THE CITY OF SAN DIEGO

South Bay Ocean Outfall

Annual Receiving Waters Monitoring & Assessment Report

2013

City of San Diego Ocean Monitoring Program

Environmental Monitoring & Technical Services Division

Public Utilities Department

THE CITY OF SAN DIEGO

June 30, 2014

Mr. David Gibson, Executive Officer
California Regional Water Quality Control Board
San Diego Region
2375 Northside Drive, Suite 100
San Diego, CA 92108

Attention: POTW Compliance Unit

Dear Mr. Gibson:

Enclosed is the 2013 Annual Receiving Waters Monitoring and Assessment Report for the South Bay Ocean Outfall, South Bay Water Reclamation Plant as required per Order No. R9-2006-0067 (superseded by Order R9-2013-0006, effective April 4, 2013), NPDES Permit No. CA0109045. This assessment report contains data summaries, analyses and interpretations of the various portions of the ocean monitoring program conducted during calendar year 2013, including oceanographic conditions, water quality, sediment conditions, macrobenthic communities, demersal fishes and megabenthic invertebrates, and bioaccumulation of contaminants in fish tissues. These data are also presented in the similar report required for the South Bay International Wastewater Treatment Plant discharge to the Pacific Ocean (Order No. 96-50, NPDES Permit No. CA0108928), which will be submitted separately by the International Boundary and Water Commission, U.S. Section.

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, 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,

Peter S. Vroom, Ph.D.
Deputy Public Utilities Director

TDS/akl

cc: U.S. Environmental Protection Agency, Region 9

DIVERSITY
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South Bay Ocean Outfall
Annual Receiving Waters Monitoring & Assessment Report, 2013

(Order No. R9-2013-0006; NPDES No. CA0109045)

Prepared by:

City of San Diego Ocean Monitoring Program

Environmental Monitoring & Technical Services Division, Public Utilities Department

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June 2014

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Examples of animals and scenery occurring in the South Bay Ocean Outfall region. Images are (clockwise from upper left): the opisthobranch *Pleurobranchaea californica*; view of the Coronado Islands from Borderfield State Park; the crab *Platymera gaudichaudii*; the common dolphin *Delphinus delphis*. Photos by N. Haring, M. Nelson, K. Barwick, and M. Nelson, respectively.

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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
ANOSIM	Analysis of Similarity
APHA	American Public Health Association
APT	Advanced Primary Treatment
AUV	Automated Underwater Vehicle
BACIP	Before-After-Control-Impact-Paired
BEST	Bio-Env + Stepwise Tests
BIO-ENV	Biological/Environmental
BOD	Biochemical Oxygen Demand
BRI	Benthic Response Index
CalCOFI	California Cooperative Fisheries Investigation
CCS	California Current System
CDIP	Coastal Data Information Program
CDOM	Colored Dissolved Organic Matter
CDPH	California Department of Public Health
CFU	Colony Forming Units
cm	centimeter
CSDMML	City of San Diego Marine Microbiology Laboratory
CTD	Conductivity, Temperature, Depth instrument
DDT	Dichlorodiphenyltrichloroethane
df	degrees of freedom
DO	Dissolved Oxygen
ELAP	Environmental Laboratory Accreditation Program
EMAP	Environmental Monitoring and Assessment Program
EMTS	Environmental Monitoring and Technical Services
ENSO	El Niño Southern Oscillation
ERL	Effects Range Low
ERM	Effects Range Mediam
F:T	Fecal to Total coliform ratio
FET	Fisher’s Exact Test
FIB	Fecal Indicator Bacteria
ft	feet
FTR	Fecal to Total coliform Ratio criterion
g	gram
Global R	ANOSIM test value that examines for global differences within a factor
H'	Shannon diversity index
HCB	Hexachlorobenzene
HCH	Hexachlorocylclohexane
IGODS	Interactive Geographical Ocean Data System
in	inches
IR	Infrared
J'	Pielou's evenness index
kg	kilogram
km	kilometer
km^2	square kilometer

Acronyms and Abbreviations

L	Liter
m	meter
m^2	square meter
MDL	Method Detection Limit
mg	milligram
mgd	millions of gallons per day
ml	maximum length
mL	milliliter
mm	millimeter
MODIS	Moderate Resolution Imaging Spectroradiometer
MRP	Monitoring and Reporting Program
mt	metric ton
n	sample size
N	number of observations used in a Chi-square analysis
ng	nanograms
no.	number
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPGO	North Pacific Gyre Oscillation
NWS	National Weather Service
O&G	Oil and Grease
OCSD	Orange County Sanitation District
OEHHA	California Office of Environmental Health Hazard Assessment
OI	Ocean Imaging
OOR	Out-of-range
p	probability
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PDO	Pacific Decadal Oscillation
pH	Acidity/Alkalinity value
PLOO	Point Loma Ocean Outfall
PLWTP	Point Loma Wastewater Treatment Plant
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PRIMER	Plymouth Routines in Multivariate Ecological Research
psu	practical salinity units
r	ANOSIM test value that examines for differences among levels within a factor
r_s	Spearman rank correlation coefficient
ROV	Remotely Operated Vehicle
SABWTP	San Antonio de los Buenos Wastewater Treatment Plant
SBIWTP	South Bay International Wastewater Treament Plant
SBOO	South Bay Ocean Outfall
SBWRP	South Bay Water Reclamation Plant
SCB	Southern California Bight

Acronyms and Abbreviations

SCBPP	Southern California Bight Pilot Project
SD	Standard Deviation
SDRWQCB	San Diego Regional Water Quiality Control Board
SIMPER	Similarity Percentages Routine
SIMPROF	Similarity Profile Analysis
SIO	Scripps Institution of Oceanography
sp	species (singular)
spp	species (plural)
SSL	Sub-surface Low Salinity Layer
SSM	Single Sample Maximum
SWRCB	Califonia State Water Resources Control Board
tDDT	total DDT
TN	Total Nitrogen
TOC	Total Organic Carbon
tPAH	total PAH
tPCB	total PCB
TSS	Total Suspended Solids
TVS	Total Volatile Solids
USEPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
USGS	United States Geological Survey
USIBWC	International Boundary and Water Commission, U.S. Section
wt	weight
yr	year
ZID	Zone of Initial Dilution
α	alpha, the probability of creating a type I error
μg	micrograms
π	summed absolute distances test statistic
ρ	rho, test statistic for RELATE and BEST tests

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Executive Summary

Executive Summary

The City of San Diego (City) conducts an extensive ocean monitoring program to evaluate potential environmental effects from the discharge of treated wastewater to the Pacific Ocean via the South Bay Ocean Outfall (SBOO). The data collected are used to determine compliance with receiving water conditions as specified in NPDES regulatory permits for the City's South Bay Water Reclamation Plant (SBWRP) and the South Bay International Wastewater Treatment Plant (SBIWTP) operated by the International Boundary and Water Commission, U.S. Section (USIBWC). Since treated effluent from these two facilities commingle before discharge to the ocean, a single monitoring and reporting program approved by the San Diego Regional Water Quality Control Board (Regional Water Board) and U.S. Environmental Protection Agency (USEPA) is conducted to comply with both permits.

The primary objectives of ocean monitoring for the South Bay outfall region are to:

- measure compliance with NPDES permit requirements and California Ocean Plan (Ocean Plan) water quality objectives,
- monitor changes in ocean conditions over space and time, and
- assess any impacts of wastewater discharge or other man-made or natural influences on the local marine environment, including effects on water quality, sediment conditions and marine life.

Overall, the state of southern San Diego's coastal waters in 2013 was in good condition based on the comprehensive scientific assessment of the South Bay outfall monitoring region. This report details the methods, scope, results and evaluation of the ocean monitoring program.

Regular (core) monitoring sites that are sampled on a weekly, monthly or semiannual basis are arranged in a grid surrounding the SBOO, which terminates approximately 5.6 km offshore at a discharge depth of 27 m. Monitoring at shoreline stations extends from Coronado, San Diego (USA) southward to Playa Blanca in northern Baja California (Mexico), while offshore monitoring occurs in waters overlying the continental shelf at depths of about 9 to 55 m. In addition to the above core monitoring, a region-wide survey of benthic conditions is typically conducted each year at a set of randomly selected sites that range from the USA/Mexico border region to northern San Diego County. These regional stations extend further offshore to waters as deep as 500 m and are used to evaluate patterns and trends over a broader geographic area. However, no such regional survey was conducted in 2013 due to a resource exchange agreement approved by the Regional Water Board and USEPA to allow the City and USIBWC to participate in the 2013 Southern California Bight Regional Monitoring Program (Bight'13). Data from Bight'13 are not yet available and are therefore not included herein. Additional information on background environmental conditions for the region is also available from a baseline study conducted by the City over a 3½ year period prior to wastewater discharge.

Details of the results and conclusions of all receiving waters monitoring activities conducted from January through December 2013 are presented and discussed in the following seven chapters. Chapter 1 represents a general introduction and overview of the City's ocean monitoring program, while chapters 2–7 include results of all monitoring at the regular core stations conducted during the year. In Chapter 2, data characterizing oceanographic conditions and water mass transport for the region are evaluated. Chapter 3 presents the results of shoreline and offshore water quality monitoring, including measurements of fecal indicator bacteria and oceanographic data to evaluate potential movement and dispersal of the plume and assess compliance with water contact standards defined in the Ocean Plan. Assessments of benthic sediment quality and the status of macrobenthic invertebrate communities are presented in Chapters 4 and 5, respectively. Chapter 6 presents the results of trawling activities designed to monitor communities of bottom dwelling (demersal) fishes and megabenthic invertebrates. Bioaccumulation assessments to measure contaminant loads in the tissues of local fishes are presented in Chapter 7. In addition to the above activities, the City and USIBWC support other projects relevant to assessing the quality and movement of ocean waters in the region. One such project involves satellite imaging of the San Diego/Tijuana coastal region, of which the 2013 results are incorporated into Chapters 2 and 3. A summary of the main findings for each of the above components is included below.

COASTAL OCEANOGRAPHIC CONDITIONS

Sea surface temperatures were slightly cooler than the long-term average during the winter (January–April) and summer (July–August), while waters were slightly warmer than normal during the spring (May–June) and fall (September–December). Ocean conditions indicative of local coastal upwelling were observed from the beginning of spring through mid-summer, but were most evident during April. As is typical for the South Bay outfall region, maximum stratification (layering) of the water column occurred in mid-summer, while well-mixed waters were present during the winter. Water clarity (% transmissivity) during the year was within historical ranges for the region, with low values predominantly associated with plumes of turbid waters originating from the Tijuana River, re-suspension of bottom sediments due to waves or storm activity, or phytoplankton blooms. The occurrence of plankton blooms often corresponded to upwelling as described above. Overall, ocean conditions during the year were consistent with well documented patterns for southern California and northern Baja California. These findings suggest that natural factors such as upwelling of deep ocean waters and changes due to climatic events such as El Niño/La Niña oscillations continue to explain most of the temporal and spatial variability observed in the coastal waters off southern San Diego.

WATER QUALITY COMPLIANCE & PLUME DISPERSION

Compliance with Ocean Plan water contact standards for fecal indicator bacteria (FIB) was evaluated for the eight shore stations located from near the USA/Mexico border to Coronado, as well as the three kelp bed and other offshore stations located west of Imperial Beach and within State jurisdictional waters (i.e., within 3 nautical miles of shore). These standards do not apply to the stations located south of the border, and were not assessed for this area. Overall compliance with the Ocean Plan's single sample maximum (SSM) and geometric mean bacterial standards was 98% for the shore, kelp bed, and other offshore stations combined in 2013. Compliance at the shore stations was ≥90% for the three geometric mean standards and each of the four SSM standards. However, six of these stations (S4, S5, S6, S10, S11, S12) fall within or adjacent to areas already listed by the State and USEPA as impaired waters due to non-outfall related sources; thus, these stations are not expected to be in compliance with Ocean Plan standards. Compliance at the remaining two northernmost shore stations (S8 and S9) was >99% in 2013. Water quality was also high at the three kelp bed and other offshore stations located within State waters during the year. Compliance at the kelp bed stations was 100% for the geometric mean standards and ≥94% for the SSMs, while compliance at the other offshore stations was ≥93% for the SSMs. Compliance was generally lowest during the wet season (October–April), when about 82% of all elevated FIB counts were detected. A relationship between rainfall and bacterial concentrations in local waters has remained consistent since monitoring began several years prior to wastewater discharge, and is likely associated with outflows of contaminated waters from the Tijuana River (USA) and Los Buenos Creek (Mexico) during and after storm events.

There was no evidence that wastewater discharged to the ocean via the SBOO reached the shoreline during 2013. Although elevated FIB densities were detected along the shore and occasionally at a few nearshore stations located along the 9-m depth contour, these results did not indicate shoreward transport of the plume, a conclusion consistently supported by remote sensing observations. Instead, other potential sources of bacterial contamination such as coastal runoff from rivers and creeks were more likely to impact coastal water quality in the South Bay outfall region, especially during the wet season. In addition, bacterial contamination was absent along the 19, 28, 38 and 55-m depth contours, including stations I12, I14 and I16 located nearest the discharge site. This low rate of FIB contamination near the outfall is expected due to chlorination of SBIWTP effluent that typically occurs between November and April, and to the initiation of full secondary treatment at the SBIWTP that began in January 2011. Detection of the wastewater plume using CDOM and salinity signatures was low (9.2%) during 2013, with most detections occurring at monitoring sites located nearest the outfall.

SEDIMENT CONDITIONS

The composition of benthic sediments at the SBOO stations was similar in 2013 to previous years, varying from fine silts to very coarse sands or other large particles. There were no changes in the amount of fine sediments at the different monitoring sites that could be attributed to wastewater discharge, nor was there any other apparent relationship between sediment grain size distributions and proximity to the outfall. Instead, the range of sediment types present in the region reflects multiple geological origins or complex patterns of transport and deposition from sources such as the Tijuana River and San Diego Bay.

Sediment quality was also similar in 2013 to previous years with overall contaminant loads remaining relatively low compared to available thresholds and other southern California coastal areas. There was no evidence of contaminant accumulation associated with wastewater discharge. Concentrations of the various organic loading indicators, trace metals, pesticides, PCBs and PAHs varied widely throughout the region, and there were no patterns that could be attributed to the outfall or other point sources. The potential for environmental degradation by various contaminants was evaluated using the effects-range low (ERL) and effects-range median (ERM) sediment quality guidelines when available. The only exceedances of these two thresholds in 2013 were for (a) arsenic, which exceeded its ERL at a single station during both surveys, (b) silver, which exceeded its ERL at five stations and its ERM at four stations during July, and (c) total DDT, which exceeded its ERL at a single station during January. Historically, chromium, lead, mercury, zinc and total PAH never exceeded their ERL or ERM thresholds, while exceedences for arsenic, cadmium, copper, nickel, silver and total DDT have been rare (i.e., $\leq$5% of samples collected). Over the past 19 years, the distribution of contaminants in SBOO sediments continued to be linked to natural environmental heterogeneity. For example, concentrations of total organic carbon, total nitrogen, total volatile solids, and several trace metals were usually higher at sites characterized by finer sediments, a pattern consistent with results from other studies.

MACROBENTHIC COMMUNITIES

Benthic macrofaunal communities surrounding the SBOO were similar in 2013 to previous years, with assemblages located near the outfall being similar to those from neighboring farfield sites. These assemblages remained dominated by polychaete worm species that occur in similar habitats throughout the Southern California Bight (SCB). Specifically, the spionid *Spiophanes norrisi* has been the most abundant and most widely distributed species recorded in the region since 2007. Overall, benthic communities in the region appear to be in good condition, remain similar to those observed prior to outfall operations, and are representative of natural indigenous communities. For example, values for several community metrics such as species richness, total abundance, diversity, evenness and dominance were within historical ranges reported for the San Diego region, and were representative of those that occur in other sandy, shallow to mid-depth habitats throughout the SCB. Benthic response index (BRI) values were also characteristic of undisturbed habitats at 74% of the sites. Only a few stations had BRI values suggestive of a minor deviation from reference condition, and these occurred mostly north of the outfall along the 19-m and 28-m contour fitting an historical pattern that has existed since monitoring began. Finally, changes in populations of pollution-sensitive or pollution-tolerant species or other indicators of benthic condition continue to provide no evidence of significant environmental degradation in the South Bay outfall region. Thus, no specific effects of wastewater discharge via the SBOO on the local macrobenthic community were identified during the year.

DEMERSAL FISHES AND MEGABENTHIC INVERTEBRATES

Speckled sanddabs dominated fish assemblages surrounding the SBOO in 2013 as they have in previous years, occurring in all trawls and accounting for 57% of the total year's catch. California lizardfish were also prevalent as they have been in three of the past four years, occurring in 95% of trawls and accounting for 27% of the total catch. Other species collected in at least half the trawls included hornyhead turbot, longspine combfish, California tonguefish, English sole, longfin sanddab, kelp pipefish, roughback sculpin, curlfin sole, and fantail sole. Although the composition and structure of the SBOO fish assemblages varied among stations and surveys, these differences appear to be due to natural fluctuations of these common species.

Trawl-caught invertebrate assemblages in the region were dominated by the sea star *Astropecten californicus* and the shrimp *Crangon nigromaculata*. These two species occurred in 95% and 52% of trawls, respectively, and accounted for 57% and 13% of the total invertebrate abundance. Other less abundant but common species included the crabs *Metacarcinus gracilis* and *Pyromaia tuberculata*, the shrimp *Sicyonia ingentis*, the cymothoid isopod *Elthusa vulgaris*, the seastar *Pisaster brevispinus*, and the gastropod *Kelletia kelletii*. As with fishes, the composition of the invertebrate assemblages varied among stations and surveys, reflecting mostly large fluctuations in populations of the above species.

Comparisons of the 2013 surveys with results from previous surveys conducted from 1995 through 2012 indicate that trawl-caught fish and invertebrate communities in the region remain unaffected by wastewater discharge. The relatively low species richness and small population sizes of most fishes and invertebrates are consistent with the predominantly shallow, sandy habitat of the region. Patterns in the abundance and distribution of individual species were similar at stations located near the SBOO and farther away, suggesting a lack of significant anthropogenic influence. Finally, external examinations of all fish captured during the year indicated that local fish populations remain healthy, with there being no evidence of physical anomalies or disease.

CONTAMINANTS IN FISH TISSUES

The accumulation of contaminants in marine fishes may be due to direct exposure to contaminated water or sediments or to the ingestion of contaminated prey. Consequently the bioaccumulation of chemical contaminants in local fishes was assessed by analyzing liver tissues from trawl-caught fishes and muscle tissues from fish captured by hook and line. Results from these analyses indicated no evidence to suggest that contaminant loads in fishes captured in the SBOO region were affected by wastewater discharge in 2013. Although a few tissue samples had concentrations of some contaminants that exceeded pre-discharge maximum levels or various standards, concentrations of most contaminants were generally similar to those observed prior to discharge. Additionally, tissue samples that did exceed pre-discharge contaminant levels were found in fishes distributed widely throughout the region. Furthermore, all contaminant concentrations were within ranges reported previously for southern California fishes.

The occurrence of trace metals and chlorinated hydrocarbons in local fishes may be due to many factors, including the ubiquitous distribution of many contaminants in southern California coastal sediments. Other factors that affect bioaccumulation in fishes include differences in physiology and life history traits of various species, while exposure to contaminants can vary greatly between species and even among individuals of the same species depending on their migration habits. For example, an individual fish may be exposed to contaminants at a polluted site and then migrate to an area that is less contaminated. This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many other potential point and non-point sources of contamination.

CONCLUSIONS

The findings and conclusions for the ocean monitoring efforts conducted for the South Bay outfall region during calendar year 2013 were consistent with previous years. Overall, there were limited impacts to local receiving waters, benthic sediments, and marine invertebrate and fish communities. There was no evidence that the wastewater plume from the South Bay outfall reached the shoreline during the year. Although elevated bacterial levels did occur in nearshore areas, such instances were largely associated with rainfall and associated runoff during the wet season and not to shoreward transport of the plume. There were also no outfall related patterns in sediment contaminant distributions, or in differences between the various invertebrate and fish assemblages. The lack of disease symptoms in local fish populations, as well as the low level of contaminants detected in fish tissues, was also indicative of a healthy marine environment.

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Chapter 1
General Introduction

Chapter 1. General Introduction

Combined municipal treated effluent originating from two separate sources is discharged to the Pacific Ocean through the South Bay Ocean Outfall. These sources include the South Bay International Wastewater Treatment Plant (SBIWTP) owned and operated by the International Boundary and Water Commission, U.S. Section (USIBWC), and the South Bay Water Reclamation Plant (SBWRP) owned and operated by the City of San Diego (City). Wastewater discharge from the SBIWTP began in January 1999 and is subject to the terms and conditions set forth in San Diego Regional Water Quality Control Board (SDRWQCB) Order No. 96–50, Cease and Desist Order No. 96–52 (NPDES Permit No. CA0108928). Discharge from the City's SBWRP began in May 2002, and in calendar year 2013 was subject to provisions set forth in Order No. R9-2013-0006 (NPDES Permit No. CA0109045).[1] The Monitoring and Reporting Program (MRP) requirements, as specified in each of the above orders, define the receiving waters monitoring requirements for the South Bay coastal region, including sampling design, types of laboratory analyses, compliance criteria, and data analysis and reporting guidelines. The main objectives of the monitoring program are to: 1) provide data that satisfy permit requirements, 2) demonstrate compliance with California Ocean Plan (Ocean Plan) provisions, 3) detect dispersion and transport of the waste field (plume), and 4) identify any environmental changes that may be associated with wastewater discharge via the outfall.

BACKGROUND

The South Bay Ocean Outfall (SBOO) is located just north of the border between the United States and Mexico where it terminates approximately 5.6 km offshore at a depth of about 27 m. Unlike other ocean outfalls in southern California that lie on the surface of the seafloor, the SBOO pipeline begins as a tunnel on land that extends from the SBIWTP/SBWRP facilities to the coastline, and then continues beneath the seabed to a distance about 4.3 km offshore. From there it connects to a vertical riser assembly that conveys effluent to a pipeline buried just beneath the surface of the seafloor. This subsurface outfall pipe then splits into a Y-shaped (wye) multiport diffuser system with the two diffuser legs each extending an additional 0.6 km to the north and south. The outfall was originally designed to discharge wastewater through 165 diffuser ports and risers, which included one riser at the center of the wye and 82 others spaced along each diffuser leg. Since discharge began, however, consistently low flow rates have led to closure of all ports along the northern diffuser leg and many along the southern diffuser leg in order for the outfall to operate effectively. Consequently, wastewater discharge is restricted primarily to the distal end of the southern diffuser leg, with the exception of a few intermediate points at or near the center of the wye.

RECEIVING WATERS MONITORING

The core sampling area for the SBOO region extends from the tip of Point Loma southward to Playa Blanca in northern Baja California (Mexico), and from the shoreline seaward to a depth of about 61 m (Figure 1.1). The offshore monitoring sites are arranged in a grid surrounding the outfall, with each station being sampled in accordance with MRP requirements. A summary of the results for quality assurance procedures performed in 2013 in support of these requirements can be found in City of San Diego (2014). Data files, detailed methodologies, completed reports, and other pertinent information submitted to the SDRWQCB and United States Environmental Protection Agency (USEPA) throughout the year are available online at the City's website (www.sandiego.gov/mwwd/environment/oceanmonitor.shtml).

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[1] Order R9-2006-0067 superseded by adoption of Order R9-2013-0006 effective April 4, 2013

All permit mandated monitoring for the South Bay outfall region has been performed by the City of San Diego since wastewater discharge began in 1999. The City also conducted pre-discharge monitoring for 3½ years in order to provide background information against which post-discharge conditions may be compared (City of San Diego 2000a). Additionally, the City has conducted annual region-wide surveys off the coast of San Diego since 1994 either as part of regular monitoring requirements (i.e., "mini-regional surveys"; see City of San Diego 1998, 1999, 2000b, 2001–2003, 2006–2008, 2010–2013) or as part of larger, multi-agency surveys of the entire Southern California Bight (SCB). The latter include the 1994 Southern California Bight Pilot Project (Allen et al. 1998, Bergen et al. 1998, 2001, Schiff and Gossett 1998) and subsequent Bight'98, Bight'03, and Bight'08 programs in 1998, 2003, and 2008 respectively (Allen et al. 2002, 2007, 2011, Noblet et al. 2002, Ranasinghe et al. 2003, 2007, 2012, Schiff et al. 2006, 2011). During 2013, the City participated in the fifth SCB-wide survey (Bight'13 CIA 2013). These large-scale surveys are useful for characterizing the ecological health of diverse coastal areas and in distinguishing reference sites from those impacted by wastewater or stormwater discharges, urban runoff, or other sources of contamination.

In addition to the above activities, the City and USIBWC jointly fund a remote sensing program for the San Diego coastal region as part of the monitoring efforts for the South Bay and Point Loma outfall areas. This program, conducted by Ocean Imaging, Inc. (Solana Beach, CA), uses satellite and aerial imagery data to produce synoptic pictures of surface water clarity that are not possible using shipboard sampling alone. With public health issues being of paramount concern for ocean monitoring programs in general, any information that helps provide a more complete understanding of ocean conditions is beneficial to the general public as well as to program managers and regulators. Results of the remote sensing program conducted from January through December 2013 are available in Svejkovsky (2014).

This annual assessment report presents the results of all receiving waters monitoring activities conducted during calendar year 2013 for the South Bay outfall monitoring region. Included are results from all regular core stations that comprise a fixed-site monitoring grid surrounding the outfall. No sampling was conducted at randomly selected "mini-regional" benthic sites in 2013 due to a resource exchange agreement to accommodate participation in the Bight'13 monitoring program (see above). The major components of the monitoring program are covered in the following six chapters: Coastal Oceanographic Conditions, Water Quality Compliance and Plume Dispersion, Sediment Conditions, Macrobenthic Communities, Demersal Fishes and Megabenthic Invertebrates, and Bioaccumulation of Contaminants in Fish Tissues.

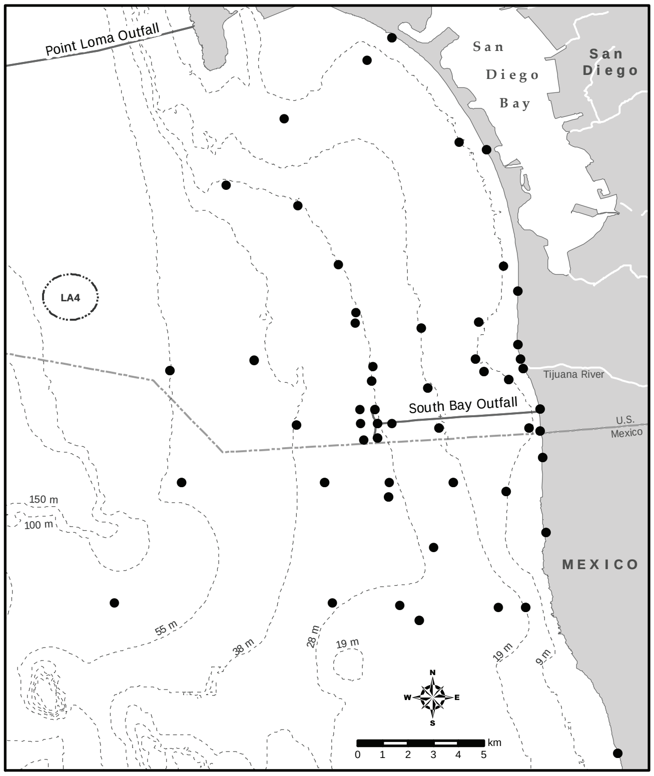

Figure 1.1
Receiving waters monitoring stations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

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Chapter 2

Coastal Oceanographic Conditions

Chapter 2. Coastal Oceanographic Conditions

INTRODUCTION

The City of San Diego collects a comprehensive suite of oceanographic data from ocean waters surrounding the South Bay Ocean Outfall (SBOO) to characterize conditions in the region and to identify possible impacts of wastewater discharge. These data include measurements of water temperature, salinity, light transmittance (transmissivity), dissolved oxygen, pH, and chlorophyll *a*, all of which are important indicators of physical and biological oceanographic processes that can impact marine life (e.g., Skirrow 1975, Mann 1982, Mann and Lazier 1991). In addition, because the fate of wastewater discharged into marine waters is determined not only by the geometry of an outfall's diffuser structure and rate of effluent discharge, but also by oceanographic factors that govern water mass movement (e.g., water column mixing, ocean currents), evaluations of physical parameters that influence the mixing potential of the water column are important components of ocean monitoring programs (Bowden 1975, Pickard and Emery 1990).

In nearshore coastal waters of the Southern California Bight (SCB) such as the region surrounding the SBOO, ocean conditions are influenced by multiple factors. These include (1) large scale climate processes such as the El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and North Pacific Gyre Oscillation (NPGO) that can affect long-term trends (Peterson et al. 2006, McClatchie et al. 2008, 2009, Bjorkstedt et al. 2010, 2011, 2012, Wells et al. 2013, NOAA/NWS 2014), (2) the California Current System coupled with local gyres that transport distinct water masses into and out of the SCB (Lynn and Simpson 1987), and (3) seasonal changes in local weather patterns (Bowden 1975, Skirrow 1975, Pickard and Emery 1990). Seasonality is responsible for the main stratification patterns observed in the coastal waters off San Diego and the rest of southern California (Terrill et al. 2009). Relatively warm waters and a more stratified water column are typically present during the dry season from May to September while cooler waters with greater mixing and weaker stratification characterize ocean conditions during the wet season from October to April (City of San Diego 2010b, 2011b, 2012b, 2013b). For example, winter storms bring higher winds, rain, and waves that typically result in a well-mixed, non-stratified water column (Jackson 1986). Surface waters begin to warm by late spring and are then subjected to increased surface evaporation. Once the water column becomes stratified, minimal mixing conditions typically remain throughout the summer and into early fall. Toward the end of the year, surface water cooling along with increased storm frequency returns the water column to well-mixed conditions.

Understanding changes in oceanographic conditions due to natural processes such as seasonal patterns is important since they can affect the transport and distribution of wastewater, storm water, and other types of plumes. In the South Bay outfall region these include sediment or turbidity plumes associated with tidal exchange from San Diego Bay, outflows from the Tijuana River off Imperial Beach and Los Buenos Creek in northern Baja California, storm drain discharges, and runoff from local watersheds. For example, outflows from San Diego Bay and the Tijuana River, that are fed by 1165 km^2 and 4483 km^2 of watersheds, respectively (Project Clean Water 2012), can contribute significantly to patterns of nearshore turbidity, sediment deposition, and bacterial contamination (see Largier et al. 2004, Terrill et al. 2009, Svejkovsky 2010).

This chapter presents analyses and interpretations of the oceanographic monitoring data collected during 2013 for the coastal waters surrounding the SBOO. The primary goals are to: (1) summarize oceanographic conditions in the region, (2) identify natural and anthropogenic sources of variability, and (3) evaluate local conditions off southern San Diego in context with regional climate processes. Results of remote sensing observations (e.g., satellite imagery) may also provide useful information on the horizontal transport of surface waters and phenomena such as phytoplankton blooms (Pickard and Emery 1990, Svejkovsky 2010, 2014). Thus, this chapter combines measurements of physical oceanographic parameters with assessments of satellite imagery to provide further insight into the transport potential in coastal waters surrounding the SBOO discharge site. The results reported herein are also referred to in subsequent chapters to explain patterns of fecal indicator bacteria distributions and plume dispersion (see Chapter 3) or other changes in the local marine environment (see Chapters 4–7).

Materials and Methods

Field Sampling

Oceanographic measurements were collected at 40 water quality monitoring stations arranged in a grid surrounding the SBOO and that encompass a total area of ~300 km^2 (Figure 2.1). These stations (designated I1–I40) are located between ~0.4 and 14.6 km offshore along or adjacent to the 9, 19, 28, 38 and 55-m depth contours. Each of these offshore stations was sampled once per month, with sampling at all 40 sites usually completed over three consecutive days (Table 2.1). The stations were grouped together as follows for sampling and analytical purposes: (1) "North Water Quality" stations I28–I38 (n = 11); (2) "Mid Water Quality" stations I12, I14–I19, I22–I27, I39, I40 (n = 15); (3) "South Water Quality" stations I1–I11, I13, I20, I21 (n = 14).

Oceanographic data were collected using a SeaBird (SBE 25) conductivity, temperature, and depth instrument (CTD). The CTD was lowered through the water column at each station to collect continuous measurements of water temperature, conductivity (used to calculate salinity), pressure (used to calculate depth), dissolved oxygen (DO), pH, transmissivity (a proxy for water clarity), and chlorophyll *a* (a proxy for phytoplankton). Water column profiles of each parameter were constructed for each station by averaging the data values recorded within each 1-m depth bin. This data reduction ensured that physical measurements used in subsequent analyses would correspond to the discrete sampling depths required for fecal indicator bacteria (see Chapter 3). Visual observations of weather and water conditions were recorded just prior to each CTD cast.

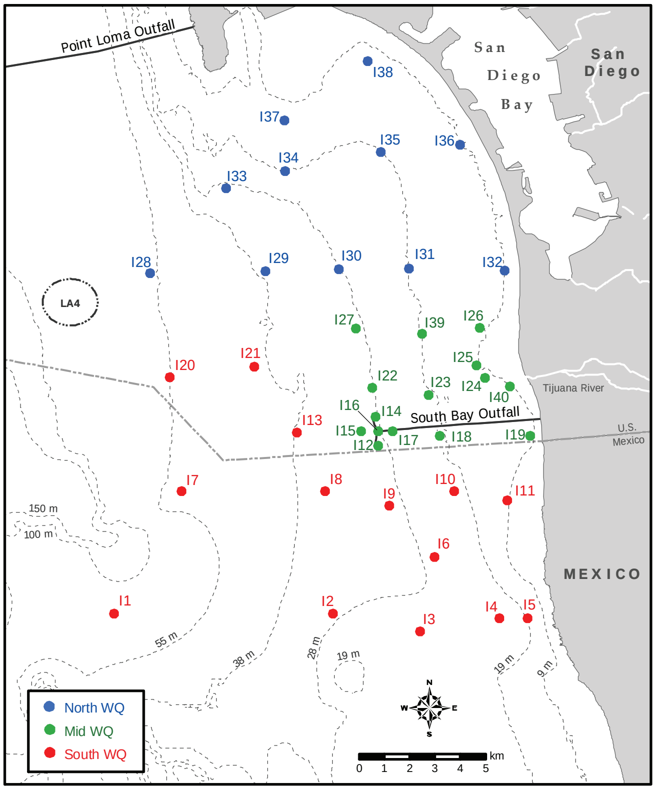

Figure 2.1
Water quality (WQ) monitoring station locations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

Remote Sensing

Coastal monitoring of the San Diego region during 2013 included remote imaging analyses performed by Ocean Imaging (OI) of Solana Beach, CA. All satellite imaging data collected during the year were made available for review and download from OI's website (Ocean Imaging 2014), while a separate report summarizing results for the year was also produced (Svejkovsky 2014). Several types of

Table 2.1

Sample dates for monthly oceanographic surveys conducted in the South Bay outfall region during 2013. Surveys were conducted within three-eight days with all stations in each station group sampled on a single day (see Figure 2.1 for stations and locations).

Station Group	2013 Sampling Dates											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North WQ	8	5	5	3	7	4	12	19	3	3	8	3
Mid WQ	9	6	12	4	9	5	10	21	5	1	7	5
South WQ	14	7	7	5	8	6	11	20	4	2	6	6

satellite imagery were analyzed, including Moderate Resolution Imaging Spectroradiometer (MODIS), Thematic Mapper TM7 color/thermal, and high resolution Rapid Eye images. While these technologies differ in terms of capacity and resolution, all are generally useful for revealing patterns in surface waters as deep as 12 m.

Data Analysis

Water column parameters measured in 2013 were summarized as monthly means pooled over all stations by the following depth layers: 1–9 m, 10–19 m, 20–28 m, 29–38 m, 39–55 m. To identify seasonal patterns and trends, temperature, salinity, DO and density data from stations I2, I3, I6, I9, I12, I14, I15, I16, I17, I22, I27, I30 and I33 located along the 28-m contour (referred to as "outfall depth" stations hereafter) were averaged for each 1-m depth bin by month. Data were limited to these 13 stations to prevent masking trends that may occur when data from multiple depth contours are combined. Vertical density profiles were constructed for the outfall depth stations to depict the pycnocline for each month and to illustrate seasonal changes in water column stratification. Buoyancy frequency (BF), a measure of the water column's static stability, was used to quantify the magnitude of stratification for each survey and was calculated as follows:

$$BF^2 = g/\rho * (d\rho/dz)$$

where g is the acceleration due to gravity, ρ is the density of seawater, and dρ/dz is the density gradient (Mann and Lazier 1991). The depth of maximum BF was used as a proxy for the depth at which stratification was the greatest.

For spatial analysis, 3-dimensional graphical views were created each month for each parameter using Interactive Geographical Ocean Data System (IGODS) software, which interpolates data between stations along each depth contour. The IGODS results reported herein are limited to data for the four surveys considered most representative of the winter (February), spring (May), summer (August), and fall (November) seasons, and that corresponded to the quarterly water quality surveys conducted as part of the coordinated Point Loma Ocean Outfall and Central Bight Regional monitoring efforts (e.g., City of San Diego 2014, OCSD 2012).

Additionally, time series plots of anomalies for temperature, salinity and DO data were created to evaluate regional oceanographic events in context with larger scale processes (i.e., ENSO events). These analyses were also limited to data from the 13 outfall depth stations combined over all depths. Anomalies were then calculated by subtracting the average of all 19 years combined (i.e., 1995–2013) from the monthly means for each year.

RESULTS AND DISCUSSION

Oceanographic Conditions in 2013

Water Temperature and Density

Surface water temperatures (1–9 m) across the South Bay outfall monitoring region ranged from 11.0 to 21.1ºC during 2013. Subsurface water temperatures ranged from 10.8 to 20.1ºC at 10–19 m, 10.7 to 16.6 ºC at 20–28 m, 10.6 to 16.1ºC at 29–38 m, and 10.3 to 14.8 ºC at 39–55 m (Appendix A.1). The maximum surface temperature recorded was ~1.1ºC lower than in 2012 (City of San Diego 2013b). Ocean temperatures varied by season as expected. For example, some of the lowest temperatures (<12ºC) were recorded at depths below 20 m at the outfall depth stations from March to April and June to August, with the lowest values occurring in April (Figure 2.2). These cold waters may be indicative of local upwelling. Similar conditions extended across the sampling region out to the stations along the 38-m and 55-m contours (e.g., Figure 2.3, May and August). Thermal stratification also followed expected seasonal patterns, with the greatest difference between surface and bottom waters (10.5ºC) occurring during July (Figures 2.2, Appendix A.1).

In shallow coastal waters of southern California and elsewhere, density is influenced primarily by temperature differences since salinity is relatively uniform (Bowden 1975, Jackson 1986, Pickard and Emery 1990). Therefore, seasonal changes in thermal stratification were mirrored by the density stratification of the water column during each month (e.g., Figure 2.4). These vertical density profiles further demonstrated how the water column ranged from well-mixed during January and February with maximum BF ≤32 cycles^2/min^2, to highly stratified in July with a maximum BF of 229 cycles^2/min^2, with stratification weakening from August through November, until becoming well-mixed in December. These results also illustrated how the depth of the pycnocline (i.e., depth layer where the density gradient was greatest) varied by season, with shallower pycnocline depths tending to correspond with greater stratification. The one exception was in May, when the water column appeared to be warmer and more mixed than normal, with a deepening of the pycnocline before it shoaled again in June.

Salinity

Salinities recorded in 2013 were similar to those reported previously for the SBOO region (e.g., City of San Diego 2012b, 2013b). Surface salinity ranged from 33.24 to 33.86 psu at 1–9 m. Subsurface salinity ranged from 33.22 to 33.79 psu at 10–19 m, 33.33 to 33.70 psu at 20–28 m, 33.35 to 33.77 psu at 29–38 m, and 33.39 to 33.8 psu at 39–55 m (Appendix A.1). As with ocean temperatures, salinity varied seasonally. For example, the narrow range of values (≤0.3 psu) throughout the water column during January, February, and December reflect the well-mixed conditions described previously for these months. Additionally, relatively high salinity ≥33.55 psu was present across most of the region from March to August at depths that corresponded with the lowest water temperatures (e.g., Figures 2.2, 2.5). Taken together, low water temperatures and high salinity may indicate local coastal upwelling that typically occurs during spring months (Jackson 1986) or that may be due to divergent southerly flow in the lee of Point Loma (Roughan et al. 2005).

As in previous years, a layer of relatively low salinity water was evident at subsurface depths throughout the region from May to August of 2013 (Figures 2.2, 2.5). For example, salinity was ≤33.50 psu between 5 and 20 m depths at the outfall depth stations during July (Figure 2.2). However, it is unlikely that this subsurface salinity minimum layer (SSML) is related to wastewater discharge via the SBOO. First, no evidence has ever been reported of the plume extending simultaneously in multiple directions across such great distances. Instead, results of remote imaging (e.g., Svejkovsky 2010), field observations, and other oceanographic studies (e.g., Terrill et al. 2009) have shown the plume to typically disperse in only one direction at any given time (e.g., south, southeast, or north) or to perhaps pool above the outfall. Second, similar SSMLs have been reported previously off San Diego and elsewhere in southern California, including Orange and Ventura Counties, which suggests that this phenomenon is related to or driven by larger-scale oceanographic processes (e.g., OCSD 2012, City of San Diego 2010a, 2011a, 2012a, 2013a). Finally, other potential indicators of wastewater, such as elevated levels of fecal indicator bacteria or colored dissolved organic matter, do not correspond to the SSML (see Chapter 3). Further investigation is required to determine the possible source or sources of this phenomenon.

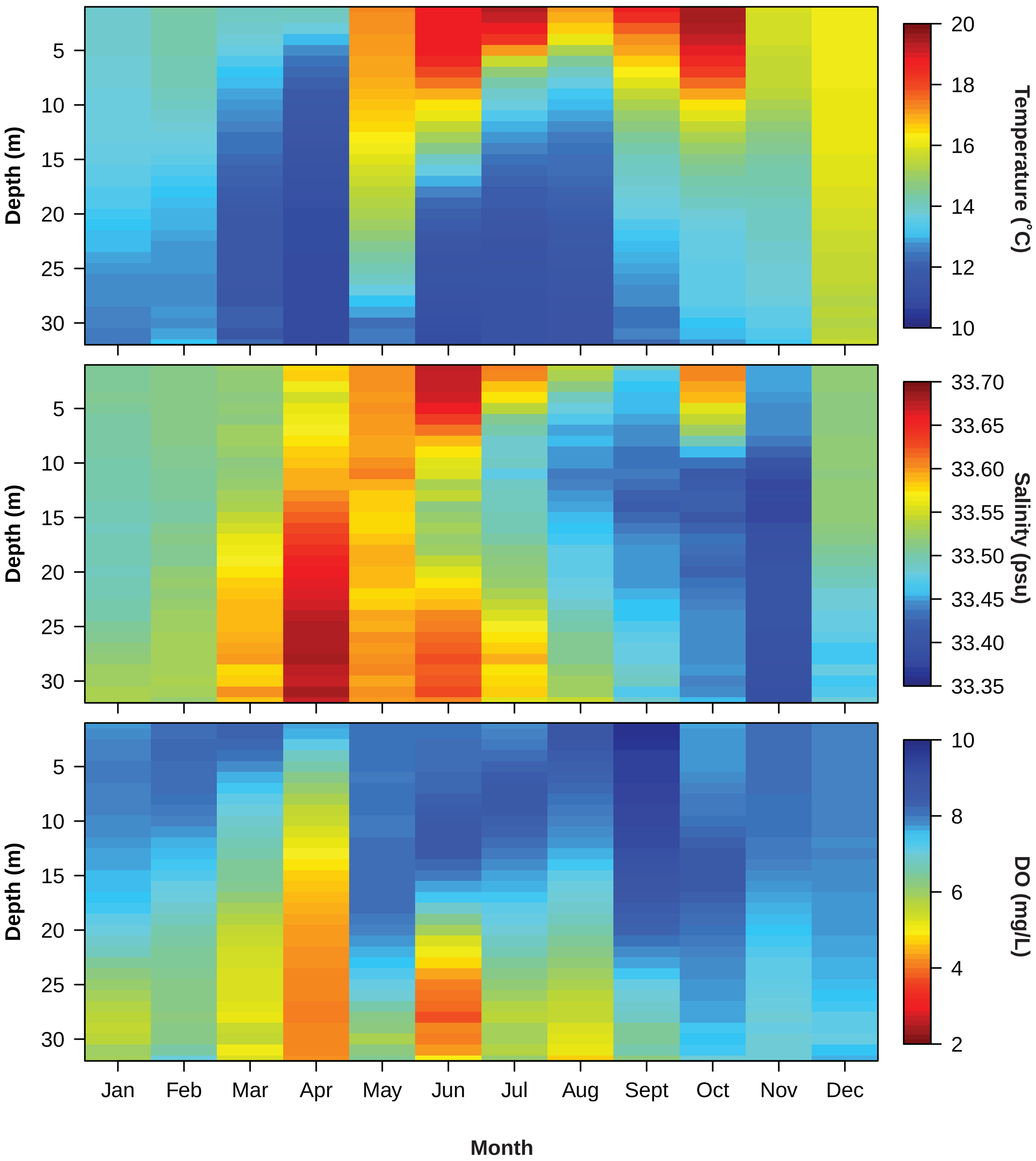

Figure 2.2
Temperature, salinity, and dissolved oxygen (DO) values recorded at outfall depth stations sampled in the SBOO region during 2013. Data are expressed as mean values for each 1-m depth bin, pooled over all 13 stations.

Dissolved oxygen and pH

Overall, DO and pH levels were similar to historical ranges throughout the year, though maximum values exceeded those of 2011 and 2012 (e.g., City of San Diego 2012b, 2013b). Surface DO ranged from 3.9 to 13.0 mg/L at 1–9 m. Subsurface DO ranged from 3.0 to 10.2 mg/L at 10–19 m, from 2.6 to 9.6 mg/L at 20–28 m, from 2.5 to 8.8 mg/L at 29–38 m, and from 3.4 to 7.4 mg/L at 39–55 m. Surface pH ranged from 7.7

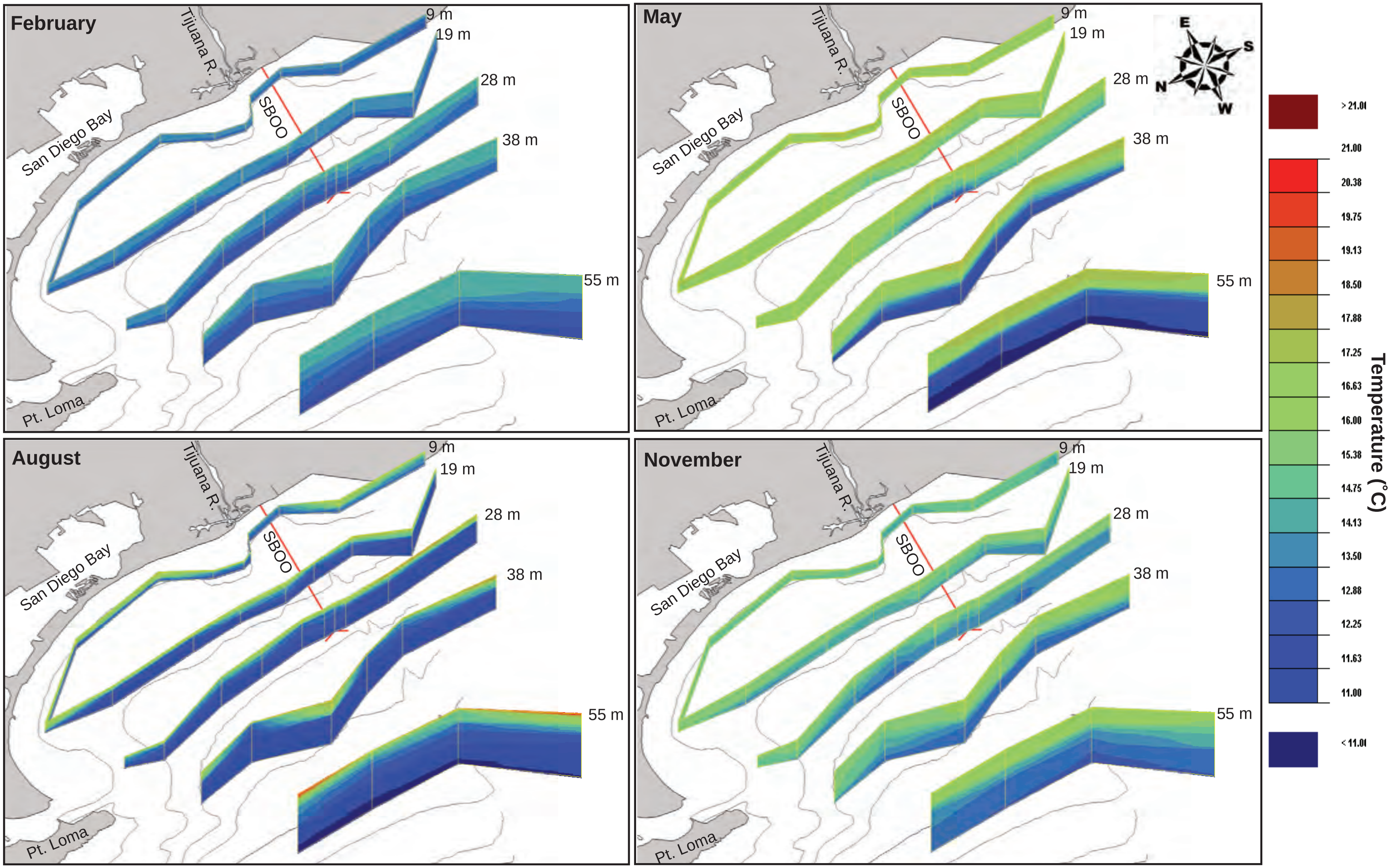

Figure 2.3

Ocean temperatures recorded in the SBOO region during winter (February), spring (May), summer (August), and fall (November) of 2013. Data were collected over three consecutive days during each of these surveys.

