg	0.583
SD21	3	English sole	Liver	Arsenic		10.9	mg/kg	0.375
SD21	3	English sole	Liver	Barium		0.0334	mg/kg	0.0066
SD21	3	English sole	Liver	Cadmium		0.861	mg/kg	0.0288
SD21	3	English sole	Liver	Chromium		0.177	mg/kg	0.0804
SD21	3	English sole	Liver	Copper		10.6	mg/kg	0.0684
SD21	3	English sole	Liver	Hexachlorobenzene	E	0.7	ug/kg	
SD21	3	English sole	Liver	Iron		132	mg/kg	0.0958
SD21	3	English sole	Liver	Lead		0.43	mg/kg	0.3
SD21	3	English sole	Liver	Lipids		5.6	%wt	0.005
SD21	3	English sole	Liver	Manganese		1.7	mg/kg	0.0071
SD21	3	English sole	Liver	Mercury		0.055	mg/kg	0.03

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD21	3	English sole	Liver	o,p-DDE	E	2.9	ug/kg	
SD21	3	English sole	Liver	p,p-DDD	E	2.9	ug/kg	
SD21	3	English sole	Liver	p,p-DDE		100	ug/kg	13.3
SD21	3	English sole	Liver	p,-p-DDMU	E	4.1	ug/kg	
SD21	3	English sole	Liver	PCB 101	E	4.4	ug/kg	
SD21	3	English sole	Liver	PCB 105	E	1.9	ug/kg	
SD21	3	English sole	Liver	PCB 110	E	3.6	ug/kg	
SD21	3	English sole	Liver	PCB 118	E	8	ug/kg	
SD21	3	English sole	Liver	PCB 128	E	1.3	ug/kg	
SD21	3	English sole	Liver	PCB 138	E	9.8	ug/kg	
SD21	3	English sole	Liver	PCB 149	E	5.2	ug/kg	
SD21	3	English sole	Liver	PCB 153/168		17	ug/kg	13.3
SD21	3	English sole	Liver	PCB 158	E	1.4	ug/kg	
SD21	3	English sole	Liver	PCB 170	E	3.4	ug/kg	
SD21	3	English sole	Liver	PCB 177	E	2.6	ug/kg	
SD21	3	English sole	Liver	PCB 180	E	7	ug/kg	
SD21	3	English sole	Liver	PCB 183	E	2	ug/kg	
SD21	3	English sole	Liver	PCB 187	E	7.6	ug/kg	
SD21	3	English sole	Liver	PCB 194	E	2.1	ug/kg	
SD21	3	English sole	Liver	PCB 201	E	2.8	ug/kg	
SD21	3	English sole	Liver	PCB 206	E	1.6	ug/kg	
SD21	3	English sole	Liver	PCB 49	E	1.3	ug/kg	
SD21	3	English sole	Liver	PCB 52	E	1.2	ug/kg	
SD21	3	English sole	Liver	PCB 66	E	1.3	ug/kg	
SD21	3	English sole	Liver	PCB 70	E	0.9	ug/kg	
SD21	3	English sole	Liver	PCB 99	E	3.9	ug/kg	
SD21	3	English sole	Liver	Selenium		1.18	mg/kg	0.06
SD21	3	English sole	Liver	Silver		0.311	mg/kg	0.0568
SD21	3	English sole	Liver	Tin		0.463	mg/kg	0.24
SD21	3	English sole	Liver	Total DDT		109.9	ug/kg	
SD21	3	English sole	Liver	Total PCB		90.3	ug/kg	
SD21	3	English sole	Liver	Total Solids		22	%wt	0.4
SD21	3	English sole	Liver	Zinc		36.6	mg/kg	0.0487

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF3	1	Brown rockfish	Muscle	Aluminum		0.94	mg/kg	0.583
RF3	1	Brown rockfish	Muscle	Arsenic		2.22	mg/kg	0.375
RF3	1	Brown rockfish	Muscle	BHC, Gamma isomer	E	0.7	ug/kg	
RF3	1	Brown rockfish	Muscle	Chromium		0.141	mg/kg	0.0804
RF3	1	Brown rockfish	Muscle	Copper		1.4	mg/kg	0.0684
RF3	1	Brown rockfish	Muscle	Iron		1.02	mg/kg	0.0958
RF3	1	Brown rockfish	Muscle	Lead		0.32	mg/kg	0.3
RF3	1	Brown rockfish	Muscle	Lipids		0.24	%wt	0.005
RF3	1	Brown rockfish	Muscle	Manganese		0.071	mg/kg	0.00712
RF3	1	Brown rockfish	Muscle	Mercury		0.043	mg/kg	0.03
RF3	1	Brown rockfish	Muscle	p,p-DDE	E	1	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 118	E	0.1	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 138	E	0.1	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 153/168	E	0.2	ug/kg	
RF3	1	Brown rockfish	Muscle	PCB 180	E	0.1	ug/kg	
RF3	1	Brown rockfish	Muscle	Selenium		0.245	mg/kg	0.06
RF3	1	Brown rockfish	Muscle	Thallium		2.68	mg/kg	0.845
RF3	1	Brown rockfish	Muscle	Total DDT		1	ug/kg	
RF3	1	Brown rockfish	Muscle	Total PCB		0.5	ug/kg	
RF3	1	Brown rockfish	Muscle	Total Solids		20.8	%wt	0.4
RF3	1	Brown rockfish	Muscle	Zinc		3.14	mg/kg	0.0487
RF3	2	Vermilion rockfish	Muscle	Arsenic		2.88	mg/kg	0.375
RF3	2	Vermilion rockfish	Muscle	Barium		0.004	mg/kg	0.00661
RF3	2	Vermilion rockfish	Muscle	Chromium		0.81	mg/kg	0.0804
RF3	2	Vermilion rockfish	Muscle	Copper		0.73	mg/kg	0.0684
RF3	2	Vermilion rockfish	Muscle	Iron		5.02	mg/kg	0.0958
RF3	2	Vermilion rockfish	Muscle	Lipids		0.47	%wt	0.005
RF3	2	Vermilion rockfish	Muscle	Manganese		0.146	mg/kg	0.00712
RF3	2	Vermilion rockfish	Muscle	Mercury		0.058	mg/kg	0.03
RF3	2	Vermilion rockfish	Muscle	Nickel		0.73	mg/kg	0.0939
RF3	2	Vermilion rockfish	Muscle	p,p-DDD	E	0.1	ug/kg	
RF3	2	Vermilion rockfish	Muscle	p,p-DDE	E	1.2	ug/kg	
RF3	2	Vermilion rockfish	Muscle	PCB 118	E	0.1	ug/kg	
RF3	2	Vermilion rockfish	Muscle	PCB 149	E	0.1	ug/kg	
RF3	2	Vermilion rockfish	Muscle	PCB 153/168	E	0.1	ug/kg	
RF3	2	Vermilion rockfish	Muscle	PCB 180	E	0.1	ug/kg	
RF3	2	Vermilion rockfish	Muscle	Selenium		0.293	mg/kg	0.06
RF3	2	Vermilion rockfish	Muscle	Thallium		2.87	mg/kg	0.845
RF3	2	Vermilion rockfish	Muscle	Total DDT		1.3	ug/kg	
RF3	2	Vermilion rockfish	Muscle	Total PCB		0.4	ug/kg	
RF3	2	Vermilion rockfish	Muscle	Total Solids		21.8	%wt	0.4
RF3	2	Vermilion rockfish	Muscle	Zinc		3.29	mg/kg	0.0487
RF3	3	Vermilion rockfish	Muscle	Aluminum		4.17	mg/kg	0.583
RF3	3	Vermilion rockfish	Muscle	Antimony		0.49	mg/kg	0.478
RF3	3	Vermilion rockfish	Muscle	Arsenic		2.73	mg/kg	0.375
RF3	3	Vermilion rockfish	Muscle	Barium		0.0101	mg/kg	0.00661