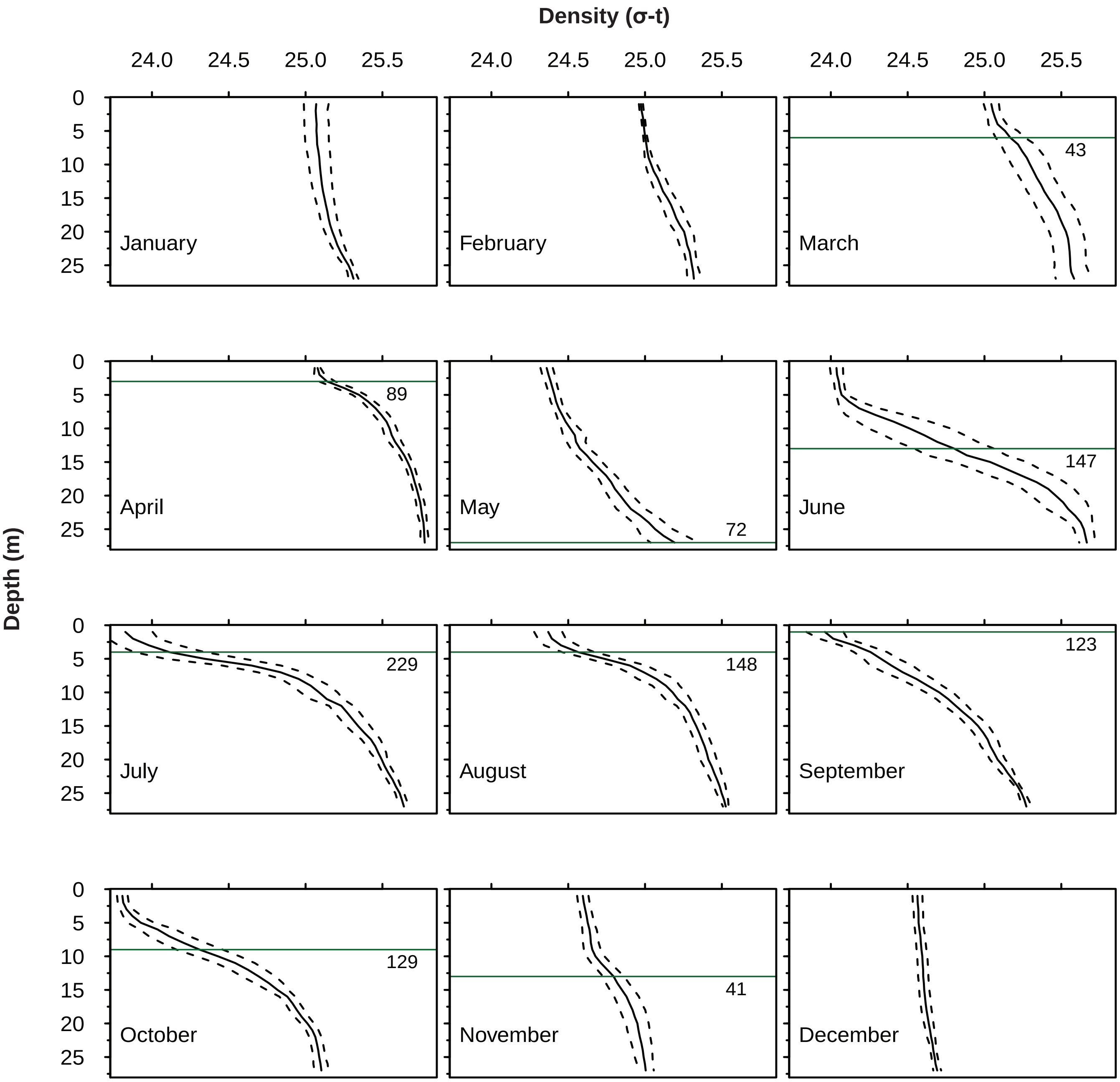

Figure 2.4

Density and maximum buoyancy frequency (BF) for each month at outfall depth stations sampled in the SBOO region during 2013. Solid lines are means, dotted lines are 95% confidence intervals (n = 13). Horizontal lines indicate depth of maximum BF with the number indicating the value in cycles^2/min^2. BF values less than 32 cycles^2/min^2 indicate a well-mixed water column and are not shown.

to 8.5 at 1–9 m. Subsurface pH ranged from 7.7 to 8.2 at 10–19 m, from 7.6 to 8.2 at 20–28 m and 29–38 m, and from 7.7 to 8.1 at 39–55 m (Appendix A.1). Changes in pH and DO were closely linked since both parameters reflect fluctuations in dissolved carbon dioxide associated with biological activity in coastal waters (Skirrow 1975). Additionally, because these parameters varied similarly across all stations, there was no evidence to indicate that the monthly surveys were not synoptic (e.g., Appendices A.2, A.3).

Changes in DO and pH followed expected patterns that corresponded to seasonal fluctuations in water

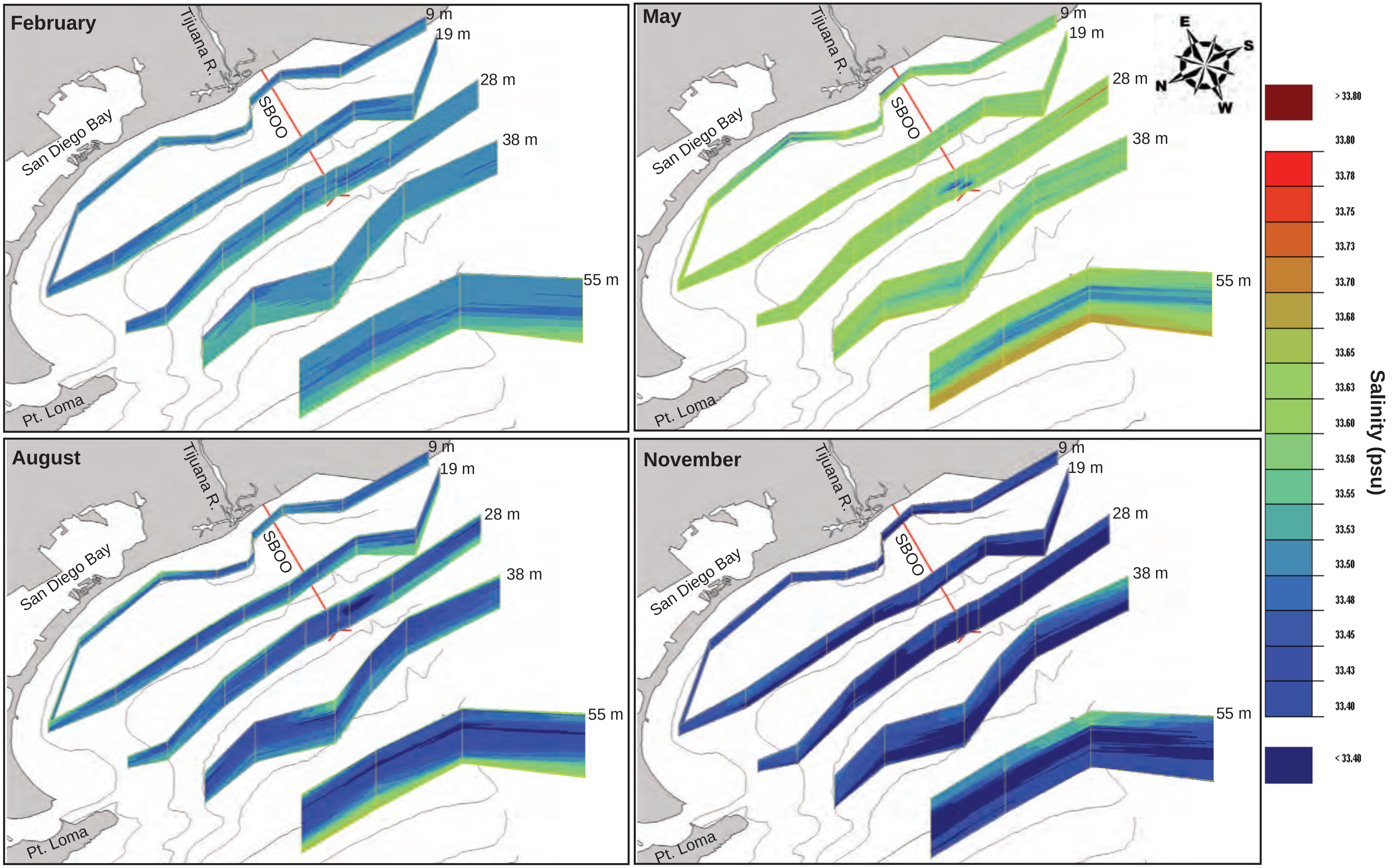

Figure 2.5

Ocean salinity recorded in the SBOO region during winter (February), spring (May), summer (August), and fall (November) of 2013. Data were collected over three consecutive days during each of these surveys.

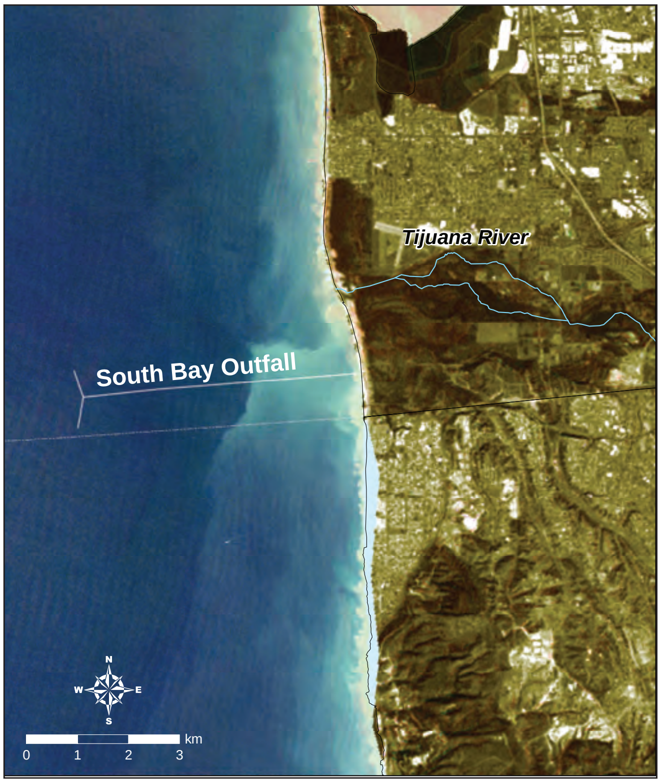

Figure 2.6
Rapid Eye image of the SBOO and coastal region acquired March 11, 2013 (Ocean Imaging 2014) depicting turbidity plumes from coastal runoff in the study area following storm events.

column stratification and phytoplankton productivity. The greatest variation and maximum stratification occurred predominately during the spring and summer (e.g., Figure 2.2; see also Appendices A.1, A.2, A.3). Low values for DO and pH that occurred at depths below 20 m at outfall depth stations during April and June were likely due to cold, saline, oxygen-poor ocean water moving inshore during periods of local upwelling as described above for temperature and salinity. Conversely, high DO concentrations (>10 mg/L) in the SBOO region during April, August, and September were associated with phytoplankton blooms as evident by high chlorophyll *a* concentrations.

Transmissivity

Overall, water clarity was within historical ranges for the SBOO region during 2013 (e.g., City of San Diego 2012b, 2013b). Surface transmissivity ranged from 5 to 90% at 1–9 m. Subsurface transmissivity ranged from 34 to 89% at 10–19 m, from 66 to 90% at 20–28 m and 29–38 m, and from 74 to 90% at 39–55 m (Appendix A.1). Water clarity was consistently greater, by as much as 80%, along 28-m, 38-m, and 55-m depth contours than along the 9-m depth contour nearest to shore (Appendix A.4). Reduced transmissivity at surface and mid-water depths tended to co-occur with peaks in chlorophyll *a* concentrations associated with phytoplankton blooms (see following section and Appendices A.1, A.4, A.5). Low transmissivity recorded during winter months may also have been due to wave and storm activity and resultant increases in suspended sediments. For example, turbidity plumes originating from the Tijuana River (Figure 2.6) coincided with reduced transmissivity throughout the water column at the 9 and 19-m stations during March (data not shown).

Chlorophyll a

Concentrations of chlorophyll *a* ranged from 0.3 to 69.0 mg/L during 2013 (Appendix A.1). Relatively high values ≥12 mg/L occurred during March, April, May, June, August, and September at depths from 1 to 27 m. As has been reported previously (e.g., Svejkovsky 2011), the highest chlorophyll concentrations tended to coincide with the upwelling events described in previous sections. Further, the high chlorophyll concentrations recorded at mid- and deeper depths (e.g., Appendix A.5) may reflect the fact that phytoplankton tend to mass at the bottom of the pycnocline where nutrients are greatest (Lalli and Parsons 1993).

Historical Assessment of Oceanographic Conditions

A review of temperature, salinity, and DO data from all outfall depth stations sampled from 1995 through 2013 (Figure 2.7) indicated how the SBOO coastal region has responded to long-term climate-related changes in the SCB, including conditions associated with ENSO, PDO, and NPGO events (Peterson et al. 2006, McClatchie et al. 2008, 2009, Bjorkstedt et al. 2010, 2011, 2012, Wells et al. 2013, NOAA/NWS 2014). For example, six major events have affected SCB coastal waters during the last two decades: (1) the 1997–98 El Niño; (2) a shift to cold ocean conditions reflected in ENSO and PDO indices between 1999 and 2002; (3) a subtle but persistent return to warm ocean conditions in the California Current System (CCS) that began in October 2002 and lasted through 2006; (4) the intrusion of subarctic waters into the CCS that resulted in lower than normal salinities during 2002–2004; (5) development of a moderate to strong La Niña in 2007 that coincided with a PDO cooling event and a return to positive NPGO values indicating an increased flow of cold, nutrient-rich water from the north; (6) development of another La Niña starting in May 2010. Temperature and salinity data for the SBOO region are consistent with all but the third of these events; while the CCS was experiencing a warming trend that lasted through 2006, the SBOO region experienced cooler than normal conditions during much of 2005 and 2006. The conditions in southern San Diego waters during 2005–2006 were more consistent with observations from northern Baja California where water temperatures were well below the decadal mean (Peterson et al. 2006). Further, below average salinities that occurred after the subarctic intrusion were likely associated with increased rainfall in the region (Goericke et al. 2007, NWS 2011). During 2013, sea surface temperatures were cooler than the long-term average January–April and July–August while May–June and September–December were warmer. However, the variation around the long-term average temperature indicated that this pattern was consistent the ENSO-neutral conditions that began in mid 2012 and persisted throughout 2013 (NOAA/NWS 2014).

Historical trends in local DO concentrations reflect several periods during which lower than normal DO has aligned with low water temperatures and high salinity, which is consistent with the cold, saline and oxygen-poor ocean waters that result from local coastal upwelling (e.g., 2002, 2005–2012). In addition, the overall decrease in DO in the SBOO region over the past decade has been observed throughout the entire CCS and may be linked to changing ocean climate (Bjorkstedt et al. 2012).

Summary

Oceanographic data collected in the South Bay outfall region were consistent with reports from NOAA that the ENSO-neutral conditions that began in mid-2012 persisted throughout 2013 (NOAA/NWS 2014). Conditions indicative of local coastal upwelling, such as relatively cold, dense, saline waters with low DO and pH at mid-depths and below, were observed from the beginning of spring through mid-summer and was most evident during April. Phytoplankton blooms, indicated by high chlorophyll *a* concentrations, were present during much of the year. Due to the depth and reduced availability of satellite data, cruise-based profiles showed that these plankton blooms covered a greater spatial and temporal extent than was evident from remote sensing alone (Svejkovsky 2014).

Overall, water column stratification in 2013 followed seasonal patterns typical for the San Diego region. Maximum stratification occurred in mid-summer, while well-mixed waters were present during the winter. Further, oceanographic conditions were either consistent with long-term trends in the SCB (Peterson et al. 2006, McClatchie et al. 2008, 2009, Bjorkstedt et al. 2010, 2011, 2012, Wells et al. 2013, NOAA/NWS 2014) or with conditions in northern Baja California (Peterson et al. 2006). These observations suggest that most of the temporal and spatial variability observed in oceanographic parameters off southern San Diego are explained by a combination of local (e.g., coastal upwelling, rain-related runoff) and large-scale oceanographic processes (e.g., ENSO, PDO, NPGO).

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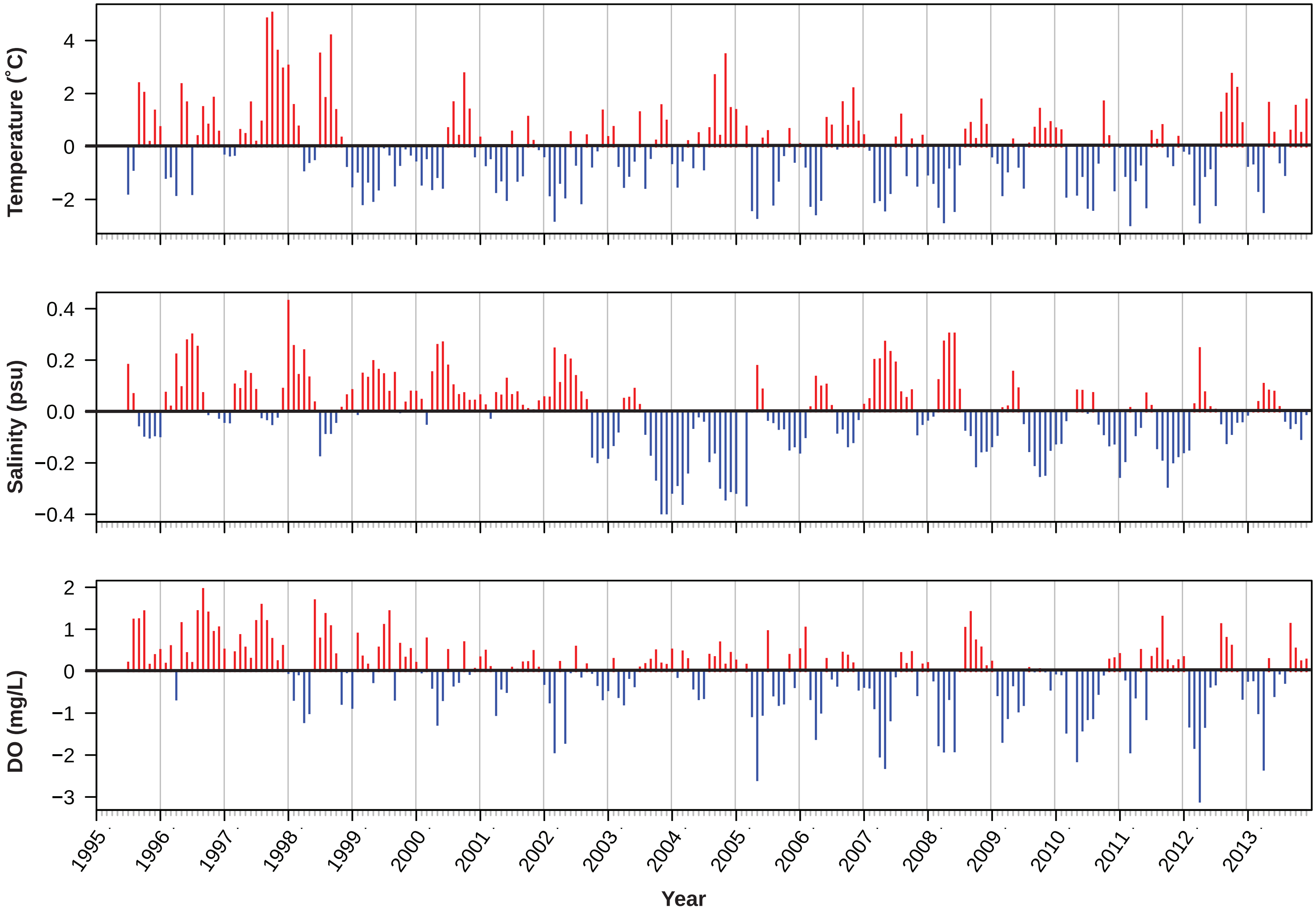

Figure 2.7
Time series of temperature, salinity, and dissolved oxygen (DO) anomalies from 1995 through 2013 at the 13 outfall depth stations sampled in the SBOO region, with all depths combined.

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Chapter 3

Water Quality Compliance & Plume Dispersion

Chapter 3. Water Quality Compliance & Plume Dispersion

Introduction

The City of San Diego analyzes seawater samples collected along the shoreline and in offshore coastal waters surrounding the South Bay Ocean Outfall (SBOO) to characterize water quality conditions in the region and to identify possible impacts of wastewater discharge on the marine environment. Densities of fecal indicator bacteria (FIB), including total coliforms, fecal coliforms and *Enterococcus* are measured and evaluated in context with oceanographic data (see Chapter 2) to provide information about the movement and dispersion of wastewater discharged into the Pacific Ocean through the outfall. Evaluation of these data may also help to identify other sources of bacterial contamination in the region. In addition, the City's water quality monitoring efforts are designed to assess compliance with the water contact standards specified in the 2009 California Ocean Plan (Ocean Plan), which defines bacterial, physical, and chemical water quality objectives and standards with the intent of protecting the beneficial uses of State ocean waters (SWRCB 2009).

Multiple sources of potential bacterial contamination exist in the South Bay outfall monitoring region in addition to the outfall. Therefore, being able to separate any effects or impacts associated with a wastewater plume from other sources of contamination is often challenging. Examples of such other non-outfall sources of contamination include outflows from San Diego Bay, the Tijuana River, and Los Buenos Creek in northern Baja California (Largier et al. 2004, Nezlin et al. 2007, Gersberg et al. 2008, Terrill et al. 2009). Likewise, storm water discharges and wet-weather runoff from local watersheds can also flush contaminants seaward (Noble et al. 2003, Reeves et al. 2004, Griffith et al. 2010, Sercu et al. 2009). Moreover, beach wrack (e.g., kelp, seagrass), storm drains impacted by tidal flushing, and beach sediments can act as reservoirs, cultivating bacteria until release into nearshore waters by returning tides, rainfall, and/or other disturbances (Gruber et al. 2005, Martin and Gruber 2005, Noble et al. 2006, Yamahara et al. 2007, Phillips et al. 2011). Further, the presence of birds and their droppings has been associated with bacterial exceedances that may impact nearshore water quality (Grant et al. 2001, Griffith et al. 2010).

In order to better understand potential impacts of a wastewater plume on water quality conditions, analytical tools based on a natural chemical tracer can be leveraged to detect effluent from an outfall and separate it from other non-point sources. For example, colored dissolved organic material (CDOM) has previously been used to identify wastewater plumes in the San Diego region (Terrill et al. 2009, Rogowski et al. 2012). By combining measurements of CDOM with additional metrics that may characterize outfall-derived waters (e.g., low salinity, low chlorophyll *a*), multiple criteria can be applied to improve the reliability of detection and facilitate the focused quantification of wastewater plume impacts on the coastal environment.

This chapter presents analyses and interpretations of the microbiological, water chemistry, and oceanographic data collected during 2013 at water quality monitoring stations surrounding the SBOO. The primary goals are to: (1) document overall water quality conditions in the region during the year; (2) distinguish between the SBOO wastewater plume and other sources of bacterial contamination; (3) evaluate potential movement and dispersal of the plume; (4) assess compliance with water contact standards defined in the 2009 Ocean Plan. Results of remote sensing data are also evaluated to provide insight into wastewater transport and the extent of

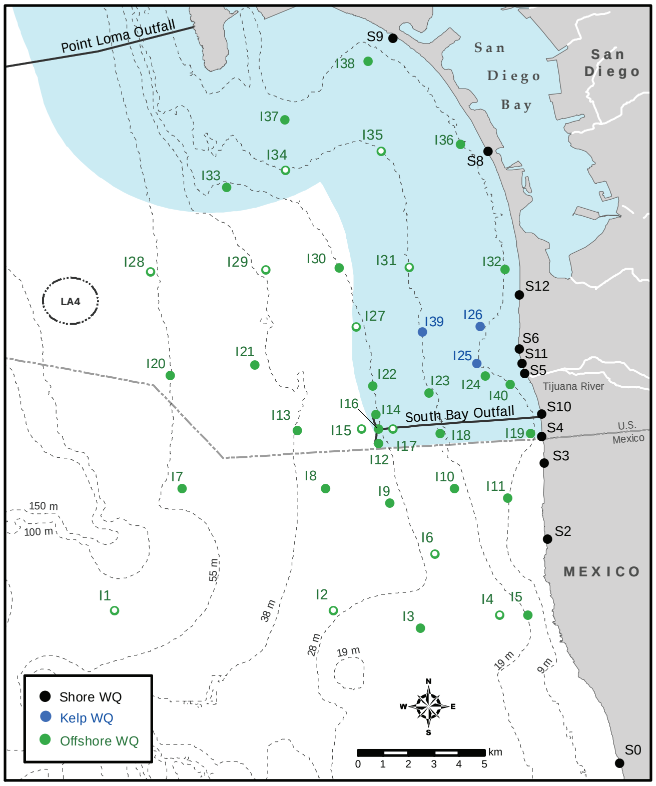

Figure 3.1

Water quality (WQ) monitoring station locations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program. Open circles are sampled by CTD only. Light blue shading represents State jurisdictional waters.

Table 3.1

Depths at which seawater samples are collected for bacteriological analysis at the SBOO kelp bed and other offshore stations.

Station Contour	Sample Depth (m) 2	6	9/11	12	18	27	37	55
Kelp Bed								
9-m	x	x	x[a]					
19-m	x			x	x			
Offshore								
9-m	x	x	x[a]					
19-m	x			x	x			
28-m	x				x	x		
38-m	x				x		x	
55-m	x				x			x

[a] Stations I25, I26, I32 and I40 sampled at 9 m; stations I11, I19, I24, I36, I37, and I38 sampled at 11 m.

significant events in surface waters during the year (e.g., turbidity plumes).

MATERIALS AND METHODS

Field Sampling

Shore stations

Seawater samples were collected weekly at 11 shore stations to monitor FIB concentrations in waters adjacent to public beaches (Figure 3.1). Of these, stations S4–S6 and S8–S12 are located in California waters between the USA/Mexico border and Coronado and are subject to Ocean Plan water contact standards (see Box 3.1). The other three stations (i.e., S0, S2, S3) are located in northern Baja California, Mexico and are not subject to Ocean Plan requirements. Seawater samples were collected from the surf zone at each shore station in sterile 250-mL bottles. The samples were then transported on blue ice to the City of San Diego's Marine Microbiology Laboratory (CSDMML) and analyzed to determine concentrations of total coliform, fecal coliform, and *Enterococcus* bacteria. In addition, visual observations of water color, surf height, human or animal activity, and weather conditions were recorded at the time of collection. These observations were reported in monthly receiving waters monitoring reports (e.g., City of San Diego 2014b).

Kelp bed and other offshore stations

Three stations located in nearshore waters within the Imperial Beach kelp forest were monitored five times a month to assess water quality conditions and Ocean Plan compliance in areas used for recreational activities such as SCUBA diving, surfing, fishing, and kayaking. These included two stations located near the inner edge of the kelp bed along the 9-m depth contour (I25 and I26), and one station located near the outer edge of the kelp bed along the 18-m depth contour (I39). An additional 25 stations were sampled once a month to monitor FIB levels and the spatial extent of the wastewater plume. These non-kelp offshore stations are arranged in a grid surrounding the discharge site along the 9, 19, 28, 38, and 55-m depth contours (Figure 3.1). Sampling of these offshore stations was generally

Box 3.1

Water quality objectives for water contact areas, 2009 California Ocean Plan (SWRCB 2009).

A. Bacterial Characteristics – Water Contact Standards; CFU = colony forming units

(a) *30-day Geometric Mean* – The following standards are based on the geometric mean of the five most recent samples from each site:
  1) Total coliform density shall not exceed 1000 CFU/100 mL.
  2) Fecal coliform density shall not exceed 200 CFU/100 mL.
  3) *Enterococcus* density shall not exceed 35 CFU/100 mL.

(b) *Single Sample Maximum*:
  1) Total coliform density shall not exceed 10,000 CFU/100 mL.
  2) Fecal coliform density shall not exceed 400 CFU/100 mL.
  3) *Enterococcus* density shall not exceed 104 CFU/100 mL.
  4) Total coliform density shall not exceed 1000 CFU/100 mL when the fecal coliform:total coliform ratio exceeds 0.1.

B. Physical Characteristics

(a) Floating particulates and oil and grease shall not be visible.
(b) The discharge of waste shall not cause aesthetically undesirable discoloration of the ocean surface.
(c) Natural light shall not be significantly reduced at any point outside of the initial dilution zone as the result of the discharge of waste.

C. Chemical Characteristics

(a) The dissolved oxygen concentration shall not at any time be depressed more than 10 percent from what occurs naturally, as a result of the discharge of oxygen demanding waste materials.
(b) The pH shall not be changed at any time more than 0.2 units from that which occurs naturally.

completed over a 3-day period each month (see Chapter 2).

Seawater samples for FIB and total suspended solids (TSS) were collected at three discrete depths at each of the kelp and non-kelp bed stations using either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles (Table 3.1). Additional samples for oil and grease (O&G) analysis were collected from surface waters only. Aliquots for each analysis were drawn into appropriate sample containers. FIB samples were refrigerated onboard ship and transported to the CSDMML for processing and analysis. TSS and O&G samples were analyzed at the City’s Wastewater Chemistry Services Laboratory. Visual observations of weather and sea conditions, and human and/or animal activity were also recorded at the time of sampling. Oceanographic data were collected monthly from these stations using a CTD to measure temperature, conductivity (salinity), pressure (depth), chlorophyll *a*, CDOM, dissolved oxygen (DO), pH, and transmissivity (see Chapter 2).

Laboratory Analyses

The CSDMML follows guidelines issued by the United States Environmental Protection Agency (USEPA) Water Quality Office and the California Department of Public Health (CDPH) Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1995, CDPH 2000, USEPA 2006). All bacterial analyses were performed within eight hours of sample collection and conformed to standard membrane filtration techniques (APHA 1995).

Enumeration of FIB density was performed and validated in accordance with USEPA (Bordner et al.

1978, USEPA 2006) and APHA (1995) guidelines. Plates with FIB 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 when calculating means and determining compliance with Ocean Plan standards.

Quality assurance tests were performed routinely on seawater samples to ensure that analyses and sampling variability did not exceed acceptable limits. Bacteriological laboratory and field duplicate samples were processed according to method requirements to measure analyst precision and variability between samples, respectively. Results of these procedures were reported under separate cover (City of San Diego 2014a).

Data Analyses

Bacteriology

FIB densities were summarized as monthly means for each shore station and by depth contour for the kelp bed and other offshore stations. TSS concentrations were also summarized by month for the offshore stations. To assess temporal and spatial trends, the bacteriological data were summarized as counts of samples in which FIB concentrations exceeded benchmark levels. For this report, water contact limits defined in the 2009 Ocean Plan for densities of total coliforms, fecal coliforms, and *Enterococcus* in individual samples (i.e., single sample maxima, see Box 3.1 and SWRCB 2009) were used as reference points to distinguish elevated FIB values (i.e., benchmarks). Bacterial densities were compared to rainfall data from Lindbergh Field, San Diego, CA (see NOAA 2014). Chi-squared Tests (χ^2) were conducted to determine if the frequency of samples with elevated FIB counts differed at the shore and kelp bed stations between wet (October–April) and dry (May–September) seasons. Satellite images of the San Diego coastal region were provided by Ocean Imaging of Solana Beach, California (Svejkovsky 2014) and used to aid in the analysis and interpretation of water quality data (see Chapter 2 for remote sensing details). Finally, compliance with Ocean Plan water-contact standards was summarized as the number of times per month that each of the eight shore stations located north of the USA/Mexico border, the three kelp bed stations, and the other offshore stations located within State jurisdictional waters (i.e., within 3 nautical miles of shore) exceeded the various standards.

Wastewater Plume Detection and Out-of-range Calculations

The potential presence or absence of wastewater plume was determined at each station using a combination of oceanographic parameters. All stations along the 9-m depth contour were excluded from analyses due to a strong CDOM signal near shore, which was likely caused by coastal runoff or nearshore sediment resuspension (Appendix B.1). Previous monitoring has consistently found that the SBOO plume is trapped below the pycnocline during seasonal water column stratification, but may rise to the surface when stratification breaks down (City of San Diego 2010–2013, Terrill et al. 2009). Water column stratification and pycnocline depth were quantified using calculations of buoyancy frequency ($\text{cycles}^2/\text{min}^2$) for each month (Chapter 2). If the water column was stratified, subsequent analyses were limited to depths below the pycnocline. Identification of a potential plume signal at a station relied on multiple criteria, including (1) high CDOM, (2) low salinity, (3) low chlorophyll *a*, and (4) visual interpretation of the overall water column profile. Detection thresholds were adaptively set for each monthly sampling period according to the following criteria: CDOM exceeding the 90th percentile, chlorophyll *a* below the 90th percentile, and salinity below the 40th percentile. The threshold for chlorophyll *a* was incorporated to exclude CDOM derived from marine phytoplankton (Nelson et al. 1998, Rochelle-Newall and Fisher 2002, Romera-Castillo et al. 2010). It should be noted that these thresholds are based on regional observations of ocean properties and are thus constrained to use within the SBOO region. Finally, water column profiles were visually interpreted to remove stations with spurious signals (e.g., CDOM signals near the sea floor that were likely caused by resuspension of sediments).

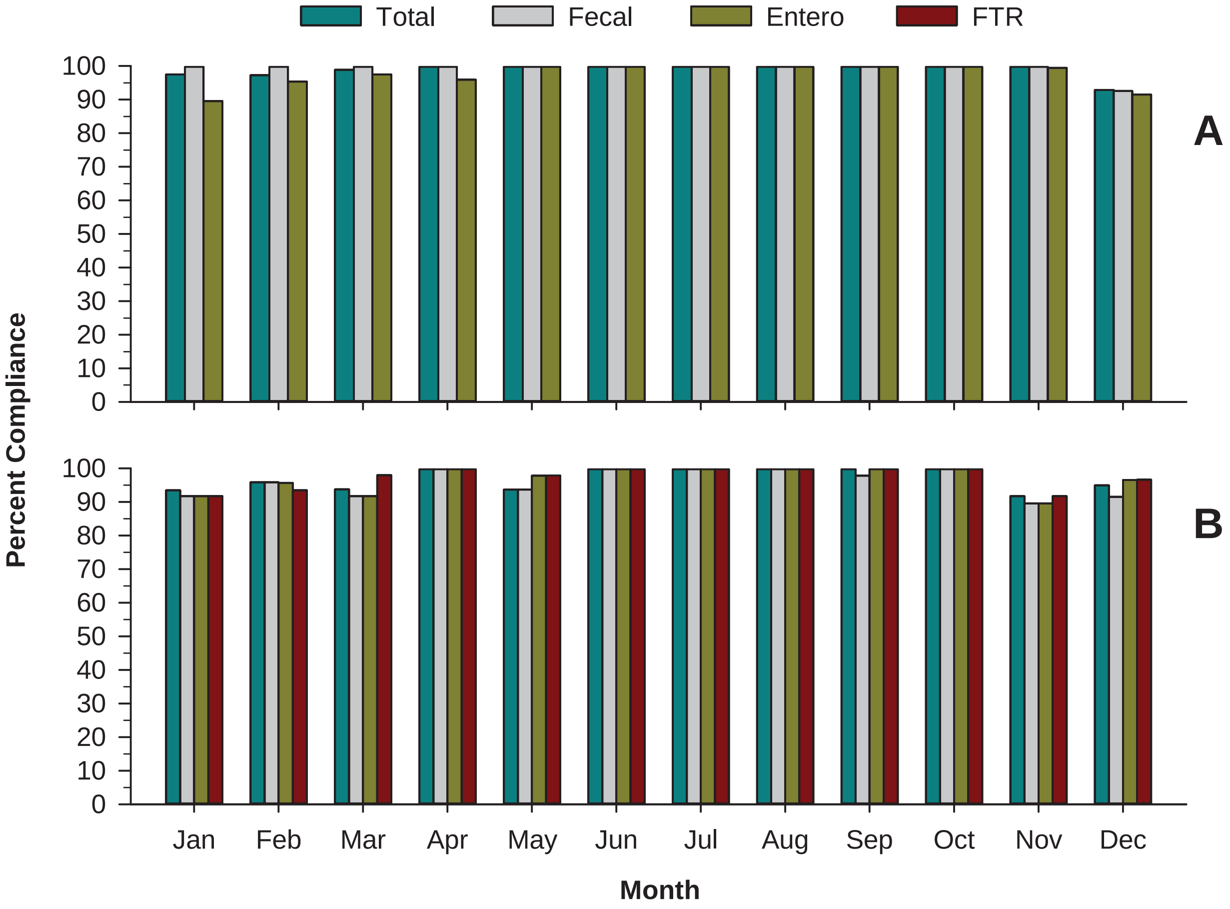

Figure 3.2

Compliance rates for (A) the three geometric mean and (B) the four single sample maximum water contact standards at SBOO shore stations during 2013.

After identifying the stations and depth-ranges where detection criteria suggested the wastewater plume may be present, the potential impact of the SBOO wastewater plume on water quality was determined by comparing mean values of DO, pH, and transmissivity within the wastewater plume to thresholds calculated for similar depths from reference stations. Any stations with CDOM below the 90th percentile were considered to lack the presence of plume and were used as reference stations for that monthly survey (Appendix B.8). Individual stations were determined to be out-of-range (OOR) for DO, pH, and transmissivity if values exceeded the narrative water quality standards for these parameters as defined by the Ocean Plan (Box 3.1). The Ocean Plan defines OOR thresholds for DO as a 10% reduction from that which occurs naturally, while the OOR threshold for pH is defined as a 0.2 unit reduction, and the OOR for transmissivity is defined as dropping below the lower 95% confidence interval from the mean. For the purposes of this report, "naturally" was defined for DO and pH as the mean minus one standard deviation (see Nezlin et al., in prep).

RESULTS AND DISCUSSION

Bacteriological Compliance and Distribution

Shore stations

During 2013, compliance for the 30-day geometric mean standards at the eight shore stations located north of the USA/Mexico border ranged from 93 to 100% for total coliforms, 93 to 100% for fecal coliforms, and 90 to 100% for *Enterococcus* (Figure 3.2A). In addition, compliance with the single sample maximum (SSM) standards ranged from 92 to 100% for total coliforms, 90 to 100% for fecal coliforms, 90 to 100% for *Enterococcus*, and 92 to 100% for the fecal:total coliform (FTR) criterion (Figure 3.2B). However, six of these stations (i.e., S4, S5, S6, S10, S11, S12) are located within or immediately adjacent to areas listed as impaired waters and are not expected to be in compliance with the various water contact standards set by the State of California and USEPA (SOC 2010). Thus, if these stations are excluded, overall compliance at the remaining two shore stations (i.e., S8 and S9) was >99% in 2013. Reduced compliance at shore stations was more prevalent during the wet season, with a low value of 90% for all standards occurring during both February and November. In contrast, compliance was greater during dry-weather months (i.e., May–September) with all standards being in compliance 100% of the time from June through August.

Monthly mean FIB densities ranged from 2 to 7044 CFU/100 mL for total coliforms, 2 to 3056 CFU/100 mL for fecal coliforms, and 2 to 3010 CFU/100 mL for *Enterococcus* at the individual stations (Appendix B.2). Of the 583 seawater samples collected along the shore during the year, 8% (n = 48) had elevated FIB (Appendix B.3), which is slightly higher than the 7% observed in 2012 (City of San Diego 2013).

Table 3.2

Number of samples with elevated FIB densities collected at SBOO shore stations during wet and dry seasons in 2013. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed north to south from top to bottom.

	Seasons		
Station	**Wet**	**Dry**	**% Wet**
S9	0	0	—
S8	0	1	0
S12	1	0	100
S6	1	0	100
S11	2	1	67
S5	7	1	88
S10	3	1	75
S4	4	0	100
S3	4	0	100
S2	5	0	100
S0	13	4	76
Rain (in)	5.26	0.31	94
Total Counts	40	8	83
n	352	231	60

The majority (83%) of the shore station samples with elevated FIB were collected during the wet season when rainfall totaled 5.26 inches, versus 0.31 inches in the dry season (Table 3.2). This general relationship between rainfall and

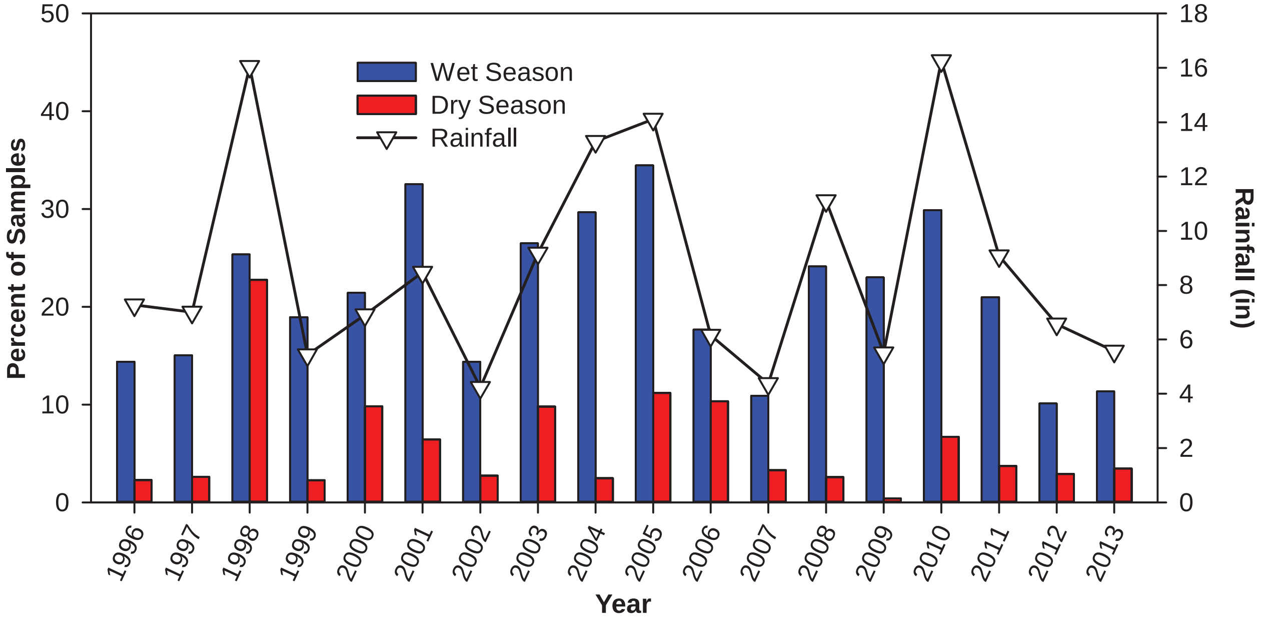

Figure 3.3

Comparison of annual rainfall to the percent of samples with elevated FIB densities in wet versus dry seasons at SBOO shore stations from 1996 through 2013. Rain data are from Lindbergh Field, San Diego, CA. Data from 1995 were excluded as sampling did not occur the entire year.

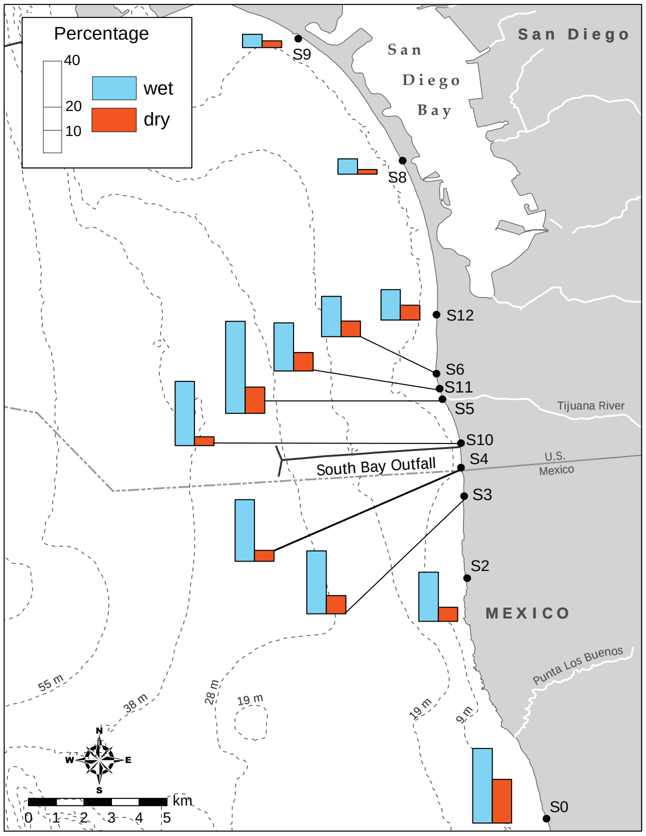

Figure 3.4

Comparison of known non-outfall sources of contamination to the percent of samples with elevated FIB densities in wet versus dry seasons at SBOO shore stations from 1995 through 2013.

elevated bacterial levels has been evident from water quality monitoring in the region since 1996 (Figure 3.3). For example, historical analyses indicate that occurrence of a sample with elevated FIB is significantly more likely during the wet than dry season (e.g., 21% versus 7%, respectively; $n = 11{,}169$, $\chi2 = 442.02$, $p < 0.0001$).

During the wet season in 2013, elevated FIB were primarily detected at stations located close to the mouth of the Tijuana River (S4, S5, S10, S11) as well as in Mexico (S0, S2, S3) (Table 3.2, Appendix B.3). Samples from two of these stations, S0 and S10, also had high FIB counts during dry conditions from June to September, and accounted for five of the eight dry weather samples with elevated FIB. The remaining samples with elevated FIB during dry weather months were collected from stations S5, S8, and S11 on May 7 and were likely caused by uncharacteristic rainfall during May 7–9. Foam and sewage-like odors were consistently observed at various shore stations within the SBOO region, with increased occurrences during the wet season. Additionally, storm drain runoff was often observed at all three stations located in Mexican waters. Results from historical analyses also indicated elevated FIB densities occur more frequently near the Tijuana River and south of the international border near Los Buenos Creek than at other shore stations, especially during the wet season (Figure 3.4). Over the past several years, high FIB counts at these stations have consistently corresponded to outflows from the Tijuana River and Los Buenos Creek, typically following rain events (City of San Diego 2008–2013).

Kelp bed stations

Compliance at the three kelp bed stations in the SBOO region was 100% throughout the year except during November when the SSMs for fecal coliforms, *Enterococcus* and the FTR criterion were exceeded (Figure 3.5A). Compliance rates for these three standards dropped to ≤96% during this month, corresponding to a period of high rainfall.

Monthly mean FIB densities at the kelp bed stations were lower than those at shore stations, ranging from 3 to 447 CFU/100 mL for total coliforms, 2 to 78 CFU/100 mL for fecal coliforms, and 2 to 36 CFU/100 mL for *Enterococcus* (Appendix B.4). Nothing of sewage origin was observed at these stations, and only three of the 540 samples (0.6%) analyzed during the year had elevated FIB, all of which were collected at stations I25 and I26 in November (Appendix B.5). Due to fewer high-rainfall events, coastal runoff from the Tijuana Estuary was lower in 2013 compared to previous years (Svejkovsky 2014) and likely resulted in the fewer incidences of elevated FIB detected throughout the year (Table 3.3). Historical water quality monitoring data for the region (Figure 3.6) indicate that elevated FIB was significantly more likely to occur during the wet season than during the dry season (8% versus 1%, respectively; $n = 8504$, $\chi^2 = 195.04$, $p < 0.0001$).

No seawater samples collected from the kelp bed stations during 2013 contained detectable levels of O&G (detection limit = 0.2 mg/L; Appendix B.6).

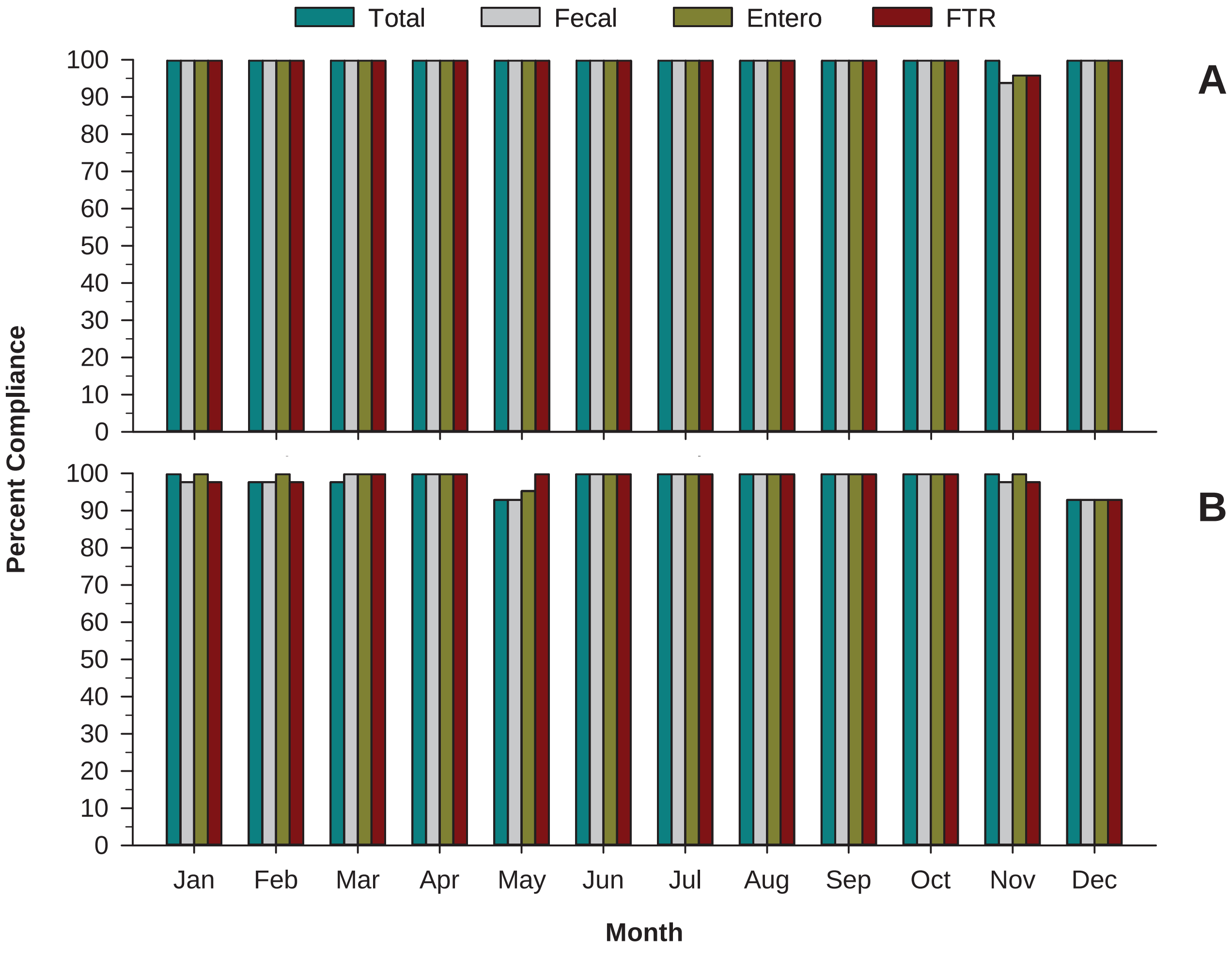

Figure 3.5

Compliance rates for the four single sample maximum water contact standards at SBOO (A) kelp bed and (B) other offshore stations during 2013. See Box 3.1 for details.

In contrast, TSS were detected in almost all samples (99%) at concentrations ranging from 1.40 to 12.00 mg/L. Of the 14 seawater samples with elevated TSS concentrations (≥8.0 mg/L), none were associated with elevated FIB densities.

Non-kelp bed stations

Compliance at the 14 offshore stations located within State waters (i.e., I12, I14, I16, I18, I19, I22–I24, I32, I33, I36–I38, I40) ranged from 93 to 100% each for total coliforms, fecal coliforms, *Enterococcus*, and for the FTR criterion (Figure 3.5B). FIB concentrations were low in seawater samples collected at these and the other 11 non-kelp bed offshore stations during 2013, with monthly means ranging from 2 to 1636 CFU/100 mL for total coliforms, 2 to 350 CFU/100 mL for fecal coliforms, and 2 to 226 CFU/100 mL for *Enterococcus* (Appendix B.4). Only seven (~1.4%) of the 504 samples collected within State waters had elevated FIB and all of these contaminated samples were from stations I19, I32, and I40 located along the 9-m depth contour and were associated with rainfall (Appendix B.7). These four sites, in combination with kelp bed stations I25 and I26 and station I5 located in Mexican waters, had the only offshore elevated FIB detections throughout the year (Figure 3.7). Given the proximity of these stations to shore, coastal runoff may be responsible for the elevated FIB levels (Chapter 2). For example, a satellite image taken on November 30 showed a plume of turbid water originating from the Tijuana River and passing over stations I5, I25, and I26 (Figure 3.8). Although taken at the end of the month, this image reflects conditions

Table 3.3

Number of samples with elevated FIB densities collected at SBOO kelp bed and other offshore stations during wet and dry seasons in 2013. Rain data are from Lindbergh Field, San Diego, CA. Missing offshore stations had no samples with elevated FIB concentrations during 2013.

	Wet	Dry	% Wet
Rain (in)	5.26	0.31	94
Kelp Bed Stations			
9-m Depth Contour			
I25	1	0	100
I26	2	0	100
Total Counts	3	0	100
n	315	225	58
Non-Kelp Bed Stations			
9-m Depth Contour			
I5	4	0	100
I19	3	0	100
I32	0	3	0
I40	1	0	100
Total Counts	8	3	73
n	525	375	58

typical for the region during November as several significant rain events occurred during the month. Additionally, scum and organic debris were observed on the ocean surface at station I10 on May 8 which was likely due to runoff from the previously mentioned rain event in May.

During 2013, water quality was excellent at the three stations closest to the SBOO south diffuser leg (i.e., outfall stations I12, I14, I16). Not a single sample with high bacteria counts was collected from these sites or any of the other 28-m stations located at the depth of wastewater discharge (Table 3.3, Figures 3.7, 3.8, 3.9, Appendix B.7). These results demonstrate improved water quality near the outfall versus previous years. Historically, samples with elevated bacterial levels have been collected more often at the three outfall stations when compared to other stations along the 28-m depth contour (12% versus 3%; $n=5249$, $\chi2=180.69$, $p<0.0001$) (Figure 3.9). In the past, samples with elevated FIB levels were predominately collected at a depth of 18 m. Consequently, it appears likely that these FIB densities were associated with wastewater discharge from the outfall.

Of the 300 samples collected during 2013, 2.3% contained detectable levels of O&G, with concentrations that ranged from 1.40 to 3.80 mg/L (Appendix B.6). Total suspended solids were detected in 92% of 996 samples, with concentrations that ranged from 1.40 to 46.70 mg/L. Only two seawater samples with elevated TSS concentrations (≥8.0 mg/L) corresponded to a sample with elevated FIB; these samples were collected from 2 and 9 m at station I32 on May 8. The location and timing of these samples in close proximity to the Tijuana River mouth and during a rain event, suggests that these elevated measurements were likely due to runoff from the river.

Plume Dispersion and Effects

The dispersion of the wastewater plume from the SBOO and its effects on natural light, DO and pH levels was assessed using the results of 336 CTD profile casts performed during 2013. Based on the criteria described in the Materials and Methods section, evidence of the plume was detected a total of 31 times from 12 different stations throughout the year (Table 3.4), while 11–19 stations were identified as reference sites during each monthly survey (Appendix B.8). Spatial distribution of the plume varied (Figure 3.10, Appendix B.9), although ~61% of the detections occurred at the fives sites located within 0.5 km of the diffuser legs (i.e., stations I12, I14–I17). Of these, the plume was detected most frequently at station I12 located near the end of the southern diffuser leg (~26% of detections), station I16 located near the center of the diffuser wye (~16% of detections), and station I15 located west of the wye (~13% of detections). About another 16% of the detections occurred at station I9 located south of the outfall. In addition, single occurrences of potential plume were detected ~2.1 km inshore of the discharge area at station I23, and >7 km north or south of the outfall at stations I29 and I3, respectively. Overall, the variation in plume dispersion is likely due to reversals in alongshore current direction in the region (see Terrill et al. 2009). Inconsistent detection of the plume was probably related to the coarse spatial scale of the SBOO sampling stations (see Terrill et al. 2009).

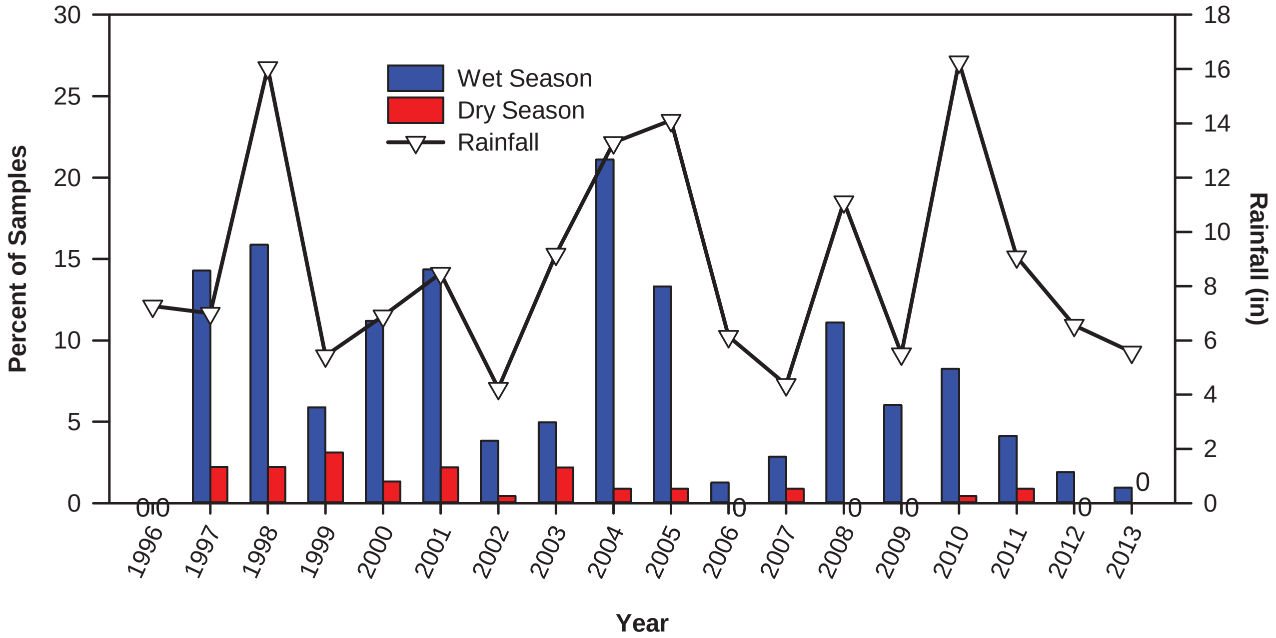

Figure 3.6

Comparison of annual rainfall to the percent of samples with elevated FIB densities in wet versus dry seasons at SBOO kelp bed stations from 1996 through 2013. Rain data are from Lindbergh Field, San Diego, CA. Data from 1995 were excluded as sampling did not occur the entire year.

Plume depth also fluctuated through time associated with differences in water column stratification and buoyancy frequency (BF). For example, periods of weak stratification (BF < 32 cycles^2/min^2) allowed the plume to rise near the surface, while stronger stratification (BF > 32 cycles^2/min^2) restricted plume rise height to depths beneath the pycnocline (Appendix B.10).

The effects of the SBOO wastewater plume on the three natural water quality indicators mentioned above were calculated for each station and depth where it was detected. For each of these, mean values for natural light (% transmissivity), DO, and pH within the plume were compared to thresholds within similar depths from non-plume reference stations (see Appendix B.11). Of the 31 plume detections that occurred during 2013, a total of 17 out-of-range (OOR) events were identified, which consisted of 16 OORs for transmissivity at various stations throughout the year, one OOR for DO at station I9 in June, and no OORs for pH (Table 3.4, Figure 3.11, Appendices B.12–B.14). A total of nine of the OOR events occurred at stations within State waters where Ocean Plan compliance standards applied at the time of sampling.

SUMMARY

Water quality conditions in the South Bay outfall region were excellent during 2013. Overall compliance with 2009 Ocean Plan water-contact standards was ~98%, which was slightly greater than the 97% compliance observed during the previous year (City of San Diego 2013). This improvement likely reflects lower rainfall, which totaled about 5.57 inches in 2013 versus 6.56 inches in 2012. Additionally, only 3.1% of all water samples analyzed in 2013 had elevated FIB, of which 82% occurred during the wet season. Of these high counts, 78% were from samples collected at the shore stations. This pattern of higher contamination along the shore during the wet season is similar to that observed during previous years (e.g., City of San Diego 2013). The few samples with high bacteria counts taken during dry weather periods also tended to occur more frequently at shore stations.

There was no evidence that wastewater discharged to the ocean via the SBOO reached the shoreline

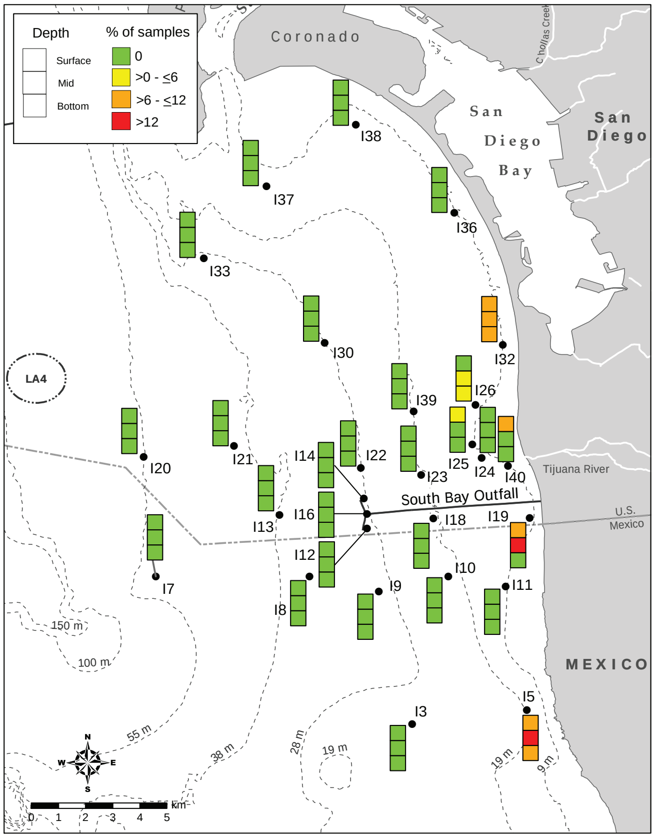

Figure 3.7

Distribution of elevated FIB samples collected at kelp bed and other offshore stations during 2013. Data are the percent of samples that contained elevated bacteria densities. See text and Table 3.1 for sampling details.

during the year. Although elevated FIB were detected along the shore and occasionally at a few nearshore stations, these results did not indicate shoreward transport of the plume, a conclusion consistently supported by remote sensing observations (e.g., Terrill et al. 2009, Svejkovsky 2010–2014). Instead, other sources such as coastal runoff from rivers and creeks were more likely to impact coastal water quality in the South Bay outfall region, especially during the wet season. For example, the shore stations located near the mouths of the Tijuana River and Los Buenos Creek have historically had higher numbers of contaminated samples than stations located farther to the north (City of San Diego 2008–2013). It is also well established that sewage-laden discharges from the Tijuana River and Los Buenos Creek are likely sources of bacteria during storms or other periods of increased flows (Svejkovsky and Jones 2001, Noble et al. 2003, Gersberg et al. 2004, 2006, 2008, Largier et al. 2004, Terrill et al. 2009, Svejkovsky 2010). Further, the general relationship between rainfall and elevated bacterial levels in the SBOO region existed before wastewater discharge began in 1999 (see also City of San Diego 2000).

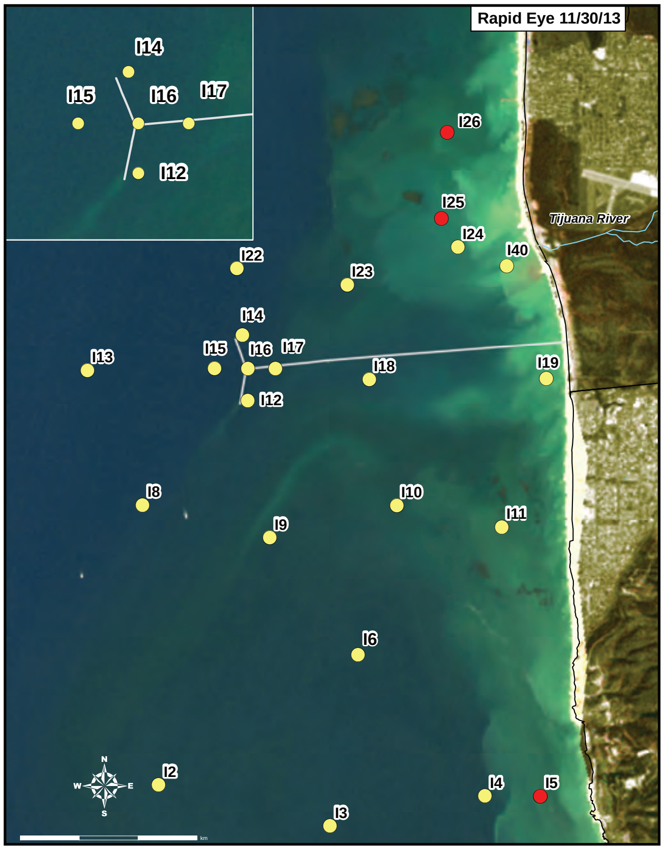

Figure 3.8

Rapid Eye satellite image showing stations near the SBOO on November 30, 2013 (Ocean Imaging 2014) combined with bacteria levels sampled during the month of November. Turbid waters from the Tijuana River, caused by several rain events during the month, can be seen overlapping stations with elevated FIB (red circles). Surfacing effluent plume[a] does not correspond with elevated FIB. See Appendices B.5 and B.7 for bacterial sample details.

[a] See inset

Finally, there was little indication of bacterial contamination in the offshore waters of the SBOO region during 2013, with only about 1.4% of all samples collected within State waters having elevated FIB. Additionally, these few high counts were all from stations located nearshore along the 9-m depth contours. No samples with elevated FIB were collected at the three stations nearest

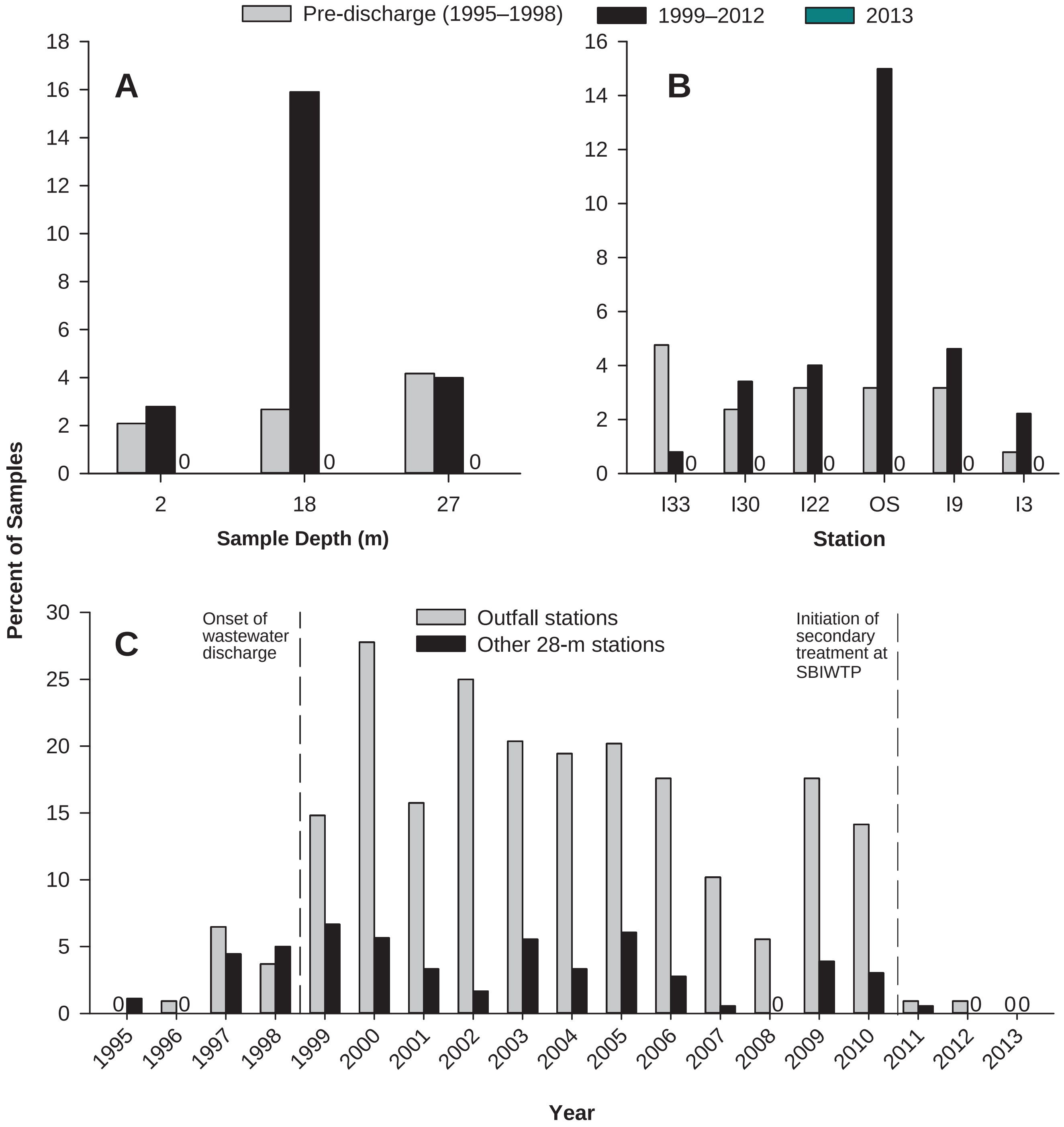

Figure 3.9
Percent of samples collected from SBOO 28-m offshore stations with elevated bacteria densities. Samples from 2013 are compared to those collected from 1995 through 2012 by (A) sampling depth, (B) station listed north to south from left to right, and (C) year. OS = outfall stations (I12, I14, I16).

the discharge site (I12, I14, I16), which is likely related to chlorination of South Bay International Water Treatment Plant effluent (November–April) and the initiation of full secondary treatment that began in January 2011. Further, detection of the wastewater plume was low (9.2%) in the SBOO region during 2013, with the majority of detections occurring at stations nearest to the outfall. Within the plume, transmissivity of light was most often significantly reduced (52% OOR) while OOR

Table 3.4

Summary of wastewater plume detections and out-of-range values at SBOO offshore stations during 2013. Stations within State jurisdictional waters are in bold. DO = dissolved oxygen; XMS = transmissivity.

		Out of Range			
Month	**Plume Detections**	**DO**	**pH**	**XMS**	**Stations**
Jan	1	0	0	1	**I12**[a]
Feb	1	0	0	1	**I12**[a]
Mar	4	0	0	3	I3[a], I6[a], I9[a], **I12**
Apr	1	0	0	0	**I12**
May	3	0	0	0	I15, **I16**, I29
Jun	2	1	0	2	I9[ab], **I12**[a]
Jul	2	0	0	1	I6[a], I9
Aug	3	0	0	3	I9[a], **I12**[a], **I16**[a]
Sep	6	0	0	0	I8, I9, **I12**, I15, **I16**, **I17**
Oct	1	0	0	0	I15
Nov	5	0	0	5	**I14**[a], I15[a], **I16**[a], **I22**[a], **I23**[a]
Dec	2	0	0	0	**I12**, **I16**
Detection Rate (%)	9.2	0.3	0.0	4.8	
Total Count	31	1	0	16	
n	336	336	336	336	

[a] Out-of-range value for transmissivity; [b] out-of-range value for dissolved oxygen

events for DO and pH were either rare or not detected (3% and 0%, respectively).

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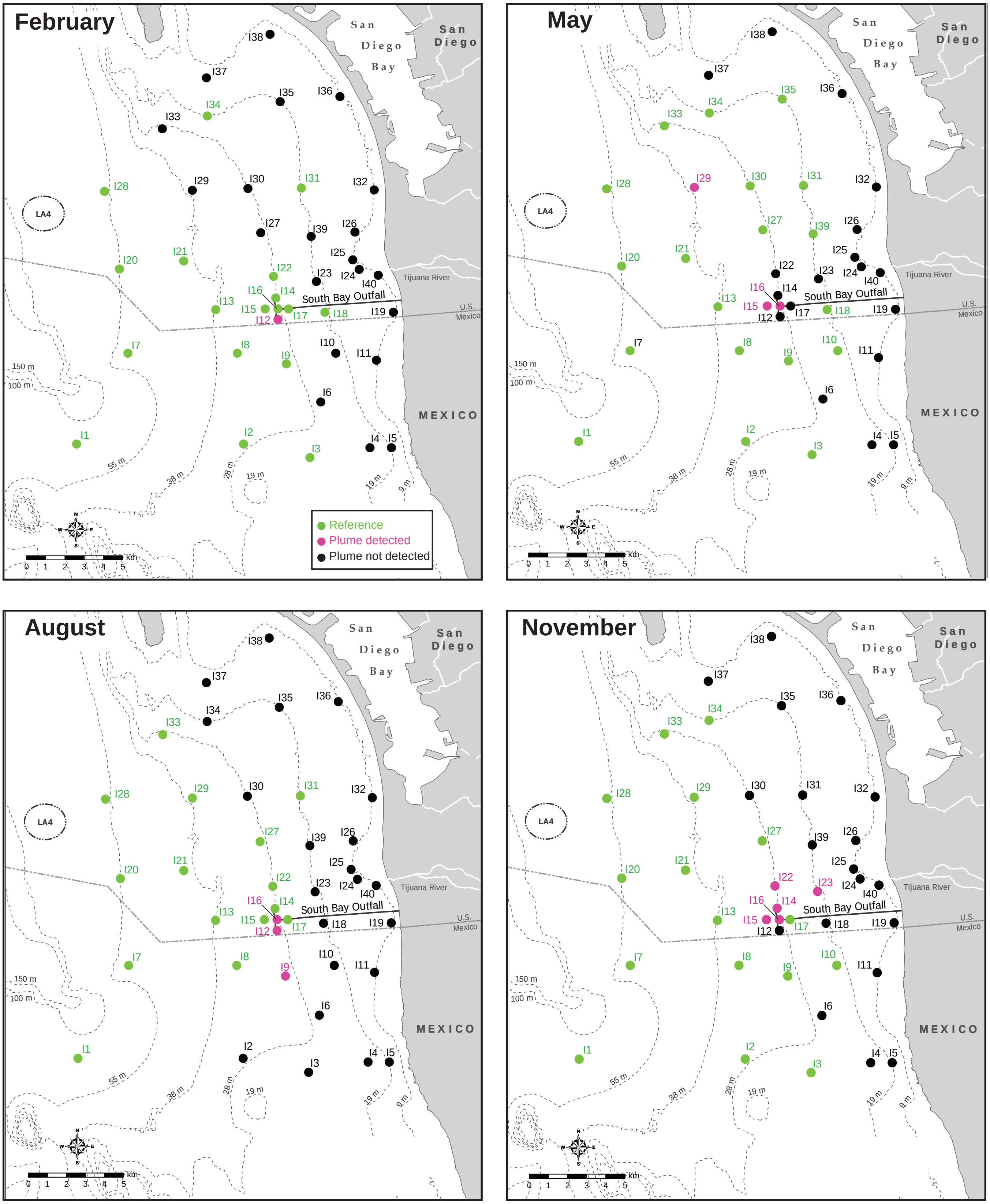

Figure 3.10
Distribution of stations where SBOO plume was potentially detected (pink) and those used as reference stations (green) during representative monthly surveys in 2013. Additional maps are located in Appendix B.9.

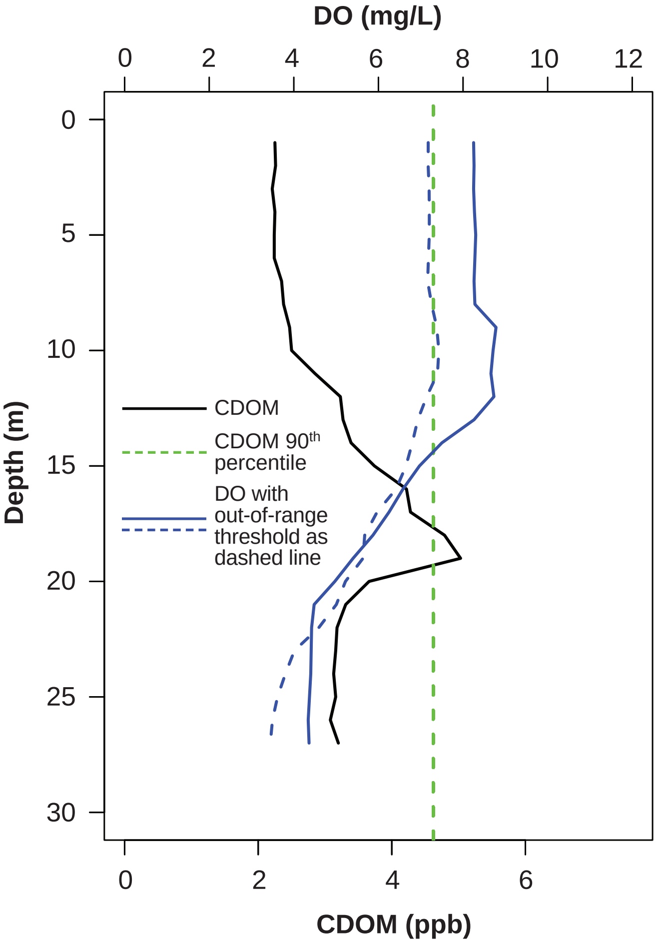

Figure 3.11
Vertical profile of CDOM and dissolved oxygen (DO) values from station I9 on June 6, 2013.

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Chapter 4
Sediment Conditions

Chapter 4. Sediment Conditions

INTRODUCTION

Ocean sediment samples are analyzed as part of the City of San Diego's Ocean Monitoring Program to examine the effects of wastewater discharge from the South Bay Ocean Outfall (SBOO) and other anthropogenic inputs on the marine benthic environment. Analyses of various sediment contaminants are conducted because anthropogenic inputs to the marine ecosystem, including municipal wastewater, can lead to increased concentrations of pollutants within the local environment. The relative percentages of sand, silt, and clay and other particle size parameters are examined because concentrations of some compounds are known to be directly linked to sediment composition (Emery 1960, Eganhouse and Venkatesan 1993). Physical and chemical sediment characteristics are also analyzed because together they define the primary microhabitats for benthic invertebrates that live within or on the seafloor, and therefore influence the distribution and presence of various species. For example, differences in sediment composition and organic loading impact the burrowing, tube building, and feeding abilities of infaunal invertebrates, thus affecting benthic community structure (Gray 1981, Snelgrove and Butman 1994). Many demersal fish species are also associated with specific sediment types that reflect the habitats of their preferred invertebrate prey (Cross and Allen 1993). Understanding the differences in sediment conditions and quality over time and space is therefore crucial to assessing coincident changes in benthic invertebrate and demersal fish populations (see Chapters 5 and 6, respectively).

Both natural and anthropogenic factors affect the composition, distribution, and stability of seafloor sediments on the continental shelf. Natural factors that affect sediment conditions include geologic history, strength and direction of bottom currents, exposure to wave action, seafloor topography, inputs from rivers and bays, beach erosion, runoff, bioturbation by fish and benthic invertebrates, and decomposition of calcareous organisms (Emery 1960). These processes affect the size and distribution of sediment particles, as well as the chemical composition of sediments. For example, erosion from coastal cliffs and shores, and flushing of terrestrial sediment and debris from bays, rivers, and streams strongly influence the overall organic content and particle size of coastal sediments. These inputs can also contribute to the deposition and accumulation of trace metals or other contaminants on the sea floor. In addition, primary productivity by phytoplankton and decomposition of marine and terrestrial organisms are major sources of organic loading to coastal shelf sediments (Mann 1982, Parsons et al. 1990).

Municipal wastewater outfalls are one of many anthropogenic factors that can directly influence sediment characteristics through the discharge of treated effluent and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected contaminants discharged via ocean outfalls are trace metals, pesticides, and various indicators of organic loading such as organic carbon, nitrogen, and sulfides (Anderson et al. 1993). In particular, organic enrichment due to wastewater discharge is of concern because it may impair habitat quality for benthic marine organisms and thus disrupt ecological processes (Gray 1981). Lastly, the physical presence of a large outfall pipe and associated ballast materials (e.g., rock, sand) may alter the hydrodynamic regime in surrounding areas, thus affecting sediment movement and transport and the resident biological communities.

This chapter presents analyses and interpretations of sediment particle size and chemistry data collected at monitoring stations surrounding the SBOO during 2013, as well as a long-term assessment of sediment conditions in the region from 1995 through 2013. The primary goals are to: (1) document sediment

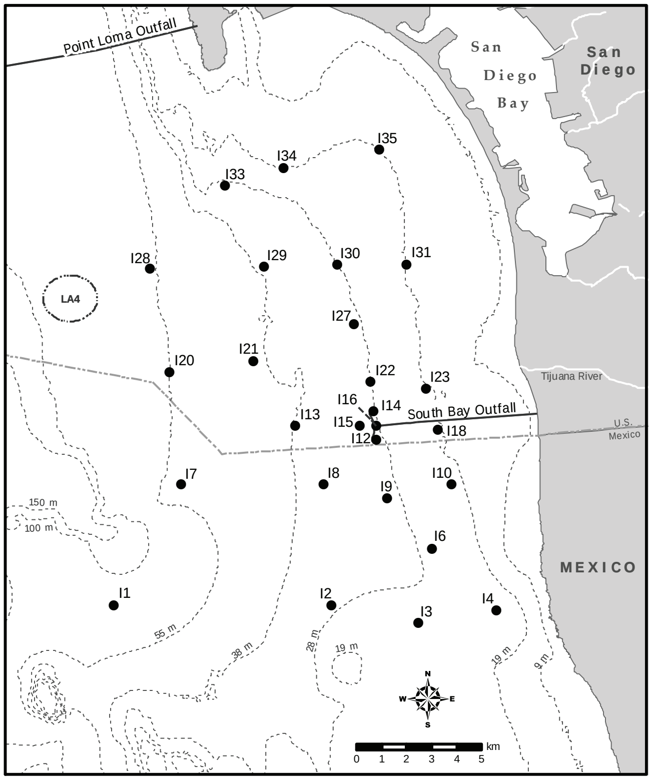


Figure 4.1
Benthic station locations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

conditions during the year, (2) identify possible effects of wastewater discharge on sediment quality in the region, and (3) identify other potential natural and anthropogenic sources of sediment contaminants to the local marine ecosystem.

Materials and Methods

Field Sampling

Sediment samples were collected at 27 monitoring stations in the SBOO region during winter (January) and summer (July) 2013 (Figure 4.1). These stations range in depth from about 18 to 60 m and are distributed along or adjacent to four main depth contours. Fifteen sites are located along the 19, 38, or 55-m depth contours, while 12 sites are located along the 28-m depth contour and are referred to as "outfall depth" stations. Outfall depth stations include the four stations located within 1000 m of the outfall diffuser structure that are considered to represent "nearfield" conditions (i.e., I12, I14, I15, I16), four "north farfield" stations (i.e., I22, I27, I30, and I33) and four "south farfield" stations (i.e., I2, I3, I6, I9).

Each sediment sample was collected from one side of a chain-rigged double Van Veen grab with a 0.1-m^2 surface area; the other grab sample from the cast was used for macrofaunal community analysis (see Chapter 5). Sub-samples for various analyses were taken from the top 2 cm of the sediment surface and handled according to standard guidelines available in USEPA (1987).

Laboratory Analyses

All sediment chemistry and particle size analyses were performed at the City of San Diego's Wastewater Chemistry Services Laboratory. A detailed description of the analytical protocols can be found in City of San Diego (2014). Briefly, sediment sub-samples were analyzed to determine concentrations of various indictors of organic loading (i.e., total organic carbon, total nitrogen, total sulfides, total volatile solids), 18 trace metals, 9 chlorinated pesticides (e.g., DDT), 40 polychlorinated biphenyl compound congeners (PCBs), and 24 polycyclic aromatic hydrocarbons (PAHs) on a dry weight basis. Data were generally limited to values above the method detection limit (MDL) for each parameter (see Appendix C.1). However, concentrations below MDLs were included as estimated values if presence of the specific constituent was verified by mass-spectrometry.

Particle size analysis was performed using either a Horiba LA-920 laser scattering particle analyzer or a set of nested sieves. The Horiba measures particles ranging in size from 0.5 to 2000 µm. Coarser sediments were removed and quantified prior to laser analysis by screening samples through a 2000 µm mesh sieve. These data were later combined with the Horiba results to obtain a complete distribution of particle sizes totaling 100%, and then classified into 4 main size fractions and 11 sub-fractions based on the Wentworth scale (Folk 1980; see Appendix C.2). When a sample contained substantial amounts of coarse sand, gravel, or shell hash that could damage the Horiba analyzer and/or where the general distribution of sediments would be poorly represented by laser analysis, a set of sieves with mesh sizes of 2000 µm, 1000 µm, 500 µm, 250 µm, 125 µm, and 63 µm was used to divide the samples into seven sub-fractions.

Data Analyses

Data summaries for the various sediment parameters included detection rate, minimum, median, maximum and mean values for all samples combined. All means were calculated using detected values only; no substitutions were made for non-detects in the data (i.e., analyte concentrations < MDL). Total DDT (tDDT), total hexachlorocyclohexane (tHCH), total chlordane, total PCB (tPCB), and total PAH (tPAH) were calculated for each sample as the sum of all constituents with reported values (see Appendix C.3 for individual constituent values). Contaminant concentrations were compared to the Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines of Long et al. (1995) when available. The ERLs represent chemical concentrations below which adverse biological effects are rarely observed, while values above the ERL but below the ERM represent levels at which effects occasionally occur. Concentrations above the ERM indicate likely biological effects, although these are not always validated by toxicity testing (Schiff and Gossett 1998).

Multivariate analyses were performed using PRIMER software to examine spatio-temporal patterns in the overall particle size composition in the South Bay outfall region (Clarke and Warwick 2001, Clarke and Gorley 2006). These included hierarchical agglomerative clustering (cluster analysis) with group-average linking and similarity profile analysis (SIMPROF) to confirm the non-random structure of the resultant cluster dendrogram (Clarke et al. 2008). Proportions of silt and clay sub-fractions were combined as percent fines to accommodate sieved samples and Euclidean distance was used as the basis for the cluster analysis.

Spearman rank correlations were calculated to assess if values for the various parameters co-varied in SBOO sediments. This non-parametric analysis accounts for non-detects in the data without the use of value substitutions (Helsel 2005). However, depending on the data distribution, the instability in rank-based analyses may intensify with increased censoring (Conover 1980). Therefore, a criterion of < 50% non-detects was used to screen eligible constituents for this analysis. Additionally, data for these analyses were limited to the past 10 years due to a change in instrumentation during 2003 that resulted in substantially lower MDLs for several parameters and therefore an increase in detection rates after that time.

RESULTS

Particle Size Distribution

Ocean sediments were diverse across the South Bay outfall region in 2013. The percent fines component (i.e., silt and clay) ranged from 0 to 55% per sample, while fine sands ranged from ~4 to 86%, medium-coarse sands ranged from 1 to 87%, and coarse particles ranged from 0 to 41% (Table 4.1, Figure 4.2). Coarser particles often comprised red relict sands, black sands, gravel, and/or shell hash (Appendix C.4). Particle size composition varied within sites between the winter and summer surveys by as much as 62% per size fraction, with the greatest differences occurring at stations I7, I13, I15, I16, I20, I28, and I34. During 2013, sediments collected from the four nearfield stations (I12, I14, I15, I16) were similar to those from the other eight outfall depth stations in containing ≤ 25% fine particles (Appendix C.4), a pattern that has been consistent since sampling began in 1995 (Figure 4.3).

Classification (cluster) analysis of 2013 particle size sub-fraction data discriminated five main cluster groups (cluster groups 1–5; Figure 4.4). Cluster group 1 represented four samples, including two collected during summer at stations I28 and I29 and both the winter and summer samples from station I35. Sediments in these samples

Table 4.1

Summary of particle sizes and chemistry concentrations in sediments from SBOO benthic stations sampled during 2013. Data include the detection rate (DR), mean, minimum, median, and maximum values for the entire survey area. The maximum value from the pre-discharge period (i.e., 1995–1998) is also presented. ERL = Effects Range Low threshold; ERM = Effects Range Median threshold.

Parameter	2013 Summary[a]					Pre-discharge Max	ERL[b]	ERM[b]
	DR (%)	**Areal Mean**	**Min**	**Median**	**Max**			
Particle Size								
Coarse Particles (%)	—	2.3	0.0	0.0	41.1	52.5	na	na
Med-Coarse sands (%)	—	26.0	1.0	5.6	87.0	99.8	na	na
Fine Sands (%)	—	55.4	4.5	64.0	85.6	97.4	na	na
Fines (%)	—	16.3	0.0	15.2	54.9	47.2	na	na
Organic Indicators								
Sulfides (*ppm*)	98	2.1	nd	1.4	9.7	222.0	na	na
TN (*% weight*)	96	0.021	nd	0.019	0.049	0.077	na	na
TOC (*% weight*)	100	0.15	0.02	0.11	1.71	0.64	na	na
TVS (*% weight*)	100	0.85	0.30	0.85	1.80	9.20	na	na
Trace Metals (ppm)								
Aluminum	100	7412	1580	7610	16,400	15,800	na	na
Antimony	69	0.77	nd	0.47	2.10	5.60	na	na
Arsenic	100	2.5	0.9	1.8	11.2	10.9	8.2	70
Barium	100	22.8	2.8	25.1	47.7	54.3	na	na
Beryllium	100	0.120	0.010	0.130	0.220	2.140	na	na
Cadmium	59	0.23	nd	0.08	0.99	0.41	1.2	9.6
Chromium	100	11.3	3.5	11.7	18.3	33.8	81	370
Copper	100	2.8	0.3	2.6	7.8	11.1	34	270
Iron	100	7916	1560	7940	15,200	17,100	na	na
Lead	98	3.7	nd	3.4	6.7	6.8	46.7	218
Manganese	100	130.4	13.4	119.0	362.0	162.0	na	na
Mercury	39	0.015	nd	nd	0.135	0.078	0.15	0.71
Nickel	100	4.13	1.30	3.86	9.45	13.60	20.9	51.6
Selenium	80	0.40	nd	0.38	0.59	0.62	na	na
Silver	28	2.98	nd	nd	11.20	nd	1.0	3.7
Thallium	2	3.10	nd	nd	3.10	17.00	na	na
Tin	81	1.38	nd	1.14	3.80	nd	na	na
Zinc	100	15.8	2.5	15.8	36.2	46.9	150	410
Pesticides (ppt)								
HCB	11	86	nd	nd	150	nd	na	na
Total DDT	41	349	nd	nd	2070	23,380	1580	46,100
Total Chlordane	4	265	nd	nd	410	nd	na	na
Total HCH	2	1280	nd	nd	1280	nd	na	na
Total PCB (ppt)	9	742	nd	nd	1418	na	na	na
Total PAH (ppb)	9	54.7	nd	nd	198.2	636.5	4022	44,792

na = not available; nd = not detected; [a] Minimum, median, and maximum values were calculated based on all samples (n = 54), whereas means were calculated on detected values only (n ≤ 54)

[b] From Long et al. 1995

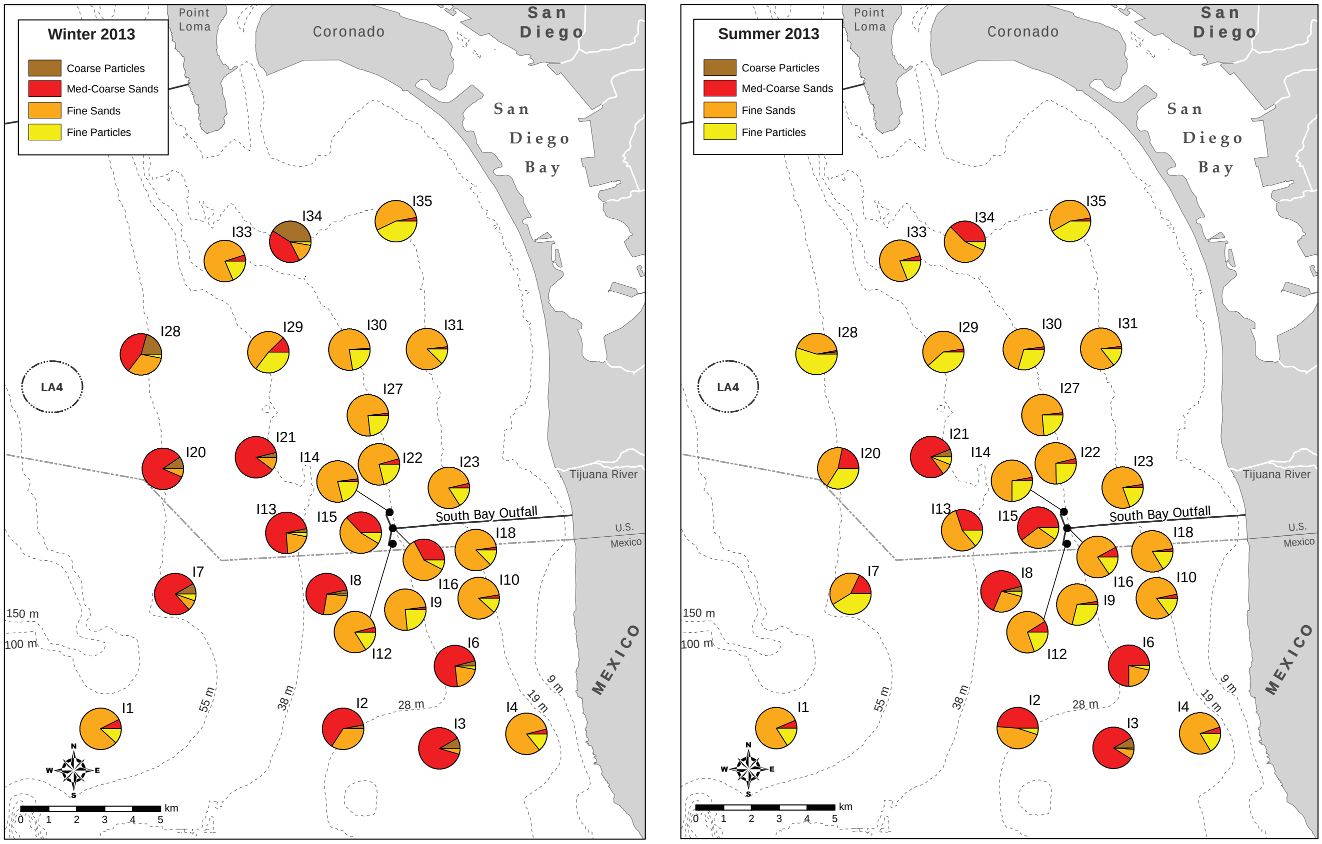


Figure 4.2
Sediment composition at SBOO benthic stations sampled in 2013 during winter and summer surveys.

averaged the largest proportion of fines (44% per sample) and the second largest proportion of very fine sand (39% per sample). Cluster group 2 comprised 27 samples collected primarily at sites located along the 19 and 28-m depth contours, including five of eight samples from the four nearfield stations. This group also had relatively fine sediments, averaging 19% fines, 53% very fine sand, and 25% fine sand. Cluster group 3 comprised eight samples, three of which were collected during winter from stations I15, I16, and I29, while the remaining five samples were collected during summer from stations I2, I7, I13, I20, and I34. Sediments represented by group 3 averaged 39% fine sand and 27% medium sand. Cluster group 4 comprised 13 samples collected at sites located east and south of the SBOO along the 28, 38, and 55-m depth contours. These sediments had the largest proportions of medium and coarse sand (41% and 34% per sample, respectively). Cluster group 5 comprised two samples from winter collected at stations I28 and I34; these were the coarsest sediments sampled during 2013, averaging 22% medium sand, 21% coarse sand, 13% very coarse sand, and 18% granules.

Historical analysis of particle size data from a subset of SBOO sites located throughout the survey area revealed considerable temporal variability at some stations and relative stability at others, with no clear patterns evident relative to depth, proximity to the outfall, or proximity to other sources of sediment plumes (e.g., San Diego Bay, Tijuana River; Figure 4.5). For example, the size of the sand particles (e.g., fine versus medium-coarse) differed substantially over time in sediments from stations I4, I7, I12, I13, I20, I28, and I29. These sites also had variable amounts of finer and coarser materials. The relative composition of the sand sub-fractions and the presence of other coarse particles may correspond to distributions of fine versus coarse red relict sands, coarse black sands, shell hash, and gravel that have been encountered previously at these stations. In contrast, stations I1, I9, I10, I30 and I35 have been consistently dominated by fine sands over the past

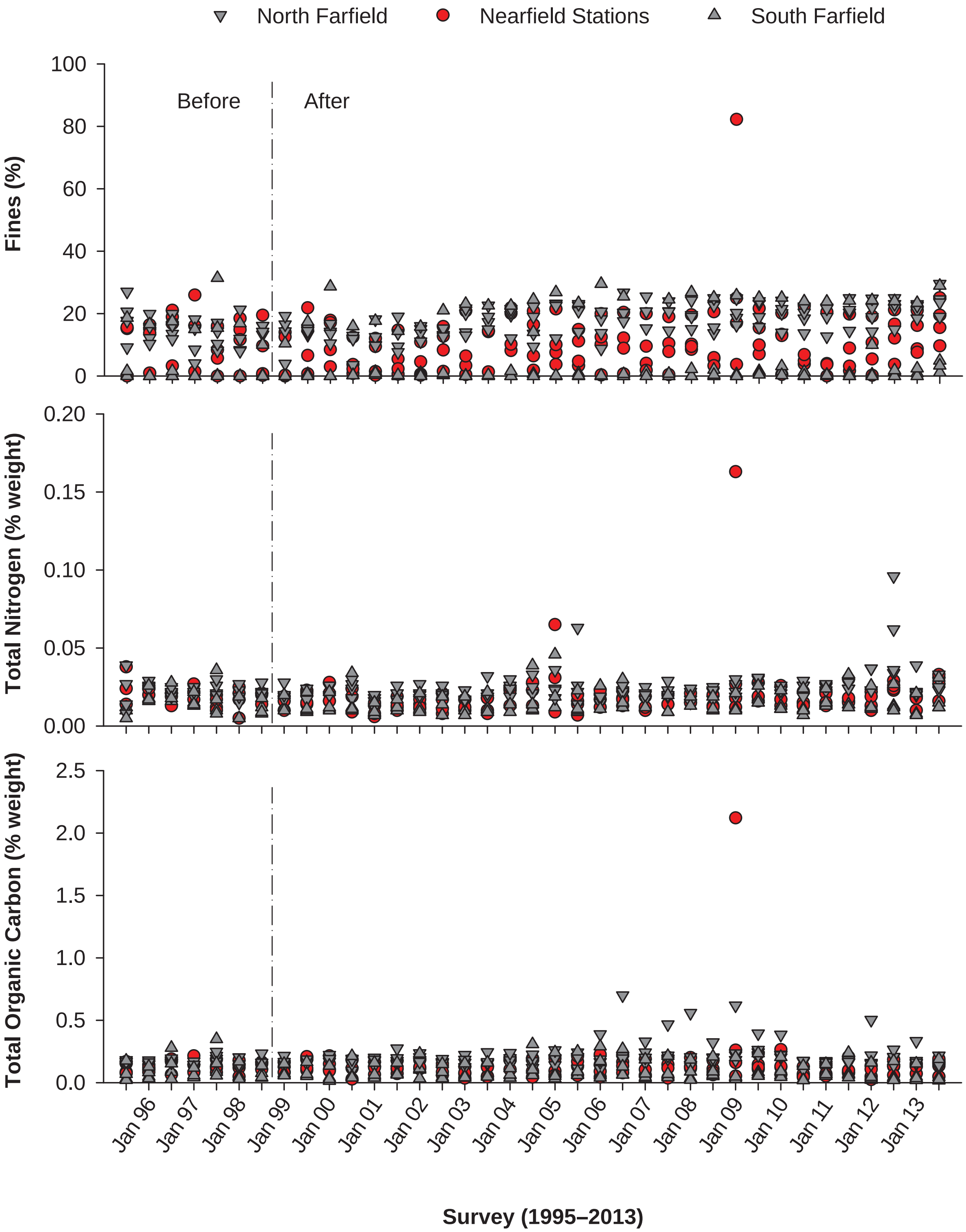


Figure 4.3

Percent fines and concentrations of organic indicators in sediments from SBOO north farfield, nearfield, and south farfield outfall depth stations sampled from 1995 through 2013. Data represent detected values from each station, n≤12 samples per survey. Dashed lines indicate onset of discharge from the SBOO.