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF3	3	Vermilion rockfish	Muscle	Copper		0.266	mg/kg	0.0684
RF3	3	Vermilion rockfish	Muscle	Hexachlorobenzene	E	0.1	ug/kg	
RF3	3	Vermilion rockfish	Muscle	Iron		1.21	mg/kg	0.0958
RF3	3	Vermilion rockfish	Muscle	Lead		0.44	mg/kg	0.3
RF3	3	Vermilion rockfish	Muscle	Lipids		1.63	%wt	0.005
RF3	3	Vermilion rockfish	Muscle	Manganese		0.101	mg/kg	0.00712
RF3	3	Vermilion rockfish	Muscle	Mercury		0.054	mg/kg	0.03
RF3	3	Vermilion rockfish	Muscle	p,p-DDD	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	p,p-DDE		4.3	ug/kg	1.33
RF3	3	Vermilion rockfish	Muscle	p,-p-DDMU	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 101	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 105	E	0.1	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 118	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 138	E	0.3	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 149	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 151	E	0.1	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 153/168	E	0.4	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 180	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 187	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	PCB 99	E	0.1	ug/kg	
RF3	3	Vermilion rockfish	Muscle	Selenium		0.275	mg/kg	0.06
RF3	3	Vermilion rockfish	Muscle	Thallium		2.87	mg/kg	0.845
RF3	3	Vermilion rockfish	Muscle	Total DDT		4.7	ug/kg	
RF3	3	Vermilion rockfish	Muscle	Total PCB		2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	Total Solids		20.8	%wt	0.4
RF3	3	Vermilion rockfish	Muscle	Trans Nonachlor	E	0.2	ug/kg	
RF3	3	Vermilion rockfish	Muscle	Zinc		3.01	mg/kg	0.0487
RF4	1	California scorpionfish	Muscle	Aluminum		4.79	mg/kg	0.583
RF4	1	California scorpionfish	Muscle	Arsenic		4.83	mg/kg	0.375
RF4	1	California scorpionfish	Muscle	Barium		0.0205	mg/kg	0.00661
RF4	1	California scorpionfish	Muscle	Copper		1.39	mg/kg	0.0684
RF4	1	California scorpionfish	Muscle	Iron		2.22	mg/kg	0.0958
RF4	1	California scorpionfish	Muscle	Lead		0.38	mg/kg	0.3
RF4	1	California scorpionfish	Muscle	Lipids		0.62	%wt	0.005
RF4	1	California scorpionfish	Muscle	Manganese		0.0459	mg/kg	0.00712
RF4	1	California scorpionfish	Muscle	Mercury		0.197	mg/kg	0.03
RF4	1	California scorpionfish	Muscle	p,p-DDE		3	ug/kg	1.33
RF4	1	California scorpionfish	Muscle	PCB 118	E	0.1	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 138	E	0.1	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 153/168	E	0.2	ug/kg	
RF4	1	California scorpionfish	Muscle	PCB 180	E	0.1	ug/kg	
RF4	1	California scorpionfish	Muscle	Selenium		0.185	mg/kg	0.06
RF4	1	California scorpionfish	Muscle	Thallium		2.71	mg/kg	0.845
RF4	1	California scorpionfish	Muscle	Total DDT		3	ug/kg	
RF4	1	California scorpionfish	Muscle	Total PCB		0.5	ug/kg	
RF4	1	California scorpionfish	Muscle	Total Solids		21.7	%wt	0.4

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF4	1	California scorpionfish	Muscle	Zinc		2.74	mg/kg	0.0487
RF4	2	California scorpionfish	Muscle	Arsenic		4.47	mg/kg	0.375
RF4	2	California scorpionfish	Muscle	Barium		0.0147	mg/kg	0.00661
RF4	2	California scorpionfish	Muscle	Chromium		0.131	mg/kg	0.0804
RF4	2	California scorpionfish	Muscle	Copper		1.1	mg/kg	0.0684
RF4	2	California scorpionfish	Muscle	Iron		3.88	mg/kg	0.0958
RF4	2	California scorpionfish	Muscle	Lead		0.355	mg/kg	0.3
RF4	2	California scorpionfish	Muscle	Lipids		0.24	%wt	0.005
RF4	2	California scorpionfish	Muscle	Manganese		0.0804	mg/kg	0.00712
RF4	2	California scorpionfish	Muscle	Mercury		0.172	mg/kg	0.03
RF4	2	California scorpionfish	Muscle	Nickel		0.0495	mg/kg	0.0939
RF4	2	California scorpionfish	Muscle	p,p-DDE		5.1	ug/kg	1.33
RF4	2	California scorpionfish	Muscle	p,-p-DDMU	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 101	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 105	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 110	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 118	E	0.2	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 138		0.25	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 153/168	E	0.4	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 170		0.05	ug/kg	1.33
RF4	2	California scorpionfish	Muscle	PCB 180	E	0.2	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 183	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 187		0.15	ug/kg	
RF4	2	California scorpionfish	Muscle	PCB 99	E	0.1	ug/kg	
RF4	2	California scorpionfish	Muscle	Selenium		0.227	mg/kg	0.06
RF4	2	California scorpionfish	Muscle	Thallium		2.54	mg/kg	0.845
RF4	2	California scorpionfish	Muscle	Total DDT		5.2	ug/kg	
RF4	2	California scorpionfish	Muscle	Total PCB		1.75	ug/kg	
RF4	2	California scorpionfish	Muscle	Total Solids		20.7	%wt	0.4
RF4	2	California scorpionfish	Muscle	Zinc		3.19	mg/kg	0.0487
RF4	3	California scorpionfish	Muscle	Aluminum		1.97	mg/kg	0.583
RF4	3	California scorpionfish	Muscle	Arsenic		3.43	mg/kg	0.375
RF4	3	California scorpionfish	Muscle	Barium		0.0467	mg/kg	0.00661
RF4	3	California scorpionfish	Muscle	Copper		0.532	mg/kg	0.0684
RF4	3	California scorpionfish	Muscle	Iron		3.13	mg/kg	0.0958
RF4	3	California scorpionfish	Muscle	Lead		0.3	mg/kg	0.3
RF4	3	California scorpionfish	Muscle	Lipids		0.32	%wt	0.005
RF4	3	California scorpionfish	Muscle	Manganese		0.0595	mg/kg	0.00712
RF4	3	California scorpionfish	Muscle	Mercury		0.843	mg/kg	0.03
RF4	3	California scorpionfish	Muscle	p,p-DDE		3.1	ug/kg	1.33
RF4	3	California scorpionfish	Muscle	PCB 118	E	0.1	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 138	E	0.1	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 153/168	E	0.2	ug/kg	
RF4	3	California scorpionfish	Muscle	PCB 180	E	0.1	ug/kg	
RF4	3	California scorpionfish	Muscle	Selenium		0.257	mg/kg	0.06
RF4	3	California scorpionfish	Muscle	Thallium		2.74	mg/kg	0.845