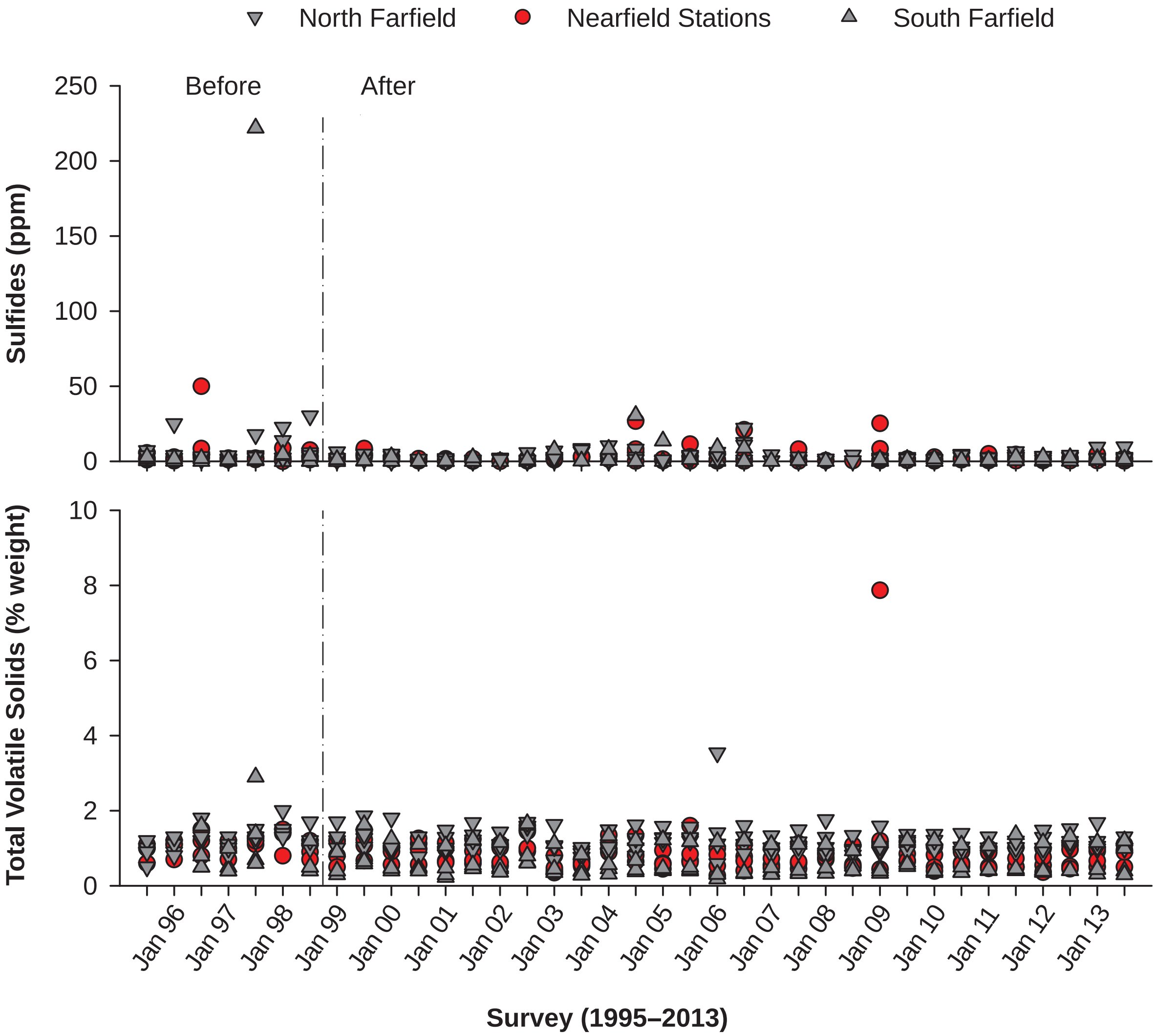


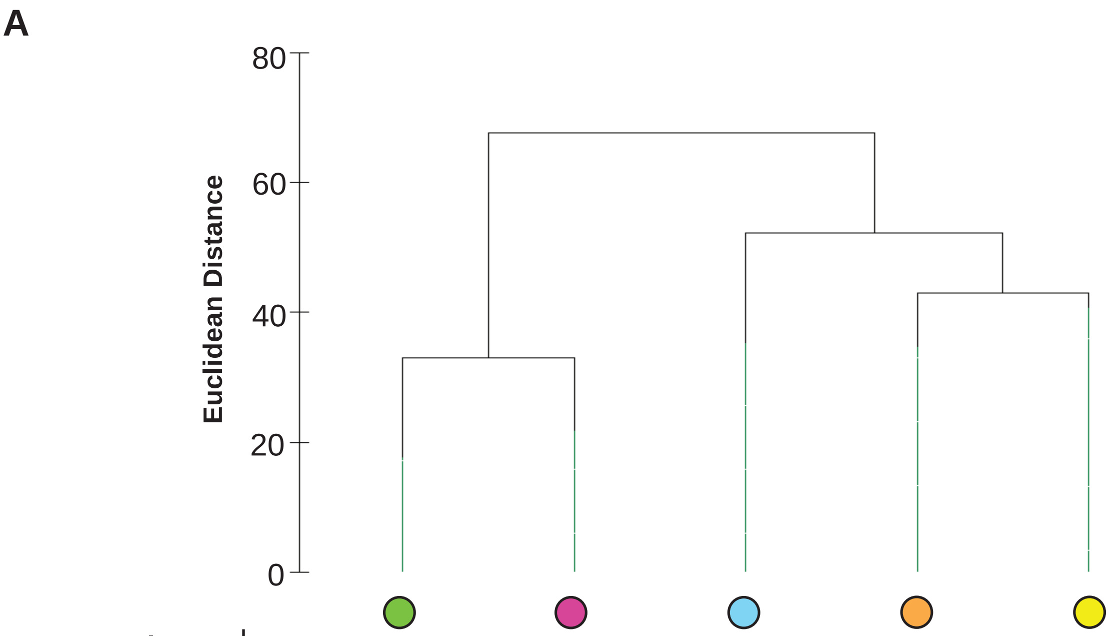
Figure 4.3 *continued*

10 years, demonstrating relative stability in their sediments over time.

Indicators of Organic Loading

Indicators of organic loading in benthic sediments, including sulfides, total nitrogen (TN), total organic carbon (TOC), and total volatile solids (TVS), had detection rates ≥96% in sediments from the South Bay outfall region in 2013 (Table 4.1). Sulfide concentrations ranged from not-detected to 9.7 ppm, while TN ranged from not-detected to 0.049% weight, TOC ranged from 0.02 to 1.71% weight, and TVS ranged from 0.3 to 1.8% weight. There was no evidence of organic enrichment near the discharge site during the year. Instead, the highest concentrations of these parameters occurred at sites located north of the outfall. For example, the highest sulfide values (≥9.4 ppm) were detected at station I33, the highest TN values (≥0.043% wt) were detected at station I28, the highest TOC value (1.71% wt) was detected at station I34, and the highest TVS values (≥1.30% wt) were detected at stations I28, I29, I33, and I35 (Appendix C.5).

Detection rates for sulfides, TN, TOC, and TVS have been ≥76% in SBOO sediments since monitoring began in 1995, with highly variable concentrations across all stations (Table 4.2). For TN, TOC and TVS, variable concentrations may be tied to regional differences in sediment particle composition, since these parameters tend to co-vary



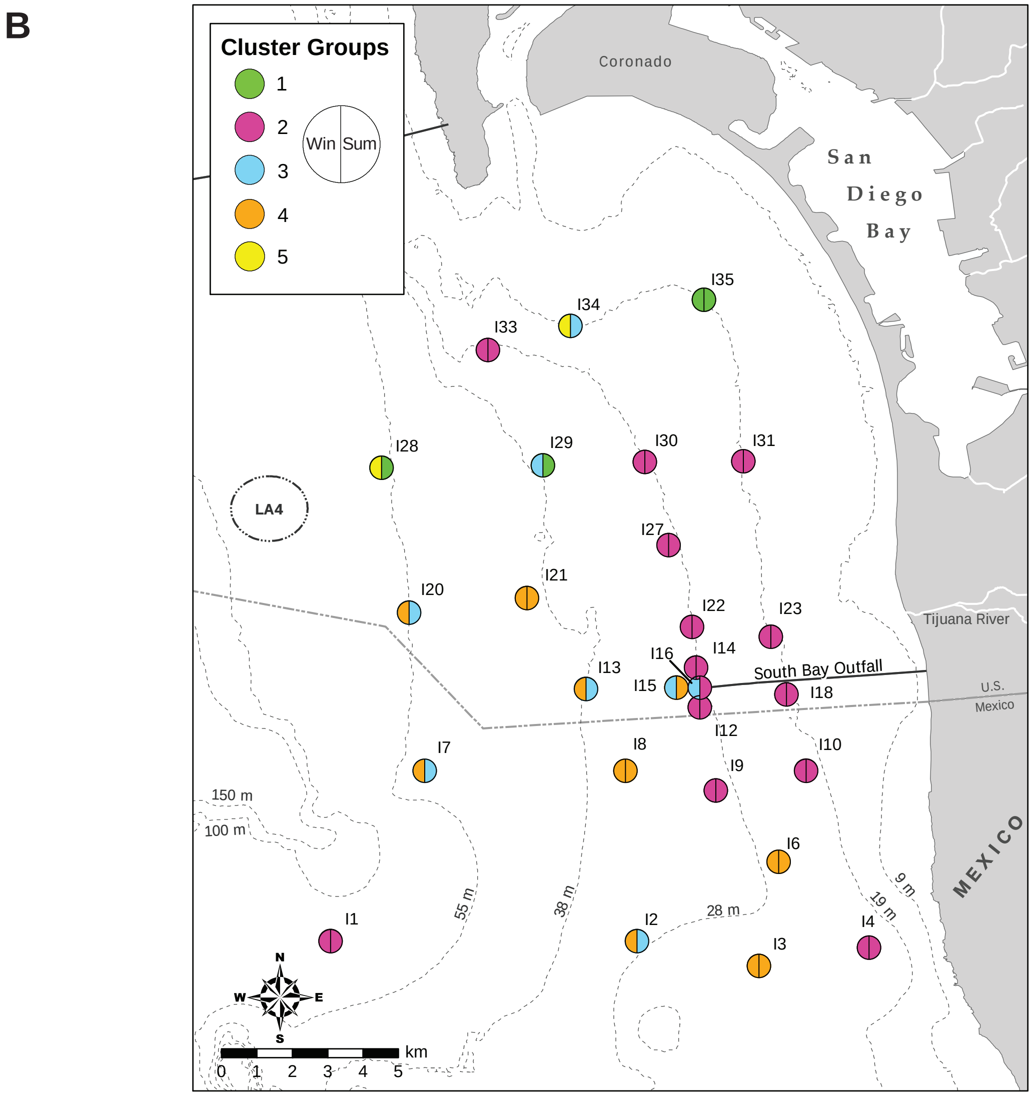
	Cluster Group	1	2	3	4	5
	n	4	27	8	13	2
	FINES	44	19	19	3	3
Fine Sands	VFSAND	39	53	12	2	14
	FSAND	14	25	39	15	10
Med-Coarse Sands	MSAND	2	3	27	41	22
	CSAND	0	0	3	34	21
Coarse Particles	VCSAND	0	0	0	5	13
	GRANULES	0	0	0	0	18

Figure 4.4
Cluster analysis of particle size sub-fraction data from SBOO benthic stations sampled during 2013. Data are presented as (A) cluster results and (B) spatial distribution of sediment samples as delineated by cluster analysis. Data for particle size sub-fractions are mean percentages calculated over all stations within a cluster group (n). VFSAND = Very Fine Sand; FSAND = Fine Sand; MSAND = Medium Sand; CSAND = Coarse Sand; VCSAND = Very Coarse Sand.

with percent fines (Appendix C.6). In contrast to the overall survey area, organic indicators have been fairly consistent at the outfall depth stations, with no patterns indicative of organic enrichment evident over the past 19 years (Figure 4.3).

Trace Metals

Ten trace metals were detected in all sediment samples collected in the SBOO region during 2013, including aluminum, arsenic, barium, beryllium, chromium, copper, iron, manganese, nickel and zinc (Table 4.1, Appendix C.7). Antimony, cadmium, lead, mercury, selenium, silver, thallium and tin were also detected, but in fewer samples (2–98%). Only two of the nine metals that have published ERLs and ERMs (see Long et al. 1995) were reported at levels above these thresholds, and none of these exceedances occurred at nearfield stations. Arsenic exceeded its ERL at station I21 during both the winter and summer surveys. During summer, silver exceeded its ERL at stations I27, I28, I30, I33,



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and I34 and its ERM at stations I23, I29, I31, and I35. The remaining metals were detected at levels within ranges reported prior to wastewater discharge in the South Bay outfall region and/or elsewhere in the Southern California Bight (SCB) (e.g., Schiff et al. 2011). During the year, concentrations of aluminum, barium, beryllium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc had no discernible spatial patterns relative to the outfall (Appendix C.7). In contrast, the highest values of antimony, cadmium, and tin were found in sediments from the nearfield stations during winter.

Detection rates for several metals have been high ever since monitoring began in 1995 (Table 4.2). For example, aluminum, arsenic, chromium, copper, iron, manganese, and zinc have been detected in ≥82% of the samples collected over the past 19 years. During this time period, chromium, lead, mercury, and zinc never exceeded their ERL or ERM thresholds, while exceedences for silver, arsenic, cadmium, copper and nickel were rare (i.e., ≤5% of samples collected). Concentrations of the remaining metals were extremely variable and most were detected at levels within ranges reported elsewhere in the SCB (e.g., Schiff et al. 2011). While high values of various metals have been occasionally recorded at the nearfield stations, there were no discernible long-term patterns that could be associated with proximity to the outfall

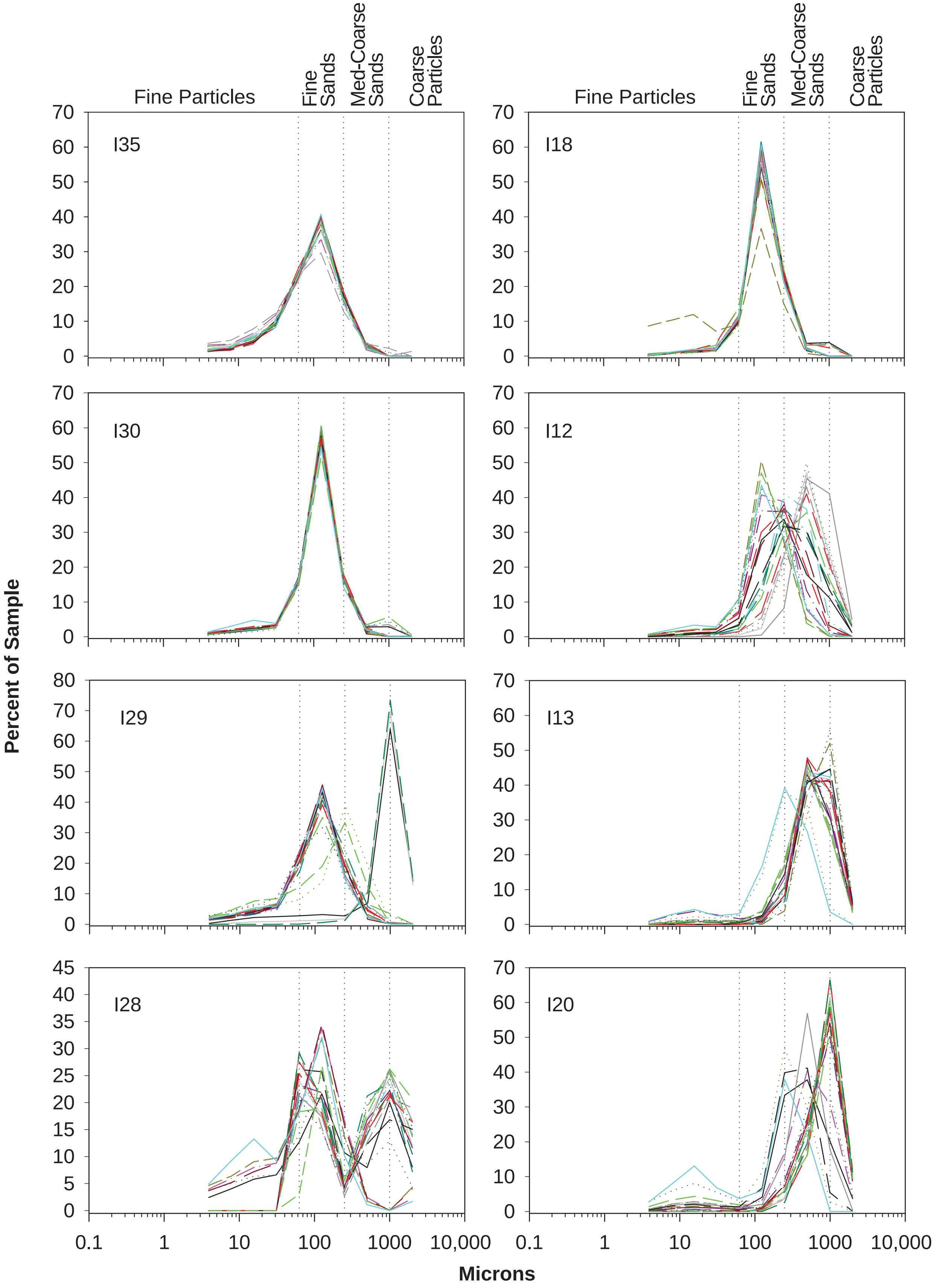

Figure 4.5

Historical particle size distributions in sediments collected from select stations in the SBOO region sampled from 2004 through 2013. Stations were selected to represent the entire survey area, and are organized east to west (top to bottom) and north to south (left to right). Each line represents an individual survey.

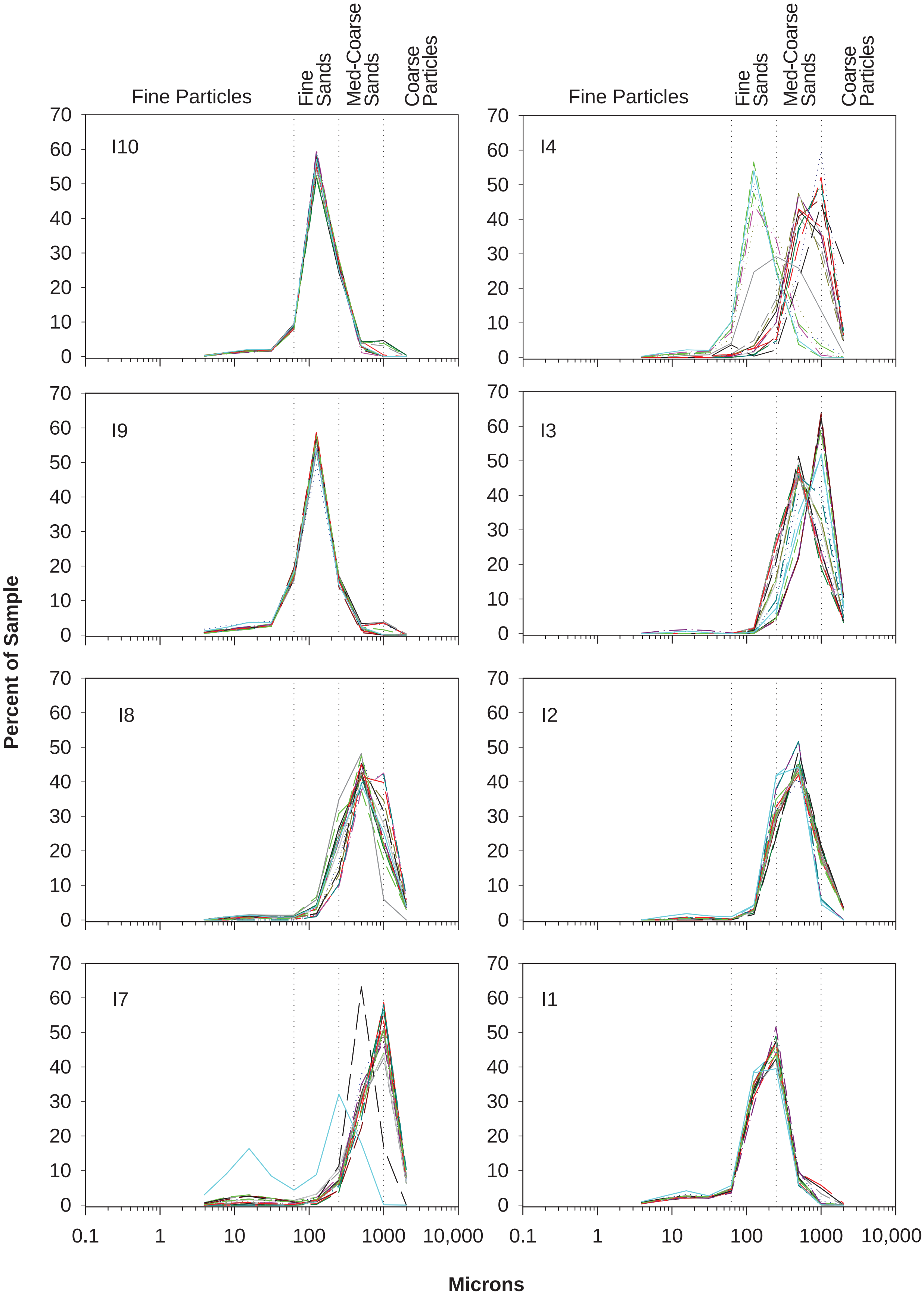

Figure 4.5 *continued*

or the onset of wastewater discharge (Figure 4.6, Appendix C.8). Instead, several metals co-varied with percent fines and with each other (Figure 4.7, Appendix C.6).

Pesticides

Four chlorinated pesticides were detected in SBOO sediments during 2013, including DDT, hexachlorobenzene (HCB), chlordane, and hexachlorocyclohexane (HCH) (Table 4.1, Appendix C.9). Total DDT, composed primarily of p,p-DDE, was detected in all sediment samples at concentrations up to 2070 ppt. Sediments with tDDT were from 15 different stations located throughout the region. Although the highest DDT concentration exceeded its ERL threshold at station I28 in winter, all DDT values were below those reported prior to wastewater discharge and within ranges reported elsewhere in the SCB (e.g., Schiff et al. 2011). Hexachlorobenzene (HCB) was detected in six samples from six different stations, including I2, I10, I28, I30, I33, and I34 at levels up to 150 ppt. Total chlordane, composed solely of heptachlor, was detected in only two sediment samples during the year, one from station I20 in winter and one from station I22 in summer. Both had heptachlor concentrations ≤410 ppt. Finally, total HCH was found in a single sample from station I20 in winter at a concentration of 1280 ppt.

Chlorinated pesticides have been detected infrequently in the SBOO region since sampling began (Table 4.2). Over the past 19 years, detection rates were 16% for tDDT, 14% for HCB, and <1% for aldrin, endosulfan, chlordane and tHCH. Dieldrin, endrin, and mirex have never been found in sediments around the SBOO. Additionally, pesticide concentrations have been consistently low, with tDDT exceeding its ERL in just 3% of the samples collected. Total DDT and total chlordane concentrations have also been below values reported previously for the SCB (e.g., Schiff et al. 2011). Finally, the occurrence of pesticides in sediments from outfall depth stations over the years has been sporadic with no patterns indicative of an outfall effect evident (e.g., Figure 4.8).

PCBs

PCBs were detected in only five sediment samples collected around the SBOO in 2013 (Table 4.1). Total PCB had a maximum concentration of 1418 ppt, reported from station I28 during the summer (Appendix C.9). Although no ERL or ERM thresholds exist for PCBs measured as congeners, all PCB values recorded during the year were within ranges reported previously for the SCB (e.g., Schiff et al. 2011). The most commonly detected PCB congeners were PCB 28, PCB 37, PCB 66, PCB 70, PCB 74, PCB 110, PCB 138, and PCB 153/168 (Appendix C.3).

PCBs have been detected in just 7% of the sediment samples collected in the SBOO region since the City started reporting the data as congeners in summer 1998 (Table 4.2). Concentrations of tPCB were highly variable over these past 17 years, with most detected values ≤1520 ppt; two exceptions included a value of 11,320 ppt recorded for station I33 in winter 2005 (Figure 4.8) and a value of 108,790 ppt recorded for station I18 in winter 2007 (City of San Diego 2008). As with chlorinated pesticides, the occurrence of PCBs in sediments from outfall depth stations has been sporadic with no patterns indicative of an outfall impact evident (Figure 4.8).

PAHs

PAHs were detected in only five sediment samples collected from the South Bay outfall region in 2013 (Table 4.1). These samples were all collected during summer from stations I16, I28, I29, I33, and I35 (Appendix C.9). Concentrations of total PAH reached 198.2 ppb during the past year, well below the pre-discharge maximum of 636.5 ppb, the ERL threshold of 4022 ppb, and the Bight'08 maximum of 14,065 ppb (Schiff et al. 2011). Individual PAHs detected during the year included 2,6-dimethylnaphthalene, pyrene, benzo[A]pyrene, phenanthrene, 3,4-benzo(B)fluoranthene, benzo[A] anthracene, chrysene, and fluoranthene (Appendix C.3). Over the past 19 years, the detection rate for tPAH was just 23% with all reported values below the ERL (Table 4.2), and there have been no

Table 4.2

Summary of particle sizes and chemistry concentrations in sediments from SBOO benthic stations sampled from 1995 through 2013. Data include detection rates (DR), minimum, median, maximum, and mean values for all samples collected ($n \leq 998$ samples). Detection rates are also provided for samples collected from 2004 through 2013 ($n \leq 540$) to show how they have changed over the past 10 years. See Table 4.1 for ERL and ERM details.

	Detection Rate		Concentrations (all years)[a]				% Exceedances	
Parameter	**All years**	**2004–2013**	**Min**	**Median**	**Max**	**Mean**	**ERL**	**ERM**
Particle Size								
Coarse Particles (%)	—	—	0	0	53.1	2.5	na	na
Med-Coarse Sands (%)	—	—	0	12.1	99.8	34.9	na	na
Fine Sands (%)	—	—	0	58.5	97.4	51.1	na	na
Fines (%)	—	—	0	9.8	82.3	11.5	na	na
Organic Indicators								
Sulfides (*ppm*)	82	76	nd	0.8	222.0	3.1	na	na
TN (*% weight*)	93	91	nd	0.017	0.163	0.021	na	na
TOC (*% weight*)	100	100	nd	0.12	6.85	0.18	na	na
TVS (*% weight*)	100	100	0.19	0.82	39.80	0.97	na	na
Trace Metals (ppm)								
Aluminum	100	100	495	4490	30,100	4939	na	na
Antimony	28	49	nd	nd	6.40	0.78	na	na
Arsenic	100	99	nd	1.8	11.9	2.4	3	0
Barium	—	100	0.9	18.9	177.0	21.1	na	na
Beryllium	40	57	nd	nd	3.090	0.236	na	na
Cadmium	33	54	nd	nd	2.00	0.15	<1	0
Chromium	99	100	nd	9.5	39.0	9.9	0	0
Copper	82	96	nd	2.6	99.2	3.8	<1	0
Iron	100	100	559	6100	29,300	6475	na	na
Lead	54	94	nd	0.86	20.00	2.6	0	0
Manganese	100	100	5.2	55.6	621.0	69.0	na	na
Mercury	27	41	nd	nd	0.135	0.012	0	0
Nickel	69	97	nd	1.45	22.80	3.23	<1	0
Selenium	16	9	nd	nd	0.62	0.24	na	na
Silver	17	29	nd	nd	11.20	1.00	5	1
Thallium	7	11	nd	nd	18.00	2.78	na	na
Tin	49	84	nd	nd	4.50	0.96	na	na
Zinc	93	100	nd	11.6	136.0	14.4	0	0
Pesticides (ppt)								
Aldrin	<1	<1	nd	nd	500	500	na	na
Endosulfan	<1	<1	nd	nd	820	820	na	na
HCB	—	14	nd	nd	2700	284	na	na
Total DDT	16	22	nd	nd	23,380	1155	3	0
Total Chlordane	<1	1	nd	nd	1620	545	na	na
Total HCH	<1	1	nd	nd	3880	1397	na	na
Total PCB (ppt)	7	11	nd	nd	108,790	2423	na	na
Total PAH (ppb)	23	41	nd	nd	1942.1	125.3	0	0

na = not available; nd = not detected; [a] minimum, median, and maximum values were calculated based on all samples, whereas means were calculated on detected values only

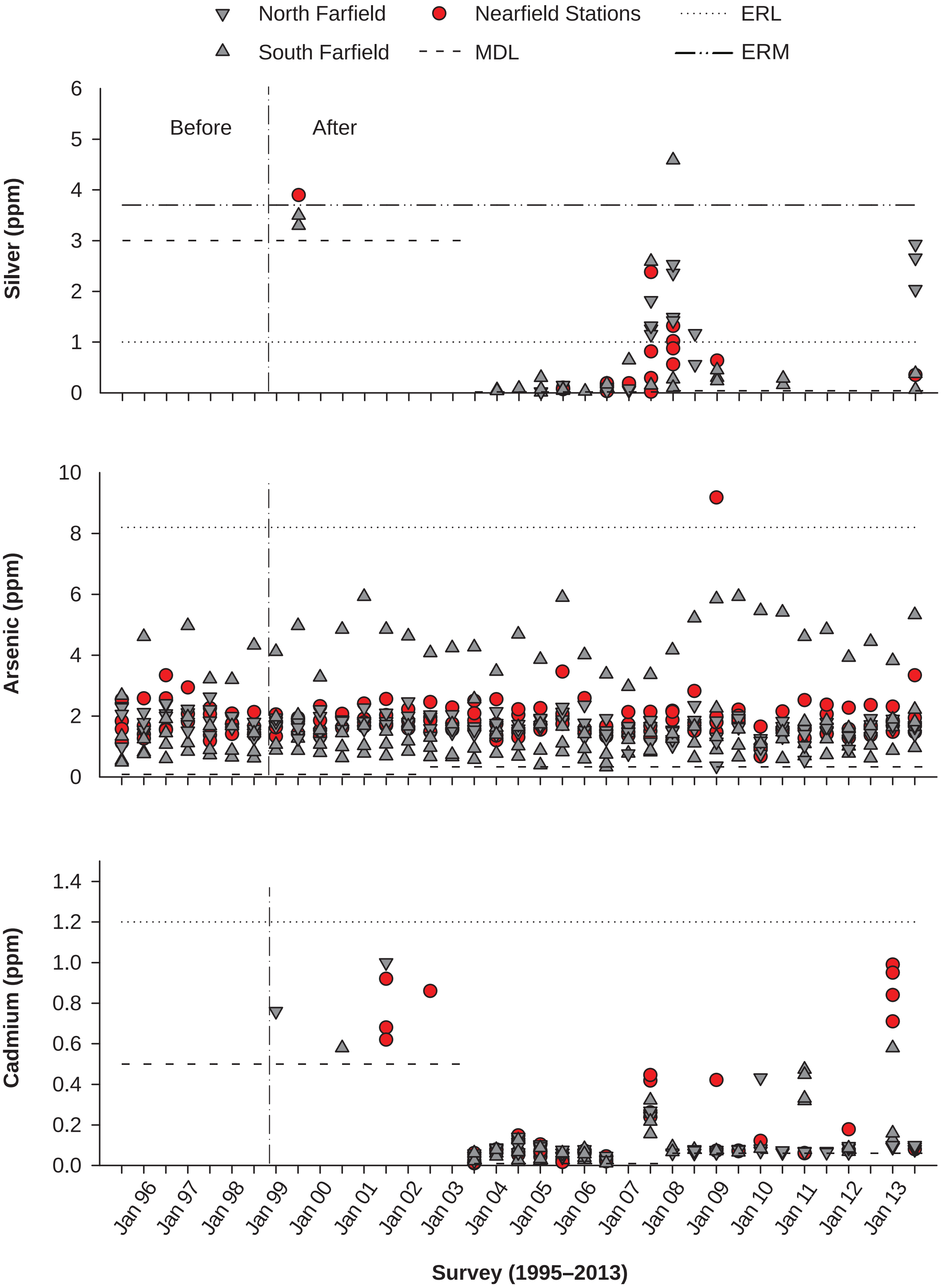

Figure 4.6

Concentrations of select metals in sediments from SBOO north farfield, nearfield, and south farfield outfall depth stations sampled from 1995 through 2013. Data represent detected values from each station, n≤12 samples per survey. Dashed lines indicate onset of discharge from the SBOO. See Table 4.1 for values of ERLs and ERMs.

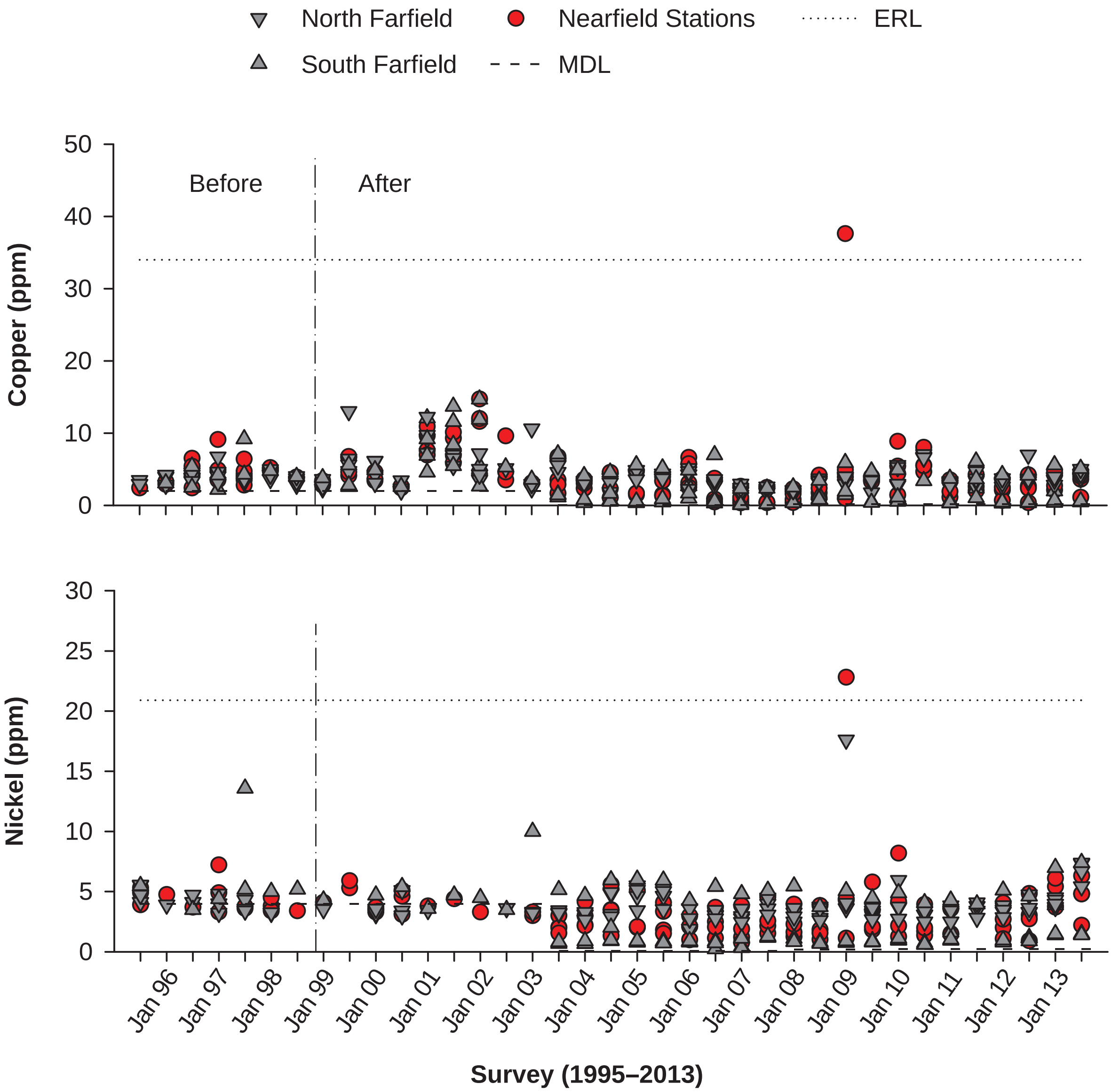

Figure 4.6 *continued*

patterns indicative of a wastewater impact at the outfall depth stations (Figure 4.8).

Discussion

Particle size composition at the SBOO stations sampled in 2013 was similar to that seen historically (Emery 1960, MBC-ES 1988) and in recent survey years (e.g., City of San Diego 2007–2013). Sands made up the largest proportion of all sediments, with the relative amounts of coarser and finer particles varying among sites. No spatial relationship was evident between sediment composition and proximity to the outfall discharge site, nor has there been any substantial increase in fine sediments at nearfield stations or throughout the region since wastewater discharge began. Instead, the diversity of sediment types in the region reflects multiple geologic origins and complex patterns of transport and deposition. In particular, the presence of red relict sands at some stations is indicative of minimal sediment deposition in recent years. Several other stations are located near or within an accretion zone for sediments moving within the Silver Strand littoral cell (MBC-ES 1988, Patsch and Griggs 2007). Therefore, the higher proportions of fine sands, silts, and clays that occur at these sites are

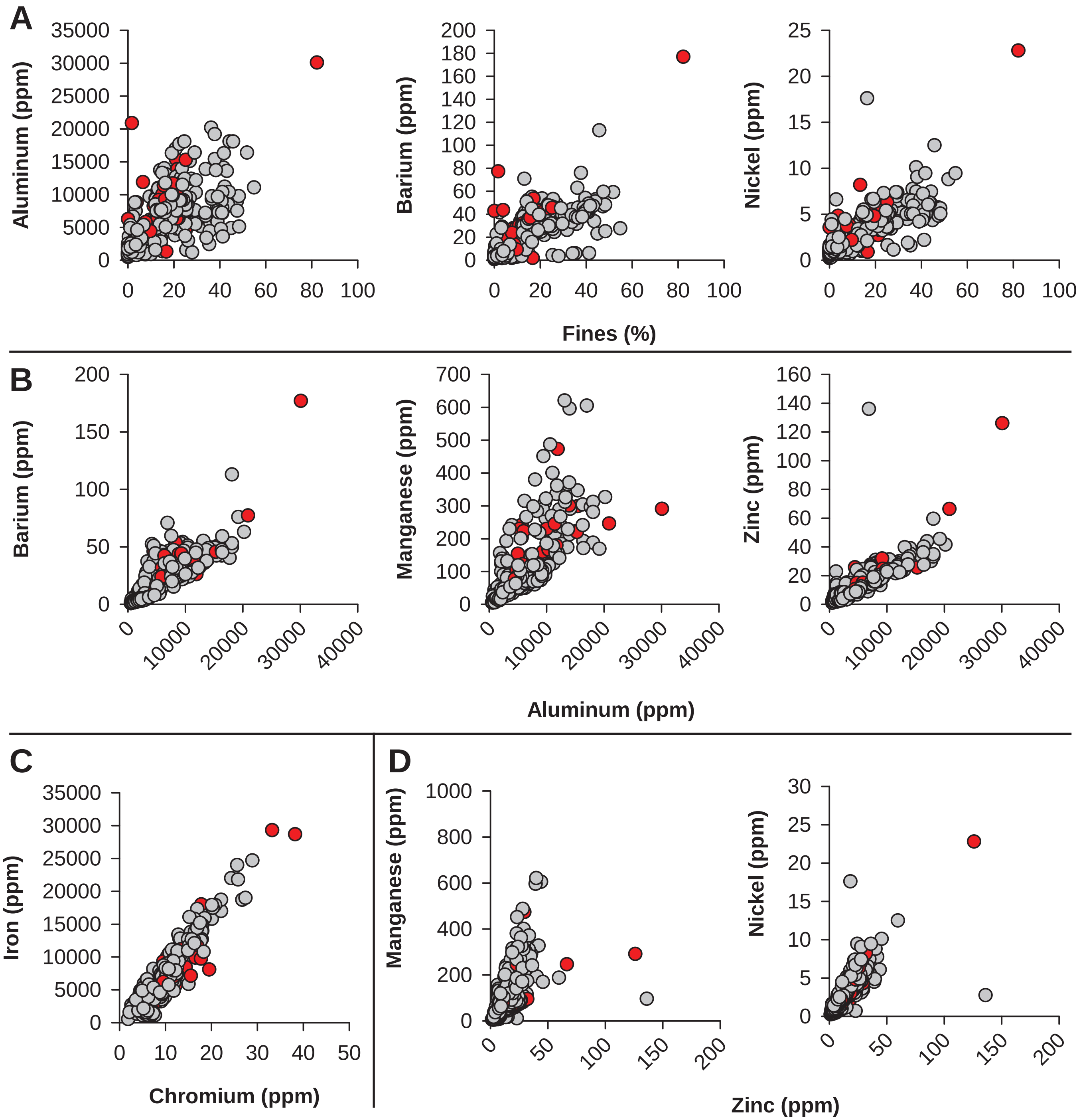

Figure 4.7

Scatterplots of various metals in sediments from SBOO stations sampled from 2004 through 2013. Samples collected from nearfield stations are indicated in red. (A) Select metals versus fine particles, (B) select metals versus aluminum, (C) iron versus chromium, (D) select metals versus zinc. See Appendix C.6 for Spearman rank correlation analysis.

likely associated with the transport of fine materials originating from the Tijuana River, the Silver Strand beach, and to a lesser extent from San Diego Bay (MBC-ES 1988). In general, sediment composition has been highly diverse throughout the South Bay outfall region since pre-discharge sampling first began in 1995 (City of San Diego 2000).

Various trace metals, pesticides, PCBs, PAHs, and organic indicators were detected in sediment

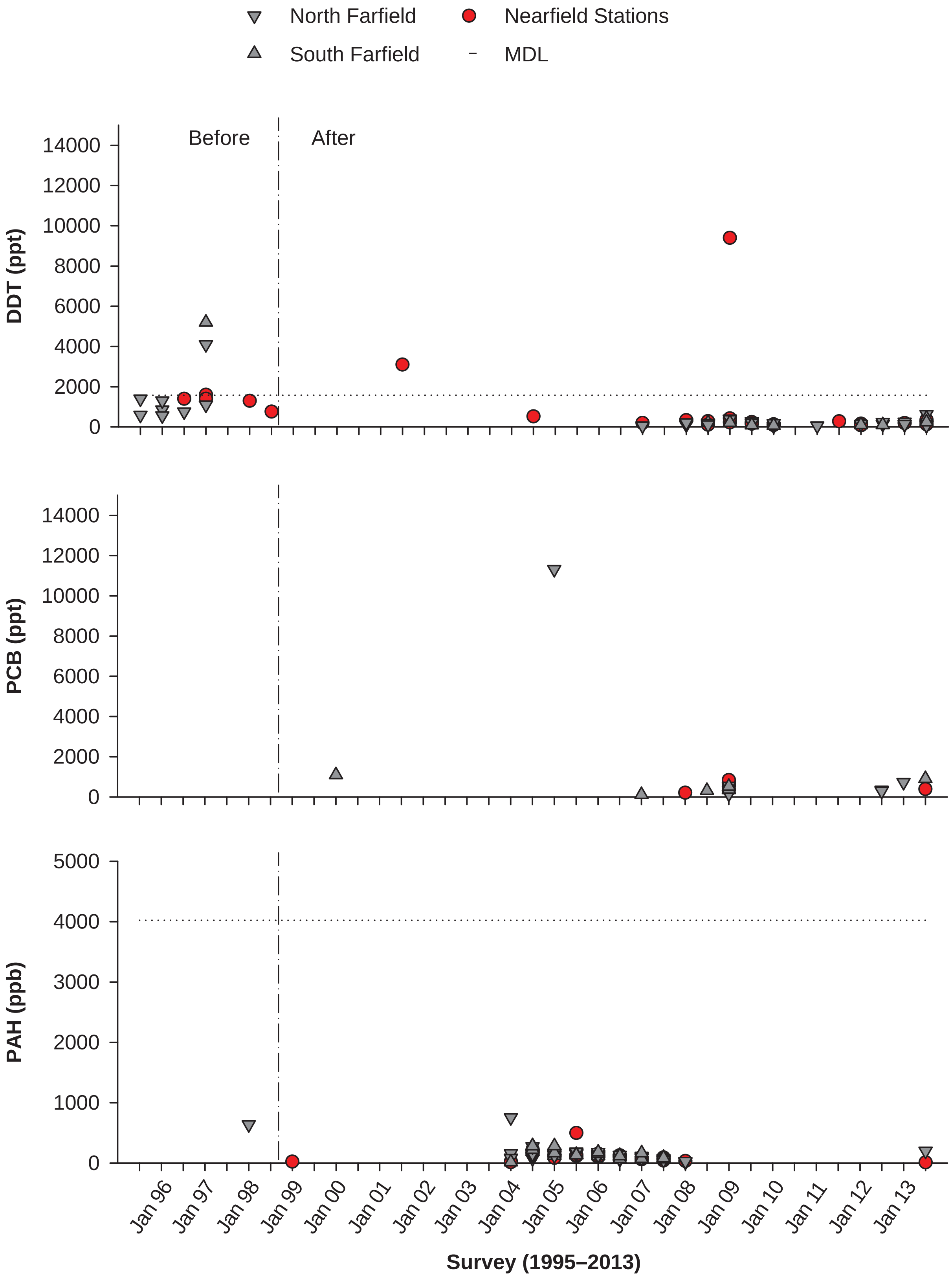

Figure 4.8

Concentrations of total DDT, total PCB, and total PAH in sediments from SBOO north farfield, nearfield, and south farfield outfall depth stations sampled from 1995 through 2013. Data represent detected values from each station, n ≤ 12 samples per survey. Dashed lines indicate onset of discharge from the SBOO. See Table 4.1 for values of ERLs.

samples collected throughout the SBOO region in 2013, though concentrations were generally below either ERL or ERM thresholds with few exceedances and/or within historical ranges. Additionally, there have been no spatial patterns consistent with an outfall effect on sediment chemistry over the past several years, with concentrations of most contaminants at the four nearfield sites falling within the range of values at the farfield stations. Instead, relatively high values of most parameters could be found throughout the region, and several organic indicators and metals co-occurred in samples characterized by finer sediments. This association is expected due to the known correlation between particle size and concentrations of these parameters (Eganhouse and Venkatesan 1993).

The broad distribution of various contaminants in sediments throughout the SBOO region is likely derived from several sources. Mearns et al. (1991) described the distribution of contaminants such as arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB, while Brown et al. (1986) determined that there may be no coastal areas in southern California that are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent surveys of SCB continental shelf habitats (Schiff and Gossett 1998, Noblet et al. 2002, Schiff et al. 2006, 2011). Further, historical assessments of sediments off of Los Angeles have shown that as wastewater treatment has improved, sediment conditions are more likely affected by other factors (Stein and Cadien 2009). These factors may include bioturbative re-exposure of buried legacy sediments (Niedoroda et al. 1996, Stull et al. 1996), large storms that assist redistribution of legacy contaminants (Sherwood et al. 2002), and stormwater discharges (Schiff et al. 2006, Nezlin et al. 2007). Possible non-outfall sources and pathways of contaminant dispersal off San Diego include transport of contaminated sediments from San Diego Bay via tidal exchange, offshore disposal of sediments dredged from the Bay, turbidity plumes from the Tijuana River, and surface runoff from local watersheds (e.g., Parnell et al. 2008).

In conclusion, there was no evidence of fine-particle loading related to wastewater discharge during the year or since the discharge through the SBOO began in early 1999. Likewise, contaminant concentrations at nearfield stations were within the range of variability observed throughout the region and do not appear to be organically enriched. Finally, the quality of SBOO sediments in 2013 was similar to previous years, and overall concentrations of all chemical contaminants remained relatively low compared to available thresholds and other southern California coastal areas (Schiff and Gossett 1998, Noblet et al. 2002, Schiff et al. 2006, 2011, Maruya and Schiff 2009).

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Chapter 5
Macrobenthic Communities

Chapter 5. Macrobenthic Communities

INTRODUCTION

The City of San Diego (City) collects small invertebrates (macrofauna) that live within or on the surface of soft-bottom habitats to examine potential effects of wastewater discharge on the marine benthos around the South Bay Ocean Outfall (SBOO). These benthic macrofauna are targeted for monitoring because they are known to play critical ecological roles in marine environments along the Southern California Bight (SCB) coastal shelf (Fauchald and Jones 1979, Thompson et al. 1993a, Snelgrove et al. 1997). Additionally, because many benthic species are relatively stationary and long-lived, they integrate the effects of pollution or disturbance over time (Hartley 1982, Bilyard 1987). The response of many species to environmental stressors is well documented, and monitoring changes in discrete populations or more complex communities can help identify locations experiencing anthropogenic impacts (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). For example, pollution-tolerant species are often opportunistic and can displace others in impacted environments. In contrast, populations of pollution-sensitive species decrease in response to toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation (Gray 1979). For these reasons, the assessment of benthic community structure has become a major component of many ocean monitoring programs.

The structure of marine macrobenthic communities is naturally influenced by factors such as ocean depth, sediment composition (e.g., percent of fine versus coarse sediments), sediment quality (e.g., contaminant loads, toxicity), oceanographic conditions (e.g., temperature, dissolved oxygen, nutrient levels, currents) and biological interactions (e.g., competition, predation, bioturbation). On the SCB coastal shelf, assemblages typically vary along depth gradients and/or with sediment particle size (Bergen et al. 2001); therefore, an understanding of natural background or reference conditions provides the context necessary to identify whether spatial differences in community structure are likely attributable to anthropogenic activities. Off the coast of San Diego, past monitoring efforts for both shelf and upper slope habitats have led to considerable understanding of regional environmental variability (City of San Diego 1999, 2013a, b, Ranasinghe et al. 2003, 2007, 2010, 2012). These efforts allow for spatial and temporal comparison of the current year's monitoring data with past surveys to determine if and where changes due to wastewater discharge have occurred.

The City relies on a suite of scientifically-accepted indices and statistical analyses to evaluate potential changes in local marine invertebrate communities. The benthic response index (BRI), Shannon diversity index and Swartz dominance index are used as metrics of invertebrate community structure, while multivariate analyses are used to detect spatial and temporal differences among communities (Warwick and Clarke 1993, Smith et al. 2001). The use of multiple analyses provides better resolution than single parameters, and some include established benchmarks for determining anthropogenically-induced environmental impacts. Collectively, these data are used to determine whether invertebrate assemblages from habitats with comparable depth and sediment particle size are similar, or whether observable impacts from outfalls or other sources occur. Minor organic enrichment caused by wastewater discharge should be evident through an increase in species richness and abundance in assemblages, whereas more severe impacts should result in decreases in overall species diversity coupled with dominance by a few pollution-tolerant species (Pearson and Rosenberg 1978).

This chapter presents analyses and interpretations of macrofaunal data collected at designated benthic monitoring stations surrounding the SBOO during 2013 and includes descriptions and comparisons of the different invertebrate communities in the region. The primary goals are to: (1) document the benthic assemblages present during the year, (2) determine the presence or absence of biological impacts associated with wastewater discharge, and (3) identify other potential natural and anthropogenic sources of variability in the local marine ecosystem.