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
RF4	3	California scorpionfish	Muscle	Total DDT		3.1	ug/kg	
RF4	3	California scorpionfish	Muscle	Total PCB		0.5	ug/kg	
RF4	3	California scorpionfish	Muscle	Total Solids		22	%wt	0.4
RF4	3	California scorpionfish	Muscle	Zinc		3.57	mg/kg	0.0487
SD15	1	California scorpionfish	Liver	Alpha (cis) Chlordane	E	3	ug/kg	
SD15	1	California scorpionfish	Liver	Aluminum		3.24	mg/kg	0.583
SD15	1	California scorpionfish	Liver	Antimony		0.69	mg/kg	0.478
SD15	1	California scorpionfish	Liver	Arsenic		3.13	mg/kg	0.375
SD15	1	California scorpionfish	Liver	Barium		0.0137	mg/kg	0.00661
SD15	1	California scorpionfish	Liver	Cadmium		0.64	mg/kg	0.0288
SD15	1	California scorpionfish	Liver	Chromium		0.166	mg/kg	0.0804
SD15	1	California scorpionfish	Liver	Cis Nonachlor	E	3.6	ug/kg	
SD15	1	California scorpionfish	Liver	Copper		9.41	mg/kg	0.0684
SD15	1	California scorpionfish	Liver	Hexachlorobenzene	E	1.1	ug/kg	
SD15	1	California scorpionfish	Liver	Iron		83.6	mg/kg	0.0958
SD15	1	California scorpionfish	Liver	Lead		0.55	mg/kg	0.3
SD15	1	California scorpionfish	Liver	Lipids		19.5	%wt	0.005
SD15	1	California scorpionfish	Liver	Manganese		0.297	mg/kg	0.00712
SD15	1	California scorpionfish	Liver	Mercury		0.06	mg/kg	0.03
SD15	1	California scorpionfish	Liver	Nickel		0.169	mg/kg	0.0939
SD15	1	California scorpionfish	Liver	o,p-DDE	E	1	ug/kg	
SD15	1	California scorpionfish	Liver	p,p-DDD	E	5.6	ug/kg	
SD15	1	California scorpionfish	Liver	p,p-DDE		190	ug/kg	13.3
SD15	1	California scorpionfish	Liver	p,-p-DDMU	E	3.6	ug/kg	
SD15	1	California scorpionfish	Liver	p,p-DDT	E	3.8	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 101	E	13	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 105	E	8.3	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 110	E	6.9	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 118		27	ug/kg	13.3
SD15	1	California scorpionfish	Liver	PCB 123	E	2.8	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 128	E	8	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 138		36	ug/kg	13.3
SD15	1	California scorpionfish	Liver	PCB 149	E	6.5	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 151	E	5.7	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 153/168		66	ug/kg	13.3
SD15	1	California scorpionfish	Liver	PCB 158	E	3.6	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 167	E	2.6	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 170	E	9.3	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 177	E	7.5	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 180		25	ug/kg	13.3
SD15	1	California scorpionfish	Liver	PCB 183	E	7.6	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 187		24	ug/kg	13.3
SD15	1	California scorpionfish	Liver	PCB 194	E	5	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 201	E	5.7	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 206	E	2.5	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 49	E	1.7	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD15	1	California scorpionfish	Liver	PCB 52	E	2.6	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 66	E	3.4	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 74	E	1.8	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 87	E	2.8	ug/kg	
SD15	1	California scorpionfish	Liver	PCB 99		16	ug/kg	13.3
SD15	1	California scorpionfish	Liver	Selenium		0.549	mg/kg	0.06
SD15	1	California scorpionfish	Liver	Thallium		4.12	mg/kg	0.845
SD15	1	California scorpionfish	Liver	Total DDT		204	ug/kg	
SD15	1	California scorpionfish	Liver	Total PCB		301.3	ug/kg	
SD15	1	California scorpionfish	Liver	Total Solids		38.3	%wt	0.4
SD15	1	California scorpionfish	Liver	Trans Nonachlor	E	7.1	ug/kg	
SD15	1	California scorpionfish	Liver	Zinc		54.9	mg/kg	0.0487
SD15	2	California scorpionfish	Liver	Alpha (cis) Chlordane	E	3.9	ug/kg	
SD15	2	California scorpionfish	Liver	Antimony		0.81	mg/kg	0.478
SD15	2	California scorpionfish	Liver	Arsenic		3.52	mg/kg	0.375
SD15	2	California scorpionfish	Liver	Barium		0.0228	mg/kg	0.00661
SD15	2	California scorpionfish	Liver	Cadmium		0.807	mg/kg	0.0288
SD15	2	California scorpionfish	Liver	Chromium		0.278	mg/kg	0.0804
SD15	2	California scorpionfish	Liver	Copper		10.4	mg/kg	0.0684
SD15	2	California scorpionfish	Liver	Hexachlorobenzene	E	1	ug/kg	
SD15	2	California scorpionfish	Liver	Iron		105	mg/kg	0.0958
SD15	2	California scorpionfish	Liver	Lead		0.41	mg/kg	0.3
SD15	2	California scorpionfish	Liver	Lipids		21.4	%wt	0.005
SD15	2	California scorpionfish	Liver	Manganese		0.489	mg/kg	0.00712
SD15	2	California scorpionfish	Liver	Mercury		0.056	mg/kg	0.03
SD15	2	California scorpionfish	Liver	Nickel		0.125	mg/kg	0.0939
SD15	2	California scorpionfish	Liver	o,p-DDE	E	1.6	ug/kg	
SD15	2	California scorpionfish	Liver	p,p-DDD	E	6.8	ug/kg	
SD15	2	California scorpionfish	Liver	p,p-DDE		230	ug/kg	13.3
SD15	2	California scorpionfish	Liver	p,-p-DDMU	E	6.5	ug/kg	
SD15	2	California scorpionfish	Liver	p,p-DDT	E	5.4	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 101	E	5.8	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 105	E	3.5	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 110	E	3.7	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 118	E	9.6	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 123	E	1.1	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 128	E	3.9	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 138		14	ug/kg	13.3
SD15	2	California scorpionfish	Liver	PCB 149	E	4.4	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 151	E	2.8	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 153/168		24	ug/kg	13.3
SD15	2	California scorpionfish	Liver	PCB 158	E	1.3	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 167	E	0.8	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 170	E	4.4	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 177	E	3.3	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 180	E	12	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD15	2	California scorpionfish	Liver	PCB 183	E	2.7	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 187	E	9.1	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 194	E	2.7	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 201	E	3	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 206	E	1.6	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 28	E	0.7	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 49	E	1.4	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 52	E	1.7	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 66	E	2.1	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 70	E	0.8	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 74	E	0.9	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 87	E	1.7	ug/kg	
SD15	2	California scorpionfish	Liver	PCB 99	E	6.4	ug/kg	
SD15	2	California scorpionfish	Liver	Selenium		0.628	mg/kg	0.06
SD15	2	California scorpionfish	Liver	Silver		0.101	mg/kg	0.0568
SD15	2	California scorpionfish	Liver	Thallium		4.85	mg/kg	0.845
SD15	2	California scorpionfish	Liver	Total DDT		250.3	ug/kg	
SD15	2	California scorpionfish	Liver	Total PCB		129.4	ug/kg	
SD15	2	California scorpionfish	Liver	Total Solids		41.1	%wt	0.4
SD15	2	California scorpionfish	Liver	Trans Nonachlor	E	6.8	ug/kg	
SD15	2	California scorpionfish	Liver	Zinc		64.9	mg/kg	0.0487
SD15	3	California scorpionfish	Liver	Alpha (cis) Chlordane	E	3	ug/kg	
SD15	3	California scorpionfish	Liver	Antimony		0.96	mg/kg	0.478
SD15	3	California scorpionfish	Liver	Arsenic		3.84	mg/kg	0.375
SD15	3	California scorpionfish	Liver	Barium		0.0068	mg/kg	0.00661
SD15	3	California scorpionfish	Liver	Chromium		0.186	mg/kg	0.0804
SD15	3	California scorpionfish	Liver	Copper		6.41	mg/kg	0.0684
SD15	3	California scorpionfish	Liver	Hexachlorobenzene	E	1.7	ug/kg	
SD15	3	California scorpionfish	Liver	Iron		38.3	mg/kg	0.0958
SD15	3	California scorpionfish	Liver	Lead		0.93	mg/kg	0.3
SD15	3	California scorpionfish	Liver	Lipids		23.6	%wt	0.005
SD15	3	California scorpionfish	Liver	Manganese		0.311	mg/kg	0.00712
SD15	3	California scorpionfish	Liver	o,p-DDE	E	1.2	ug/kg	
SD15	3	California scorpionfish	Liver	p,p-DDD	E	4.8	ug/kg	
SD15	3	California scorpionfish	Liver	p,p-DDE		140	ug/kg	13.3
SD15	3	California scorpionfish	Liver	p,-p-DDMU	E	3.4	ug/kg	
SD15	3	California scorpionfish	Liver	p,p-DDT	E	2.7	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 101	E	5.7	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 105	E	2.9	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 110	E	4	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 118	E	8.8	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 123	E	1.1	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 128	E	2.7	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 138	E	13	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 149	E	4	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 151	E	2.9	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD15	3	California scorpionfish	Liver	PCB 153/168		23	ug/kg	13.3
SD15	3	California scorpionfish	Liver	PCB 158	E	1.2	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 167	E	0.8	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 170	E	4	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 177	E	3	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 180	E	9.6	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 183	E	2.9	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 187	E	8.7	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 194	E	1.9	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 201	E	2.9	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 49	E	1.1	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 52	E	1.5	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 66	E	1.5	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 74	E	0.8	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 87	E	1.5	ug/kg	
SD15	3	California scorpionfish	Liver	PCB 99	E	5.5	ug/kg	
SD15	3	California scorpionfish	Liver	Selenium		0.657	mg/kg	0.06
SD15	3	California scorpionfish	Liver	Thallium		5.18	mg/kg	0.845
SD15	3	California scorpionfish	Liver	Total DDT		152.1	ug/kg	
SD15	3	California scorpionfish	Liver	Total PCB		115	ug/kg	
SD15	3	California scorpionfish	Liver	Total Solids		44.8	%wt	0.4
SD15	3	California scorpionfish	Liver	Trans Nonachlor	E	4.6	ug/kg	
SD15	3	California scorpionfish	Liver	Zinc		47.2	mg/kg	0.0487
SD16	1	Hornyhead turbot	Liver	Aluminum		5.33	mg/kg	0.583
SD16	1	Hornyhead turbot	Liver	Arsenic		3.91	mg/kg	0.375
SD16	1	Hornyhead turbot	Liver	Barium		0.018	mg/kg	0.00661
SD16	1	Hornyhead turbot	Liver	Cadmium		3.31	mg/kg	0.0288
SD16	1	Hornyhead turbot	Liver	Chromium		1.23	mg/kg	0.0804
SD16	1	Hornyhead turbot	Liver	Copper		5.24	mg/kg	0.0684
SD16	1	Hornyhead turbot	Liver	Iron		64.9	mg/kg	0.0958
SD16	1	Hornyhead turbot	Liver	Lead		0.61	mg/kg	0.3
SD16	1	Hornyhead turbot	Liver	Lipids		8.65	%wt	0.005
SD16	1	Hornyhead turbot	Liver	Manganese		1.66	mg/kg	0.0071
SD16	1	Hornyhead turbot	Liver	Mercury		0.0785	mg/kg	0.03
SD16	1	Hornyhead turbot	Liver	Nickel		0.31	mg/kg	0.0939
SD16	1	Hornyhead turbot	Liver	o,p-DDE	E	1.2	ug/kg	
SD16	1	Hornyhead turbot	Liver	p,p-DDD	E	2.3	ug/kg	
SD16	1	Hornyhead turbot	Liver	p,p-DDE		110	ug/kg	13.3
SD16	1	Hornyhead turbot	Liver	p,-p-DDMU	E	5.3	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 101	E	1.5	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 105	E	1	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 118	E	3.1	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 138	E	5.2	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 149	E	1.3	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 151	E	0.7	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 153/168	E	9.4	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD16	1	Hornyhead turbot	Liver	PCB 158	E	0.6	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 170	E	2.1	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 180	E	5.8	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 183	E	1.6	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 187	E	4.2	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 206	E	0.9	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 49	E	0.7	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 52	E	0.6	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 66	E	0.7	ug/kg	
SD16	1	Hornyhead turbot	Liver	PCB 99	E	2.4	ug/kg	
SD16	1	Hornyhead turbot	Liver	Selenium		0.604	mg/kg	0.06
SD16	1	Hornyhead turbot	Liver	Thallium		2.79	mg/kg	0.845
SD16	1	Hornyhead turbot	Liver	Total DDT		118.8	ug/kg	
SD16	1	Hornyhead turbot	Liver	Total PCB		41.8	ug/kg	
SD16	1	Hornyhead turbot	Liver	Total Solids		24.7	%wt	0.4
SD16	1	Hornyhead turbot	Liver	Zinc		34.2	mg/kg	0.0487
SD16	2	California scorpionfish	Liver	Alpha (cis) Chlordane	E	3	ug/kg	
SD16	2	California scorpionfish	Liver	Aluminum		4.03	mg/kg	0.583
SD16	2	California scorpionfish	Liver	Antimony		0.885	mg/kg	0.478
SD16	2	California scorpionfish	Liver	Arsenic		3.33	mg/kg	0.375
SD16	2	California scorpionfish	Liver	Barium		0.0152	mg/kg	0.00661
SD16	2	California scorpionfish	Liver	Cadmium		3.36	mg/kg	0.0288
SD16	2	California scorpionfish	Liver	Chromium		0.47	mg/kg	0.0804
SD16	2	California scorpionfish	Liver	Cis Nonachlor	E	5.8	ug/kg	
SD16	2	California scorpionfish	Liver	Copper		24.7	mg/kg	0.0684
SD16	2	California scorpionfish	Liver	Hexachlorobenzene	E	1	ug/kg	
SD16	2	California scorpionfish	Liver	Iron		211	mg/kg	0.0958
SD16	2	California scorpionfish	Liver	Lead		0.585	mg/kg	0.3
SD16	2	California scorpionfish	Liver	Lipids		17.4	%wt	0.005
SD16	2	California scorpionfish	Liver	Manganese		0.451	mg/kg	0.00712
SD16	2	California scorpionfish	Liver	Mercury		0.44	mg/kg	0.03
SD16	2	California scorpionfish	Liver	o,p-DDE	E	1.7	ug/kg	
SD16	2	California scorpionfish	Liver	p,p-DDD	E	10	ug/kg	
SD16	2	California scorpionfish	Liver	p,p-DDE		885	ug/kg	13.3
SD16	2	California scorpionfish	Liver	p,-p-DDMU	E	6.7	ug/kg	
SD16	2	California scorpionfish	Liver	p,p-DDT	E	10	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 101		14	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 105	E	10	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 110	E	9	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 118		31	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 119	E	0.6	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 123	E	3.5	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 128	E	11	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 138		47	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 149	E	7.8	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 151	E	8.1	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD16	2	California scorpionfish	Liver	PCB 153/168		89	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 156	E	6	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 157	E	1.7	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 158	E	4.5	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 167	E	3.1	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 170		14	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 177	E	10	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 180		40	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 183	E	11	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 187		32	ug/kg	13.3
SD16	2	California scorpionfish	Liver	PCB 194	E	7.1	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 201	E	11	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 206	E	3.6	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 28	E	0.4	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 49	E	1.8	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 52	E	2	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 66	E	3	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 74	E	1.6	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 87	E	3.1	ug/kg	
SD16	2	California scorpionfish	Liver	PCB 99		17	ug/kg	13.3
SD16	2	California scorpionfish	Liver	Selenium		0.86	mg/kg	0.06
SD16	2	California scorpionfish	Liver	Silver		0.291	mg/kg	0.0568
SD16	2	California scorpionfish	Liver	Thallium		4.83	mg/kg	0.845
SD16	2	California scorpionfish	Liver	Total DDT		913.4	ug/kg	
SD16	2	California scorpionfish	Liver	Total PCB		403.9	ug/kg	
SD16	2	California scorpionfish	Liver	Total Solids		40.7	%wt	0.4
SD16	2	California scorpionfish	Liver	Trans Nonachlor	E	11	ug/kg	
SD16	2	California scorpionfish	Liver	Zinc		75.1	mg/kg	0.0487
SD16	3	California scorpionfish	Liver	Alpha (cis) Chlordane	E	5	ug/kg	
SD16	3	California scorpionfish	Liver	Aluminum		9.47	mg/kg	0.583
SD16	3	California scorpionfish	Liver	Antimony		0.85	mg/kg	0.478
SD16	3	California scorpionfish	Liver	Arsenic		3.65	mg/kg	0.375
SD16	3	California scorpionfish	Liver	Barium		0.01	mg/kg	0.00661
SD16	3	California scorpionfish	Liver	Cadmium		0.902	mg/kg	0.0288
SD16	3	California scorpionfish	Liver	Cis Nonachlor	E	5.9	ug/kg	
SD16	3	California scorpionfish	Liver	Copper		12.3	mg/kg	0.0684
SD16	3	California scorpionfish	Liver	Hexachlorobenzene	E	1.2	ug/kg	
SD16	3	California scorpionfish	Liver	Iron		104	mg/kg	0.0958
SD16	3	California scorpionfish	Liver	Lead		0.78	mg/kg	0.3
SD16	3	California scorpionfish	Liver	Lipids		22	%wt	0.005
SD16	3	California scorpionfish	Liver	Manganese		0.309	mg/kg	0.00712
SD16	3	California scorpionfish	Liver	Mercury		0.099	mg/kg	0.03
SD16	3	California scorpionfish	Liver	o,p-DDE	E	5.4	ug/kg	
SD16	3	California scorpionfish	Liver	p,p-DDD		14	ug/kg	13.3
SD16	3	California scorpionfish	Liver	p,p-DDE		1460	ug/kg	13.3
SD16	3	California scorpionfish	Liver	p,-p-DDMU		20	ug/kg	13.3