Materials and Methods

Field Sampling

Benthic samples were collected at 27 monitoring stations in the SBOO region during winter (January) and summer (July) 2013 (Figure 5.1). These stations range in depth from about 18 to 60 m and are distributed along or adjacent to four main depth contours. Fifteen sites are located along the 19, 38, or 55-m depth contours, while 12 sites are located along the 28-m depth contour and are referred to as “outfall depth” stations. Outfall depth stations include the four stations located within 1000 m of the outfall diffuser structure that are considered to represent “nearfield” conditions (i.e., I12, I14, I15, I16), four “north farfield” stations (i.e., I22, I27, I30, and I33) and four “south farfield” stations (i.e., I2, I3, I6, I9).

Samples for benthic community analysis were collected from one side of a double 0.1-m^2 Van Veen grab, while samples from the adjacent grab were used for sediment quality analyses (see Chapter 4). During the winter survey, a second macrofaunal grab was collected from a subsequent cast; the second replicate was not collected during the summer as part of the Bight’13 resource exchange agreement (see Chapter 1). 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. Macrofaunal organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution and then fixed with buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All macrofauna were sorted from the raw material into major taxonomic groups by a subcontractor and then identified to species (or the lowest taxon possible) and enumerated by City marine biologists. All identifications followed nomenclatural standards established by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT 2013).

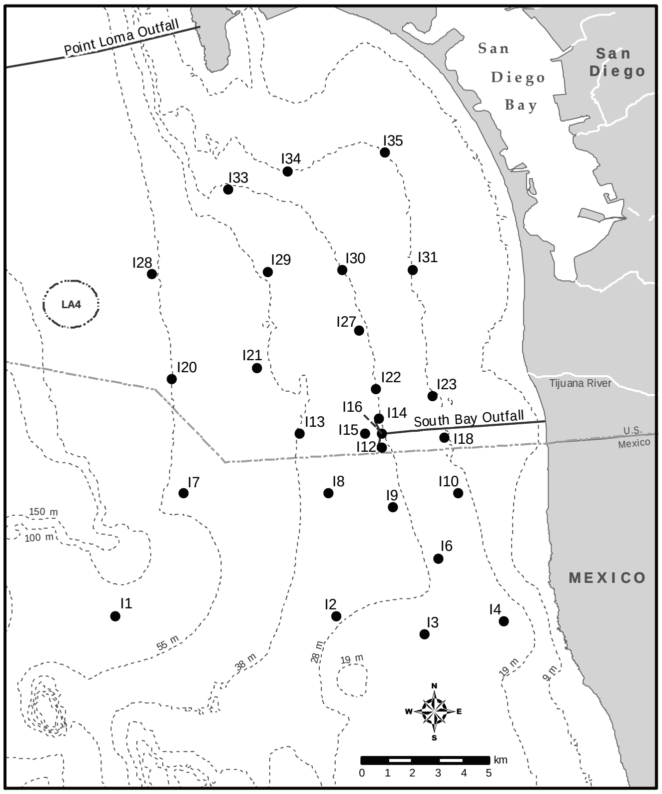

Figure 5.1

Benthic station locations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

Data Analyses

Each grab sample was considered an independent replicate for analysis. The following community structure parameters were determined for each station per 0.1-m^2 grab: species richness (number of taxa), abundance (number of individuals), Shannon diversity index (H’), Pielou’s evenness index (J’), Swartz dominance (see Swartz et al. 1986, Ferraro et al. 1994) and benthic response index (BRI; see Smith et al. 2001).

To further examine spatial and temporal patterns among benthic communities in the SBOO region, multivariate analyses were conducted on macrofaunal grabs that had a corresponding sediment sample. These analyses were performed using PRIMER and included hierarchical agglomerative clustering (cluster analysis) with group-average linking and similarity profile analysis (SIMPROF) to confirm the non-random structure of the resultant cluster dendrogram (Clarke and Warwick 2001, Clarke and Gorley 2006, Clarke et al. 2008). The Bray-Curtis measure of similarity was used as the basis for the cluster analysis, and abundance data were square-root transformed to lessen the influence of the most abundant species and increase the importance of rare species. Major ecologically-relevant clusters receiving SIMPROF support were retained, and similarity percentages analysis (SIMPER) was used to determine which organisms were responsible for the greatest contributions to within-group similarity (i.e., characteristic species) and between-group dissimilarity for retained clusters. To determine whether macrofaunal communities varied by sediment particle size fractions, a RELATE test was used to compare patterns of rank abundance in the macrofauna Bray-Curtis similarity matrix with rank abundance in the sediment Euclidean distance matrix (see Chapter 4). When significant similarity was found, a BEST test using the BIO-ENV procedure was conducted to determine which subset of sediment subfractions was the best explanatory variable for similarity between the two resemblance matrices.

RESULTS AND DISCUSSION

Community Parameters

Species richness

A total of 702 taxa were identified during the 2013 SBOO surveys. Of these, 567 (81%) were identified to species, while the rest could only be identified to higher taxonomic levels. Most taxa occurred at multiple stations, although 20% (n = 142) were recorded only once. Two likely new species not previously reported by the City’s Ocean Monitoring Program were encountered, the nemertean Hoplonemertea sp D and an unidentified peanut worm in the family Sipunculidae.

Mean species richness ranged from 33 taxa per grab at station I3 to 134 per grab at station I28 (Table 5.1). No clear patterns relative to the discharge site, depth, or sediment particle size were observed, with the lowest and highest values occurring at stations located 7.4 to 9.8 km from the physical structure of the SBOO. Species richness values were within the range of 6–192 taxa per grab reported from 1995 to 2012, with higher values occurring during the summer survey than during the winter survey in 70% of the samples (Appendix D.1). During summer of 2013, species richness values at the outfall depth were among the highest recorded since monitoring began; however this phenomenon is regional and not related to wastewater discharge (Figure 5.2A).

Macrofaunal abundance

A total of 47,993 macrofaunal individuals were identified in 2013. Mean abundance ranged from 163 animals per grab at station I3 (the same station that also had the lowest species richness) to 1204 at station I15 (Table 5.1). No clear patterns relative to distance from the discharge site or sediment particle size were observed; however, species abundance was typically highest along the outfall depth. Abundance values were within the historical range of 8–3216 individuals per grab, with higher values occurring during the summer survey than during the winter survey in 93% of the samples (Appendix D.1). High values during the summer correlated to a population increase of the spionid polychaete *Spiophanes norrisi*, a species that has been the primary source of variation in abundance observed across the region since 2007 (Figures 5.2B, 5.3). Since populations of this species have fluctuated at both nearfield and farfield sites, changes in abundance are likely a regional phenomenon that is not associated with wastewater discharge.

Species diversity, evenness, and dominance

Shannon diversity (H’) index values ranged from 1.9 to 4.1 per grab for each station, while mean evenness

Table 5.1

Summary of macrofaunal community parameters for SBOO benthic stations sampled during 2013. SR=species richness; Abun=abundance; H'=Shannon diversity; J'=evenness; Dom=Swartz dominance; BRI=benthic response index. Data for each station are expressed as annual means (n=3 grabs). Stations are listed north to south from top to bottom for each depth contour.

	Station	SR	Abun	H'	J'	Dom	BRI
19-m Stations	I35	72	233	3.7	0.86	29	27
	I34	51	894	2.2	0.56	5	19
	I31	53	242	2.6	0.67	12	16
	I23	71	199	3.8	0.89	28	22
	I18	56	371	2.7	0.68	14	18
	I10	63	769	2.3	0.59	12	19
	I4	49	441	2.7	0.72	11	13
28-m Stations	I33	114	853	3.5	0.75	23	29
	I30	105	873	3.4	0.75	23	24
	I27	81	680	3.0	0.69	18	24
	I22	95	598	3.2	0.72	21	25
	I14[a]	86	686	2.9	0.66	16	26
	I16[a]	89	861	2.6	0.58	9	25
	I15[a]	86	1204	2.5	0.55	12	24
	I12[a]	122	1111	3.0	0.63	18	25
	I9	96	986	3.0	0.68	19	25
	I6	62	1142	1.9	0.46	4	15
	I2	52	465	2.2	0.56	7	18
	I3	33	163	2.4	0.68	8	12
38-m Stations	I29	83	477	3.3	0.79	19	18
	I21	69	331	3.0	0.72	17	16
	I13	79	451	3.3	0.76	17	23
	I8	57	460	2.4	0.59	8	23
55-m Stations	I28	134	600	4.1	0.83	37	18
	I20	57	267	3.0	0.73	13	14
	I7	74	371	3.1	0.72	19	12
	I1	70	269	3.6	0.85	22	17
All Grabs	Mean	76	593	2.9	0.69	16	20
	95% CI	6	132	0.2	0.04	2	1
	Minimum	19	76	0.8	0.20	1	-4
	Maximum	157	2626	4.2	0.92	43	30

[a] nearfield station

ranged from 0.46 to 0.89 (Table 5.1). The lowest values for diversity and evenness co-occurred at station I6. Highest diversity and evenness occurred at stations I28 and I23, respectively. No spatial patterns relative to wastewater discharge, depth, or sediment particle size were evident for these parameters. High abundances of *S. norrisi* during the summer survey led to lower individual grab values for both parameters (Appendix D.1), particularly at the outfall depth stations (Figures 5.2C, D, 5.3). However, diversity remained within the range of 0.5–4.7 observed from 1995 through 2012. These parameters indicate that local benthic communities remain characterized by relatively diverse assemblages of evenly distributed species. Swartz dominance averaged from 4 to 37 taxa per grab at each station, with the lowest dominance (highest index value) occurring at station I28 and the highest dominance (lowest index value) occurring at station I6 (Table 5.1). No patterns relative to wastewater discharge, depth, or sediment particle size were evident. High abundances of *S. norrisi* during the summer survey led to higher dominance in the summer than during the winter (Appendix D.1); however, all values were within the range of 1–67 per grab observed from 1995 through 2012.

Benthic response index

The benthic response index (BRI) is an important tool for gauging anthropogenic impacts to coastal seafloor habitats throughout the SCB. BRI values below 25 are considered indicative of reference conditions, while values above 34 represent increasing levels of disturbance or environmental degradation (Smith et al. 2001). In 2013, 72% of the individual benthic samples collected in the South Bay outfall region were characteristic of reference conditions (Appendix D.1), and 74% of the benthic stations sampled had mean BRI <25 (Table 5.1). Seven stations had BRI values of 25–29 that corresponded to a minor deviation from reference conditions: six occurred along the 28-m outfall depth contour located from 0.1 km south to 10.8 km north of the outfall (i.e., stations I9, I12, I14, I16, I22, I33), and one occurred along the 19-m contour located about 11 km north of the outfall (i.e., I35). Slightly higher BRI values at these stations are not unexpected because of naturally higher levels of organic matter often occurring at depths <30 m (Smith et al. 2001). The lowest BRI (i.e., 12) co-occurred at stations I3 and I7. No consistent seasonal pattern was evident between winter and summer surveys (Appendix D.1). Historically, BRI at the four nearfield stations have been similar to values at the four northern farfield stations (Figure 5.2F), indicating that the slightly elevated values are likely a regional phenomenon that is not associated with wastewater discharge.

Species of Interest

Dominant taxa

Polychaete worms were the dominant taxonomic group found in the SBOO region in 2013 and accounted for 50% of all taxa collected (Table 5.2). Crustaceans accounted for 20% of taxa reported, while molluscs, echinoderms, and all other taxa combined each contributed to ≤13% of mean total invertebrate composition. Polychaetes were also the most numerous animals, accounting for 75% of the total abundance. Crustaceans accounted for 12% of the animals collected, while molluscs, echinoderms, and all other taxa combined each contributed to ≤6% of mean total abundance. Overall, the percentage of taxa that occurred within each of the above major taxonomic groupings and their relative abundances were similar to those observed in 2012 and have remained consistent since monitoring began in 1995 (City of San Diego 2000, 2013a).

The 10 most abundant species in 2013 were all polychaetes and included the spionids *Spiophanes norrisi* and *Prionospio (Prionospio) jubata*, the chaetopterid *Spiochaetopterus costarum* Cmplx, the magelonid *Magelona sacculata*, the amphinomid *Chloeia pinnata*, the maldanid *Axiothella* sp, the capitellids *Mediomastus* sp and *Notomastus latericeus*, the cirratulid *Monticellina siblina*, and the phyllodocid *Phyllodoce hartmanae* (Table 5.3). *Spiophanes norrisi* was the most abundant species overall, accounting for ~47% of invertebrates collected, and ~60% of invertebrates found during just the summer survey. Of the 10 most abundant species, *S. norrisi* was also the most widely distributed species and occurred in 99% of grabs, with mean abundance of ~279 individuals per grab. This species has been the most abundant taxon recorded for the SBOO region since 2007 (Figure 5.3), with up to 3009 individuals found in a single grab at station I16 during the summer of 2010.

Five of the above most abundant species in 2013 occurred in historically high numbers, including *Magelona sacculata* (554/grab), *Chloeia pinnata* (346/grab), *Prionospio (Prionospio) jubata* (213/grab), *Axiothella* sp (177/grab), and *Spiochaetopterus costarum* Cmplx (161/grab). Although high abundances of *S. costarum* Cmplx, *P. (P.) jubata*, and *M. sacculata* were distributed across both nearfield and farfield outfall depth stations (see Figure 5.3), high abundances of other taxa were more localized. For instance,

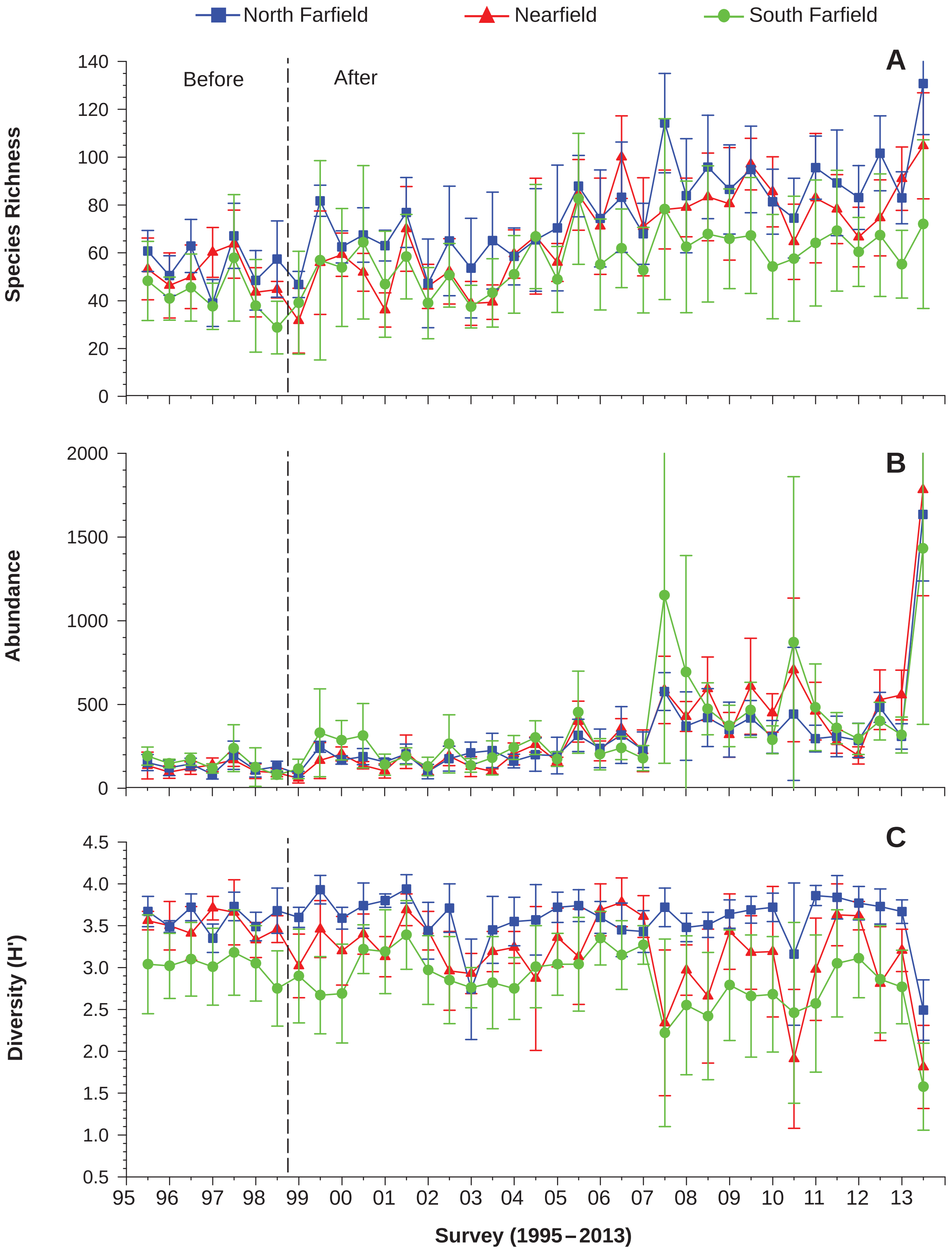

Figure 5.2

Comparison of community parameters at SBOO nearfield, north farfield, and south farfield stations sampled from 1995 through 2013. Parameters include: (A) species richness; (B) infaunal abundance; (C) diversity (H'); (D) evenness (J'); (E) Swartz dominance; (F) benthic response index (BRI). Data for each station group are expressed as means ±95% confidence intervals per grab (n=8 except for summer 2013 when n=4). Dashed lines indicate onset of wastewater discharge.

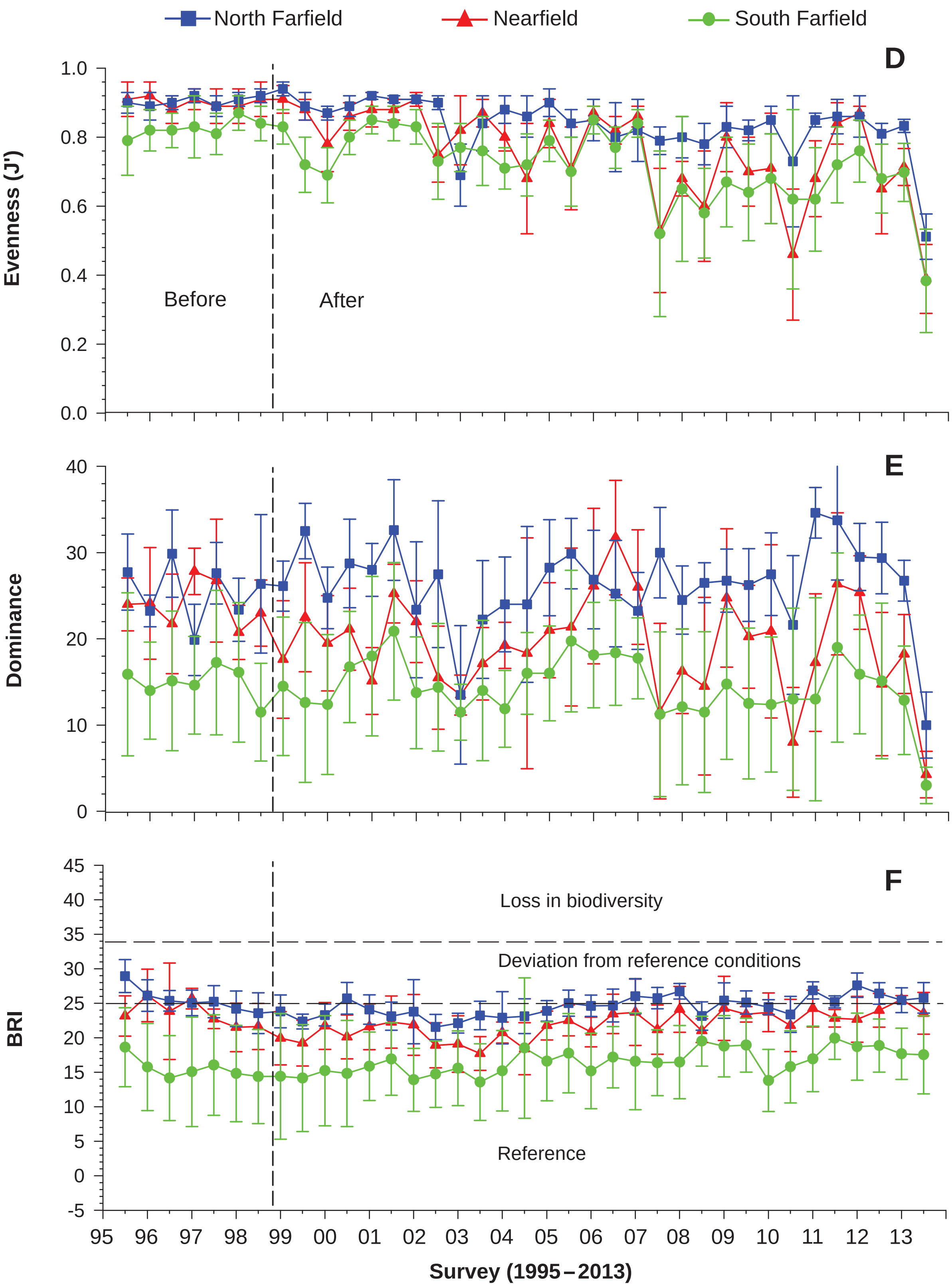

Figure 5.2 *continued*

unusually high abundances of *C. pinnata* only occurred at two stations along the 55-m depth contour (data not shown). Populations of *C. pinnata* equivalent to about 480 individuals per 0.1 m^2 grab have been reported previously in healthy environments of the SCB (Jones and Thompson 1987), and the high abundances of this and other species in the SBOO region during

2013 likely represent natural population cycles not related to wastewater discharge.

Three of the ten most abundant taxa collected during 2013, *Spiophanes norrisi*, *Monticellina siblina*, *Mediomastus* sp, were also among the five most abundant taxa recorded over the past 19 years (Figure 5.3, Appendix D.2). Other historically-dominant species included the spionid polychaete *Spiophanes duplex*, which was recorded in relatively high numbers from 2003 through 2011, and the maldanid polychaete species complex Euclymeninae sp A/B, which had a population surge from 2007 through 2011. It is hypothesized that population fluctuations of *S. duplex* and E. sp A/B may follow cyclical "boom and bust" patterns that take years or decades to complete.

Indicator species

Several species known to be useful indicators of environmental change that occur in the SBOO region include the polychaete *Capitella teleta* (considered within the *Capitella capitata* species complex), the bivalve *Solemya pervernicosa*, and amphipods in the genera *Ampelisca* and *Rhepoxynius*. For example, increased abundances of pollution-tolerant species such as *C. teleta* and *S. pervernicosa* and decreased abundances of pollution-sensitive taxa such as *Ampelisca* spp and *Rhepoxynius* spp are often indicative of organic enrichment and may indicate habitats impacted by human activity (Barnard and Ziesenhenne 1961, Anderson et al. 1998, Linton and Taghon 2000, Smith et al. 2001, Kennedy et al. 2009, McLeod and Wing 2009). Only 3 individuals of *C. teleta* and 58 individuals of *S. pervernicosa* were identified from all SBOO

Table 5.2

Percent composition and abundance of major taxonomic groups in SBOO benthic grabs sampled during 2013; n = 81.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	50 (26 – 67)	75 (33 – 95)
Arthropoda (Crustacea)	20 (9 – 34)	12 (2 – 54)
Mollusca	13 (0 – 32)	5 (0 – 21)
Echinodermata	5 (0 – 15)	3 (0 – 24)
Other Phyla	13 (1 – 30)	6 (<1 – 22)

Table 5.3

The 10 most abundant macroinvertebrate taxa collected at the SBOO benthic stations during 2013. Abundance values are expressed as mean number of individuals per grab. Percent occurrence = percentage of grabs in which a species occurred.

Species	Taxonomic Classification	Abundance per Grab	Percent Occurrence
Spiophanes norrisi	Polychaeta: Spionidae	278.7	99
Spiochaetopterus costarum Cmplx	Polychaeta: Chaetopteridae	19.9	89
Prionospio (*Prionospio*) *jubata*	Polychaeta: Spionidae	16.1	80
Magelona sacculata	Polychaeta: Magelonidae	13.0	53
Chloeia pinnata	Polychaeta: Amphinomidae	7.1	7
Axiothella sp	Polychaeta: Maldanidae	6.9	49
Mediomastus sp	Polychaeta: Capitellidae	6.7	64
Monticellina siblina	Polychaeta: Cirratulidae	6.3	57
Notomastus latericeus	Polychaeta: Capitellidae	5.5	59
Phyllodoce hartmanae	Polychaeta: Phyllodocidae	5.4	65

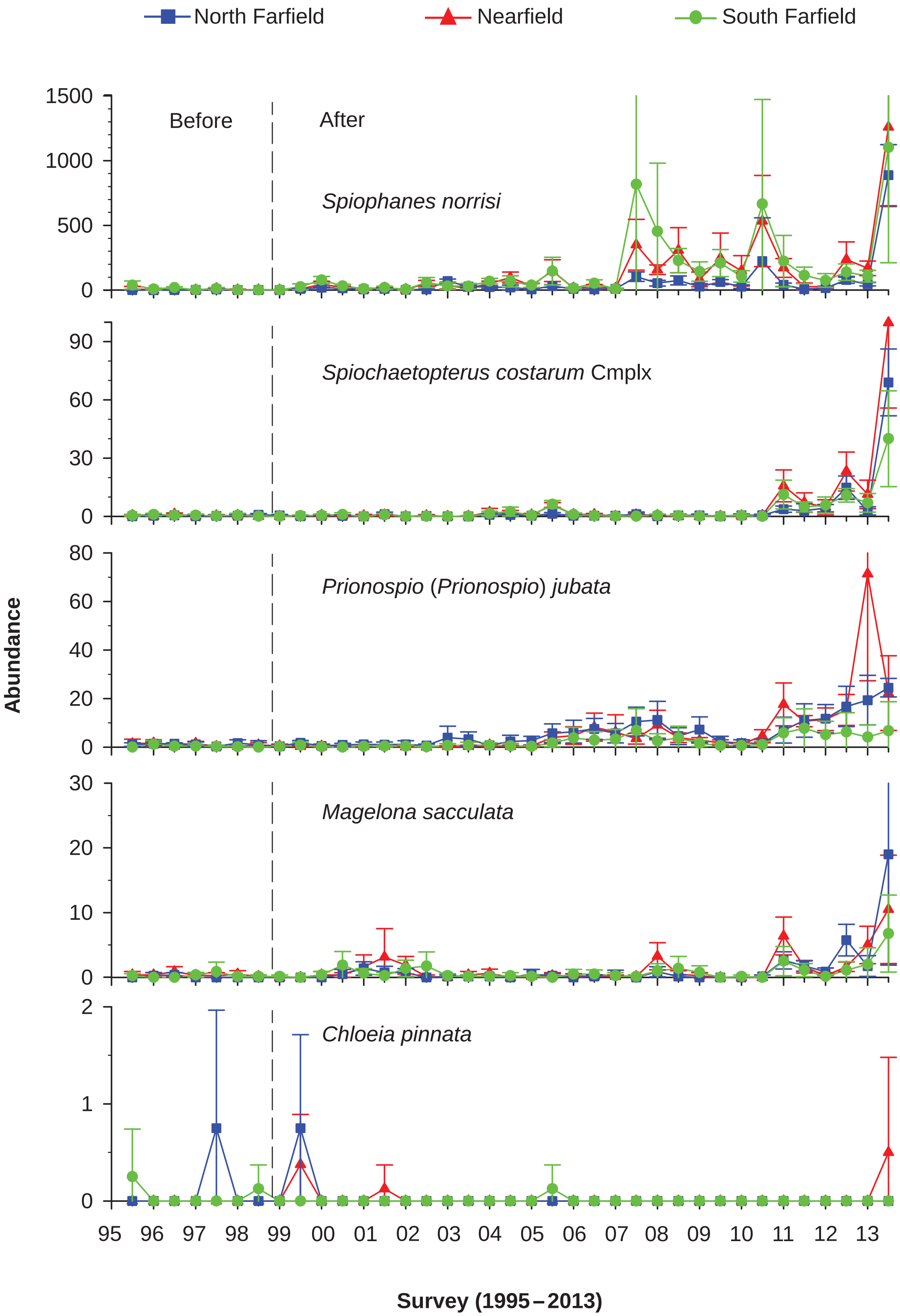

Figure 5.3
Abundances of the five most numerically dominant taxa (presented in order) recorded during 2013 at SBOO north farfield, nearfield, and south farfield stations from 1995 through 2013. Data for each station group are expressed as means ±95% confidence intervals per grab (n=8 except for summer 2013 when n=4). Dashed lines indicate onset of wastewater discharge.

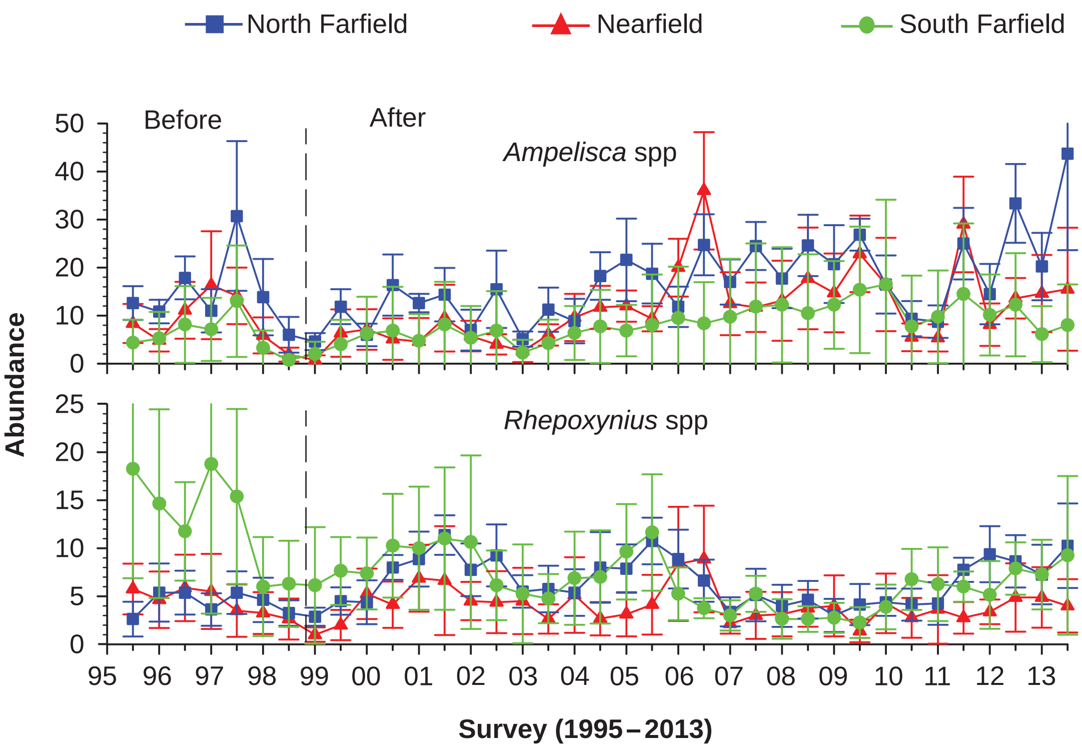

Figure 5.4

Abundances of representative ecologically important pollution-sensitive indicator taxa at SBOO north farfield, nearfield, and south farfield stations from 1995 through 2013. Data for each station group are expressed as means ±95% confidence intervals per grab (n=8 except for summer 2013 when n=4). Dashed lines indicate onset of wastewater discharge.

benthic samples during 2013. In contrast, *Ampelisca* and *Rhepoxynius* averaged up to 44 individuals per grab at the outfall depth stations. When compared to previous years, abundances of these two taxa either increased in 2013 or remained similar at both nearfield and farfield stations (Figure 5.4). These results suggest limited impact of wastewater discharge to the region.

Classification of Macrobenthic Assemblages

Similarity of Assemblages

Classification (cluster) analysis was used to discriminate between macrofaunal assemblages from 54 individual grab samples collected at 27 stations in 2013, resulting in eight ecologically-relevant SIMPROF-supported groups (Figures 5.5, 5.6, Appendix D.3). These assemblages (referred to herein as cluster groups A–H) represented from 2 to 19 grabs each, and exhibited mean species richness ranging from 47 to 127 taxa per grab and mean abundances of 174 to 1000 individuals per grab. The assemblages appear to be primarily influenced by sediment particle size, depth, or season as described below.

Cluster group A represented the macrofaunal assemblages from two samples collected during winter at stations I29 and I34 located north of the SBOO on the 38-m and 19-m depth contours, respectively (Figure 5.6). Group A had the lowest mean species richness (47 taxa/grab), and the third lowest mean abundance (299 individuals/grab) of any cluster group (Figure 5.5). The seven most abundant taxa included the polychaetes *Micropodarke dubia*, *Spio maculata*, *Spiophanes norrisi*, *Pareurythoe californica*, *Prionospio* (*Prionospio*) *jubata* and *Pisione* sp, as well as unidentified species of nematodes (phylum Nematoda), all of which had mean abundances ranging from 12 to 54 individuals per grab (Appendix D.3). No other taxon had abundances >9 individuals per grab. A single species, *Micropodarke dubia*, was responsible for contributing to 25% of within group similarity.

High numbers of this species and nematodes distinguished assemblages represented by group A from the other groups (Figure 5.7). Group A also differed from other groups because of a lack of the ostracod *Euphilomedes carcharodonta* and the polychaete *Sthenelanella uniformis*. Sediments associated with this cluster group varied greatly, with fine sands and percent fines (i.e., silts and clays) representing over 75% of the sediment at station I29 and coarse particles and medium-coarse sands dominating the sediments at I34 (Appendix C.4). Despite these differences, both grabs in cluster A had unusually high quantities of shell hash. Additionally, red relict sand occurred at station I29 and gravel was found at station I34.

Cluster group B represented the winter and summer assemblages from the two samples collected at station I28 located on the 55-m contour in the northern section of the region (Figure 5.6). The mean species richness of 127 taxa per grab was the highest of all cluster groups, whereas the mean abundance of 549 individuals was within mid-range of all other groups (Figure 5.5). The seven most abundant species were the polychaetes *Spiophanes norrisi*, *Sthenelanella uniformis*, *Prionospio* (*Prionospio*) *jubata*, *Spiochaetopterus costarum* Cmplx, and *Chaetozone hartmanae*, the amphipod *Photis californica,* and the ostracod *Euphilomedes carcharodonta*, all of which had mean abundances ranging from 17 to 60 individuals per grab (Appendix D.3). No other taxa had abundances >12 individuals per grab. Species contributing to 25% of within group similarity included *Spiophanes norrisi*, *Prionospio* (*Prionospio*) *jubata*, *Sthenelanella uniformis*, *Photis californica*, *Euphilomedes carcharodonta*, and *Chaetozone hartmanae*, and the ophiuroid *Amphiodia urtica*. Compared to other cluster groups (and in direct contrast to group A above), the group B assemblages had high abundances of *Euphilomedes carcharodonta* and *Sthenelanella uniformis*, and lacked nematodes (Figure 5.7). As with cluster group A, sediments associated with this cluster group varied greatly with coarse particles and medium-coarse sands representing over 65% of the sediments during the winter survey, and fine sands and percent fines representing over 95% of the sediments during the summer survey. Grabs from this group were the only ones that contained coarse black sand (Appendix C.4). The summer grab also contained pea gravel.

Cluster group C represented winter and summer assemblages from the two samples at station I1 located along the 55-m depth contour (Figure 5.6). Mean species richness and abundance were within the range of all other cluster groups at 69 taxa and 298 individuals per grab (Figure 5.5). The most abundant species was the amphipod *Photis californica* with an average of 48 individuals per grab, distantly followed by the polychaetes *Chloeia pinnata*, *Sthenelanella uniformis* and *Prionospio* (*Prionospio*) *jubata*, and the ostracod *Euphilomedes carcharodonta*, all of which averaged from 12 to 15 individuals per grab (Appendix D.3). No other taxa had abundances >12 individuals per grab. Taxa contributing to 25% of within group similarity included the polychaetes *Prionospio* (*Prionospio*) *jubata*, *Spiochaetopterus costarum* Cmplx, *Sthenelanella uniformis*, the ostracod *Euphilomedes carcharodonta*, and the cumacean *Mesolamprops bispinosus*. The anomalously high number of 94 *Photis californica* during the winter survey is one feature that sets this cluster apart from all other groups (Figure 5.7). Sediments associated with group C contained percent fines ranging from 12 to 16%, fine sands ranging from 78 to 81%, and no coarse particles (Appendix C.4).

Cluster group D represented the assemblages from six winter grabs and one summer grab collected from six different stations along the 19-m depth contour (Figure 5.6). This group had the second lowest mean species richness of 57 taxa and the lowest mean abundance of 174 individuals per grab (Figure 5.5). The five most abundant species included the polychaetes *Spiophanes norrisi, Spiophanes duplex, Magelona sacculata, Nereis* sp A and *Paraprionospio alata*, all of which had mean abundances ranging from 5 to 36 individuals per grab (Appendix D.3). No other taxa had abundances >4 individuals per grab. Species contributing to 25% of within group similarity included *Spiophanes norrisi, Spiophanes duplex, Magelona sacculata*, and the bivalve *Tellina modesta*. Fine sands dominated the sediments

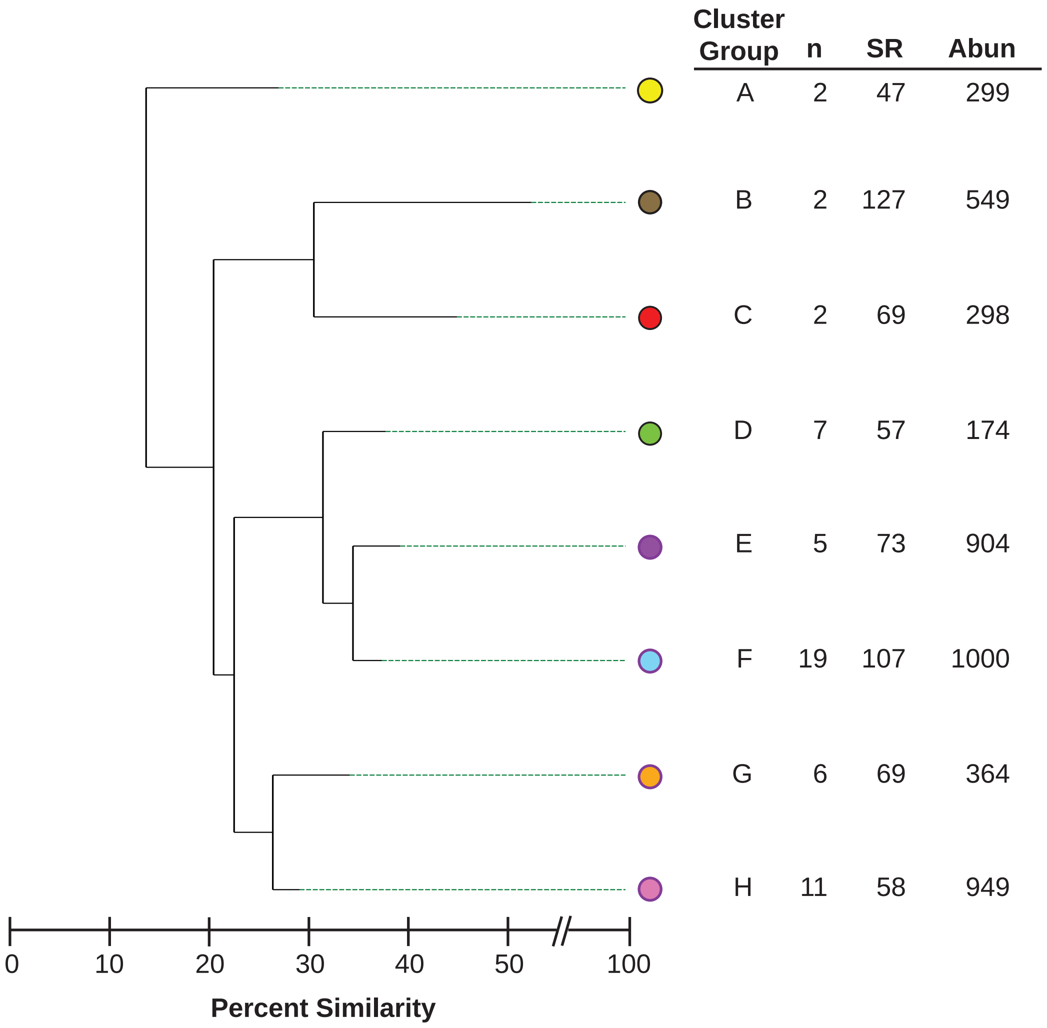

Figure 5.5
Cluster analysis of macrofaunal assemblages at SBOO stations sampled during 2013. Data for species richness (SR) and infaunal abundance (Abun) are expressed as mean values per 0.1-m^2 over all stations in each group (n).

associated with group D, with values ranging from 54 to 86%. Percent fines ranged from 12 to 43%. Organic debris (mostly worm tubes) and some shell hash were also observed (Appendix C.4).

Cluster group E represented the summer assemblages from five stations along the 19-m depth contour (Figure 5.6). Group E had mean species richness in range of all other cluster groups (73 taxa per grab), and the third highest mean abundance of 904 individuals per grab (Figure 5.5). Assemblages were dominated by the polychaete *Spiophanes norrisi*, which averaged 652 individuals per grab. Other abundant taxa included the polychaetes *Mediomastus* sp, *Magelona sacculata*, *Spiochaetopterus costarum* Cmplx, and *Apoprionospio pygmaea* (Appendix D.3) that averaged from 13 to 22 individuals per grab. No other taxa had abundances >11 individuals per grab. Taxa contributing to 25% of within group similarity included just *Spiophanes norrisi* and *Mediomastus* sp. Sediments associated with this group were similar to Group D, with percent fines ranging from ranged from 14 to 19%, fine sands ranging from 78 to 84%, medium-coarse sands ranging from 2 to 5%, and no coarse particles. Organic debris such as worm tubes and algae were also observed (Appendix C.4).

Cluster group F comprised assemblages from 19 grabs at 11 stations ranging in depth from 28 to 38 m (Figure 5.6). This group represents

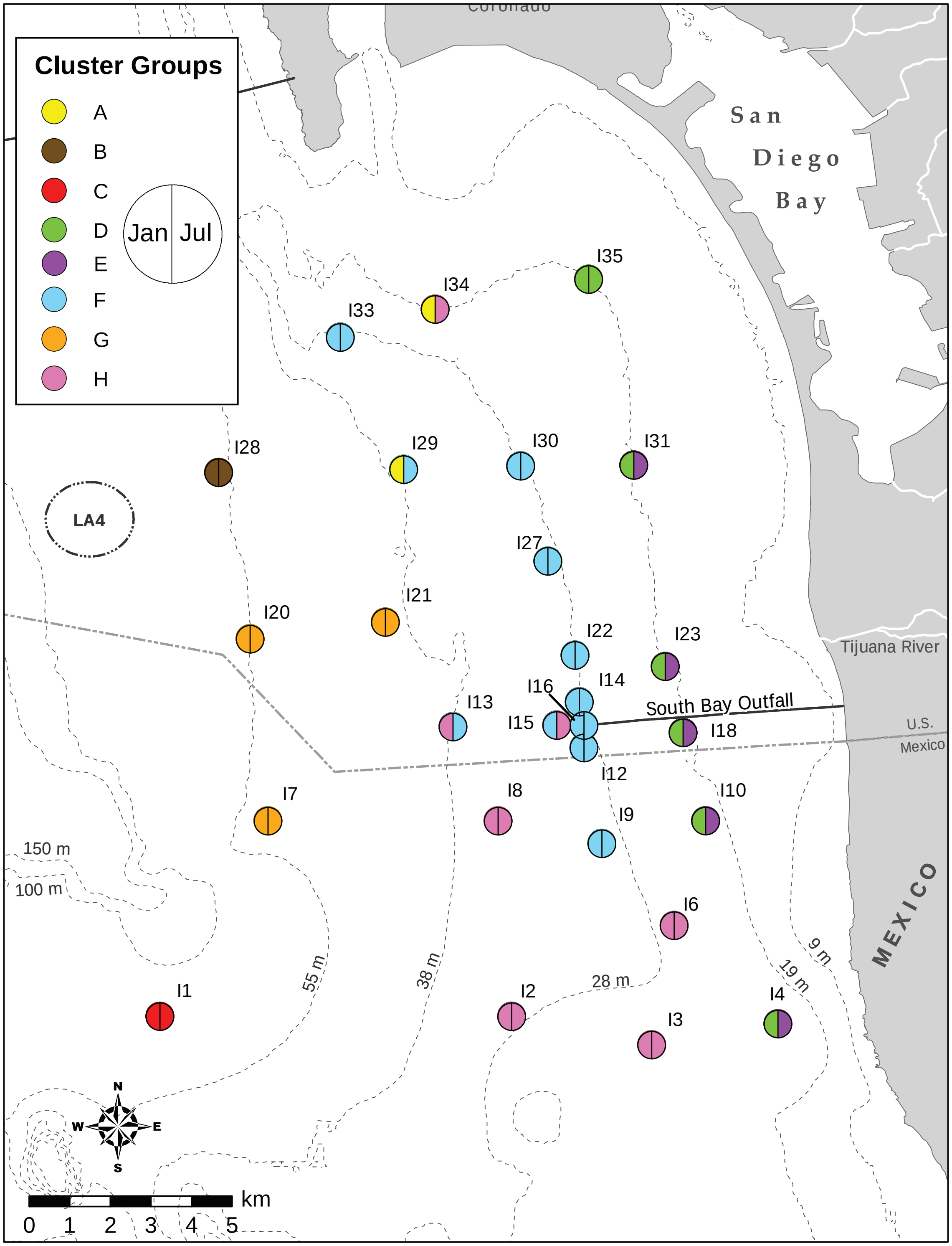

Figure 5.6
Distribution of cluster groups in the SBOO region during winter (January) and summer (July) 2013. Colors of each circle correspond to colors in Figure 5.5.

typical inner shelf assemblages for the SCB and contained all nearfield grabs except for at station I15 during the summer survey. Mean species richness was the second highest of all cluster groups at 107 taxa per grab, while usually high abundances the polychaete *Spiophanes norrisi* (502/grab) were responsible for the highest mean abundance of 1000 individuals per grab (Figure 5.5). The polychaetes *Spiochaetopterus costarum* Cmplx, *Prionospio* (*Prionospio*) *jubata*,

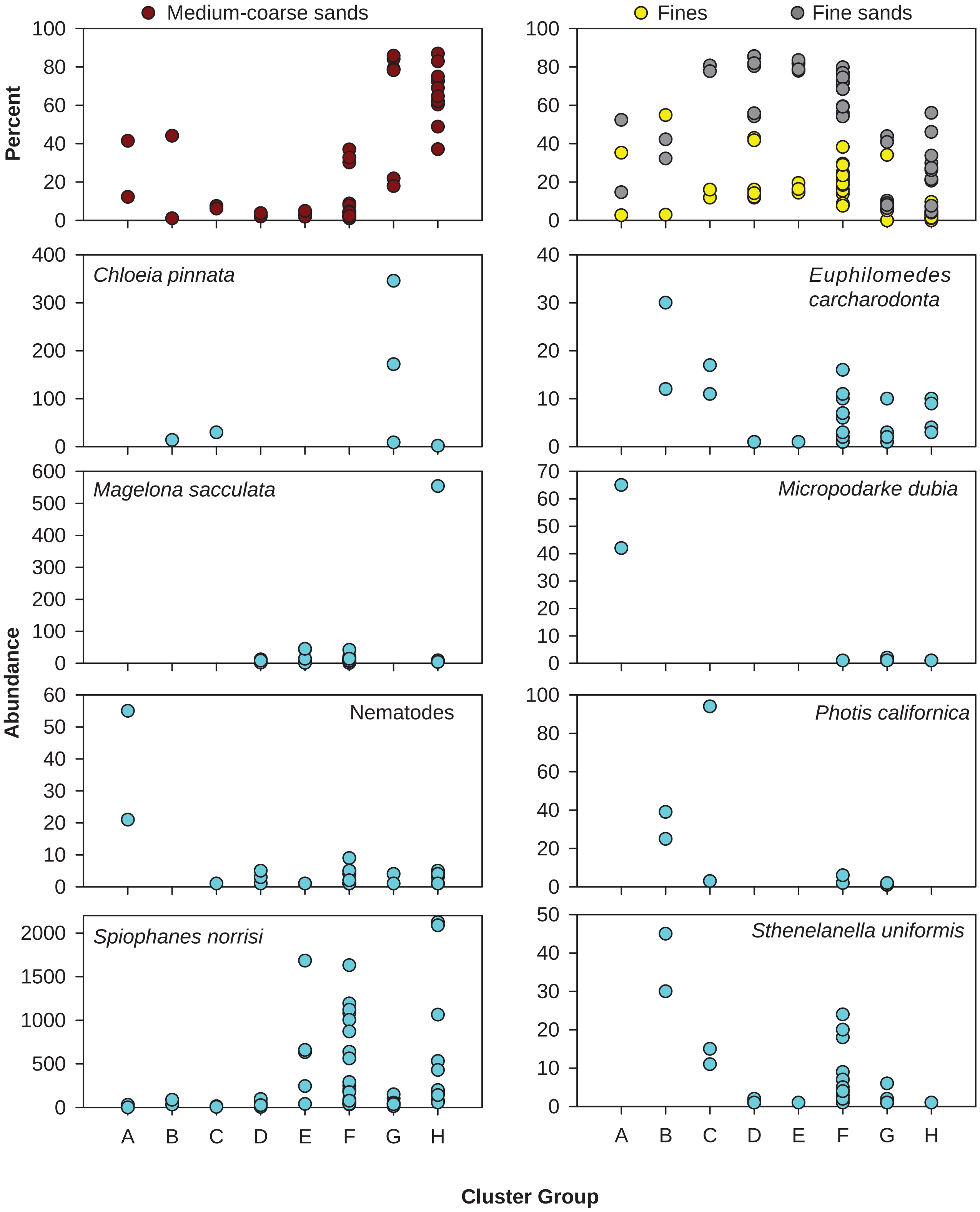

Figure 5.7
Sediment composition and abundances of select species that contributed to cluster group dissimilarities in the SBOO region in 2013 (see Figure 5.5). Each data point represents a single sediment or grab sample.

Mediomastus sp, and *Monticellina siblina* were also abundant (Figure 5.7, Appendix D.3), averaging from 17 to 42 individuals per grab. No other taxa had abundances >12 individuals per grab. Species contributing to 25% of within group similarity included the polychaetes *Spiophanes norrisi*, *Prionospio* (*Prionospio*) *jubata*, *Spiochaetopterus costarum* Cmplx, and *Spiophanes duplex*, and the amphipod *Ampelisca brevisimulata*. Sediments associated with group F were generally finer than those from most other groups, and contained from 8 to 30% fines, with fine sands ranging from 54 to 80%. Worm tubes and shell hash were also observed (Appendix C.4).

Cluster group G represented mid-shelf assemblages from all six grabs collected at stations I7, I20 and I21 located along the 38-m and 55-m depth contours (Figure 5.6). Mean species richness and abundance values of 69 taxa and 364 individuals per grab, respectively, were within range of other cluster groups (Figure 5.5). The most abundant taxa were the polychaetes *Chloeia pinnata*, *Spiophanes norrisi* and *Spiochaetopterus costarum* Cmplx, all of which had mean abundances ranging from 21 to 88 individuals per grab. No other taxa had abundances >12 individuals per grab. Taxa contributing to 25% of within group similarity included the polychaetes *Spio maculata*, *Spiophanes norrisi*, *Spiochaetopterus costarum* Cmplx, and *Mooreonuphis* sp. Some grabs in group G had considerably higher abundances of *Chloeia pinnata* than found in the other cluster groups (Figure 5.7). Medium-coarse sands, which ranged from 18 to 86%, dominated sediments associated with this group. Percent fines ranged from 0 to 41%. Red relict sand and shell hash were also observed (Appendix C.4).

Cluster group H comprised the assemblages from 11 grabs at seven stations along the 19-m, 28-m and 38-m contours including the summer grab from nearfield station I15 (Figure 5.6). Although the mean species richness of 58 taxa per grab was the third lowest recorded, the mean abundance of 949 individuals per grab was the second highest of all other cluster groups (Figure 5.5). As with the assemblages from cluster groups E and F, *Spiophanes norrisi* was dominant with an average of 640 individuals per grab. Other abundant taxa included the polychaetes *Magelona sacculata*, *Spiochaetopterus costarum* Cmplx, and *Axiothella* sp, all of which had mean abundances ranging from 17 to 52 individuals per grab (Appendix D.3). No other taxa had abundances >13 individuals per grab. *Spiophanes norrisi* alone contributed to 25% of within group similarity. Sediments associated with group H had up to 10% fines, while medium-coarse sands ranged from 37 to 87%. Worm tubes, red relict sand, and shell hash were also observed (Appendix C.4).

Comparison of macrobenthic and sediment assemblages

Similar patterns of variation occurred in the benthic macrofaunal and sediment similarity/dissimilarity matrices (see Chapter 4) used to generate cluster dendrograms, confirming that macrofaunal assemblages in the SBOO region are correlated to sediment composition (RELATE $\rho = 0.597$, $p = 0.0001$). The sediment subfractions that were most highly correlated to macrofaunal communities included percent fines (e.g., clay, very fine silt, fine silt, and medium silt all lumped together before analysis), very fine sand, very coarse sand, and granules (BEST $\rho = 0.642$, $p = 0.001$) (Appendix C.1). Although no macrofaunal cluster groups corresponded exactly to sediment cluster groups, the macrofaunal and sediment dendrograms presented in this chapter (Figure 5.5) and Chapter 4 (Figure 4.4), respectively, indicated that macrofaunal assemblages occurring at sites with high amounts of granules (the coarsest sediment category) separate from assemblages occurring in finer sediments. Specifically, winter grab samples from stations I28 and I34 (in macrofaunal clusters A and B) formed sediment cluster 4. The majority of grabs from macrofaunal cluster groups G and H correspond to sediment cluster group 5 that contains the highest proportion of coarse sand (range = 24–64%), whereas the majority of grabs from macrofaunal cluster groups D–F correspond to sediment cluster 2 that contains the highest proportion of very fine sand (range = 35–62%). Despite these correlations, it is unlikely that differences in macrofaunal assemblages are caused solely by differences in the sediment subfractions measured. Additional factors influencing these benthic assemblages may include: (1) differences in concentrations of organic material, (2) differences in depth, (3) differences in biological factors (e.g., predation pressure), or (4) differences in ephemeral habitat alteration (e.g., in the case of cluster group E, the presence of algae that may temporarily support a unique macrofaunal assemblage).

SUMMARY

Analyses of the 2013 macrofaunal data do not suggest that wastewater discharged through the SBOO has affected macrobenthic communities in the region, with invertebrate assemblages located near the outfall being similar to those from neighboring farfield sites. Species richness, abundance, diversity, evenness and dominance were within historical ranges reported for the San Diego region (City of San Diego 2000, Chapter 9 in City of San Diego 2013a), and were representative of those that occur in other sandy, shallow to mid-depth habitats throughout the SCB (Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, Thompson et al. 1987, 1993b, Zmarzly et al. 1994, Diener and Fuller 1995, Bergen et al. 1998, 2000, 2001, City of San Diego 1999, Ranasinghe et al. 2003, 2007, 2010, 2012, Mikel et al. 2007). Typically, assemblages in the South Bay outfall monitoring region were indicative of the ambient sediment and/or depth characteristics, with stations of comparable physical attributes supporting similar types of benthic assemblages. Benthic response index (BRI) values determined for most sites during the year were characteristic of undisturbed habitats, with only a few stations having values suggestive of possible minor deviation from reference conditions. Mean BRI values at the 19-m and 28-m depth contour stations have typically been higher than along the deeper 38-m and 55-m contours ever since monitoring began. Higher BRI at shallower depths is not unexpected because of naturally higher levels of organic matter often occurring close to shore (Smith et al. 2001). A similar phenomenon is reported across the SCB where Smith et al. (2001) found a pattern of lower index values at mid-depth stations (25–130 m) versus shallower (10–35 m) or deeper (110–324 m) stations.

Changes in populations of pollution-sensitive or pollution-tolerant species or other indicators of benthic condition provide little to no evidence of significant environmental degradation in the South Bay outfall region. For instance, populations of opportunistic species such as the polychaete *Capitella teleta* and the bivalve *Solemya pervernicosa* were low during 2013, while populations of pollution-sensitive amphipod genera (*Ampelisca* and *Rhepoxynius*) have remained stable or increased slightly since before the onset of wastewater discharge. Additionally, although spionid polychaetes have been observed to form extensive communities in other areas of the world that naturally possess high organic matter (Díaz-Jaramillo et al. 2008), they are known to be a stable dominant component of many healthy environments in the SCB (Rodríguez-Villanueva et al. 2003). Thus, ubiquitous, large populations of *Spiophanes norrisi* observed at most SBOO stations from 2007 through 2013 suggest that their distribution is not indicative of habitat degradation related to wastewater discharge, but that population fluctuations of this species over the past few years likely correspond to natural changes in large-scale oceanographic conditions.

Benthic macrofaunal communities appear to be in good condition in the South Bay outfall region, remain similar to those observed prior to outfall operations, and are representative of natural indigenous communities from similar habitats on the southern California continental shelf. Although only 74% of the sites surveyed in 2013 were classified in reference condition based on assessments using the BRI, the elevated BRI north of the outfall fits into the historical pattern that has existed since before operation of the outfall began. Thus, no specific effects of wastewater discharge via the SBOO on the local macrobenthic community could be identified during the year.

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Chapter 6
Demersal Fishes and Megabenthic Invertebrates

Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

The City of San Diego (City) collects bottom dwelling (demersal) fishes and relatively large (megabenthic) mobile invertebrates by otter trawl to examine the potential effects of wastewater discharge or other disturbances on the marine environment around the South Bay Ocean Outfall (SBOO). These fishes and invertebrates are targeted for monitoring because they are known to play critical ecological roles on the southern California coastal shelf (e.g., Allen et al. 2006, Thompson et al. 1993a, b). Because trawled species live on or near the seafloor, they may be impacted by sediment conditions affected by both point and non-point sources such as discharges from ocean outfalls, runoff from watersheds, outflows from rivers and bays, or the disposal of dredged sediments (see Chapter 4). For these reasons, assessment of fish and invertebrate communities has become an important focus of ocean monitoring programs throughout the world, but especially in the Southern California Bight (SCB) where they have been sampled extensively on the mainland shelf for four decades (e.g., Stein and Cadien 2009).

In healthy ecosystems, fish and invertebrate communities are known to be inherently variable and influenced by many natural factors. For example, prey availability, bottom topography, sediment composition, and changes in water temperatures associated with large scale oceanographic events such as El Niño can affect migration or recruitment of fish (Cross et al. 1985, Helvey and Smith 1985, Karinen et al. 1985, Murawski 1993, Stein and Cadien 2009). Population fluctuations may also be due to the mobile nature of many species (e.g., fish schools, urchin aggregations). Therefore, an understanding of natural background conditions is necessary before determining whether observed differences or changes in community structure may be related to anthropogenic activities. Pre-discharge and regional monitoring efforts by the City and other researchers since 1994 provide baseline information on the variability of demersal fish and megabenthic communities in the San Diego region critical for such comparative analyses (e.g., Allen et al. 1998, 2002, 2007, 2011, City of San Diego 2000).

The City relies on a suite of scientifically-accepted indices and statistical analyses to evaluate changes in local fish and invertebrate communities. These include univariate measures of community structure such as species richness, abundance and the Shannon diversity index, while multivariate analyses are used to detect spatial and temporal differences among communities (e.g., Warwick 1993). The use of multiple analyses provides better resolution than single parameters for determining anthropogenically-induced environmental impacts. In addition, trawled fishes are inspected for evidence of physical anomalies or diseases that have previously been found to be indicators of degraded habitats (e.g., Cross and Allen 1993, Stein and Cadien 2009). Collectively, these data are used to determine whether fish and invertebrate assemblages from habitats with comparable depth and sediment characteristics are similar, or whether observable impacts from wastewater discharge or other sources have occurred.

This chapter presents analyses and interpretations of demersal fish and megabenthic invertebrate data collected during 2013, as well as long-term assessments of these communities from 1995 through 2013. The primary goals are to: (1) document assemblages present during the year, (2) determine the presence or absence of biological impacts associated with wastewater discharge, and (3) identify other potential natural and anthropogenic sources of variability to the local marine ecosystem.

MATERIALS AND METHODS

Field Sampling

Trawl surveys were conducted at seven monitoring stations in the SBOO region during winter, spring, and summer 2013 (i.e., January, April, and July, respectively). No survey was conducted during the fourth quarter (October) in order to accommodate participation in the Bight'13 regional project (see Chapter 1). These stations, designated SD15–SD21, are all located along the 28-m depth contour ranging from 7 km south to 8.5 km north of the SBOO (Figure 6.1). Stations SD17 and SD18 are located within 1000 m of the outfall wye, and represent the "nearfield" station group. Stations SD15 and SD16 are located >1.8 km south of the outfall and represent the "south farfield" station group, while SD19, SD20 and SD21 are located >1.7 km north of the outfall and represent the "north farfield" station group.

A single trawl was performed at each station during each survey using a 7.6-m Marinovich otter trawl fitted with a 1.3-cm cod-end mesh net. The net was towed for 10 minutes of bottom time at a speed of about 2.0 knots along a predetermined heading. The catch from each trawl was brought onboard the ship for sorting and inspection. All fishes and invertebrates captured were identified to species or to the lowest taxon possible (Eschmeyer and Herald 1998, Lawrence et al. 2013, SCAMIT 2013). If an animal could not be identified in the field, it was returned to the laboratory for identification. The total number of individuals and total biomass (kg, wet weight) were recorded for each species of fish. Additionally, each fish was inspected for the presence of physical anomalies, tumors, fin erosion, discoloration or other indicators of disease, as well as the presence of external parasites (e.g., copepods, cymothoid isopods). The length of each fish was measured to the nearest centimeter size class; total length (TL) was measured for cartilaginous fishes and standard length (SL) was measured for bony fishes (SCCWRP 2013). For invertebrates, the total number of individuals was also recorded for each species. Due to the small size of most invertebrate species, biomass was typically measured as a composite weight of all taxa combined, though large or exceptionally abundant species were weighed separately.

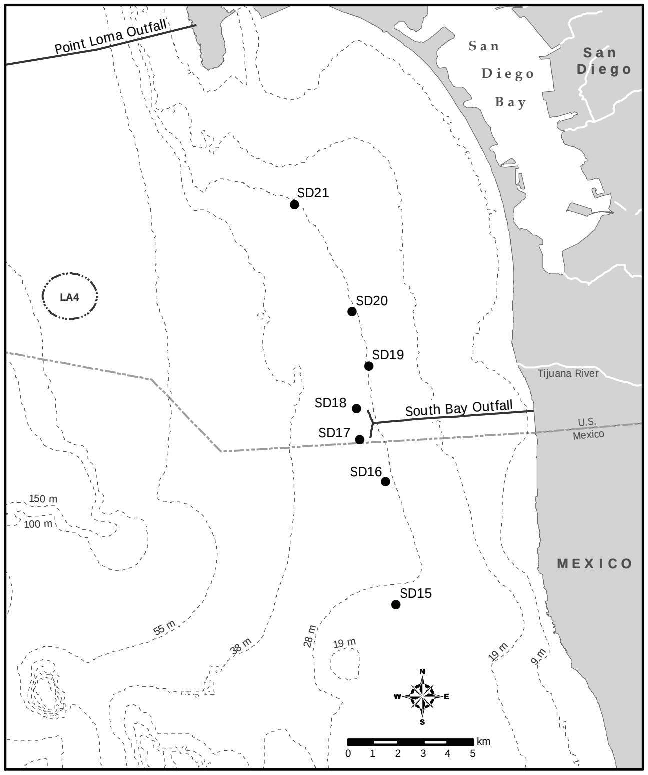

Figure 6.1
Trawl station locations sampled around the South Bay Ocean Outfall as part of City of San Diego's Ocean Monitoring Program.

Data Analyses

Population characteristics of all fish and invertebrate species were summarized as percent abundance (number of individuals per species/total abundance of all species), frequency of occurrence (percentage of stations at which a species was collected), mean abundance per haul (number of individuals per species/total number sites sampled), and mean abundance per occurrence (number individuals per species/number of sites at which the species was collected). Additionally, the following community structure parameters were calculated per trawl for both fishes and invertebrates: species richness (number of species), total abundance (number of individuals), Shannon diversity index (H'), and total biomass.

Multivariate analyses were performed in PRIMER using demersal fish and megabenthic invertebrate data collected from 1995 through 2013 (Clarke 1993, Warwick 1993, Clarke and Gorley 2006). Prior to these analyses, all data were limited to summer surveys only to reduce statistical noise from natural seasonal variations evident in previous studies (e.g., City of San Diego 1997, 2013). Analyses included hierarchical agglomerative clustering (cluster analysis) with group-average linking and similarity profile analysis (SIMPROF) to confirm the non-random structure of the resultant cluster dendrogram (Clarke et al. 2008). The Bray-Curtis measure of similarity was used as the basis for the cluster analysis, and abundance data were square-root transformed to lessen the influence of the most abundant species and increase the importance of rare species. The major ecologically-relevant clusters supported by SIMPROF were retained, and similarity percentages analysis (SIMPER) was used to determine which organisms were responsible for at least 75% of within-group similarity (i.e., characteristic species). Additionally, a 2-way crossed analysis of similarity (ANOSIM) was conducted (max. no. permutations = 9999) for each set of historical data where station group (i.e., nearfield, north farfield, south farfield) and year were provided as factors. SIMPER analyses were subsequently used to identify which species were most characteristic for each factor level when significant differences were found.

RESULTS AND DISCUSSION

Demersal Fishes

Community Parameters

Forty-two species of fish were collected in the area surrounding the SBOO in 2013 (Table 6.1, Appendix E.1). The total catch for the year was 8958 individuals (Appendix E.2), representing an average of ~427 fish per trawl. Of 24 families represented, 7 accounted for 98% of the total abundance (i.e., Cottidae, Cynoglossidae, Hexagrammidae, Paralichthyidae, Pleuronectidae, Sciaenidae, Synodontidae). Overall, the average catch per haul for 2013 was 52% larger than in 2012, and continued to be dominated by speckled sanddabs (Table 6.1). This species occurred in every haul and accounted for 57% of all fishes collected at an average of 242 individuals per trawl. California lizardfish were also prevalent in 2013 occurring in 95% of the trawls and accounting for 27% of all fishes collected (116/haul). No other species contributed to more than 3% of the total catch. For example, hornyhead turbot occurred in every haul, but averaged only eight individuals per occurrence. Other species collected in at least 50% of the trawls, but in relatively low numbers (≤6/haul), included longspine combfish, California tonguefish, English sole, longfin sanddab, kelp pipefish, roughback sculpin, curlfin sole, and fantail sole.

More than 99% of the fishes collected during 2013 were < 30 cm in length (Appendix E.1). Larger fishes included eight California halibut (30–84 cm), one California skate (32 cm), and one Pacific electric ray (65 cm). Median lengths per haul for the two most abundant species ranged from 4 to 9 cm for speckled sanddabs and from 9 to 14 cm for California lizardfish (Figure 6.2). Some minor seasonal and site differences were observed during the past year. For example, the smallest speckled sanddabs (median lengths ≤ 5 cm) were found at stations SD15, SD19, SD20 and the smallest California lizardfish (median lengths ≤ 9 cm) were found at station SD20 during the spring. No California lizardfish were captured at station SD21 during the spring survey. The largest speckled sanddabs (median length = 9 cm) were collected at station SD15 during the summer, while California lizardfish individuals ≥ 20 cm were captured at stations SD15, SD17, and SD21 during the winter, at station SD17 during the spring, and at stations SD15, SD20 and SD21 during the summer.

Fish community structure varied among stations and between surveys during the year (Table 6.2, Appendices E.2, E.3). For each haul, species richness ranged from 8 to 18 species, diversity (H') ranged from 0.4 to 1.8, total abundance ranged from 101 to 1229 individuals, and total biomass ranged from 2.0 to 20.5 kg. Species richness and diversity tended to be lowest at the southern farfield stations SD15 and SD16 and highest at the northern farfield stations SD20 and SD21. Abundances ≥ 437 individuals were recorded at

Table 6.1

Species of demersal fish collected from 21 trawls conducted in the SBOO region during 2013. PA = percent abundance; FO = frequency of occurrence; MAH = mean abundance per haul; MAO = mean abundance per occurrence.

Species	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Speckled sanddab	57	100	242	242	Stripetail rockfish	<1	14	<1	3
California lizardfish	27	95	116	121	Shiner perch	<1	5	<1	8
White croaker	3	14	13	90	Specklefin midshipman	<1	10	<1	2
Pacific sanddab	2	19	10	51	Queenfish	<1	10	<1	2
Hornyhead turbot	2	100	8	8	Southern spearnose poacher	<1	10	<1	2
Longspine combfish	1	76	6	8	California scorpionfish	<1	10	<1	2
California tonguefish	1	81	6	7	California skate	<1	14	<1	1
Yellowchin sculpin	1	33	4	12	Kelp bass	<1	5	<1	3
English sole	1	81	4	5	Northern anchovy	<1	5	<1	3
Longfin sanddab	1	62	3	5	Spotted turbot	<1	14	<1	1
Kelp pipefish	1	52	3	5	Basketweave cusk-eel	<1	10	<1	1
Roughback sculpin	1	62	2	4	Giant kelpfish	<1	10	<1	1
Curlfin sole	<1	52	2	4	Sarcastic fringehead	<1	10	<1	1
Pacific pompano	<1	14	2	11	Bluebarred prickleback	<1	5	<1	1
Fantail sole	<1	57	1	2	Chilipepper	<1	5	<1	1
Vermilion rockfish	<1	33	1	3	Pacific chub mackerel	<1	5	<1	1
Plainfin midshipman	<1	43	1	2	Unidentified goby	<1	5	<1	1
Bay pipefish	<1	5	1	12	Lingcod	<1	5	<1	1
California halibut	<1	43	<1	1	Ocean whitefish	<1	5	<1	1
Calico rockfish	<1	24	<1	2	Pacific electric ray	<1	5	<1	1
Pygmy poacher	<1	29	<1	2	Spotfin sculpin	<1	5	<1	1

stations SD15 and SD21 during the spring, and at all stations during the summer. These large hauls reflect considerable numbers of speckled sanddabs at station SD15 and white croaker at station SD21 during the spring, as well as high numbers of Pacific sanddabs at station SD15, speckled sanddabs at stations SD16–SD21, and California lizardfish at stations SD18–SD21 during the summer. High biomass values recorded during 2013 typically corresponded to the large number of fish in individual hauls. However, the high biomass recorded at station SD18 in the spring was due to two large California halibut that together made up 14.0 kg of the 20.5 kg total weight for that haul.

Large population fluctuations of a few numerically dominant species have contributed to the high variation in fish community structure in the South Bay outfall region since 1995 (Figures 6.3, 6.4). Over the years, mean species richness and diversity have remained within narrow ranges (i.e., SR = 6–14 species per haul, H' = 0.4–1.7) despite considerable variability in abundance (i.e., 43–537 fishes per haul). Differences in abundance primarily track changes in speckled sanddab populations, since this species has been numerically dominant in the SBOO region since sampling began (see following section and City of San Diego 2000). Additionally, occasional spikes in abundance have been due to large hauls of other individual species such as California lizardfish, yellowchin sculpin, white croaker, roughback sculpin, and longspine combfish. Overall, none of the observed changes appear to be associated with wastewater discharge.

Multivariate Analyses of Fish Assemblages

An analysis of demersal fish assemblages sampled during the summer surveys from 1995 through 2013 showed significant differences by year, but not by nearfield, north farfield or south farfield station groups (Table 6.3). Pairwise comparisons showed that the 2013 assemblages differed from those present in all other years except 2011 (Appendix E.4). Species that contributed to

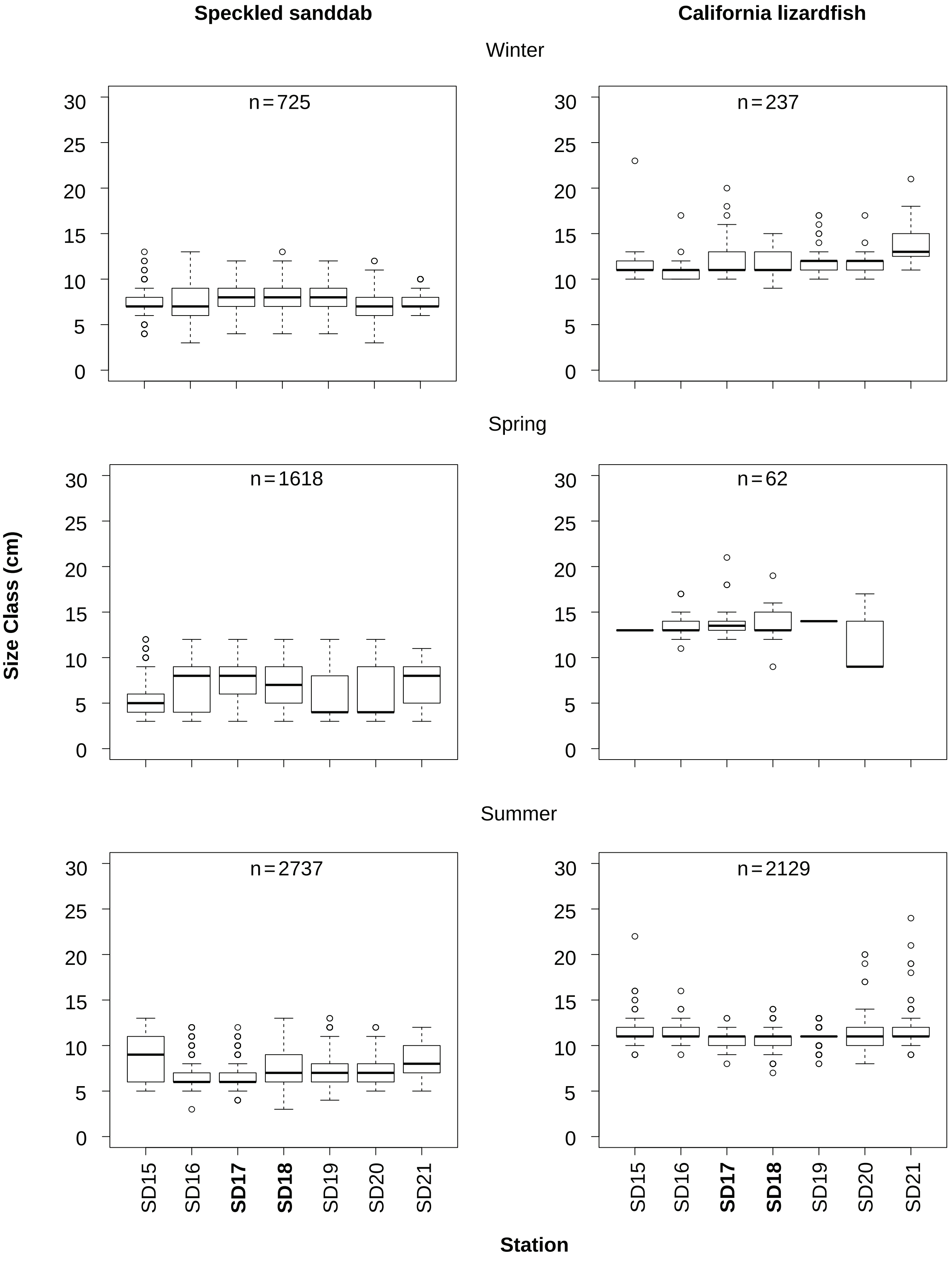

Figure 6.2

Summary of fish lengths by station and survey for each of the two most abundant species collected in the SBOO region during 2013. Data are median, upper and lower quartiles, 1.5 times the interquartile range (whiskers), and outliers (open circles). Stations SD17 and SD18 are considered nearfield (bold; see text).

Table 6.2

Summary of demersal fish community parameters for SBOO trawl stations sampled during 2013. Data are included for species richness, abundance, diversity (H'), and biomass (kg, wet weight). SD = standard deviation.

				Annual						Annual	
Station	**Win**	**Spr**	**Sum**	**Mean**	**SD**	**Station**	**Win**	**Spr**	**Sum**	**Mean**	**SD**
Species richness						*Abundance*					
SD15	9	10	9	9	1	SD15	147	437	442	342	169
SD16	8	11	13	11	3	SD16	187	215	476	293	159
SD17	11	12	14	12	2	SD17	184	210	525	306	190
SD18	12	17	11	13	3	SD18	114	342	842	433	372
SD19	9	13	12	11	2	SD19	208	379	1216	601	539
SD20	11	15	18	15	4	SD20	224	240	767	410	309
SD21	15	16	14	15	1	SD21	101	473	1229	601	575
Survey Mean	11	13	13			Survey Mean	166	328	785		
Survey SD	2	3	3			Survey SD	47	108	333		
Diversity						*Biomass*					
SD15	0.8	0.4	1.3	0.8	0.5	SD15	2.0	3.3	8.2	4.5	3.3
SD16	1.0	1.2	0.7	1.0	0.2	SD16	2.7	3.7	4.8	3.7	1.1
SD17	1.3	1.3	1.0	1.2	0.2	SD17	2.7	5.4	6.0	4.7	1.8
SD18	1.4	0.9	0.8	1.1	0.3	SD18	6.7	20.5	9.9	12.4	7.2
SD19	1.2	0.7	1.0	1.0	0.2	SD19	2.6	4.1	14.9	7.2	6.7
SD20	1.3	1.3	1.2	1.3	0.1	SD20	3.2	3.5	11.2	6.0	4.5
SD21	1.8	1.2	1.2	1.4	0.4	SD21	2.1	12.3	16.2	10.2	7.3
Survey Mean	1.3	1.0	1.0			Survey Mean	3.1	7.5	10.2		
Survey SD	0.3	0.4	0.2			Survey SD	1.6	6.5	4.3		

the uniqueness of individual surveys over the past 19 years included California halibut, California lizardfish, California scorpionfish, California tonguefish, English sole, hornyhead turbot, longfin sanddabs, longspine combfish, roughback sculpin, speckled sanddabs, spotted turbot, and yellowchin sculpin (Figure 6.5).

Classification (cluster) analysis discriminated between six main types of fish assemblages in the South Bay outfall region over the past 19 years (i.e., cluster groups A–F; Figure 6.6). The distribution of assemblages in 2013 was generally similar to the previous year, and there were no discernible patterns associated with proximity to the outfall. Instead, assemblages appear influenced by long-term climate-related changes in the SCB (e.g., El Niño/La Niña) or unique characteristics of a specific station location. For example, cluster groups A and C were distinguished by very low numbers of speckled sanddabs (≤40 fish/haul) that coincided with or followed generally warm water conditions such as the 1994/1995 and the 1997/1998 El Niño, while groups D–F had relatively high numbers of speckled sanddabs (≥117 fish/haul) that coincided with generally cold water conditions such as the 2007 and 2010 La Niña (see Chapter 2). In addition, station SD15 located south of the outfall off northern Baja California often grouped apart from the remaining stations, possibly due to habitat differences such as sandier sediments (see Chapter 4). The species composition and main descriptive characteristics of each cluster group are described below and summarized in Table 6.4.

Cluster group A comprised 11 hauls, including those from stations SD15–SD17 and SD20 sampled in 1997, station SD15 sampled in 1998, and stations SD15–SD20 sampled in 2001. Assemblages represented by this group averaged 7 species of fish and 36 individuals per haul, and had the lowest

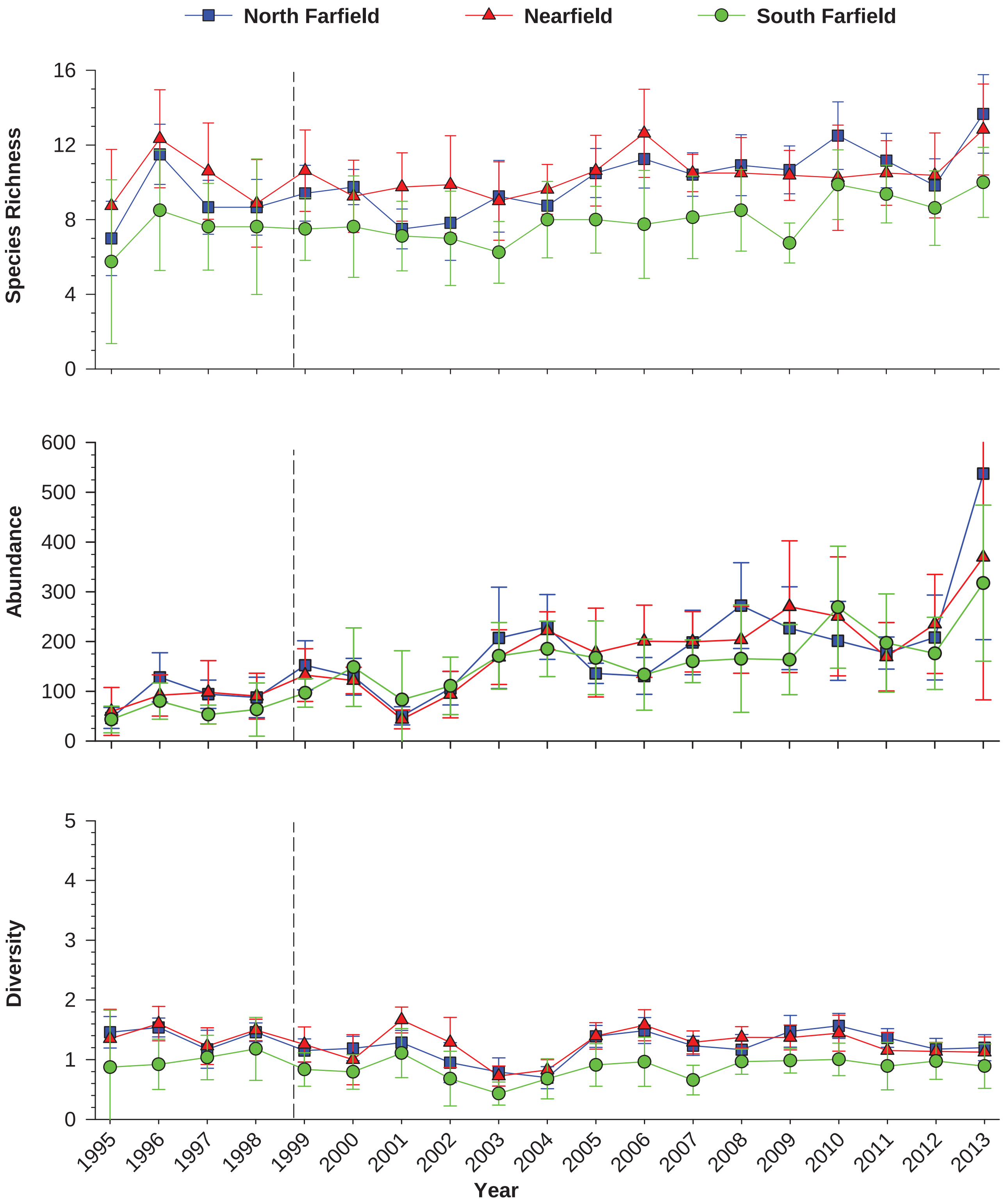

Figure 6.3

Species richness, abundance, and diversity of demersal fishes collected from SBOO trawl stations sampled from 1995 through 2013. Data are annual means with 95% confidence intervals for nearfield stations (n≤8), north farfield stations (n≤12), and south farfield stations (n≤8). Dashed lines indicate onset of wastewater discharge.

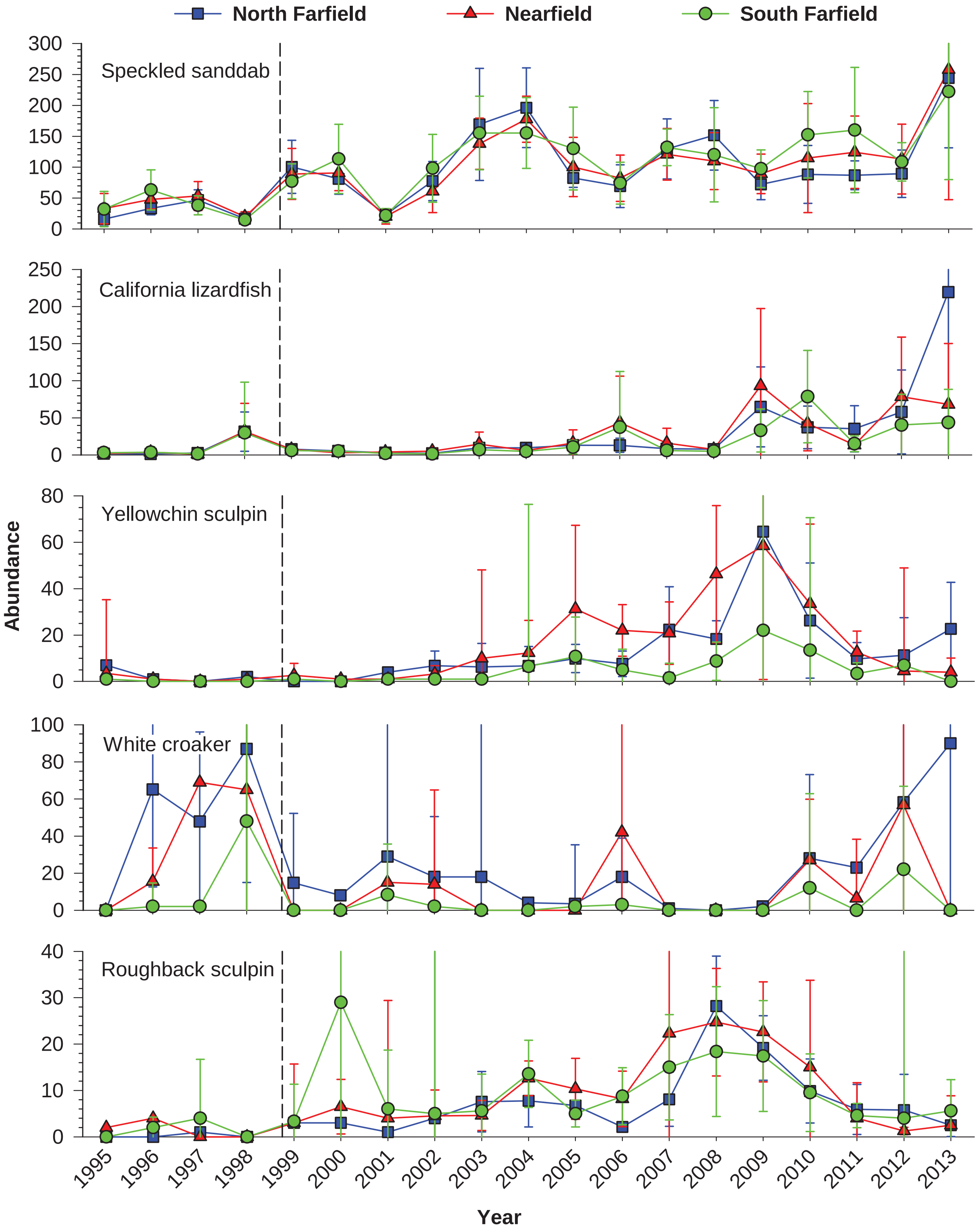

Figure 6.4
The ten most abundant fish species (presented in order) collected from SBOO trawl stations sampled from 1995 through 2013. Data are annual means with 95% confidence intervals for nearfield stations (n≤8), north farfield stations (n≤12), and south farfield stations (n≤8). Dashed lines indicate onset of wastewater discharge.

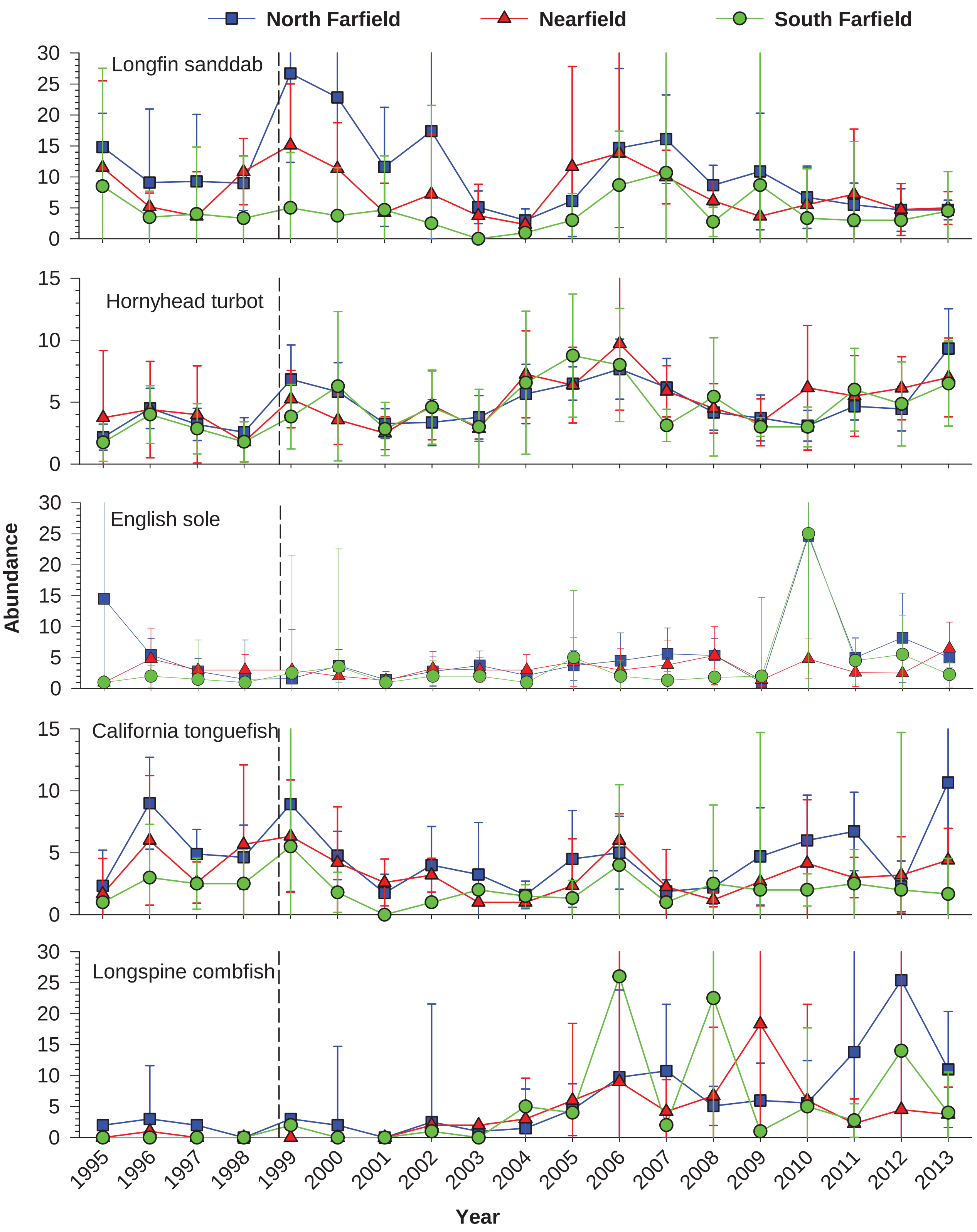

Figure 6.4 *continued*

numbers of speckled sanddabs (23/haul). Other characteristic species that contributed to ≥75% within-group similarity (see Methods) for group A included hornyhead turbot and spotted turbot.

Cluster group B represented a single trawl from station SD21 sampled in 2011. This assemblage had the highest species richness (15 species), the second highest abundance (243 individuals), the

Table 6.3

Results of 2-way crossed ANOSIM (with replicates) for demersal fish assemblages sampled around the SBOO from 1995 through 2013. Data were limited to summer surveys.

Global Test: Factor A (station groups)	
Tests for differences between station groups (across all years)	
Sample statistic (Global R):	0.205[a]
Significance level of sample statistic:	0.02%
Number of permutations:	9999
Number of permuted statistics greater than or equal to Global R:	1
Global Test: Factor B (years)	
Tests for differences between years (across all station groups)	
Sample statistic (Global R):	0.574[a]
Significance level of sample statistic:	0.01%
Number of permutations:	9999
Number of permuted statistics greater than or equal to Global R:	0

[a] Test is considered not significant when Global R < 0.25; if Global R is 0.25–0.749 and the significance level is < 5%, significance is assumed (Clarke and Gorley 2006).

highest number of longspine combfish (79 fish) and white croaker (22 fish), the second highest number of California lizardfish (75 fish), and the second lowest number of speckled sanddabs (26 fish) of any other cluster group.

Cluster group C comprised 22 hauls from one to six sites sampled from 1995 through 2000. This group included 94% of the trawls conducted at stations SD16–SD21 during 1995, 1996, and 1998; it never occurred at station SD15. The assemblages represented by group C averaged 10 species, 95 individuals, and 40 speckled sanddabs per haul, and had the highest numbers of longfin sanddab (22/haul). Other characteristic species for this group included California lizardfish, hornyhead turbot, and English sole.

Cluster group D comprised 34 hauls from one to six sites sampled every summer except during 1998, 2001, 2009, 2010 and 2013. This group included 63% of the trawls conducted at stations SD16–SD20 from 1999 through 2004, and 68% of the trawls conducted at station SD15 over the past 19 years; it never occurred at station SD21. Assemblages represented by group D averaged 7 species of fish and 132 individuals per haul. This group was characterized by 117 speckled sanddabs per haul and very low numbers of all other species.

Cluster group E was the largest group, representing assemblages from a total of 45 hauls that included 76% (n = 41) of the trawls conducted at stations SD16−SD21 from 2003 through 2011, as well as the trawl from station SD18 in 1995, the trawls from station SD21 in 2001 and 2002, and the trawl from station SD20 in 2012; this group never occurred at station SD15. Assemblages represented by group E averaged 10 species, 224 individuals, and 132 speckled sanddabs per haul. They also had the highest numbers of yellowchin sculpin (34/haul). Other characteristic species included California lizardfish and longfin sanddab.

Cluster group F was the only group to occur at all stations; it represented assemblages from a total of 20 hauls, including three trawls from stations SD16−SD18 in 2006, the trawl from station SD15 in 2009, and 76% (n = 16) of the trawls conducted during 2010, 2012, and 2013. These assemblages had the second highest species richness (11 species/haul), the highest abundance (515 individuals/haul), and the highest abundances of speckled sanddab (250/haul) and California lizardfish (201/haul) of any cluster

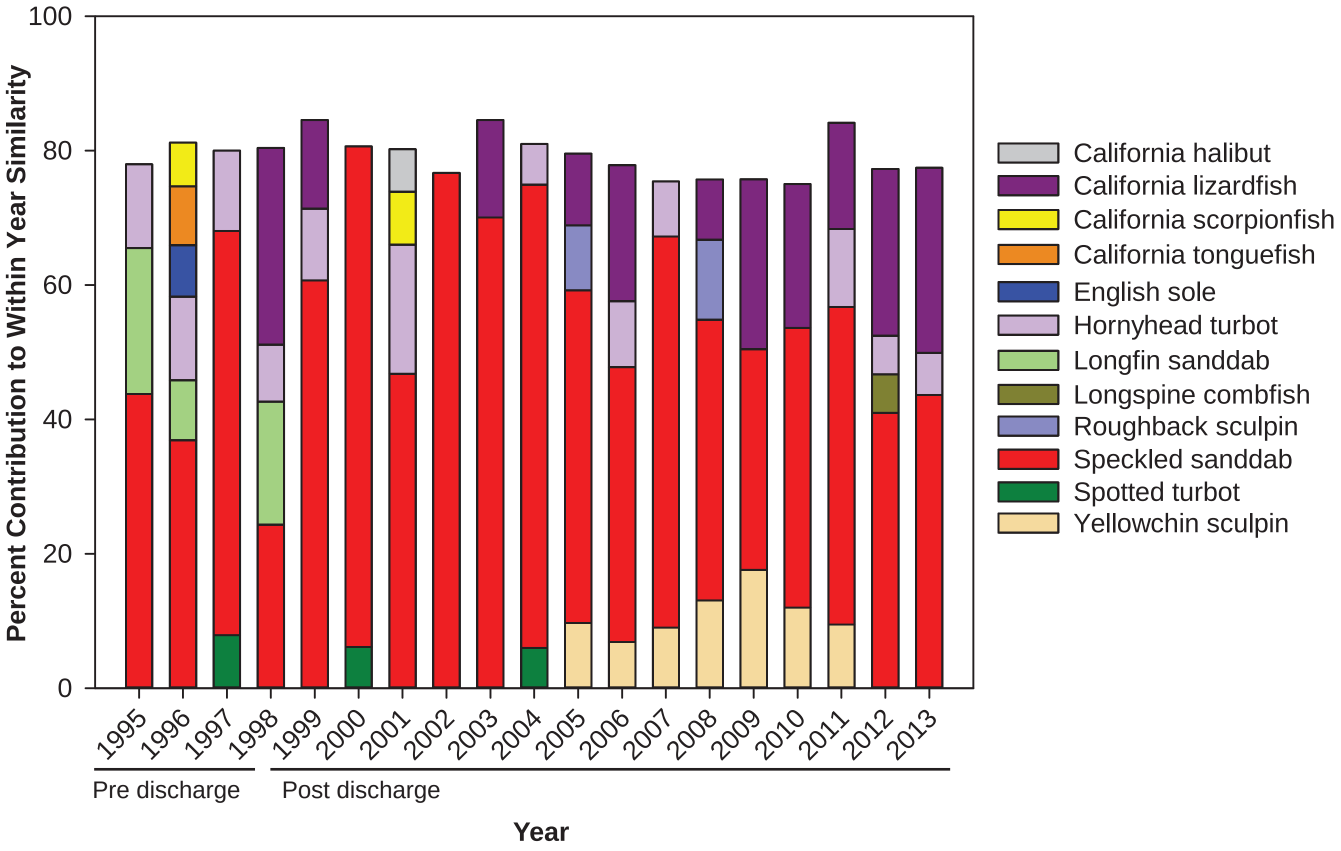

Figure 6.5

Characteristic demersal fish species collected from SBOO trawl stations sampled during summer surveys from 1995 through 2013 that contribute to ≥75% of within group similarity for each year group (Factor B, see Table 6.3) according to SIMPER analysis.

group. This group was also characterized by hornyhead turbot.

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the SBOO region during 2013. There were no incidences of fin rot, skin lesions, or tumors among fishes collected during the year. However, one instance of skeletal deformation was recorded for a California tonguefish, and four instances of ambicoloration were recorded (two each, English sole and fantail sole). Evidence of parasitism was also very low (0.2%) for trawl-caught fishes in the region. The copepod *Phrixocephalus cincinnatus* infected < 1.0% of the speckled sanddabs (16 individuals) collected during the year; this eye parasite was found on fish from all stations. The cymothoid isopod *Elthusa vulgaris* (a gill parasite), was noted on a single curlfin sole. In addition, 64 *E. vulgaris* were identified as part of invertebrate trawl catches during the year (see Appendix E.5). Since *E. vulgaris* often become detached from their hosts during retrieval and sorting of the trawl catch, it is unknown which fishes were actually parasitized by these individuals. However, *E. vulgaris* is known to be especially common on sanddabs and California lizardfish in southern California waters, where it may reach infestation rates of 3% and 80%, respectively (see Brusca 1978, 1981). Two leeches were also collected as part of invertebrate trawl catches during 2013; although these leeches are also known to commonly feed on fishes, no individuals were found attached to their hosts.

Megabenthic Invertebrates

Community Parameters

A total of 2304 megabenthic invertebrates (~110/haul) representing 63 taxa from 5 phyla were collected in 2013 (Table 6.5, Appendices E.5, E.6).