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD16	3	California scorpionfish	Liver	p,p-DDT	E	7.8	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 101		15	ug/kg	13.3
SD16	3	California scorpionfish	Liver	PCB 105	E	8.3	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 110	E	8.1	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 118		23	ug/kg	13.3
SD16	3	California scorpionfish	Liver	PCB 119	E	0.8	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 123	E	3	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 128	E	8	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 138		34	ug/kg	13.3
SD16	3	California scorpionfish	Liver	PCB 149	E	9.7	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 151	E	7.1	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 153/168		57	ug/kg	13.3
SD16	3	California scorpionfish	Liver	PCB 156	E	3.8	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 158	E	3.2	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 167	E	2.3	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 170	E	11	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 177	E	7.4	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 180		32	ug/kg	13.3
SD16	3	California scorpionfish	Liver	PCB 183	E	7.9	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 187		24	ug/kg	13.3
SD16	3	California scorpionfish	Liver	PCB 194	E	6.7	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 201	E	9.1	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 206	E	3.2	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 28	E	0.7	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 49	E	2.3	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 52	E	2.9	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 66	E	4.4	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 70	E	1.2	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 74	E	2.2	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 87	E	3.9	ug/kg	
SD16	3	California scorpionfish	Liver	PCB 99	E	13	ug/kg	
SD16	3	California scorpionfish	Liver	Selenium		0.574	mg/kg	0.06
SD16	3	California scorpionfish	Liver	Silver		0.084	mg/kg	0.0568
SD16	3	California scorpionfish	Liver	Thallium		5.34	mg/kg	0.845
SD16	3	California scorpionfish	Liver	Total DDT		1507.2	ug/kg	
SD16	3	California scorpionfish	Liver	Total PCB		315.2	ug/kg	
SD16	3	California scorpionfish	Liver	Total Solids		47.3	%wt	0.4
SD16	3	California scorpionfish	Liver	Trans Nonachlor	E	13	ug/kg	
SD16	3	California scorpionfish	Liver	Zinc		76	mg/kg	0.0487
SD17	1	Hornyhead turbot	Liver	Aluminum		8.07	mg/kg	0.583
SD17	1	Hornyhead turbot	Liver	Antimony		0.57	mg/kg	0.478
SD17	1	Hornyhead turbot	Liver	Arsenic		3.49	mg/kg	0.375
SD17	1	Hornyhead turbot	Liver	Barium		0.0115	mg/kg	0.00661
SD17	1	Hornyhead turbot	Liver	Cadmium		3.04	mg/kg	0.0288
SD17	1	Hornyhead turbot	Liver	Chromium		0.168	mg/kg	0.0804
SD17	1	Hornyhead turbot	Liver	Copper		3.13	mg/kg	0.0684

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD17	1	Hornyhead turbot	Liver	Hexachlorobenzene	E	0.7	ug/kg	
SD17	1	Hornyhead turbot	Liver	Iron		49.5	mg/kg	0.0958
SD17	1	Hornyhead turbot	Liver	Lead		0.56	mg/kg	0.3
SD17	1	Hornyhead turbot	Liver	Lipids		9.24	%wt	0.005
SD17	1	Hornyhead turbot	Liver	Manganese		0.752	mg/kg	0.00712
SD17	1	Hornyhead turbot	Liver	Mercury		0.085	mg/kg	0.03
SD17	1	Hornyhead turbot	Liver	Nickel		0.108	mg/kg	0.0939
SD17	1	Hornyhead turbot	Liver	o,p-DDE	E	1.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	p,p-DDD	E	3.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	p,p-DDE		82	ug/kg	13.3
SD17	1	Hornyhead turbot	Liver	p,-p-DDMU	E	3.2	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 101	E	1.2	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 105	E	0.8	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 118	E	2.1	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 128	E	1	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 138	E	3.9	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 149	E	1.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 151	E	0.6	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 153/168	E	6.4	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 170	E	1.5	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 180	E	4.2	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 183	E	1.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 187	E	3.2	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 194	E	1.5	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 201	E	1.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 206	E	1	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 28	E	0.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 49	E	0.5	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 52	E	0.4	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 66	E	0.6	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 70	E	0.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 74	E	0.3	ug/kg	
SD17	1	Hornyhead turbot	Liver	PCB 99	E	1.4	ug/kg	
SD17	1	Hornyhead turbot	Liver	Selenium		0.741	mg/kg	0.06
SD17	1	Hornyhead turbot	Liver	Thallium		3.71	mg/kg	0.845
SD17	1	Hornyhead turbot	Liver	Total DDT		89.8	ug/kg	
SD17	1	Hornyhead turbot	Liver	Total PCB		35.1	ug/kg	
SD17	1	Hornyhead turbot	Liver	Total Solids		30.5	%wt	0.4
SD17	1	Hornyhead turbot	Liver	Zinc		41.9	mg/kg	0.0487
SD17	2	Hornyhead turbot	Liver	Aluminum		2.77	mg/kg	0.583
SD17	2	Hornyhead turbot	Liver	Antimony		0.49	mg/kg	0.478
SD17	2	Hornyhead turbot	Liver	Arsenic		4.66	mg/kg	0.375
SD17	2	Hornyhead turbot	Liver	Cadmium		1.82	mg/kg	0.0288
SD17	2	Hornyhead turbot	Liver	Chromium		0.165	mg/kg	0.0804
SD17	2	Hornyhead turbot	Liver	Copper		7.49	mg/kg	0.0684
SD17	2	Hornyhead turbot	Liver	Hexachlorobenzene	E	1	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD17	2	Hornyhead turbot	Liver	Iron		31.2	mg/kg	0.0958
SD17	2	Hornyhead turbot	Liver	Lead		0.44	mg/kg	0.3
SD17	2	Hornyhead turbot	Liver	Lipids		16.1	%wt	0.005
SD17	2	Hornyhead turbot	Liver	Manganese		0.851	mg/kg	0.00712
SD17	2	Hornyhead turbot	Liver	Mercury		0.068	mg/kg	0.03
SD17	2	Hornyhead turbot	Liver	o,p-DDE	E	1.6	ug/kg	
SD17	2	Hornyhead turbot	Liver	p,p-DDD	E	5.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	p,p-DDE		120	ug/kg	13.3
SD17	2	Hornyhead turbot	Liver	p,-p-DDMU	E	5.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	p,p-DDT	E	1.4	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 101	E	2.7	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 105	E	1.7	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 110	E	1.4	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 118	E	4.6	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 123	E	0.6	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 128	E	1.8	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 138	E	7.9	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 149	E	3.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 151	E	1.3	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 153/168	E	13	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 158	E	0.9	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 167	E	0.5	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 170	E	3.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 177	E	1.3	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 180	E	7.6	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 183	E	2.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 187	E	6	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 194	E	2.5	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 201	E	2.1	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 206	E	1.5	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 28	E	0.5	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 49	E	1	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 52	E	1.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 66	E	1.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 70	E	0.7	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 74	E	0.6	ug/kg	
SD17	2	Hornyhead turbot	Liver	PCB 99	E	3.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	Selenium		0.541	mg/kg	0.06
SD17	2	Hornyhead turbot	Liver	Silver		0.121	mg/kg	0.0568
SD17	2	Hornyhead turbot	Liver	Thallium		3.84	mg/kg	0.845
SD17	2	Hornyhead turbot	Liver	Total DDT		133.2	ug/kg	
SD17	2	Hornyhead turbot	Liver	Total PCB		74.3	ug/kg	
SD17	2	Hornyhead turbot	Liver	Total Solids		35	%wt	0.4
SD17	2	Hornyhead turbot	Liver	Trans Nonachlor	E	2.3	ug/kg	
SD17	2	Hornyhead turbot	Liver	Zinc		66.3	mg/kg	0.0487
SD17	3	California scorpionfish	Liver	Alpha (cis) Chlordane	E	3.1	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD17	3	California scorpionfish	Liver	Aluminum		2.34	mg/kg	0.583
SD17	3	California scorpionfish	Liver	Arsenic		2.99	mg/kg	0.375
SD17	3	California scorpionfish	Liver	Barium		0.0114	mg/kg	0.00661
SD17	3	California scorpionfish	Liver	Cadmium		1.63	mg/kg	0.0288
SD17	3	California scorpionfish	Liver	Chromium		0.367	mg/kg	0.0804
SD17	3	California scorpionfish	Liver	Cis Nonachlor	E	3	ug/kg	
SD17	3	California scorpionfish	Liver	Copper		16.6	mg/kg	0.0684
SD17	3	California scorpionfish	Liver	Hexachlorobenzene	E	1.3	ug/kg	
SD17	3	California scorpionfish	Liver	Iron		124	mg/kg	0.0958
SD17	3	California scorpionfish	Liver	Lead		0.525	mg/kg	0.3
SD17	3	California scorpionfish	Liver	Lipids		17.2	%wt	0.005
SD17	3	California scorpionfish	Liver	Manganese		0.527	mg/kg	0.00712
SD17	3	California scorpionfish	Liver	Mercury		0.24	mg/kg	0.03
SD17	3	California scorpionfish	Liver	Nickel		0.21	mg/kg	0.0939
SD17	3	California scorpionfish	Liver	o,p-DDE	E	1.5	ug/kg	
SD17	3	California scorpionfish	Liver	p,p-DDD	E	5	ug/kg	
SD17	3	California scorpionfish	Liver	p,p-DDE		320	ug/kg	13.3
SD17	3	California scorpionfish	Liver	p,-p-DDMU	E	6.5	ug/kg	
SD17	3	California scorpionfish	Liver	p,p-DDT	E	2.8	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 101	E	6.1	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 105	E	3.7	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 110	E	3.2	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 118	E	11	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 123	E	1.1	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 128	E	3.1	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 138		15	ug/kg	13.3
SD17	3	California scorpionfish	Liver	PCB 149	E	4	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 151	E	2.5	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 153/168		26	ug/kg	13.3
SD17	3	California scorpionfish	Liver	PCB 158	E	1.5	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 167	E	1	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 170	E	4.8	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 177	E	2.7	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 180	E	13	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 183	E	3.7	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 187	E	10	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 194	E	3.3	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 201	E	3.9	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 206	E	1.9	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 28	E	0.4	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 49	E	1.1	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 52	E	1.5	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 66	E	1.7	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 70	E	0.7	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 74	E	0.9	ug/kg	
SD17	3	California scorpionfish	Liver	PCB 87	E	1.2	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD17	3	California scorpionfish	Liver	PCB 99	E	6.1	ug/kg	
SD17	3	California scorpionfish	Liver	Selenium		0.761	mg/kg	0.06
SD17	3	California scorpionfish	Liver	Silver		0.27	mg/kg	0.0568
SD17	3	California scorpionfish	Liver	Thallium		4.29	mg/kg	0.845
SD17	3	California scorpionfish	Liver	Total DDT		335.8	ug/kg	
SD17	3	California scorpionfish	Liver	Total PCB		135.1	ug/kg	
SD17	3	California scorpionfish	Liver	Total Solids		38.8	%wt	0.4
SD17	3	California scorpionfish	Liver	Trans Nonachlor	E	7.7	ug/kg	
SD17	3	California scorpionfish	Liver	Zinc		82.2	mg/kg	0.0487
SD18	1	Hornyhead turbot	Liver	Alpha (cis) Chlordane	E	3.3	ug/kg	
SD18	1	Hornyhead turbot	Liver	Aluminum		9.76	mg/kg	0.583
SD18	1	Hornyhead turbot	Liver	Antimony		0.54	mg/kg	0.478
SD18	1	Hornyhead turbot	Liver	Arsenic		4.14	mg/kg	0.375
SD18	1	Hornyhead turbot	Liver	Barium		0.0421	mg/kg	0.00661
SD18	1	Hornyhead turbot	Liver	Cadmium		1.63	mg/kg	0.0288
SD18	1	Hornyhead turbot	Liver	Chromium		0.674	mg/kg	0.0804
SD18	1	Hornyhead turbot	Liver	Cis Nonachlor	E	3.1	ug/kg	
SD18	1	Hornyhead turbot	Liver	Copper		5.65	mg/kg	0.0684
SD18	1	Hornyhead turbot	Liver	Hexachlorobenzene	E	0.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	Iron		36.3	mg/kg	0.0958
SD18	1	Hornyhead turbot	Liver	Lead		0.75	mg/kg	0.3
SD18	1	Hornyhead turbot	Liver	Lipids		14.4	%wt	0.005
SD18	1	Hornyhead turbot	Liver	Manganese		0.916	mg/kg	0.00712
SD18	1	Hornyhead turbot	Liver	Mercury		0.042	mg/kg	0.03
SD18	1	Hornyhead turbot	Liver	Nickel		0.313	mg/kg	0.0939
SD18	1	Hornyhead turbot	Liver	o,p-DDD	E	0.8	ug/kg	
SD18	1	Hornyhead turbot	Liver	o,p-DDE	E	5.8	ug/kg	
SD18	1	Hornyhead turbot	Liver	p,p-DDD	E	8.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	p,p-DDE		260	ug/kg	13.3
SD18	1	Hornyhead turbot	Liver	p,-p-DDMU	E	13	ug/kg	
SD18	1	Hornyhead turbot	Liver	p,p-DDT	E	2.3	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 101	E	5.3	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 105	E	2.1	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 110	E	2.4	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 118	E	7.9	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 123	E	0.9	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 128	E	1.8	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 138	E	9.9	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 149	E	3.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 151	E	1.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 153/168		18	ug/kg	13.3
SD18	1	Hornyhead turbot	Liver	PCB 158	E	1.4	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 167	E	1	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 170	E	3.7	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 177	E	1.1	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 180	E	10	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD18	1	Hornyhead turbot	Liver	PCB 183	E	2.9	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 187	E	7	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 194	E	2.8	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 201	E	2.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 206	E	1.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 28	E	1.1	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 49	E	1.8	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 52	E	1.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 66	E	2.1	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 70	E	1.2	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 74	E	1.4	ug/kg	
SD18	1	Hornyhead turbot	Liver	PCB 99	E	4.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	Selenium		0.713	mg/kg	0.06
SD18	1	Hornyhead turbot	Liver	Silver		0.085	mg/kg	0.0568
SD18	1	Hornyhead turbot	Liver	Thallium		3.75	mg/kg	0.845
SD18	1	Hornyhead turbot	Liver	Total DDT		290.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	Total PCB		101.6	ug/kg	
SD18	1	Hornyhead turbot	Liver	Total Solids		31.7	%wt	0.4
SD18	1	Hornyhead turbot	Liver	Trans Nonachlor	E	7.3	ug/kg	
SD18	1	Hornyhead turbot	Liver	Zinc		42.4	mg/kg	0.0487
SD18	2	California scorpionfish	Liver	Alpha (cis) Chlordane	E	3.5	ug/kg	
SD18	2	California scorpionfish	Liver	Aluminum		3.57	mg/kg	0.583
SD18	2	California scorpionfish	Liver	Antimony		0.5	mg/kg	0.478
SD18	2	California scorpionfish	Liver	Arsenic		3.26	mg/kg	0.375
SD18	2	California scorpionfish	Liver	Barium		0.0086	mg/kg	0.00661
SD18	2	California scorpionfish	Liver	Cadmium		0.99	mg/kg	0.0288
SD18	2	California scorpionfish	Liver	Cis Nonachlor	E	4.6	ug/kg	
SD18	2	California scorpionfish	Liver	Copper		8.57	mg/kg	0.0684
SD18	2	California scorpionfish	Liver	Hexachlorobenzene	E	1	ug/kg	
SD18	2	California scorpionfish	Liver	Iron		182	mg/kg	0.0958
SD18	2	California scorpionfish	Liver	Lead		0.4	mg/kg	0.3
SD18	2	California scorpionfish	Liver	Lipids		27.4	%wt	0.005
SD18	2	California scorpionfish	Liver	Manganese		0.351	mg/kg	0.00712
SD18	2	California scorpionfish	Liver	Mercury		0.059	mg/kg	0.03
SD18	2	California scorpionfish	Liver	p,p-DDD	E	5.7	ug/kg	
SD18	2	California scorpionfish	Liver	p,p-DDE		380	ug/kg	13.3
SD18	2	California scorpionfish	Liver	p,-p-DDMU	E	4	ug/kg	
SD18	2	California scorpionfish	Liver	p,p-DDT	E	2.4	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 101		14	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 105	E	12	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 110	E	10	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 118		37	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 119	E	0.9	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 123	E	4.4	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 128	E	13	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 138		66	ug/kg	13.3