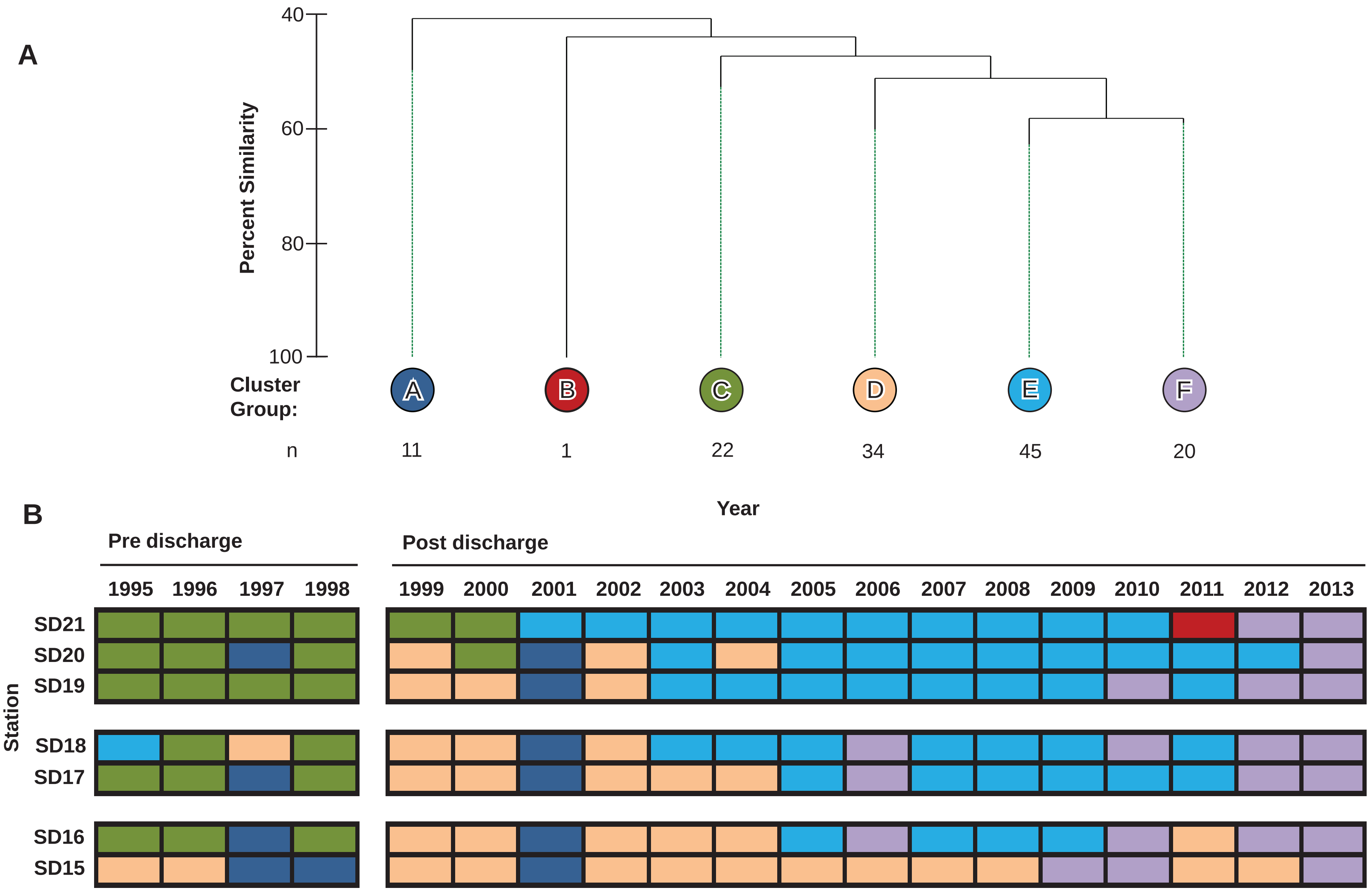

Figure 6.6
Results of cluster analysis of demersal fish assemblages from SBOO trawl stations from 1995 through 2013. Data are limited to summer surveys only and presented as (A) a dendrogram of major cluster groups and (B) a matrix showing distribution of cluster groups over time. Major ecologically relevant SIMPROF supported clades with <59% similarity were retained; n = number of hauls.

Table 6.4

Description of demersal fish cluster groups A–F defined in Figure 6.6. Species included represent the five most abundant taxa recorded for each cluster group. Bold values indicate species considered most characteristic of that group (i.e., contributing to ≥ 75% within-group similarity) according to SIMPER analysis.

	Cluster Groups					
	A	B[a]	C	D	E	F
Number of Hauls	11	1	22	34	45	20
Mean Species Richness	7	15	10	7	10	11
Mean Abundance	36	243	95	132	224	515
Species	**Mean Abundance**					
Speckled sanddab	**23**	26	**40**	**117**	**132**	**250**
Hornyhead turbot	**3**	3	**4**	4	4	**6**
California lizardfish	2	75	**10**	3	**21**	**201**
Spotted turbot	**2**		1	2	1	<1
California scorpionfish	2	2	1	1	1	<1
California tonguefish	1	6	4	1	2	5
Longfin sanddab	<1	8	**22**	<1	**11**	4
English sole	<1	6	**4**	1	3	4
Longspine combfish		79	<1	<1	1	11
White croaker		22	4	<1	<1	
Yellowchin sculpin		5	1	<1	**34**	13
Roughback sculpin		5	<1	1	10	6
Pacific sanddab			1	<1	1	9

[a] SIMPER analysis only conducted on cluster groups that contained more than one trawl.

Overall, the average catch per haul for 2013 was 31% larger than in 2012, and continued to be dominated by echinoderms and crustaceans. The sea star *Astropecten californicus* was the most abundant and most frequently occurring trawl-caught invertebrate, averaging 62 individuals per haul (=57% of total abundance) and occurring in 95% of the trawls. The shrimp *Crangon nigromaculata* accounted for 12% of the total invertebrate abundance (14/haul) and occurred in 52% of the trawls. No other species contributed to more than 4% of the total catch. Other species collected during the year in at least 50% of the trawls but in low numbers (i.e., ≤4/haul) included the crabs *Metacarcinus gracilis* and *Pyromaia tuberculata*, the shrimp *Sicyonia ingentis*, the cymothoid isopod *Elthusa vulgaris*, the seastar *Pisaster brevispinus*, and the gastropod *Kelletia kelletii*.

Megabenthic invertebrate community structure varied among stations and between surveys during the year (Table 6.6). For each haul, species richness ranged from 7 to 26 species, diversity (H') ranged from 0.4 to 2.6, total abundance ranged from 21 to 497 individuals, and biomass ranged from 0.3 to 4.7 kg. During 2013, species richness values ≥16 were recorded at nearfield stations SD17 and SD18, while values ≤10 occurred at farfield stations SD15, SD19, and SD21. In addition, diversity values ≥2.2 were recorded at stations SD17, SD18, and SD20, while values ≤1.0 occurred at farfield stations SD15, SD16, and SD21. Patterns of total invertebrate abundance mirrored variation in populations of *Astropecten californicus* or *Crangon nigromaculata* because of their prevalence at select stations at different times of the year (Appendix E.6). For example, station SD15 had the highest total abundances during each of the three surveys due to large hauls of *A. californicus* (e.g., 108–443/haul), while *C. nigromaculata* was dominant at station SD21 in the spring (i.e., 197 individuals).

As described above for demersal fishes, large population fluctuations of a few numerically

Table 6.5

Megabenthic invertebrates collected from 21 trawls conducted in the SBOO region during 2013. PA = percent abundance; FO = frequency of occurrence; MAH = mean abundance per haul; MAO = mean abundance per occurrence.

Taxa	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Astropecten californicus	57	95	62	65	*Loxorhynchus crispatus*	<1	10	<1	2
Crangon nigromaculata	12	52	14	26	*Calliostoma annulatum*	<1	5	<1	3
Latulambrus occidentalis	4	48	4	9	*Dendronotus venustus*	<1	5	<1	3
Metacarcinus gracilis	3	81	4	4	*Ericerodes hemphillii*	<1	5	<1	3
Elthusa vulgaris	3	62	3	5	*Flabellina iodinea*	<1	14	<1	1
Dendraster terminalis	2	24	2	8	*Luidia foliolata*	<1	14	<1	1
Kelletia kelletii	2	52	2	4	*Pteropurpura festiva*	<1	10	<1	2
Pyromaia tuberculata	2	62	2	3	*Acanthoptilum* sp	<1	10	<1	1
Acanthodoris brunnea	1	33	1	4	*Aglaja ocelligera*	<1	10	<1	1
Caesia perpinguis	1	19	1	6	*Aphrodita refulgida*	<1	10	<1	1
Octopus rubescens	1	38	1	3	*Calliostoma tricolor*	<1	10	<1	1
Pisaster brevispinus	1	57	1	2	*Euspira lewisii*	<1	5	<1	2
Sicyonia ingentis	1	52	1	2	*Heptacarpus palpator*	<1	5	<1	2
Crangon alba	1	33	1	3	*Heptacarpus stimpsoni*	<1	10	<1	1
Sicyonia penicillata	1	48	1	2	Hirudinea (unidentified)	<1	10	<1	1
Dendronotus iris	1	29	1	2	*Lepidozona scrobiculata*	<1	5	<1	2
Lytechinus pictus	1	24	1	3	*Megastraea undosa*	<1	10	<1	1
Ophiothrix spiculata	1	33	1	2	*Paguristes ulreyi*	<1	10	<1	1
Pagurus spilocarpus	<1	29	1	2	*Podochela lobifrons*	<1	10	<1	1
Philine auriformis	<1	19	1	3	*Randallia ornata*	<1	10	<1	1
Hemisquilla californiensis	<1	38	<1	1	*Amphiodia psara*	<1	5	<1	1
Ophiura luetkenii	<1	19	<1	2	*Euspira draconis*	<1	5	<1	1
Crassispira semiinflata	<1	33	<1	1	*Leptopecten latiauratus*	<1	5	<1	1
Armina californica	<1	19	<1	2	Majoidea (unidentified)	<1	5	<1	1
Luidia armata	<1	19	<1	2	*Megastraea turbanica*	<1	5	<1	1
Loxorhynchus grandis	<1	19	<1	2	*Octopus bimaculatus*	<1	5	<1	1
Megasurcula carpenteriana	<1	24	<1	1	*Pandalus danae*	<1	5	<1	1
Pagurus armatus	<1	19	<1	2	*Pleurobranchaea californica*	<1	5	<1	1
Platymera gaudichaudii	<1	24	<1	1	*Pugettia producta*	<1	5	<1	1
Stylatula elongata	<1	19	<1	2	*Romaleon antennarium*	<1	5	<1	1
Acanthodoris rhodoceras	<1	14	<1	2	*Tritonia tetraquetra*	<1	5	<1	1
Crossata ventricosa	<1	19	<1	1					

dominant species have contributed to the high variation in trawl-caught invertebrate community structure in the South Bay outfall region since 1995 (Figures 6.7, 6.8). Over the years, mean diversity and species richness have remained within narrow ranges (i.e., H' = 0.8–2.2, SR = 5–20 species/haul), despite considerable variation in abundance (i.e., 12–293 individuals/haul). Differences in overall invertebrate abundance primarily track changes in populations of the sea star *Astropecten californicus*, the urchin *Lytechinus pictus* and the sand dollar *Dendraster terminalis*. These species have all been prevalent in the SBOO region at different times. For example, fluctuations of *A. californicus* and *D. terminalis* populations have contributed greatly to changes in abundance at the south farfield stations, while sporadic occurrences of large numbers of *L. pictus* have influenced total

Table 6.6

Summary of megabenthic invertebrate community parameters for SBOO stations sampled during 2013. Data are included for species richness, abundance, and diversity (H') and biomass (kg, wet weight). SD = standard deviation.

				Annual						Annual	
Station	Win	Spr	Sum	Mean	SD	Station	Win	Spr	Sum	Mean	SD
Species richness						*Abundance*					
SD15	8	10	11	10	2	SD15	122	308	497	309	188
SD16	13	11	12	12	1	SD16	52	45	124	74	44
SD17	16	18	20	18	2	SD17	61	68	131	87	39
SD18	20	20	26	22	3	SD18	44	83	99	75	28
SD19	8	10	16	11	4	SD19	36	70	62	56	18
SD20	14	11	13	13	2	SD20	47	71	39	52	17
SD21	7	12	14	11	4	SD21	21	239	85	115	112
Survey Mean	12	13	16			Survey Mean	55	126	148		
Survey SD	5	4	5			Survey SD	32	103	157		
Diversity						*Biomass*					
SD15	0.6	0.4	0.5	0.5	0.1	SD15	0.4	2.7	1.9	1.7	1.2
SD16	1.7	1.2	0.9	1.3	0.4	SD16	3.1	0.3	1.0	1.5	1.5
SD17	2.1	2.2	1.9	2.1	0.2	SD17	2.0	0.8	3.1	2.0	1.2
SD18	2.6	2.1	2.6	2.4	0.3	SD18	1.2	1.4	1.7	1.4	0.3
SD19	1.6	1.3	2.0	1.6	0.3	SD19	0.3	0.9	0.9	0.7	0.3
SD20	2.2	1.7	2.2	2.0	0.3	SD20	1.1	0.3	4.7	2.0	2.3
SD21	1.6	0.8	2.1	1.5	0.7	SD21	0.4	1.1	1.1	0.9	0.4
Survey Mean	1.8	1.4	1.7			Survey Mean	1.2	1.1	2.1		
Survey SD	0.7	0.7	0.8			Survey SD	1.0	0.8	1.4		

abundance at south farfield and nearfield stations. Overall, none of the observed changes appear to be associated with wastewater discharge.

Multivariate Analysis of Invertebrate Assemblages

An analysis of the trawl-caught invertebrate assemblages sampled during the summer surveys from 1995 through 2013 showed significant differences by year, but not by nearfield, north farfield, or south farfield station groups (Table 6.7). As with the fish, pairwise comparisons showed that the 2013 invertebrate assemblages differed from those present in all other years except for 2011 (Appendix E.7). Species that contributed to the uniqueness of individual surveys over the past 19 years included the sea stars *Astropecten californicus* and *Pisaster brevispinus*, the urchin *Lytechinus pictus*, the crabs, *Latulambrus occidentalis* (formerly *Heterocrypta occidentalis*), *Loxorhynchus crispatus*, *Loxorhynchus grandis*, *Metacarcinus gracilis*, *Platymera gaudichaudii*, and *Pyromaia tuberculata*, the shrimp *Crangon nigromaculata*, the cymothoid isopod *Elthusa vulgaris*, the gastropods *Crassispira semiinflata* and *Kelletia kelletii*, the sea slugs *Acanthodoris brunnea*, *Dentronotus iris*, *Flabellina iodinea*, and *Pleurobranchaea californica*, the cephalopod *Octopus rubescens*, and leeches (Hirudinea) (Figure 6.9).

Classification (cluster) analysis discriminated between ten main types of invertebrate assemblages in the outfall region over the past 19 years (i.e., cluster groups A–J; Figure 6.10). These included eight small groups representative of one to seven hauls each (groups A–H), and two larger groups representing ~84% of all trawls (groups I and J). The distribution of assemblages in 2013 was generally similar to those observed since 1995 and there continued to be no discernible patterns associated with proximity to the outfall. Instead,

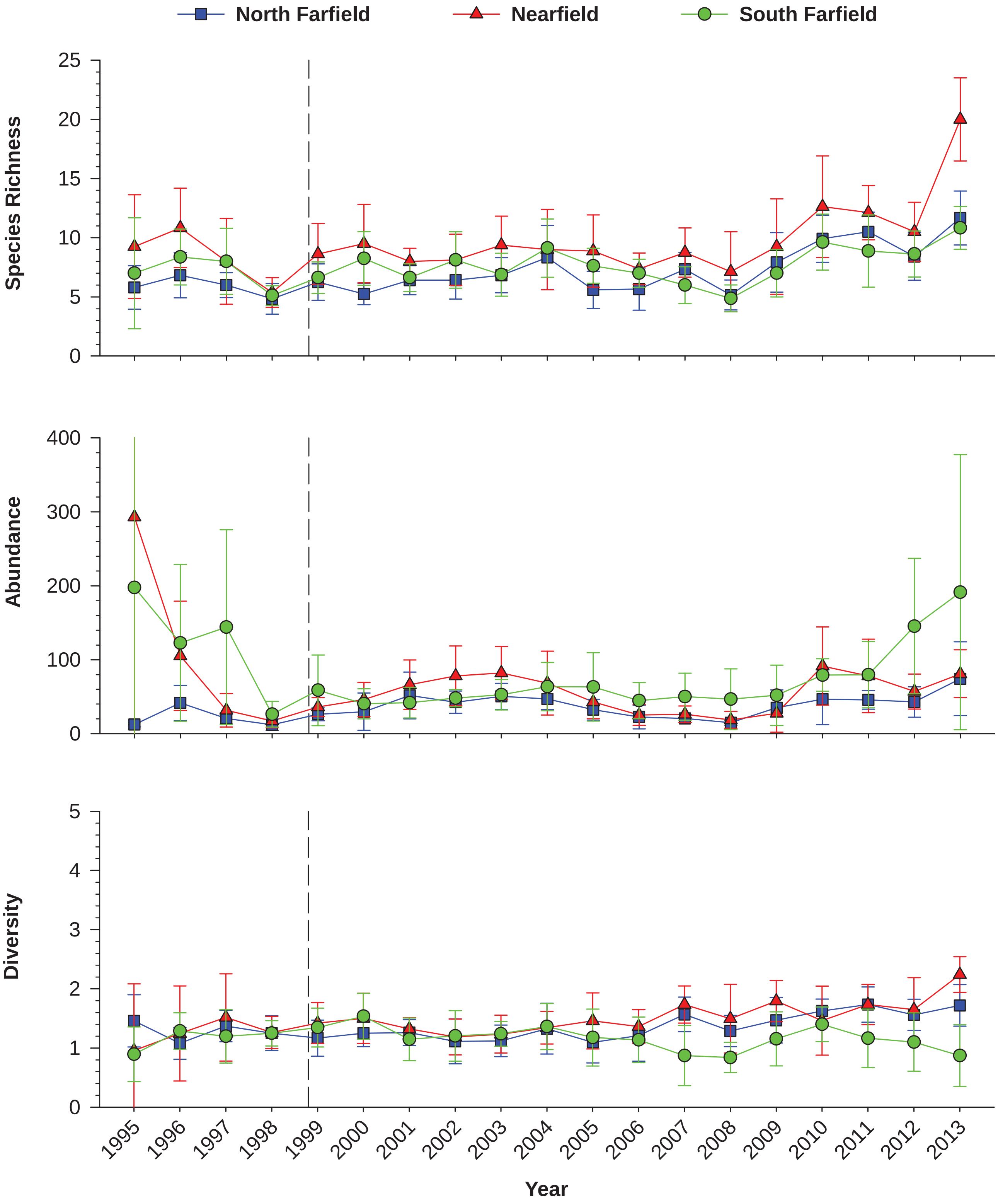

Figure 6.7

Species richness, abundance, and diversity of megabenthic invertebrates collected from SBOO trawl stations sampled from 1995 through 2013. Data are annual means with 95% confidence intervals for nearfield stations (n ≤ 8), north farfield stations (n ≤ 12), and south farfield stations (n ≤ 8). Dashed lines indicate onset of wastewater discharge.

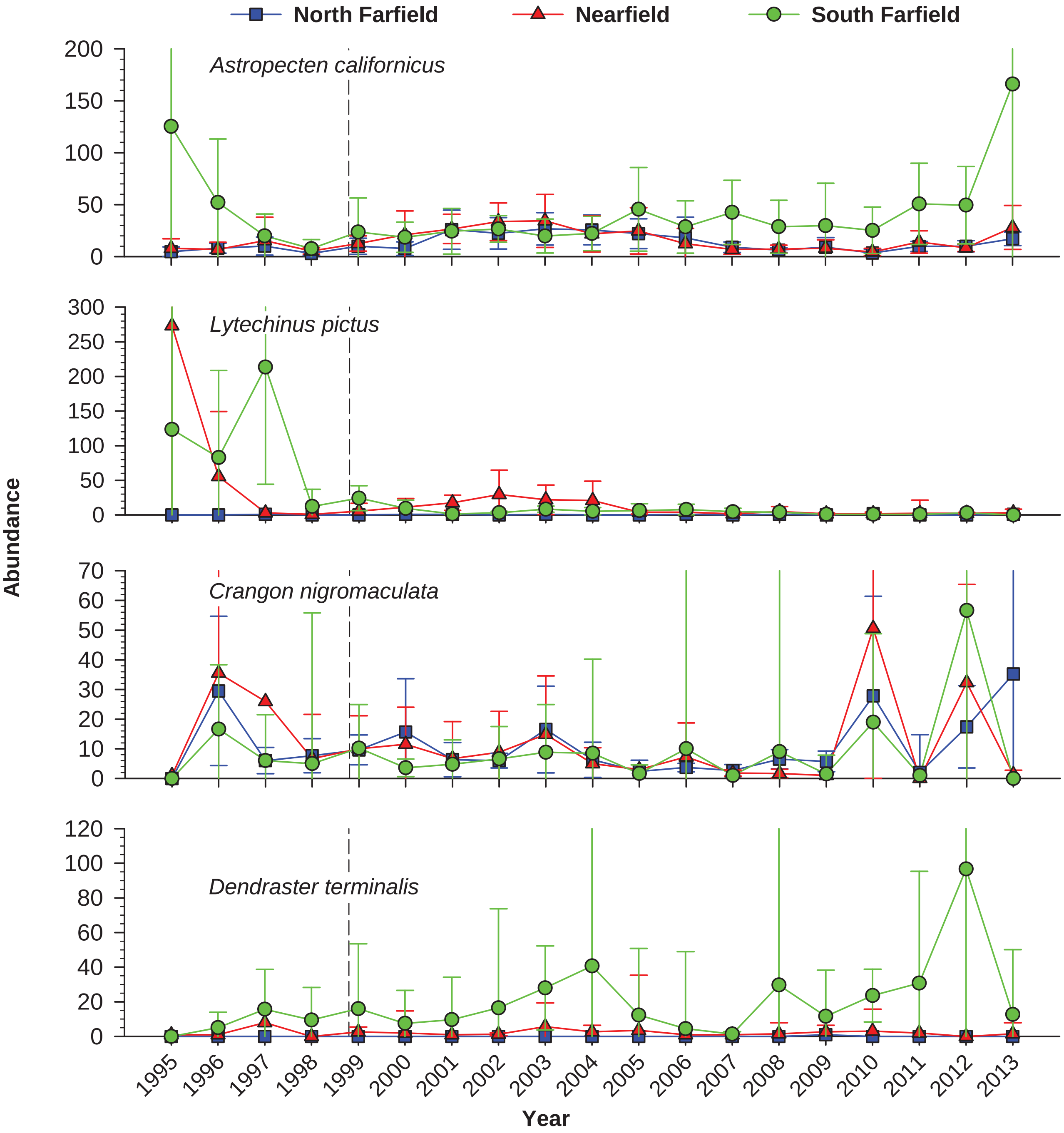

Figure 6.8

The seven most abundant megabenthic invertebrate species (presented in order) collected from SBOO trawl stations sampled from 1995 through 2013. Data are annual means with 95% confidence intervals for nearfield stations (n≤8), north farfield stations (n≤12), and south farfield stations (n≤8). Dashed lines indicate onset of wastewater discharge.

assemblages appear influenced by the distribution of the more abundant species or the unique characteristics of a specific station location. For example, station SD21 located the farthest north of the outfall off Coronado Beach often grouped apart from the remaining stations. The species composition and main descriptive characteristics of each cluster group are described below and summarized in Table 6.8.

Cluster group A represented a single trawl from station SD15 sampled in 2009. This assemblage contained 8 species, 84 individuals, the highest abundance of the brittle star *Ophiura*

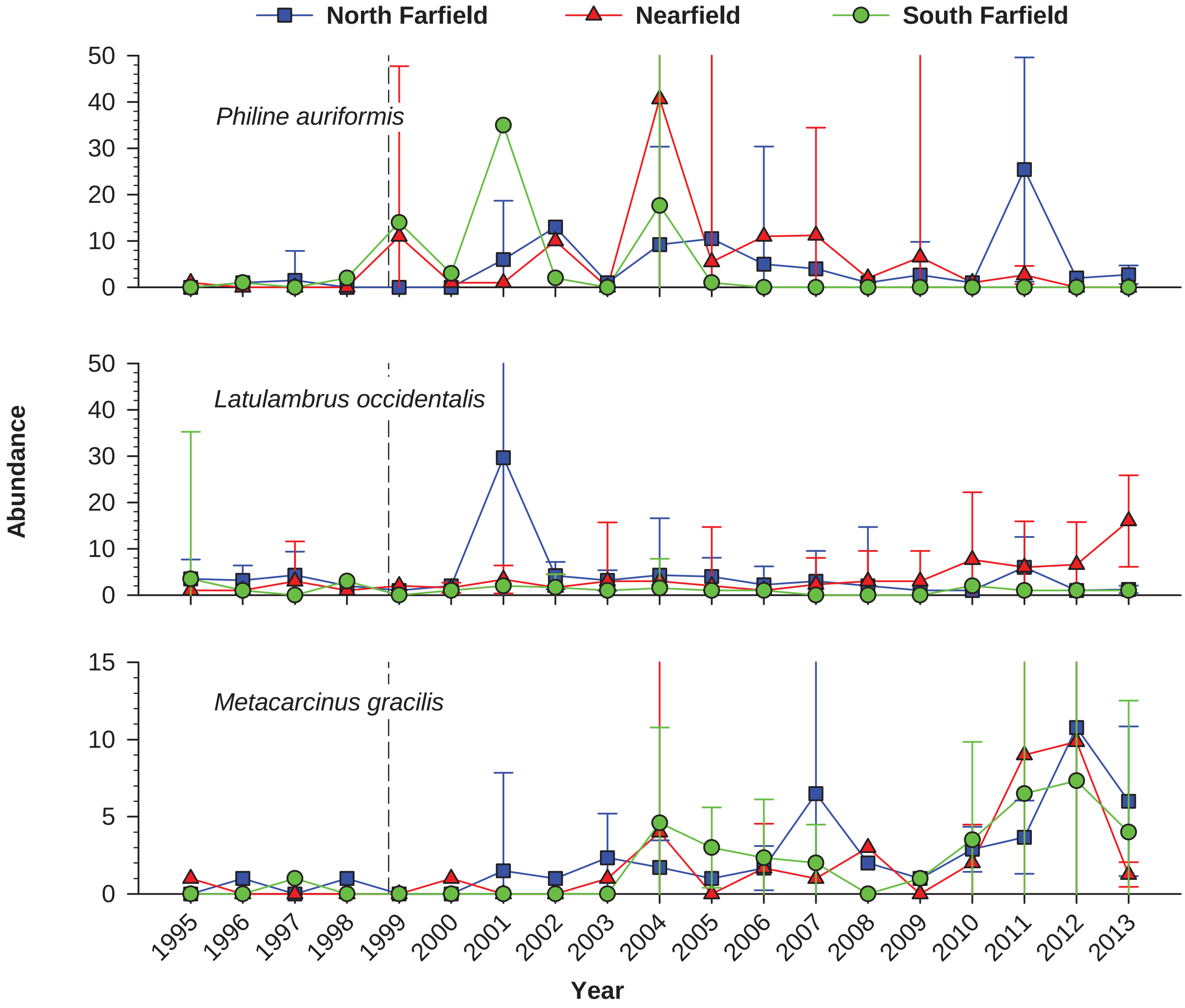

Figure 6.8 *continued*

luetkenii (72 individuals), ≤3 individuals of the brittle star *Ophiothrix spiculata*, the sand dollar *Dendraster terminalis*, the shrimp *Crangon alba*, the crab *Pyromaia tuberculata*, the hermit crab *Pagurus spilocarpus*, and the cephalopod *Octopus rubescens*, and was the only cluster to contain the gastropod *Megastraea turbanica.*

Cluster group B comprised four hauls from stations SD17, SD18, SD20, and SD21 sampled in 2000. Assemblages represented by this group averaged 8 species and 23 individuals per haul, and had higher abundances of the crab *Loxorhynchus grandis* (3/haul) than any other cluster group. Other characteristic species that contributed to ≥75% within-group similarity (see Methods) included the gastropod *Caesia perpinguis* and unidentified leeches.

Cluster group C represented a single trawl from station SD19 sampled in 1997. This assemblage contained 6 species and 10 individuals, and included ≤4 of each of the following: the sea stars *Astropecten ornatissimus*, *Pisaster brevispinus* and *Luidia armata*, the sea slug *Flabellina iodinea*, the shrimp *Heptacarpus stimpsoni*, and the crab *Latulambrus occidentalis.*

Cluster group D represented a single trawl from station SD17 sampled in 1995. This assemblage had the highest species richness (12 species), the highest abundance (975 individuals) and the highest number of the sea urchin *Lytechinus pictus* (951 urchins) of any other cluster group.

Cluster group E comprised five hauls, including those from stations SD17, SD18, and SD20 sampled

Table 6.7

Results of 2-way crossed ANOSIM (with replicates) for megabenthic invertebrates assemblages sampled around the SBOO from 1995 through 2013. Data were limited to summer surveys.

Global Test: Factor A (station groups)	
Tests for differences between station groups (across all years)	
Sample statistic (Global R):	0.218[a]
Significance level of sample statistic:	0.05%
Number of permutations:	9999
Number of permuted statistics greater than or equal to Global R:	4
Global Test: Factor B (years)	
Tests for differences between years (across all station groups)	
Sample statistic (Global R):	0.266[a]
Significance level of sample statistic:	0.01%
Number of permutations:	9999
Number of permuted statistics greater than or equal to Global R:	0

[a] Test is considered not significant when Global R < 0.25; if Global R is 0.25–0.749 and the significance level is < 5%, significance is assumed (Clarke and Gorley 2006).

in 2009 and those from stations SD17 and SD21 sampled in 2012. Assemblages represented by this group averaged 8 species and 14 individuals per haul, and had the highest abundance of the opisthobranch *Acanthodoris brunnea* (3/haul) of any cluster group. In addition to *A. brunnea*, characteristic species included the sea star *Astropecten californicus*, the cymothoid isopod *Elthusa vulgaris*, the gastropod *Kelletia kelletii*, and the cephalopod *Octopus rubescens*.

Cluster group F represented a single trawl from station SD19 sampled in 1998. This assemblage had the lowest species richness (4 species) and abundance (4 individuals), and included one of each of the following: the sea stars *Astropecten californicus* and *Pisaster brevispinus*, the gastropod *Crossata ventricosa*, and the cephalopod *Doryteuthis opalescens*.

Cluster group G represented a single trawl from station SD15 sampled in 2013. This assemblage had the second highest species richness (11 species) and abundance (497 individuals). Group G also had the highest abundances of the sea star *Astropecten californicus* (443), the sand dollar *Dendraster terminalis* (30), *Elthusa vulgaris* (8), the shrimp *Crangon alba* (4), the sea pen *Stylatula elongata* (3), and the gastropod *Dendronotus venustus* (3) of any cluster group.

Cluster group H comprised seven hauls, including those from station SD21 sampled in 1995, 2004, 2007, 2008, and 2011 and those from station SD16 sampled in 1997 and 2009. The assemblages represented by group H averaged 10 species and 25 individuals per haul. Characteristic species of this group included the brittle star *Ophiothrix spiculata*, the crab *Pyromaia tuberculata*, and the sea stars *Astropecten californicus* and *Pisaster brevispinus*.

Cluster group I was the second largest cluster group, representing assemblages from 21 hauls that included: station SD16 sampled in 1996; station SD17 sampled from 2005−2008, 2010, and 2011; station SD18 sampled in 2007, 2010, and 2011; station SD19 sampled from 2009−2011; and station SD21 sampled eight times between 1996 and 2010. These assemblages averaged 10 species and 32 individuals per haul. Characteristic species of this group included the crabs *Latulambrus occidentalis* and *Pyromaia tuberculata*, the shrimp *Crangon nigromaculata*, the sea stars *Astropecten californicus* and *Pisaster brevispinus*, and the gastropod *Kelletia kelletii*.

Cluster group J was the largest cluster group, representing assemblages from 91 hauls (~68% of all trawls collected). This group occurred at every station and in all but one year throughout the course

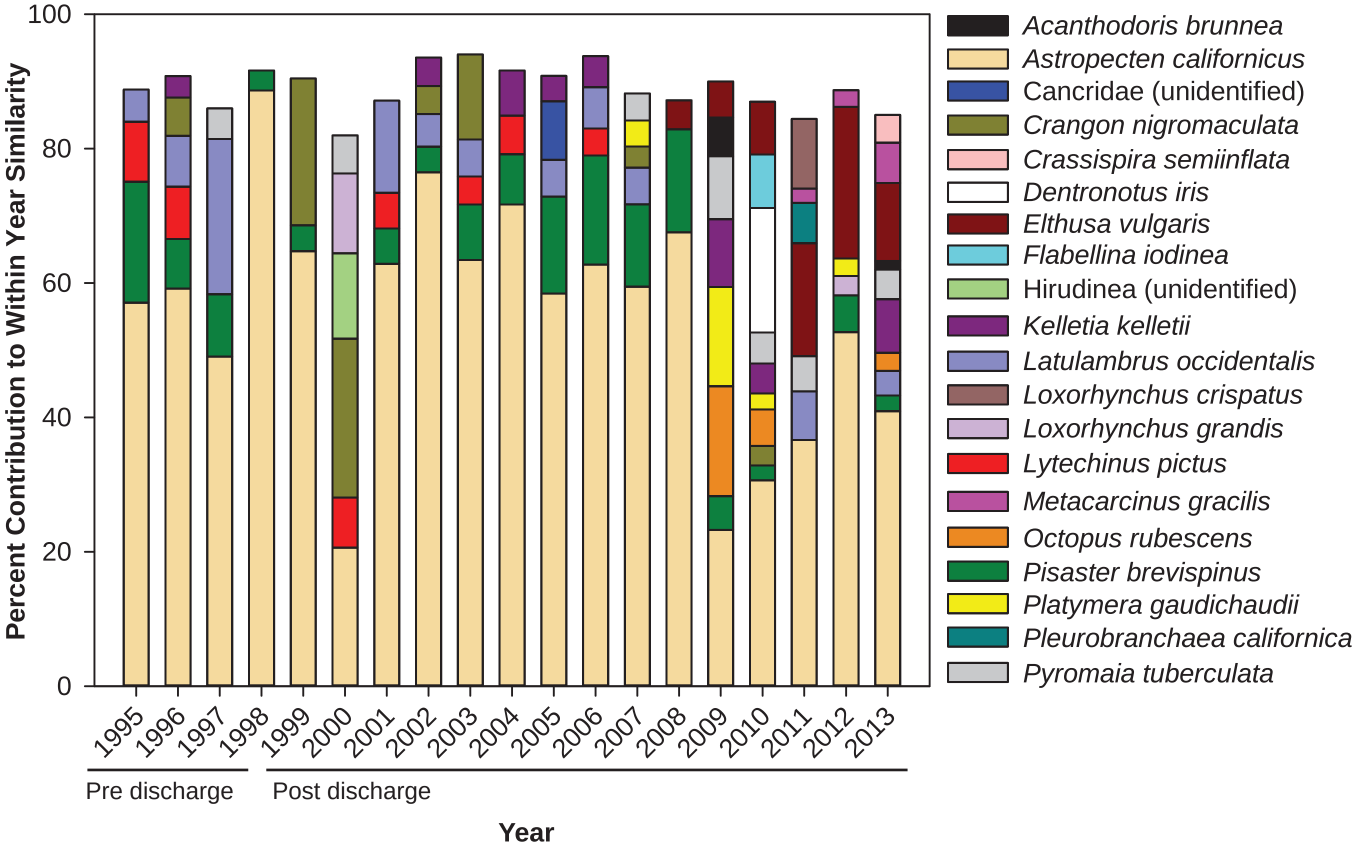

Figure 6.9

Characteristic megabenthic invertebrate species collected from SBOO trawl stations sampled during summer surveys from 1995 through 2013 that contribute to ≥75% of within group similarity for each year group (Factor B, see Table 6.7) according to SIMPER analysis.

of monitoring, and may represent "background" conditions in the SBOO region during the summer. Group J averaged 7 species and 58 individuals per haul, and had the second highest abundance of the sea star *Astropecten californicus* (33). The sea star *Pisaster brevispinus* was also characteristic of this group.

SUMMARY

Speckled sanddabs dominated fish assemblages surrounding the SBOO in 2013 as they have since monitoring began in 1995. This species occurred in all trawls and accounted for 57% of the total catch. California lizardfish were also prevalent during 2013, as they have been in three of the past four years; this species occurred in 95% of trawls and accounted for 27% of the total catch. Other commonly captured, but less abundant species, included hornyhead turbot, longspine combfish, California tonguefish, English sole, longfin sanddab, kelp pipefish, roughback sculpin, curlfin sole, and fantail sole. Almost all fishes collected were <30 cm in length. Although the composition and structure of the fish assemblages varied among stations and surveys in 2013 as in previous years, these differences appear to be due to natural fluctuations of common species.

Assemblages of trawl-caught invertebrates in 2013 were dominated by the sea star *Astropecten californicus* and the shrimp *Crangon nigromaculata* at different times of the year. These two species occurred in 95% and 52% of trawls, respectively, and accounted for 57% and 13% of the total invertebrate abundance. Other frequently collected megabenthic invertebrates included the crabs *Metacarcinus gracilis* and *Pyromaia tuberculata*, the shrimp *Sicyonia ingentis*, the

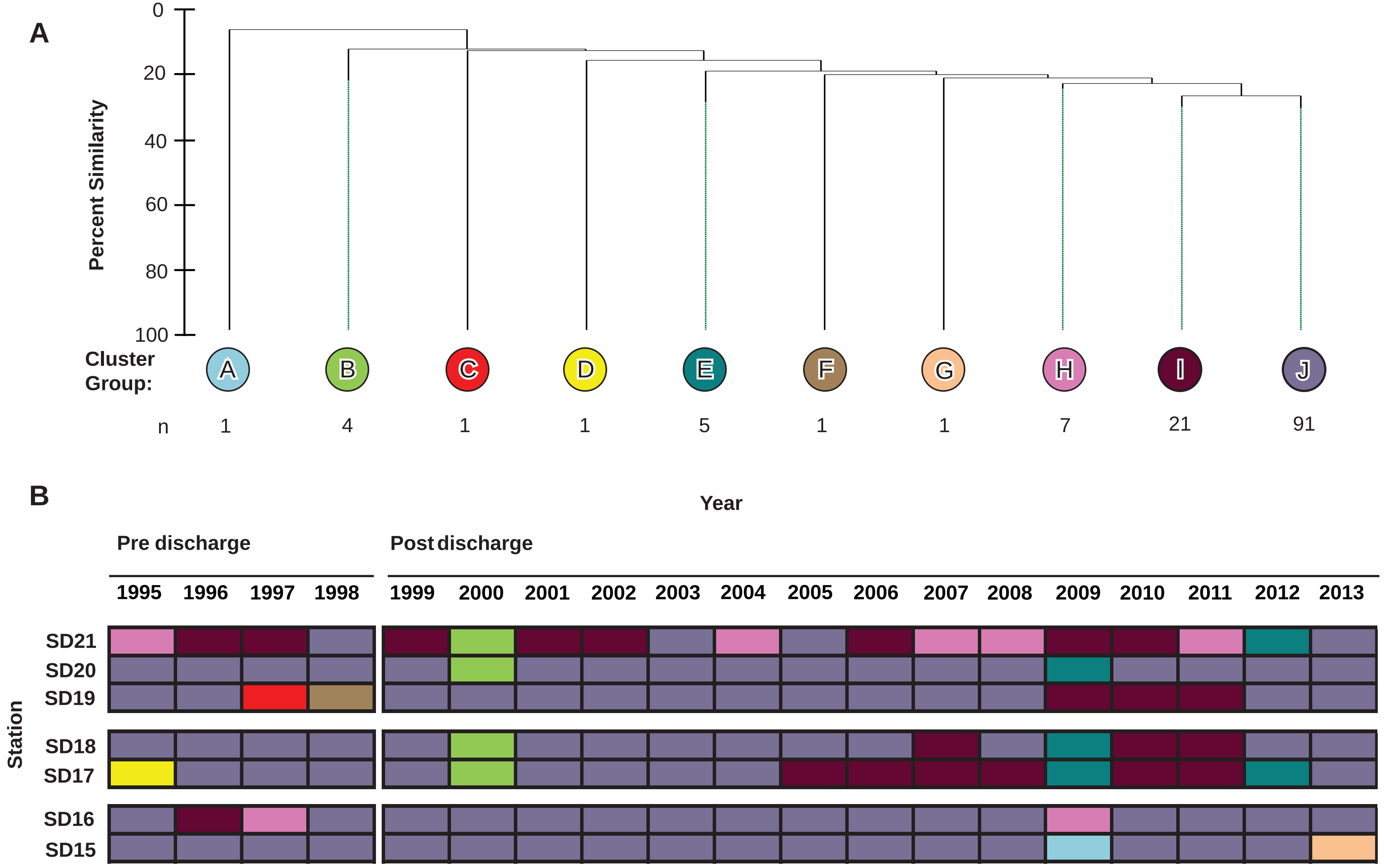

Figure 6.10
Results of cluster analysis of megabenthic invertebrate assemblages from SBOO trawl stations from 1995 through 2013. Data are limited to summer surveys only and are presented as (A) a dendrogram of major cluster groups and (B) a matrix showing distribution of cluster groups over time. Major ecologically relevant SIMPROF supported clades with <31% similarity were retained; n = number of hauls.

Table 6.8

Description of megabenthic invertebrate cluster groups A–J defined in Figure 6.10. Species included represent the five most abundant taxa recorded for each cluster group. Bold values indicate species considered most characteristic of that group (i.e., contributing to ≥ 75% within-group similarity) according to SIMPER analysis.

	Cluster Group									
	A[a]	B	C[a]	D[a]	E	F[a]	G[a]	H	I	J
Number of Hauls	1	4	1	1	5	1	1	7	21	91
Mean Species Richness	8	8	6	12	8	4	11	10	10	7
Mean Abundance	84	23	10	975	14	4	497	25	32	58
Taxa	**Mean abundance**									
Ophiura luetkenii	72							<1	2	<1
Ophiothrix spiculata	3			4			1	**4**	<1	<1
Dendraster terminalis	3						30			1
Crangon alba	2			1			4			<1
Pyromaia tuberculata	1	2		4	<1			**2**	**2**	<1
Pagurus spilocarpus	1	<1							<1	<1
Octopus rubescens	1				**<1**			2	<1	<1
Megastraea turbanica	1									
Lytechinus pictus		8		951	<1				<1	11
Loxorhynchus grandis		**3**			<1			<1	<1	<1
Caesia perpinguis		**2**			<1				<1	<1
Hirudinea (unidentified)		**2**							<1	<1
Astropecten californicus		2		6	**2**	1	443	**4**	**6**	**33**
Latulambrus occidentalis		<1	1		<1			<1	**4**	2
Heptacarpus stimpsoni		<1	1					2	<1	<1
Luidia armata		<1	1						<1	<1
Crangon nigromaculata		<1		1					**3**	<1
Elthusa vulgaris		<1			**1**		8	<1	1	<1
Crossata ventricosa		<1				1			<1	<1
Philine auriformis		<1						2	3	<1
Astropecten ornatissimus			4							<1
Pisaster brevispinus			2	2		1	1	**2**	**1**	**<1**
Flabellina iodinea			1						<1	<1
Heptacarpus palpator				2				1		
Doryteuthis opalescens				1		1			<1	1
Halosydna latior				1					<1	<1
Pisaster giganteus capitatus				1						
Romaleon jordani				1						
Acanthodoris brunnea					**3**				<1	<1
Kelletia kelletii					**1**			<1	**1**	<1
Metacarcinus gracilis					<1			<1	<1	<1
Platymera gaudichaudii					<1			<1	<1	<1
Stylatula elongata							3		<1	<1
Dendronotus venustus							3			<1
Pagurus armatus							2		<1	<1
Acanthodoris rhodoceras							1		<1	<1
Megastraea undosa							1			<1

[a] SIMPER analysis only conducted on cluster groups that contained more than one trawl.

parasitic cymothoid isopod *Elthusa vulgaris*, the seastar *Pisaster brevispinus*, and the gastropod *Kelletia kelletii*. As with demersal fishes in the SBOO region, the composition of the trawl-caught invertebrate assemblages varied among stations and surveys, generally reflecting population fluctuations in the species mentioned above.

Overall, there is no evidence that wastewater discharged through the SBOO affected demersal fish or megabenthic invertebrate communities in 2013. Although highly variable, patterns in the abundance and distribution of species were similar at stations located near the outfall and farther away. Instead, the high variability in these assemblages during the year was similar to that observed in previous years including before wastewater discharge began (City of San Diego 2000, 2006–2013). In addition, the low species richness and relatively small populations of these fish and invertebrates are consistent with expectations for the relatively shallow, sandy habitats characteristic of the SBOO region (Allen et al. 1998, 2002, 2007, 2011). Consequently, changes in local community structure of these organisms is more likely due to natural factors such as changes in ocean temperatures associated with El Niño or other large-scale oceanographic events, and the mobile nature of many resident species. Finally, the absence of disease indicators or other physical abnormalities in local fishes suggests that populations in the region 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 City of San Diego's (City) Ocean Monitoring Program to evaluate if contaminants in wastewater discharged from the South Bay Ocean Outfall (SBOO) are bioaccumulating in their tissues. Anthropogenic inputs to coastal waters can result in increased concentrations of pollutants within the local marine environment, and subsequently in the tissues of fishes and their prey. This accumulation occurs through the biological uptake and retention of chemicals derived via various exposure pathways like the absorption of dissolved chemicals directly from seawater and the ingestion and assimilation of pollutants contained in different food sources (Connell 1988, Cardwell 1991, Rand 1995, USEPA 2000). In addition, demersal fishes may accumulate contaminants through the ingestion of suspended particulates or sediments because of their proximity to the seafloor. For this reason, contaminant levels in the tissues of these fish are often related to those found in the environment (Schiff and Allen 1997), thus making these types of assessments useful in biomonitoring programs.

The bioaccumulation portion of the City's monitoring program consists of two components: (1) analyzing liver tissues from trawl-caught fishes; (2) analyzing muscle tissues from fishes collected by hook and line (rig fishing). Species targeted by trawling activities (see Chapter 6) are considered representative of the general demersal fish community off San Diego due to their numerical dominance. The chemical analysis of liver tissues in these trawl-caught fishes is important for assessing population effects because this is the organ where contaminants typically bioaccumulate. In contrast, species targeted for capture by rig fishing represent fish that are more characteristic of a typical sport fisher's catch, and are therefore considered of recreational and commercial importance and more directly relevant to human health concerns. Consequently, muscle samples are analyzed from these fishes because this is the tissue most often consumed by humans. All liver and muscle tissue samples collected during the year are analyzed for contaminants as specified in the NPDES discharge permits that governs monitoring requirements for the SBOO (see Chapter 1). Most of these contaminants are also sampled for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program, which was initiated to detect and monitor changes in the environmental quality of the nation's estuarine and coastal waters by tracking contaminants of environmental concern (Lauenstein and Cantillo 1993).

This chapter presents the results of all chemical analyses performed on the tissues of fishes collected in the South Bay outfall region during 2013. The primary goals are to: (1) document levels of contaminant loading in local demersal fishes, (2) identify whether any contaminant bioaccumulation detected in fishes collected around the SBOO may be due to the outfall discharge, and (3) identify other potential natural and anthropogenic sources of pollutants to the local marine environment.

MATERIALS AND METHODS

Field Collection

Fishes were collected during April and October 2013 at seven otter trawl and two rig fishing stations (Figure 7.1, Table 7.1). Three species were collected at the trawl stations for analysis of liver tissues, including English sole (*Parophrys vetulus*), hornyhead turbot (*Pleuronichthys verticalis*) and longfin sanddab (*Citharichthys xanthostigma*). In addition, eight species were collected at the two rig fishing stations for the analysis of muscle tissues. These species included the

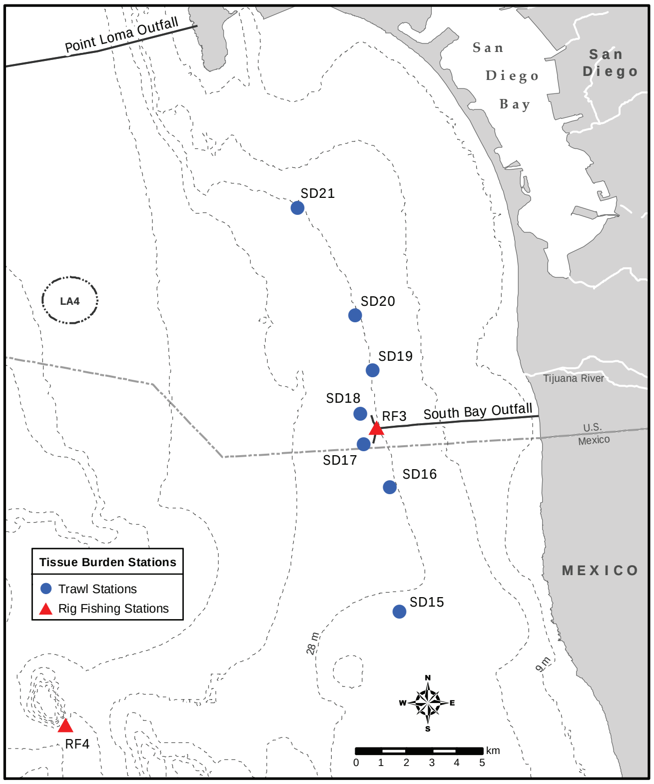

Figure 7.1
Trawl and rig fishing station locations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

brown rockfish (*Sebastes auriculatus*), California scorpionfish (*Scorpaena guttata*), copper rockfish (*Sebastes caurinus*), gopher rockfish (*Sebastes carnatus*), olive rockfish (*Sebastes serranoides*), starry rockfish (*Sebastes constellatus*), treefish (*Sebastes serriceps*), and vermilion rockfish (*Sebastes miniatus*). All trawl-caught fishes were collected following City of San Diego guidelines (see Chapter 6 for collection methods). Efforts to collect target species at the trawl stations were limited to five 10-minute (bottom time) trawls per site. Fishes collected at the two rig fishing stations were caught within 1 km of the nominal station coordinates using standard rod and reel procedures; fishing effort was limited to 5 hours at each station. Occasionally, insufficient numbers of the target species were obtained despite this effort, which resulted in inadequate amounts of tissue to complete the full suite of chemical analyses.

Only fishes with a standard length ≥13 cm were retained in order to facilitate collection of sufficient tissue for analysis. These fishes were sorted into three composite samples per station, with a minimum of three individuals in each composite. All fishes were wrapped in aluminum foil, labeled, sealed in re-sealable plastic bags, placed on dry ice, and then transported to the City's Marine Biology Laboratory where they were stored at -20°C prior to dissection and tissue processing.

Tissue Processing and Chemical Analyses

All dissections were performed according to standard techniques for tissue analysis. A brief summary follows, but see City of San Diego (in prep) for additional details. Prior to dissection, each fish was partially defrosted, cleaned with a paper towel to remove loose scales and excess mucus, and the standard length (cm) and weight (g) were recorded (Appendix F.1). Dissections were carried out on Teflon® pads that were cleaned between samples. The liver or muscle tissues from each fish were removed and placed in separate glass jars for each composite sample, sealed, labeled, and stored in a freezer at -20°C prior to chemical analyses. All samples were subsequently delivered to the City's Wastewater Chemistry Services Laboratory within 10 days of dissection.