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD18	2	California scorpionfish	Liver	PCB 149	E	8.8	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 151	E	9	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 153/168		120	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 156	E	7.1	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 158	E	5.3	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 167	E	4.5	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 170		17	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 177	E	13	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 180		46	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 183	E	13	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 187		40	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 189	E	1.1	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 194	E	10	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 201		14	ug/kg	13.3
SD18	2	California scorpionfish	Liver	PCB 206	E	5.2	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 28	E	0.6	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 49	E	2.3	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 52	E	3.1	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 66	E	3.7	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 70	E	0.9	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 74	E	1.9	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 87	E	3.7	ug/kg	
SD18	2	California scorpionfish	Liver	PCB 99		24	ug/kg	13.3
SD18	2	California scorpionfish	Liver	Selenium		0.873	mg/kg	0.06
SD18	2	California scorpionfish	Liver	Silver		0.182	mg/kg	0.0568
SD18	2	California scorpionfish	Liver	Thallium		3.88	mg/kg	0.845
SD18	2	California scorpionfish	Liver	Total DDT		392.1	ug/kg	
SD18	2	California scorpionfish	Liver	Total PCB		511.5	ug/kg	
SD18	2	California scorpionfish	Liver	Total Solids		44.9	%wt	0.4
SD18	2	California scorpionfish	Liver	Trans Nonachlor	E	6.5	ug/kg	
SD18	2	California scorpionfish	Liver	Zinc		67.9	mg/kg	0.0487
SD18	3	California scorpionfish	Liver	Alpha (cis) Chlordane		3.35	ug/kg	
SD18	3	California scorpionfish	Liver	Aluminum		3.86	mg/kg	0.583
SD18	3	California scorpionfish	Liver	Arsenic		3	mg/kg	0.375
SD18	3	California scorpionfish	Liver	Barium		0.316	mg/kg	0.00661
SD18	3	California scorpionfish	Liver	Cadmium		0.655	mg/kg	0.0288
SD18	3	California scorpionfish	Liver	Chromium		0.106	mg/kg	0.0804
SD18	3	California scorpionfish	Liver	Cis Nonachlor		3.2	ug/kg	
SD18	3	California scorpionfish	Liver	Copper		13.8	mg/kg	0.0684
SD18	3	California scorpionfish	Liver	Hexachlorobenzene		1.05	ug/kg	
SD18	3	California scorpionfish	Liver	Iron		95.7	mg/kg	0.0958
SD18	3	California scorpionfish	Liver	Lead		0.89	mg/kg	0.3
SD18	3	California scorpionfish	Liver	Lipids		24.2	%wt	0.005
SD18	3	California scorpionfish	Liver	Manganese		0.408	mg/kg	0.00712
SD18	3	California scorpionfish	Liver	Mercury		0.105	mg/kg	0.03
SD18	3	California scorpionfish	Liver	o,p-DDE		1.6	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD18	3	California scorpionfish	Liver	p,p-DDD	E	10	ug/kg	
SD18	3	California scorpionfish	Liver	p,p-DDE		985	ug/kg	13.3
SD18	3	California scorpionfish	Liver	p,-p-DDMU		6.9	ug/kg	
SD18	3	California scorpionfish	Liver	p,p-DDT		3.3	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 101		9.2	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 105		5.2	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 110	E	4.9	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 118		14	ug/kg	13.3
SD18	3	California scorpionfish	Liver	PCB 123		1.8	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 128		4.1	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 138		17.5	ug/kg	13.3
SD18	3	California scorpionfish	Liver	PCB 149		6.9	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 151	E	3	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 153/168		30	ug/kg	13.3
SD18	3	California scorpionfish	Liver	PCB 158		1.55	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 167		1.25	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 170		5.05	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 177		3.7	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 180	E	11	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 183		3.25	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 187	E	11	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 194		3.3	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 201		3.75	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 206		1.55	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 28	E	0.6	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 49	E	1.5	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 52		2.35	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 66		2.15	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 70	E	0.8	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 74		1.4	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 87		2.35	ug/kg	
SD18	3	California scorpionfish	Liver	PCB 99		6.95	ug/kg	
SD18	3	California scorpionfish	Liver	Selenium		0.782	mg/kg	0.06
SD18	3	California scorpionfish	Liver	Silver		0.084	mg/kg	0.0568
SD18	3	California scorpionfish	Liver	Thallium		5.02	mg/kg	0.845
SD18	3	California scorpionfish	Liver	Total DDT		1006.8	ug/kg	
SD18	3	California scorpionfish	Liver	Total PCB		160.1	ug/kg	
SD18	3	California scorpionfish	Liver	Total Solids		43.5	%wt	0.4
SD18	3	California scorpionfish	Liver	Trans Nonachlor		7.3	ug/kg	
SD18	3	California scorpionfish	Liver	Zinc		113	mg/kg	0.0487
SD19	1	California scorpionfish	Liver	Alpha (cis) Chlordane	E	2.7	ug/kg	
SD19	1	California scorpionfish	Liver	Aluminum		3.32	mg/kg	0.583
SD19	1	California scorpionfish	Liver	Antimony		0.74	mg/kg	0.478
SD19	1	California scorpionfish	Liver	Arsenic		2.72	mg/kg	0.375
SD19	1	California scorpionfish	Liver	Barium		0.0081	mg/kg	0.00661
SD19	1	California scorpionfish	Liver	Cadmium		1.06	mg/kg	0.0288

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD19	1	California scorpionfish	Liver	Chromium		0.244	mg/kg	0.0804
SD19	1	California scorpionfish	Liver	Copper		15	mg/kg	0.0684
SD19	1	California scorpionfish	Liver	Hexachlorobenzene	E	1.3	ug/kg	
SD19	1	California scorpionfish	Liver	Iron		108	mg/kg	0.0958
SD19	1	California scorpionfish	Liver	Lead		0.42	mg/kg	0.3
SD19	1	California scorpionfish	Liver	Lipids		30.2	%wt	0.005
SD19	1	California scorpionfish	Liver	Manganese		0.4	mg/kg	0.00712
SD19	1	California scorpionfish	Liver	Mercury		0.06	mg/kg	0.03
SD19	1	California scorpionfish	Liver	Nickel		0.119	mg/kg	0.0939
SD19	1	California scorpionfish	Liver	o,p-DDE	E	1.6	ug/kg	
SD19	1	California scorpionfish	Liver	p,p-DDD	E	6.4	ug/kg	
SD19	1	California scorpionfish	Liver	p,p-DDE		400	ug/kg	13.3
SD19	1	California scorpionfish	Liver	p,-p-DDMU	E	5	ug/kg	
SD19	1	California scorpionfish	Liver	p,p-DDT	E	2.3	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 101	E	8.1	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 105	E	5.2	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 110	E	4.5	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 118	E	13	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 123	E	1.5	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 128	E	4.3	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 138		21	ug/kg	13.3
SD19	1	California scorpionfish	Liver	PCB 149	E	6.2	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 151	E	3.7	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 153/168		35	ug/kg	13.3
SD19	1	California scorpionfish	Liver	PCB 158	E	1.9	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 167	E	1.5	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 170	E	6.6	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 177	E	4.5	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 180		15	ug/kg	13.3
SD19	1	California scorpionfish	Liver	PCB 183	E	4.3	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 187		14	ug/kg	13.3
SD19	1	California scorpionfish	Liver	PCB 194	E	3.6	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 201	E	4.2	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 206	E	1.8	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 28	E	0.6	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 49	E	1.9	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 52	E	2.4	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 66	E	2.4	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 70	E	0.6	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 74	E	1.2	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 87	E	2.1	ug/kg	
SD19	1	California scorpionfish	Liver	PCB 99	E	8.2	ug/kg	
SD19	1	California scorpionfish	Liver	Selenium		1	mg/kg	0.06
SD19	1	California scorpionfish	Liver	Silver		0.258	mg/kg	0.0568
SD19	1	California scorpionfish	Liver	Thallium		4.89	mg/kg	0.845
SD19	1	California scorpionfish	Liver	Total DDT		415.3	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD19	1	California scorpionfish	Liver	Total PCB		179.3	ug/kg	
SD19	1	California scorpionfish	Liver	Total Solids		46.3	%wt	0.4
SD19	1	California scorpionfish	Liver	Trans Nonachlor	E	6.3	ug/kg	
SD19	1	California scorpionfish	Liver	Zinc		86.4	mg/kg	0.0487
SD19	2	Hornyhead turbot	Liver	Aluminum		4.54	mg/kg	0.583
SD19	2	Hornyhead turbot	Liver	Arsenic		3.67	mg/kg	0.375
SD19	2	Hornyhead turbot	Liver	Barium		0.0115	mg/kg	0.00661
SD19	2	Hornyhead turbot	Liver	Cadmium		2.72	mg/kg	0.0288
SD19	2	Hornyhead turbot	Liver	Chromium		0.149	mg/kg	0.0804
SD19	2	Hornyhead turbot	Liver	Copper		4.87	mg/kg	0.0684
SD19	2	Hornyhead turbot	Liver	Hexachlorobenzene	E	0.6	ug/kg	
SD19	2	Hornyhead turbot	Liver	Iron		24.8	mg/kg	0.0958
SD19	2	Hornyhead turbot	Liver	Lead		0.84	mg/kg	0.3
SD19	2	Hornyhead turbot	Liver	Lipids		12.8	%wt	0.005
SD19	2	Hornyhead turbot	Liver	Manganese		0.861	mg/kg	0.00712
SD19	2	Hornyhead turbot	Liver	Mercury		0.06	mg/kg	0.03
SD19	2	Hornyhead turbot	Liver	o,p-DDE	E	1.3	ug/kg	
SD19	2	Hornyhead turbot	Liver	p,p-DDD	E	3.7	ug/kg	
SD19	2	Hornyhead turbot	Liver	p,p-DDE		130	ug/kg	13.3
SD19	2	Hornyhead turbot	Liver	p,-p-DDMU	E	6.4	ug/kg	
SD19	2	Hornyhead turbot	Liver	p,p-DDT	E	1.5	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 101	E	2.9	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 105	E	1.1	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 118	E	3.3	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 128	E	1.3	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 138	E	6.8	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 149	E	2.7	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 151	E	1.6	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 153/168	E	11	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 158	E	0.7	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 167	E	0.6	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 170	E	2.9	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 177	E	1.5	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 180	E	6.1	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 183	E	1.8	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 187	E	5.5	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 194	E	1.8	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 201	E	1.9	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 206	E	1.3	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 28	E	0.4	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 49	E	1	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 52	E	0.9	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 66	E	0.9	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 70	E	0.5	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 74	E	0.5	ug/kg	
SD19	2	Hornyhead turbot	Liver	PCB 99	E	2.9	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD19	2	Hornyhead turbot	Liver	Selenium		0.528	mg/kg	0.06
SD19	2	Hornyhead turbot	Liver	Silver		0.119	mg/kg	0.0568
SD19	2	Hornyhead turbot	Liver	Thallium		3.71	mg/kg	0.845
SD19	2	Hornyhead turbot	Liver	Total DDT		142.9	ug/kg	
SD19	2	Hornyhead turbot	Liver	Total PCB		61.9	ug/kg	
SD19	2	Hornyhead turbot	Liver	Total Solids		31.7	%wt	0.4
SD19	2	Hornyhead turbot	Liver	Zinc		45.6	mg/kg	0.0487
SD19	3	California scorpionfish	Liver	Alpha (cis) Chlordane	E	4.3	ug/kg	
SD19	3	California scorpionfish	Liver	Aluminum		7.45	mg/kg	0.583
SD19	3	California scorpionfish	Liver	Antimony		0.75	mg/kg	0.478
SD19	3	California scorpionfish	Liver	Arsenic		2.93	mg/kg	0.375
SD19	3	California scorpionfish	Liver	Barium		0.0121	mg/kg	0.00661
SD19	3	California scorpionfish	Liver	Cadmium		3.22	mg/kg	0.0288
SD19	3	California scorpionfish	Liver	Cis Nonachlor	E	2.8	ug/kg	
SD19	3	California scorpionfish	Liver	Copper		12.7	mg/kg	0.0684
SD19	3	California scorpionfish	Liver	Hexachlorobenzene	E	0.9	ug/kg	
SD19	3	California scorpionfish	Liver	Iron		166	mg/kg	0.0958
SD19	3	California scorpionfish	Liver	Lead		0.74	mg/kg	0.3
SD19	3	California scorpionfish	Liver	Lipids		17.7	%wt	0.005
SD19	3	California scorpionfish	Liver	Manganese		0.515	mg/kg	0.00712
SD19	3	California scorpionfish	Liver	Mercury		0.268	mg/kg	0.03
SD19	3	California scorpionfish	Liver	Nickel		0.1	mg/kg	0.0939
SD19	3	California scorpionfish	Liver	o,p-DDE	E	1.6	ug/kg	
SD19	3	California scorpionfish	Liver	p,p-DDD		19	ug/kg	13.3
SD19	3	California scorpionfish	Liver	p,p-DDE		2170	ug/kg	13.3
SD19	3	California scorpionfish	Liver	p,-p-DDMU		19	ug/kg	13.3
SD19	3	California scorpionfish	Liver	p,p-DDT	E	3.9	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 101		17	ug/kg	13.3
SD19	3	California scorpionfish	Liver	PCB 105	E	10	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 110	E	9.5	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 118		26	ug/kg	13.3
SD19	3	California scorpionfish	Liver	PCB 119	E	0.8	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 123	E	3.3	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 128	E	6.7	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 138		33	ug/kg	13.3
SD19	3	California scorpionfish	Liver	PCB 149	E	8.1	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 151	E	5.6	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 153/168		54	ug/kg	13.3
SD19	3	California scorpionfish	Liver	PCB 156	E	4.8	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 157	E	1.3	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 158	E	3.3	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 167	E	2.2	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 170	E	9.5	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 177	E	6.3	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 180		23	ug/kg	13.3
SD19	3	California scorpionfish	Liver	PCB 183	E	6.2	ug/kg	

Appendix D.3

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

Station	Rep	Species	Tissue	Parameter		Value	Units	MDL
SD19	3	California scorpionfish	Liver	PCB 187		20	ug/kg	13.3
SD19	3	California scorpionfish	Liver	PCB 194	E	5.2	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 201	E	6.9	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 206	E	2.8	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 28	E	0.6	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 49	E	2.9	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 52	E	3.5	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 66	E	6.4	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 74	E	3.6	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 87	E	5.3	ug/kg	
SD19	3	California scorpionfish	Liver	PCB 99		16	ug/kg	13.3

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Appendix E

Supporting Data

2005 Regional Survey Stations

Sediment Characteristics

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Appendix E.1

Particle size statistics for July 2005 regional survey stations. Sediment observations include observations from chemistry and macrofauna grab observations, including screened debris. Skw=skewness; Krt=kurtosis.

Station	Depth (m)	Mean (phi)	Mean (mm)	SD (phi)	Median (phi)	Skw	Krt	Coarse (%)	Sand (%)	Silt (%)	Clay (%)	Sediment observations
Shallow shelf												
2032	12	3.0	0.129	1.0	2.9	0.1	1.5	0.2	87.9	11.5	0.4	Fine sand
2036	16	0.0	0.987	1.2	-0.3	0.4	0.7	55.1	44.9	0.0	0.0	Sand, coarse sand, relict red sand, shell hash
2039	16	3.3	0.104	0.9	3.1	0.4	4.9	0.7	86.6	12.2	0.5	Fine sand
2046	22	3.0	0.122	1.0	3.0	0.0	1.7	0.7	89.4	9.4	0.4	Silt, fine sand, hydroid fragments, polychaete tubes
2037	24	2.1	0.232	1.1	2.3	-0.1	1.3	1.8	92.5	5.5	0.2	Fine sand, silt
2016	25	2.7	0.158	0.8	2.6	0.0	1.7	0.8	94.2	4.9	0.1	Fine sand, silt, surf grass
2047	29	3.3	0.101	1.0	3.0	0.5	3.5	0.4	84.9	13.9	0.8	Fine sand, polychaete tubes, shell hash
Mean	20	2.5	0.262	1.0	2.4	0.2	2.2	8.5	82.9	8.2	0.3	
Mid-shelf												
2049	31	3.3	0.099	0.8	3.2	0.4	1.9	0.0	84.6	14.7	0.7	Fine sand
2014	38	3.7	0.080	1.3	3.4	0.4	1.5	0.0	71.2	26.7	2.1	Silt, surf grass, algae
2030	47	4.3	0.052	1.8	3.6	0.4	1.0	0.2	58.1	37.6	4.1	Silt, sand, shell hash
2051	49	0.9	0.549	0.8	0.8	0.2	1.2	11	87.1	2.3	0.0	Relict red sand
2038	52	4.2	0.055	1.7	3.6	0.5	1.0	0.0	60.0	36.7	3.2	Silt,fine sand, clay, coarse black sand, gravel, shell hash
2027	58	4.2	0.054	1.7	3.8	0.4	1.0	0.0	56.8	40.0	3.1	Fine sand, clay, shell hash
2012	59	4.1	0.059	1.5	3.5	0.6	1.2	0.1	63.9	33.1	2.9	Silt, clay, coarse black sand, shell hash
2021	67	4.3	0.051	1.7	3.8	0.4	0.9	0.0	55.1	41.4	3.4	Silt, fine sand, sand, shell hash
2026	68	4.5	0.045	1.6	4.1	0.3	1.1	0.0	46.0	50.7	3.3	Fine sand, silt
2042	68	3.5	0.090	2.2	2.9	0.3	1.2	1.8	67.3	28.4	2.5	Fine sand, silt, coarse black sand, shell hash
2017	69	4.3	0.052	1.6	3.7	0.5	1.1	0.0	58.4	38.3	3.3	Silt, pea gravel, shell hash
2022	72	4.3	0.051	1.6	3.8	0.4	1.0	0.0	55.2	41.5	3.3	Silt
2013	73	3.8	0.071	1.5	3.3	0.6	1.4	0.0	70.3	27.0	2.7	Silt, clay, shell hash
2031	74	4.4	0.048	1.6	4.0	0.4	1.0	0.0	51.0	45.6	3.4	Silt
2034	81	4.5	0.044	1.6	4.2	0.3	1.0	0.0	46.0	50.1	3.8	Silt, pea gravel
2020	82	4.5	0.045	1.8	4.1	0.3	0.9	0.0	47.7	47.9	4.4	Silt, coarse sand, pea gravel, shell hash
2045	84	4.2	0.053	1.8	3.5	0.5	1.2	0.4	60.0	36.2	3.4	Silt, fine sand, rocks, shell hash
2018	85	4.5	0.044	1.6	4.2	0.3	1.0	0.0	45.7	50.8	3.6	Silt
2023	90	2.3	0.210	2.3	3.1	-0.5	0.5	25.5	40.8	33.7	0.0	Fine sand, gravel, mud, pea gravel, rocks
2025	95	4.1	0.058	1.6	3.7	0.4	1.2	0.0	60.1	37.0	2.8	Fine sand, silt, shell hash
2050	101	3.4	0.092	1.5	3.0	0.5	1.6	0.2	76.9	21.0	1.8	Silt, fine sand
2040	102	1.9	0.272	1.2	2.0	-0.2	1.8	7.1	81.6	11.3	0.0	Clay, silt, fine and coarse sand, pea gravel, rock, shell hash
2033	104	3.9	0.068	1.5	3.5	0.4	1.3	0.0	68.6	28.7	2.6	Silt, fine sand, shell hash
2015	108	4.1	0.057	1.7	3.7	0.4	1.2	0.0	61.4	35.6	3.0	Silt, coarse black sand, shell hash
Mean	73	3.8	0.096	1.6	3.4	0.3	1.2	1.9	61.4	34.0	2.7	
Deep shelf												
2041	137	1.6	0.321	1.5	1.6	0.3	1.5	5.7	85.8	7.9	0.7	Coarse sand, sand, pea gravel, rock, shell hash
2035	152	2.0	0.248	1.7	1.9	0.3	1.9	3.5	82.6	12.8	1.1	Coarse sand, pea gravel
2043	171	1.9	0.273	1.6	2.0	0.1	1.7	4.6	82.2	12.3	1.0	Coarse sand, pea gravel, rock, shell hash
2044	179	2.7	0.151	2.3	2.0	0.4	1.4	4.5	74.2	19.2	2.1	Sand, pea gravel, shell hash
2028	190	4.7	0.037	1.7	4.4	0.3	0.9	0.0	38.6	56.9	4.6	Clay, silt, *Spiochaetopterus* (polychaete) tubes
Mean	129	2.6	0.206	1.8	2.4	0.3	1.5	3.6	72.7	21.8	1.9	
Area Mean	76	3.4	0.143	1.5	3.1	0.3	1.4	3.4	67.2	27.3	2.1	

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