Chemical constituents were measured on a wet weight basis, and included 18 trace metals, 9 chlorinated pesticides (e.g., DDT), 40 polychlorinated biphenyl compound congeners (PCBs), and 24 polycyclic aromatic hydrocarbons (PAHs) (see Appendix F.2). Data were generally limited to values above the method detection limit (MDL) for each parameter. However, concentrations below MDLs were included as estimated values if the presence of the specific constituent was verified by mass-spectrometry. A more detailed description of the analytical protocols is provided by the Wastewater Chemical Services Laboratory (City of San Diego 2014a).

Data Analyses

Data summaries for each contaminant include detection rate, minimum, maximum, and mean detected values of each parameter by species. All means were calculated using detected values only; no substitutions were made for non-detects

Table 7.1

Species of fish collected from each SBOO trawl and rig fishing station during April and October 2013.

Survey	Station	Composite 1	Composite 2	Composite 3
April 2013	RF3	Mixed rockfish[b]	California scorpionfish	Gopher rockfish
	RF4	Mixed rockfish[c]	Mixed rockfish[d]	Treefish
	SD15	English sole	English sole	Hornyhead turbot[a]
	SD16	Longfin sanddab	English sole	Hornyhead turbot[a]
	SD17	English sole	Longfin sanddab	English sole[a]
	SD18	English sole	Hornyhead turbot	Longfin sanddab
	SD19	Hornyhead turbot	English sole	Longfin sanddab
	SD20	English sole	English sole	English sole
	SD21	English sole	Hornyhead turbot	Hornyhead turbot
October 2013	RF3	Vermilion rockfish	Mixed rockfish[e]	Mixed rockfish[a,f]
	RF4	California scorpionfish	California scorpionfish	California scorpionfish[a]
	SD15	Hornyhead turbot	Hornyhead turbot	Hornyhead turbot
	SD16	Longfin sanddab	Hornyhead turbot	Longfin sanddab
	SD17	Hornyhead turbot	Hornyhead turbot	Hornyhead turbot
	SD18	Hornyhead turbot	Hornyhead turbot	Longfin sanddab
	SD19	Hornyhead turbot	Longfin sanddab	Longfin sanddab
	SD20	Longfin sanddab	Longfin sanddab	Longfin sanddab
	SD21	Longfin sanddab	Longfin sanddab	Longfin sanddab

[a] No PAHs analyzed for these samples; [b] Includes brown rockfish, vermilion rockfish, and treefish; [c] includes vermilion, and copper rockfish; [d] includes olive rockfish and treefish; [e] includes brown and olive rockfish; [f] includes starry rockfish and treefish

(i.e., analyte concentrations < MDL) in the data. Total DDT (tDDT), total chlordane, total hexachlorocyclohexane (HCH), total PCB (tPCB), and total PAH (tPAH) were calculated for each sample as the sum of all constituents with reported values (see Appendix F.3 for individual constituent values). In addition, the distribution of contaminants with detection rates ≥20% was assessed by comparing values in fishes collected from "nearfield" stations located within 1000 m of the outfall diffuser structure (SD17, SD18, RF3) to those from "farfield" stations located farther away to the south (SD15, SD16), north (SD19–SD21), and west (RF4). Contaminant concentrations were also compared to maximum values reported during the pre-discharge period (1995–1998). Because contaminant levels can vary drastically among different species of fish, only intra-species comparisons were used for these assessments.

Contaminant levels in fish muscle tissue samples were compared to state, national, and international limits and standards in order to address seafood safety and public health issues, including: (1) the California Office of Environmental Health Hazard Assessment (OEHHA), which has developed fish contaminant goals for chlordane, DDT, methylmercury, selenium, and PCBs (Klasing and Brodberg 2008); (2) the United States Food and Drug Administration (USFDA), which has set limits on the amount of mercury, DDT, and chlordane in seafood that is to be sold for human consumption (Mearns et al. 1991); (3) international standards for acceptable concentrations of various metals and DDT (Mearns et al. 1991).

RESULTS

Contaminants in Trawl-Caught Fishes

Trace Metals

Nine trace metals occurred in 100% of the liver tissue samples from trawl-caught fishes collected in the South Bay outfall region during 2013 (Table 7.2). These included arsenic, cadmium, chromium, copper, iron, manganese, mercury, selenium, and zinc. Aluminum, antimony, barium, lead, nickel, silver, thallium, and tin were also detected but at rates of 5–95%. Beryllium was the only metal not detected in any liver samples collected during the year. Several metals were found at levels higher than pre-discharge values (Figure 7.2). These included aluminum, arsenic, cadmium, copper, iron, manganese, mercury, selenium and zinc which exceeded pre-discharge values in 6–91% of the samples. However, intra-species comparisons between nearfield and farfield stations suggest that there was no clear relationship between metal concentrations in fish liver tissues and proximity to the outfall. For example, most of the relatively high concentrations occurred in various species collected throughout the region (i.e., not just at the "nearfield" stations).

Pesticides

Only three chlorinated pesticides were detected in fish liver tissues during 2013 (Table 7.3). DDT was found in every tissue sample collected in the SBOO region, with tDDT concentrations ranging from 14 to 460 ppb. The DDT metabolite p,p-DDE was found in 100% of the samples, whereas o,p-DDE, p,p-DDD, p,p-DDMU, and p,p-DDT were detected in at least 14% of the samples (Appendix F.3). Hexachlorobenzene (HCB) also occurred frequently at a rate of 71%, while chlordane (composed solely of trans nonachlor) had low detection rates ≤5%; both pesticides had low concentrations ≤11 ppb.

All tDDT concentrations measured during 2013 were below the maximum levels reported prior to wastewater discharge (Figure 7.3). This comparison could not be made for HCB since it was not detected prior to discharge. In 2013, tDDT and HCB were present in samples from all stations at variable concentrations, with the highest values occurring in longfin sanddab tissues from stations SD16, SD17, and SD18. Chlordane was detected in a single longfin sanddab sample from stations SD18 and SD21 (Appendix F.3).

PCBs and PAHs

PCBs were detected in every liver tissue sample collected from the South Bay outfall region during 2013 (Table 7.3). Total PCB concentrations were highly variable, ranging from 3 to 608 ppb. PCB 153/168 occurred in all samples, while the PCB congeners 49, 66, 101, 118, 138, 149, 151, 180, 183, 187 were detected 52–95% of the time (Appendix F.3). Overall, PCB concentrations during the year were below pre-discharge values (Figure 7.3), and did not demonstrate a clear relationship with proximity to the outfall. The highest value of tPCB occurred in a longfin sanddab sample from station SD21. In contrast to PCBs, the detection rate for PAHs was just 14%, with tPAH concentrations ≤185.8 ppb. Individual PAHs found during the year included 1-methylphenanthrene, 2,6-dimethylnaphthalene, fluoranthene, phenanthrene, and pyrene; each of these were detected in ≤5% of the samples. PAHs occurred in liver tissues from longfin sanddabs and hornyhead turbots collected from stations SD18, SD19, and SD20.

Contaminants in Fishes Collected by Rig Fishing

Only five trace metals occurred in all fish muscle tissue samples collected at the SBOO rig fishing stations during 2013, including arsenic, chromium, mercury, selenium and zinc (Table 7.4). Aluminum, barium, copper, iron, lead, thallium, and tin were also detected, but at lower rates of 8–92%. In contrast, antimony, beryllium, cadmium, manganese, nickel and silver were not detected in any samples. Seven metals were found at levels higher than pre-discharge values (Figure 7.4). These included aluminum, arsenic, chromium, iron, mercury, selenium and zinc which exceeded pre-discharge values in 8–33% of the samples. Metal concentrations appeared to be somewhat similar in fish tissue samples collected at the two rig fishing stations despite the different species collected.

Two pesticides were detected in fish muscle tissues during 2013; DDT was detected in all samples, while HCB occurred in 50% of the samples

Table 7.2

Summary of metals in liver tissues of fishes collected from SBOO trawl stations during 2013. Data include the number of detected values (n), minimum, maximum and mean[a] detected concentrations for each species, and the detection rate and maximum value for all species. Concentrations are expressed as parts per million (ppm); the number of samples per species is indicated in parentheses. See Appendix F.2 for MDLs and names for each metal represented by periodic table symbol.

	Al	**Sb**	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Mn**	**Hg**	**Ni**	**Se**	**Ag**	**Tl**	**Sn**	**Zn**
English sole																		
n (out of 11)	9	0	11	1	0	11	11	11	11	11	11	11	1	11	11	1	9	11
Min	nd	—	4.9	nd	—	0.79	0.20	2.7	128.0	0.40	0.9	0.040	nd	1.33	0.050	nd	nd	25.4
Max	8.5	—	29.1	0.040	—	2.14	0.45	27.1	436.0	2.20	2.2	0.186	0.350	3.27	0.210	0.25	0.500	51.7
Mean	5.9	—	17.0	0.040	—	1.59	0.27	8.7	232.1	0.82	1.6	0.084	0.350	2.01	0.129	0.25	0.333	34.6
Hornyhead turbot																		
n (out of 16)	7	1	16	2	0	16	16	16	16	0	16	16	0	16	15	1	16	16
Min	nd	nd	2.5	nd	—	0.97	0.14	2.9	31.0	—	0.7	0.037	—	0.55	nd	nd	0.300	32.7
Max	12.5	0.200	12.9	0.100	—	7.19	0.40	9.4	107.0	—	2.6	0.126	—	1.60	0.180	0.40	1.530	64.4
Mean	6.9	0.200	5.0	0.069	—	2.78	0.26	5.8	49.7	—	1.4	0.073	—	0.93	0.119	0.40	0.901	51.0
Longfin sanddab																		
n (out of 15)	7	2	15	3	0	15	15	15	15	4	15	15	1	15	10	1	15	15
Min	nd	nd	3.9	nd	—	1.02	0.14	3.6	43.0	nd	0.7	0.041	nd	0.52	nd	nd	0.200	22.4
Max	16.0	0.300	35.6	0.049	—	11.20	0.34	9.5	126.0	0.53	2.0	0.356	0.230	2.21	0.290	0.57	3.370	39.5
Mean	6.6	0.275	9.0	0.043	—	4.26	0.25	6.1	87.2	0.36	1.5	0.137	0.230	1.27	0.143	0.57	1.743	29.8
All species																		
Detection rate (%)	55	7	100	14	0	100	100	100	100	36	100	100	5	100	86	7	95	100
Max	16.0	0.300	35.6	0.100	—	11.20	0.45	27.1	436.0	2.20	2.6	0.356	0.350	3.27	0.290	0.57	3.370	64.4

nd = not detected

[a] Minimum and maximum values were calculated based on all samples, whereas means were calculated from detected values only

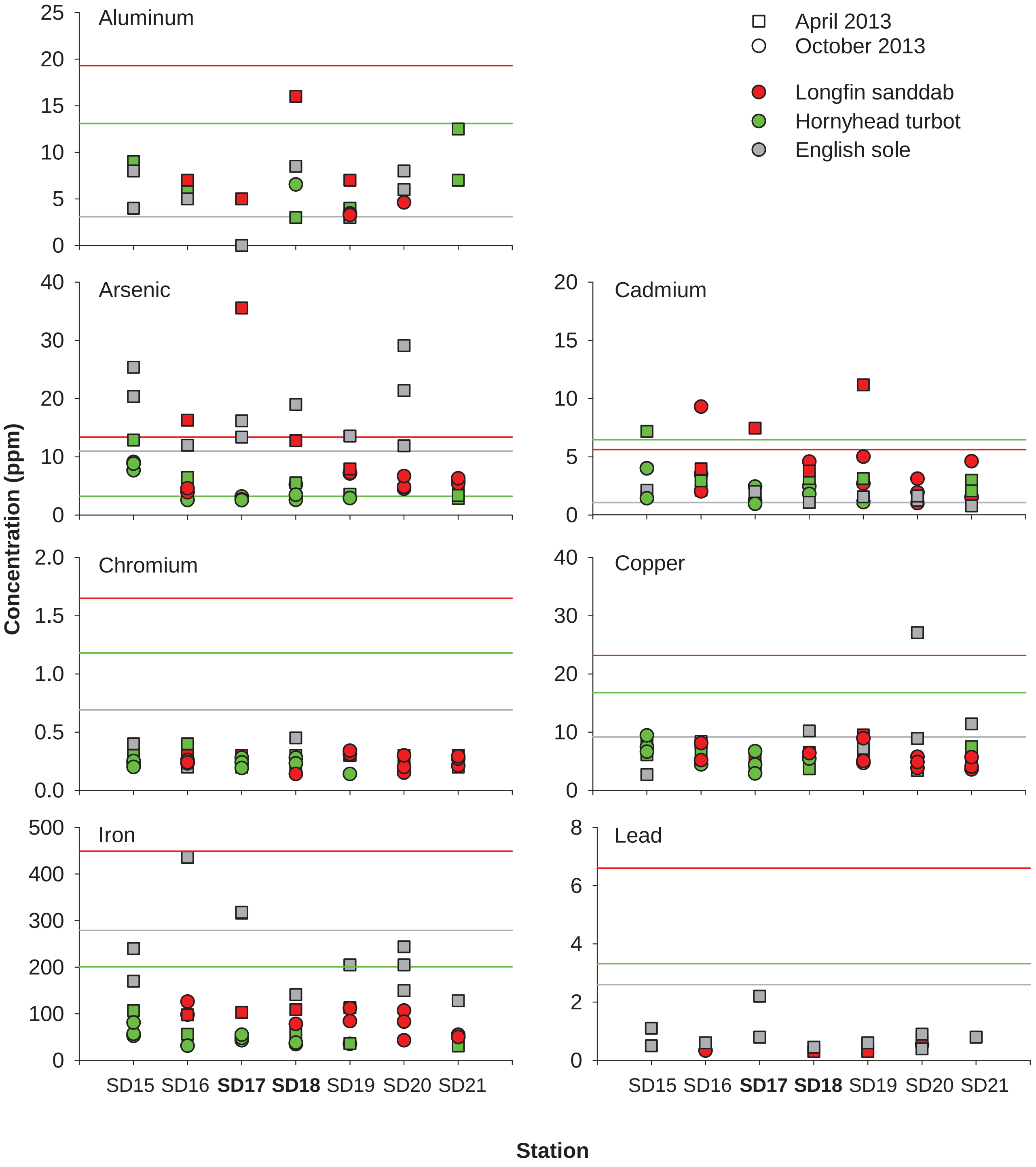

Figure 7.2

Concentrations of metals with detection rates ≥ 20% in liver tissues of fishes collected from each SBOO trawl station during 2013. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for each species; missing lines indicate metals were not detected in that species pre-discharge. All missing values are non-detects. Stations SD17 and SD18 are considered nearfield (bold; see text).

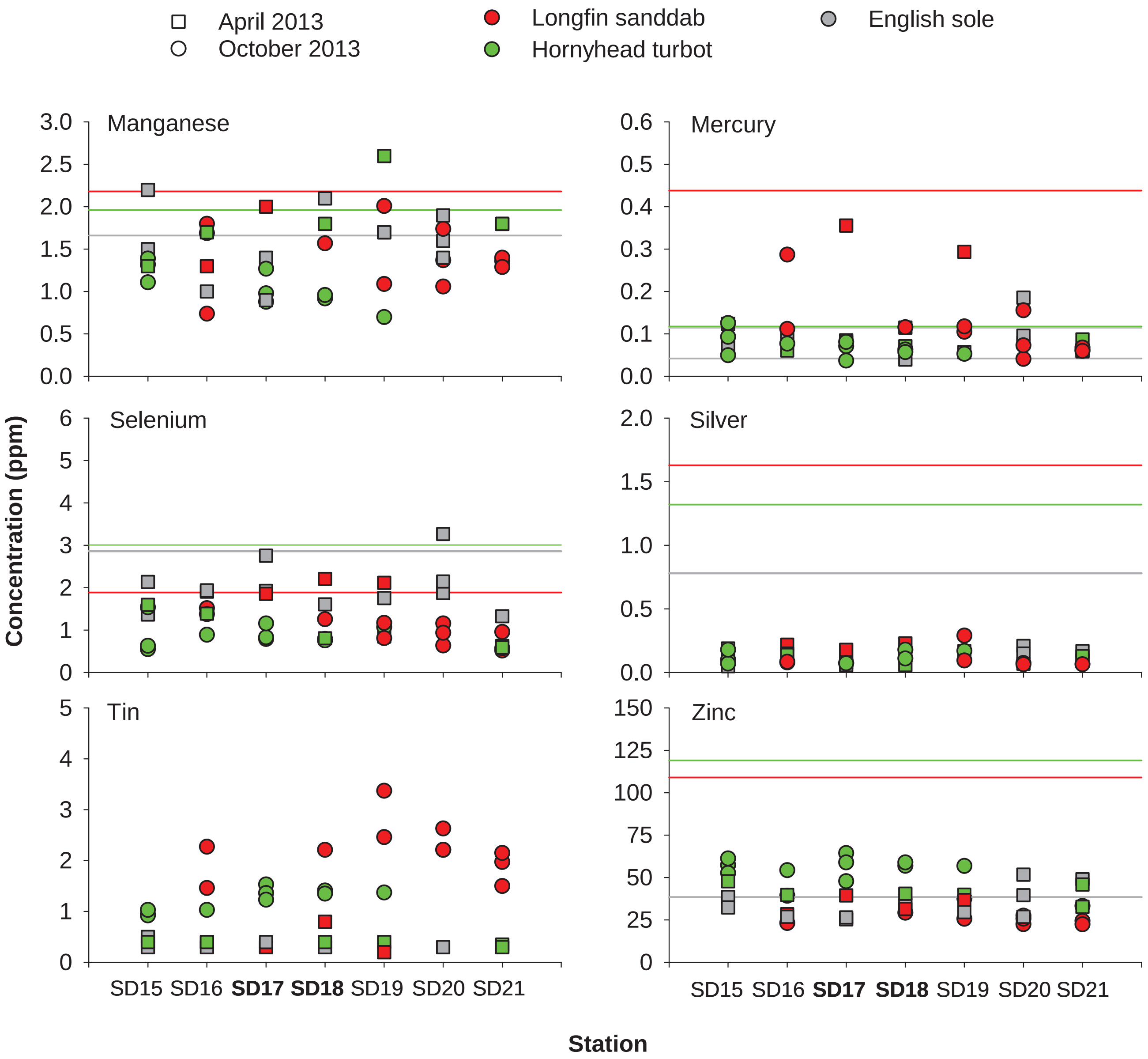

Figure 7.2 *continued*

(Table 7.5). The detection rate for PCBs in muscle tissues was also high at 100%. Concentrations of all three of these contaminants were below 12 ppb. Neither tDDT nor tPCB exceeded pre-discharge values, whereas HCB was not detected during that period (Figure 7.4). As with metals, concentrations of HCB, tDDT and tPCB appeared to be somewhat similar in fish tissue samples collected at the two rig fishing stations despite the different species collected. Total DDT values in muscle tissue samples were composed primarily of p,p-DDE (Appendix F.3). PCB 153/168 was detected in 92% of the samples, while another sixteen PCB congeners were detected at rates ≤58%. No PAHs were detected in muscle tissues during 2013.

Most contaminants detected in fish muscle tissues during 2013 occurred at concentrations below state, national, and international limits and standards (Tables 7.4, 7.5). However, arsenic exceeded its median international standard in 66% of the samples from station RF3 and 66% of the samples from station RF4; these included three

Table 7.3

Summary of pesticides, total PCB, total PAH and lipids in liver tissues of fishes collected from SBOO trawl stations during 2013. Data include the number of detected values (n), minimum, maximum, and mean[a] detected concentrations for each species, and the detection rate (DR) and maximum value for all species. Concentrations are expressed in ppb for all parameters except lipids, which are % weight; the number of samples per species is indicated in parentheses. See Appendix F.2 for MDLs and Appendix F.3 for values of individual constituents summed for tDDT, total chlordane (tChlor), tPCB and tPAH.

	Pesticides					
	HCB	**tDDT**	**tChlor**	**tPCB**	**tPAH**	**Lipids**
English sole						
n (out of 11)	8	11	0	11	0	11
Min	nd	47.0	—	21.8	—	3.3
Max	3.3	460.0	—	130.3	—	6.3
Mean	1.9	144.2	—	66.0	—	4.5
Hornyhead turbot						
n (out of 16)	7	16	0	16	2	16
Min	nd	14.0	—	2.9	nd	1.8
Max	3.4	161.9	—	54.0	185.8	13.4
Mean	1.5	51.9	—	18.3	123.1	6.9
Longfin sanddab						
n (out of 15)	15	15	2	15	2	15
Min	1.2	116.5	nd	65.3	nd	9.0
Max	11.0	448.5	4.5	608.5	111.1	47.2
Mean	3.2	284.5	3.5	193.8	81.3	29.6
All Species:						
DR(%)	71	100	5	100	14	100
Max	11.0	460.0	4.5	608.5	185.8	47.2

nd = not detected; [a] Minimum and maximum values were calculated based on all samples, whereas means were calculated from detected values only

samples of California scorpionfish, two samples of mixed rockfish, and single samples of gopher rockfish, treefish, and vermilion rockfish. Selenium exceeded its median international standard in 100% of the samples from station RF3 and 50% of the samples from station RF4, which included five samples of mixed rockfish and single samples of California scorpionfish, gopher rockfish, treefish, and vermilion rockfish. Total PCB exceeded the OEHHA fish contaminant goal in a single sample of mixed rockfish from station RF3.

DISCUSSION

Several trace metals, PCB congeners, PAHs and the chlorinated pesticides chlordane, DDT, and HCB were detected in liver tissues from three different species of fish collected in the South Bay outfall region during 2013. Many of the same metals, DDT, HCB, and PCBs were also detected in muscle tissues during the year, although often less frequently and/or in lower concentrations. Although tissue contaminant concentrations varied among different species of fish and between stations, all values were within ranges reported previously for Southern California Bight (SCB) fishes (e.g., Mearns et al. 1991, Allen et al. 1998, City of San Diego 2007a). Additionally, all muscle tissue samples from sport fish collected in the region had concentrations of mercury and DDT below USFDA action limits. However, some tissue samples from gopher rockfish, California scorpionfish, vermilion rockfish, treefish, and "mixed rockfish" composites had concentrations of arsenic and selenium above median international standards for human consumption, and a single mixed rockfish sample exceeded the OEHHA limit for total PCB. Elevated levels of these contaminants are not uncommon in sport fish from the SBOO survey area (City of San Diego 2000–2006, 2007b, 2008–2013) or from other parts of the San Diego region (see City of San Diego 2014b and references therein). For example, muscle tissue samples from fishes collected since 1991 off Point Loma have occasionally had concentrations of contaminants such as arsenic, selenium, mercury and PCB that exceeded different consumption limits.

The frequent occurrence of metals and chlorinated hydrocarbons in the tissues of fish captured in the SBOO region may be due to multiple factors. Many metals occur naturally in the environment, although little information is available on background levels in fish tissues. Brown et al. (1986) determined that there may be no area in the SCB sufficiently free of chemical contaminants to be considered a reference site, while Mearns et al. (1991) described the distribution of several contaminants such as arsenic, mercury, DDT and PCBs as

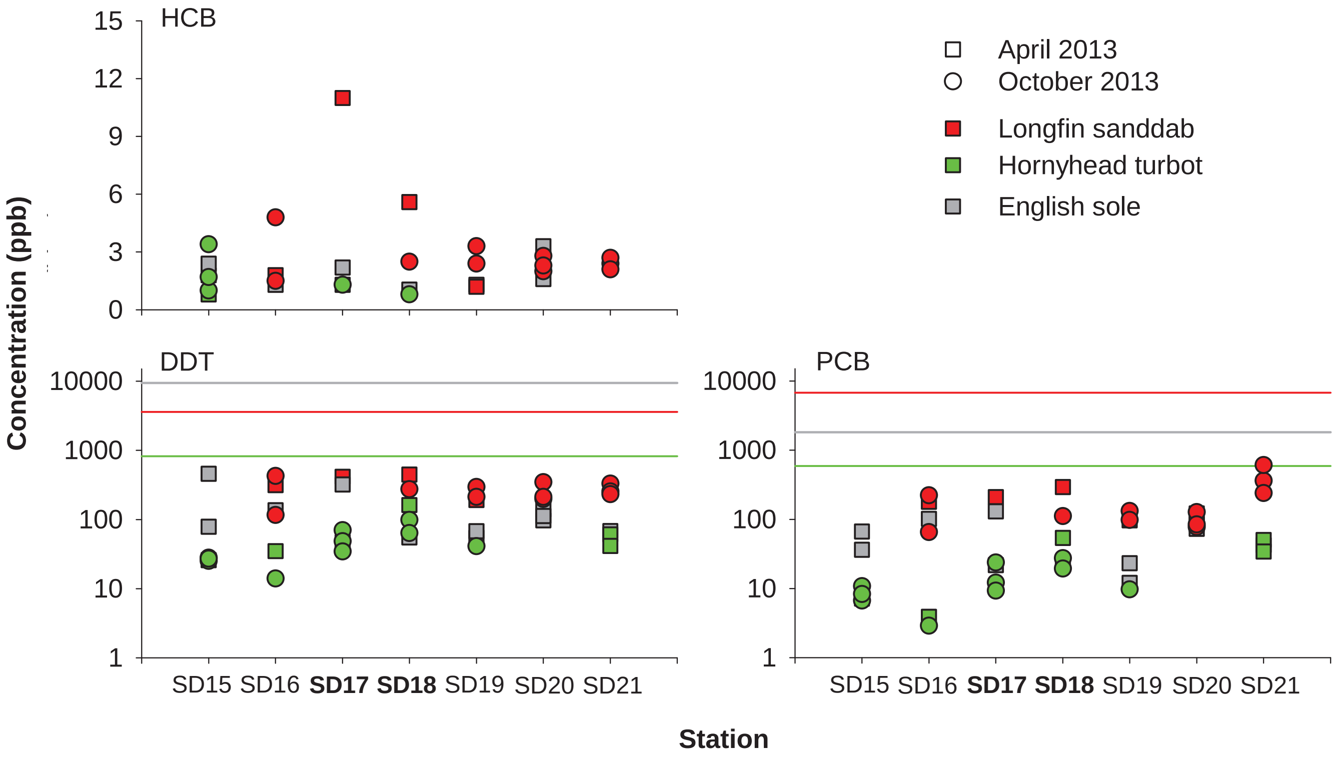

Figure 7.3

Concentrations of HCB, total DDT, and total PCB in liver tissues of fishes collected from each SBOO trawl station during 2013. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for each species; missing lines indicate parameters were not detected in that species pre-discharge. All missing values are non-detects. Stations SD17 and SD18 are considered nearfield (bold; see text).

being ubiquitous. The wide-spread distribution of contaminants in SCB fishes has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998, 2002) and is supported in the South Bay outfall region by the presence of many contaminants in fish tissues prior to the initiation of wastewater discharge in 1999 (City of San Diego 2000).

Other factors that affect contaminant loading in fish tissues include the physiology and life history of different species (see Groce 2002 and references therein). Exposure to contaminants can also vary greatly between different species and among individuals of the same species depending on migration habits (Otway 1991). Fishes may be exposed to contaminants in an area that is highly polluted and then move into an area that is not. For example, California scorpionfish tagged in Santa Monica Bay have been recaptured as far south as the Coronado Islands (Hartmann 1987, Love et al. 1987). This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many point and non-point sources that may contribute to contamination in the region, including the Tijuana River, San Diego Bay, and offshore dredged material disposal sites (see Chapters 2–4; Parnell et al. 2008). In contrast, assessments of contaminant loading in sediments surrounding the outfall have revealed no evidence to indicate that the SBOO is a major source of pollutants to the area (Chapter 4).

Overall, there was no evidence of contaminant bioaccumulation in SBOO fishes during 2013 that could be associated with wastewater discharge from the outfall. Although several muscle or liver tissue samples had concentrations of some contaminants that exceeded pre-discharge maxima, concentrations of most contaminants were generally similar to or below pre-discharge levels (see also City of San Diego 2000). In addition, most tissue samples that did exceed pre-discharge levels were widely distributed among stations

Table 7.4

Summary of metals in muscle tissues of fishes collected from SBOO rig fishing stations during 2013. Data include the number of detected values (n), minimum, maximum, and mean[a] detected concentrations per species, and the detection rate and maximum value for all species. Concentrations are expressed as parts per million (ppm). The number of samples per species is indicated in parentheses. Bold values meet or exceed OEHHA fish contaminant goals, USFDA action limits, or median international standards (IS). See Appendix F.2 for MDLs and names for each metal represented by periodic table symbol.

	Al	**Sb**	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Mn**	**Hg**	**Ni**	**Se**	**Ag**	**Tl**	**Sn**	**Zn**
Gopher rockfish																		
n (out of 1)	1	0	1	0	0	0	1	0	0	1	0	1	0	1	0	0	1	1
Value	4.0	—	**1.7**	—	—	—	0.10	—	—	0.2	—	0.120	—	**0.35**	—	—	0.400	3.4
California scorpionfish																		
n (out of 4)	2	0	4	1	0	0	4	0	0	0	0	4	0	4	0	0	4	4
Min	nd	—	0.9	nd	—	—	0.10	—	—	—	—	0.057	—	0.22	—	—	0.300	3.7
Max	3.6	—	**8.1**	0.032	—	—	0.19	—	—	—	—	0.162	—	**0.32**	—	—	0.860	6.8
Mean	3.3	—	**3.6**	0.032	—	—	0.13	—	—	—	—	0.120	—	0.26	—	—	0.577	4.8
Mixed rockfish																		
n (out of 5)	3	0	5	0	0	0	5	1	2	0	0	5	0	5	0	1	5	5
Min	nd	—	0.3	—	—	—	0.10	nd	nd	—	—	0.040	—	**0.34**	—	nd	0.200	3.2
Max	5.5	—	**2.4**	—	—	—	0.20	0.1	5.6	—	—	0.090	—	**0.43**	—	0.45	0.970	4.3
Mean	4.2	—	**1.5**	—	—	—	0.13	0.1	4.3	—	—	0.069	—	**0.38**	—	0.45	0.462	3.8
Vermilion rockfish																		
n (out of 1)	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	1	1
Value	—	—	**2.3**	—	—	—	0.16	—	—	—	—	0.029	—	**0.30**	—	—	0.890	3.6
Treefish																		
n (out of 1)	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1
Value	6.0	—	**2.1**	—	—	—	0.20	—	—	—	—	0.218	—	**0.39**	—	—	—	3.6
All Species:																		
Detection Rate (%)	58	0	100	8	0	0	100	8	17	8	0	100	0	100	0	8	92	100
Max Value	6.0	—	**8.1**	0.032	—	—	0.20	0.1	5.6	0.2	—	0.218	—	**0.43**	—	0.45	0.970	6.8
OEHHA[b]	na	na	na	na	na	na	na	na	na	na	na	0.22	na	7.4	na	na	na	na
USFDA Action Limit[c]	na	na	na	na	na	na	na	na	na	na	na	1	na	na	na	na	na	na
Median IS[c]	na	na	1.4	na	na	1.0	1.0	20	na	2.0	na	0.50	na	0.30	na	na	175	70

na = not available; nd=not detected

[a] Minimum and maximum values were calculated based on all samples, whereas means were calculated from detected values only

[b] From the California OEHHA (Klasing and Brodberg 2008)

[c] From Mearns et al. 1991. USFDA mercury action limits and all international standards (IS) are for shellfish, but are often applied to fish

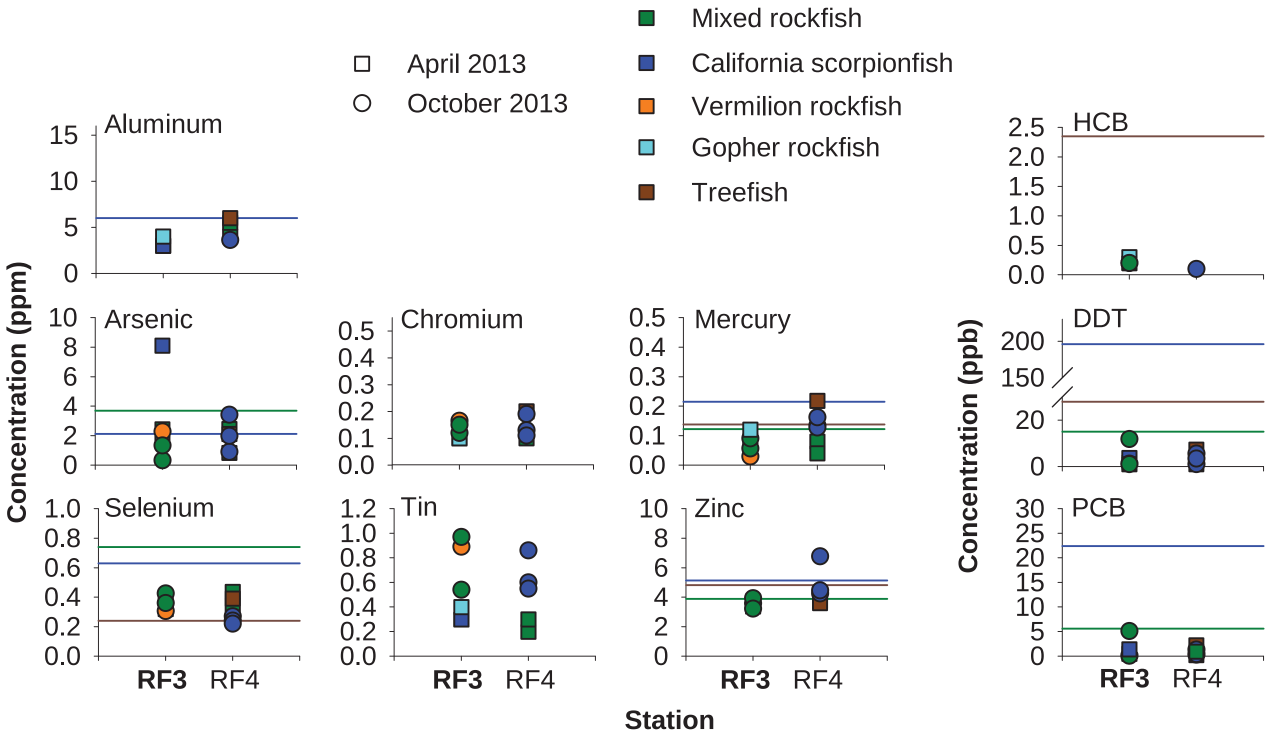

Figure 7.4

Concentrations of contaminants with detection rates ≥20% in muscle tissues of fishes collected from each SBOO rig fishing station during 2013. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for each species; missing lines indicate parameters were not detected in that species prior to discharge, or the species was not collected during those surveys. All missing values are non-detects. Station RF3 is considered nearfield (bold; see text).

and showed no outfall-related spatial patterns. Finally, there were no other indications of poor fish health in the region, such as the presence of fin rot, other indicators of disease, or any physical anomalies (see Chapter 6).

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Table 7.5

Summary of pesticides, total PCB, and lipids in muscle tissues of fishes collected from SBOO rig fishing stations during 2013. Data include the number of detected values (n), minimum, maximum, and mean[a] detected concentrations per species and the detection rate and maximum value for all species. The number of samples per species is indicated in parentheses. Bold values meet or exceed OEHHA fish contaminant goals, USFDA action limits, or median international standards (IS). See Appendix F.2 for MDLs and Appendix F.3 for values of individual constituents summed for tDDT and tPCB.

	Pesticides			
	HCB (ppb)	tDDT (ppb)	tPCB (ppb)	Lipids (% wt)
Gopher rockfish				
n (out of 1)	1	1	1	1
Value	0.3	1.0	0.6	0.5
California scorpionfish				
n (out of 4)	2	4	4	4
Min	nd	1.0	0.3	0.4
Max	0.2	5.6	1.4	0.9
Mean	0.1	3.4	0.8	0.6
Mixed rockfish				
n (out of 5)	2	5	5	5
Min	nd	1.0	0.1	0.1
Max	0.2	11.9	**5.1**	2.6
Mean	0.2	4.0	1.4	0.8
Vermilion rockfish				
n (out of 1)	1	1	1	1
Value	0.2	1.3	0.1	0.5
Treefish				
n (out of 1)	0	1	1	1
Value	—	7.3	2.2	0.7
All Species:				
Detection Rate (%)	50	100	100	100
Max Value	0.3	11.9	**5.1**	2.6
OEHHA[b]	na	21	3.6	na
U.S. FDA Action Limit[c]	300	5000	na	na
Median IS[c]	100	5000	na	na

na = not available; nd = not detected

[a] Minimum and maximum values were calculated based on all samples, whereas means were calculated from detected values only

[b] From the California OEHHA (Klasing and Brodberg 2008)

[c] From Mearns et al. 1991. USFDA action limits and all international standards (IS) are for shellfish, but are often applied to fish

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Appendices

Appendix A

Supporting Data

2013 SBOO Stations

Oceanographic Conditions

Appendix A.1

Summary of temperature, salinity, dissolved oxygen (DO), pH, transmissivity, and chlorophyll *a* for various depth layers as well as the entire water column for all SBOO stations during 2013. For each month n= 358 to 360 (1–9 m), n=271 to 272 (10–19 m), n=150 (20–28 m), n= 72 to 75 (29–38 m), n=55 to 56 (39–55 m). Sample sizes differed due to sensor issues at individual stations.

		Depth (m)					
Temperature (°C)		**1–9**	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
January	min	12.3	12.6	12.3	11.6	11.3	11.3
	max	14.6	14.4	14.2	13.0	12.7	14.6
	mean	13.5	13.4	13.0	12.3	11.8	13.2
February	min	12.8	12.5	12.4	12.2	11.9	11.9
	max	14.6	14.6	14.4	13.5	12.9	14.6
	mean	14.0	13.6	13.1	12.8	12.4	13.5
March	min	11.4	10.9	10.9	11.4	10.8	10.8
	max	14.7	14.3	14.3	13.2	12.0	14.7
	mean	13.6	12.7	12.2	11.9	11.4	12.8
April	min	11.0	10.8	10.7	10.6	10.3	10.3
	max	16.0	14.7	13.5	12.1	11.2	16.0
	mean	13.3	11.7	11.3	11.0	10.7	12.2
May	min	15.6	14.0	11.8	11.2	10.9	10.9
	max	18.2	17.4	16.6	12.7	11.3	18.2
	mean	17.0	16.1	13.9	11.7	11.0	15.4
June	min	11.6	11.0	10.8	10.6	10.3	10.3
	max	21.0	18.9	14.9	11.8	11.0	21.0
	mean	18.3	14.4	11.7	10.9	10.6	15.0
July	min	12.4	11.3	11.1	10.9	10.6	10.6
	max	21.1	17.1	14.7	13.2	12.2	21.1
	mean	17.0	12.7	11.8	11.5	11.2	14.1
August	min	12.1	11.4	11.3	11.2	10.5	10.5
	max	20.4	16.7	13.6	12.7	11.6	20.4
	mean	15.0	12.6	12.0	11.7	11.2	13.3
September	min	13.8	13.2	12.2	11.9	11.4	11.4
	max	20.3	16.8	15.1	13.1	12.6	20.3
	mean	16.7	14.5	13.3	12.4	11.9	14.8
October	min	15.5	13.1	12.3	12.1	11.6	11.6
	max	20.4	20.1	15.6	13.6	12.5	20.4
	mean	18.8	15.5	13.5	12.8	12.0	16.0
November	min	14.2	13.5	13.3	13.1	12.6	12.6
	max	17.0	17.0	15.7	14.4	13.3	17.0
	mean	15.6	14.8	14.0	13.4	13.1	14.8
December	min	15.5	15.3	14.9	14.2	13.3	13.3
	max	16.7	16.7	16.3	16.1	14.8	16.7
	mean	16.1	16.0	15.7	14.9	14.0	15.8
Annual	min	11.0	10.8	10.7	10.6	10.3	10.3
	max	21.1	20.1	16.6	16.1	14.8	21.1
	mean	15.8	14.0	13.0	12.3	11.8	14.3

Appendix A.1 *continued*

		Depth (m)					
Salinity (psu)		**1–9**	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
January	min	33.47	33.46	33.35	33.43	33.48	33.35
	max	33.54	33.53	33.52	33.56	33.69	33.69
	mean	33.51	33.50	33.49	33.51	33.57	33.50
February	min	33.47	33.41	33.48	33.48	33.52	33.41
	max	33.55	33.57	33.54	33.55	33.59	33.59
	mean	33.51	33.51	33.52	33.52	33.55	33.51
March	min	33.32	33.39	33.49	33.50	33.54	33.32
	max	33.59	33.64	33.65	33.60	33.64	33.65
	mean	33.53	33.54	33.56	33.55	33.59	33.54
April	min	33.51	33.51	33.51	33.48	33.54	33.48
	max	33.73	33.69	33.70	33.74	33.80	33.80
	mean	33.58	33.60	33.63	33.63	33.68	33.61
May	min	33.24	33.45	33.42	33.50	33.59	33.24
	max	33.63	33.79	33.62	33.66	33.70	33.79
	mean	33.59	33.59	33.57	33.59	33.66	33.59
June	min	33.40	33.39	33.45	33.47	33.51	33.39
	max	33.78	33.66	33.64	33.67	33.73	33.78
	mean	33.64	33.53	33.56	33.59	33.64	33.59
July	min	33.24	33.36	33.47	33.48	33.50	33.24
	max	33.76	33.70	33.63	33.77	33.63	33.77
	mean	33.57	33.51	33.53	33.57	33.58	33.54
August	min	33.34	33.30	33.39	33.40	33.47	33.30
	max	33.64	33.56	33.57	33.52	33.66	33.66
	mean	33.49	33.46	33.47	33.48	33.55	33.48
September	min	33.30	33.30	33.36	33.44	33.46	33.30
	max	33.86	33.5	33.50	33.52	33.54	33.86
	mean	33.45	33.44	33.45	33.48	33.5	33.45
October	min	33.38	33.33	33.34	33.38	33.42	33.33
	max	33.66	33.65	33.46	33.49	33.48	33.66
	mean	33.56	33.44	33.43	33.44	33.47	33.48
November	min	33.36	33.22	33.33	33.35	33.39	33.22
	max	33.56	33.56	33.47	33.41	33.42	33.56
	mean	33.45	33.41	33.39	33.39	33.41	33.42
December	min	33.38	33.42	33.42	33.39	33.39	33.38
	max	33.60	33.59	33.56	33.54	33.42	33.60
	mean	33.52	33.52	33.49	33.44	33.41	33.50
Annual	min	33.24	33.22	33.33	33.35	33.39	33.22
	max	33.86	33.79	33.70	33.77	33.80	33.86
	mean	33.53	33.50	33.51	33.52	33.55	33.52

Appendix A.1 *continued*

		Depth (m)					
DO (mg/L)		**1–9**	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
January	min	6.7	6.0	5.5	5.1	4.2	4.2
	max	8.6	8.5	7.7	7.4	6.8	8.6
	mean	7.9	7.7	6.8	6.0	5.2	7.4
February	min	5.9	5.6	5.9	5.6	5.5	5.5
	max	8.9	8.5	8.4	7.4	7.0	8.9
	mean	8.0	7.4	6.8	6.5	6.1	7.4
March	min	4.9	4.6	4.6	4.9	4.5	4.5
	max	9.5	9.1	8.6	7.3	5.8	9.5
	mean	8.0	7.0	6.0	5.6	5.0	7.0
April	min	4.2	4.0	3.9	3.7	3.5	3.5
	max	10.7	8.8	8.2	6.1	5.5	10.7
	mean	7.4	5.4	4.8	4.6	4.2	6.0
May	min	7.3	6.8	5.8	4.5	3.9	3.9
	max	8.5	9.0	9.3	6.7	5.2	9.3
	mean	8.0	8.1	7.5	5.5	4.4	7.5
June	min	3.9	3.0	2.6	2.5	3.4	2.5
	max	9.3	9.6	8.0	6.9	6.0	9.6
	mean	8.0	7.6	5.6	4.9	4.6	7.0
July	min	6.4	5.7	5.4	5.2	4.8	4.8
	max	9.5	9.5	9.5	7.8	7.2	9.5
	mean	8.2	7.7	6.9	6.3	5.8	7.6
August	min	5.1	4.3	4.2	4.8	4.4	4.2
	max	13.0	10.2	8.2	7.8	6.7	13.0
	mean	8.4	7.3	6.7	6.3	5.6	7.4
September	min	6.1	7.0	6.3	5.8	5.2	5.2
	max	12.1	9.8	9.6	8.4	6.8	12.1
	mean	9.5	8.9	8.0	6.8	6.1	8.6
October	min	6.1	7.1	6.9	6.3	6.0	6.0
	max	8.5	9.1	9.0	8.8	7.3	9.1
	mean	7.8	8.3	7.9	7.2	6.4	7.8
November	min	6.8	6.6	6.5	6.5	6.2	6.2
	max	8.5	8.6	8.2	7.7	6.9	8.6
	mean	8.0	7.9	7.4	7.0	6.6	7.7
December	min	7.5	6.4	7.0	6.4	6.3	6.3
	max	8.4	8.3	8.3	7.9	7.4	8.4
	mean	8.0	7.9	7.7	7.2	6.7	7.8
Annual	min	3.9	3.0	2.6	2.5	3.4	2.5
	max	13.0	10.2	9.6	8.8	7.4	13.0
	mean	8.1	7.6	6.9	6.2	5.6	7.4

Appendix A.1 *continued*

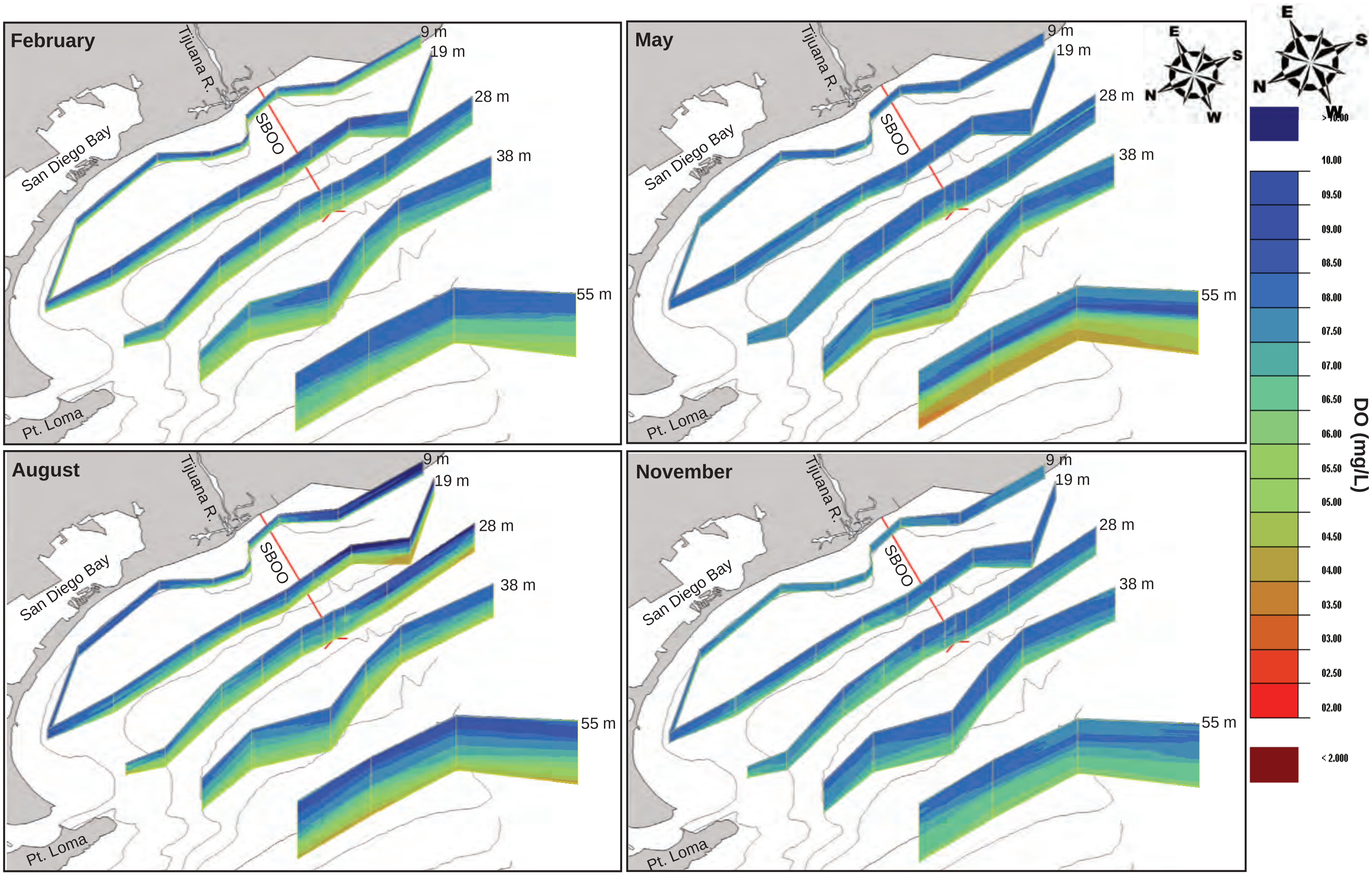
pH		**Depth (m)**					
		1–9	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
January	min	8.0	8.0	7.9	7.9	7.8	7.8
	max	8.2	8.2	8.2	8.1	8.1	8.2
	mean	8.2	8.1	8.1	8.0	8.0	8.1
February	min	8.1	8.0	8.0	8.0	8.0	8.0
	max	8.2	8.2	8.2	8.2	8.1	8.2
	mean	8.1	8.1	8.1	8.1	8.0	8.1
March	min	7.9	7.8	7.8	7.8	7.8	7.8
	max	8.2	8.2	8.2	8.1	8.0	8.2
	mean	8.1	8.0	8.0	7.9	7.9	8.0
April	min	7.8	7.8	7.7	7.8	7.7	7.7
	max	8.3	8.2	8.1	8.0	7.9	8.3
	mean	8.1	7.9	7.8	7.8	7.8	7.9
May	min	8.1	8.1	7.9	7.8	7.8	7.8
	max	8.2	8.2	8.2	8.0	7.9	8.2
	mean	8.2	8.2	8.1	7.9	7.8	8.1
June	min	7.7	7.7	7.6	7.6	7.7	7.6
	max	8.2	8.2	8.1	8.0	7.9	8.2
	mean	8.1	8.1	7.9	7.8	7.8	8.0
July	min	8.1	8.0	7.9	7.9	7.9	7.9
	max	8.3	8.2	8.2	8.1	8.1	8.3
	mean	8.2	8.1	8.1	8.0	7.9	8.1
August	min	7.8	7.8	7.8	7.9	7.8	7.8
	max	8.5	8.2	8.1	8.1	8.0	8.5
	mean	8.2	8.1	8.0	8.0	7.9	8.1
September	min	7.9	8.0	7.9	7.9	7.8	7.8
	max	8.5	8.2	8.2	8.1	8.0	8.5
	mean	8.2	8.1	8.1	8.0	7.9	8.1
October	min	8.0	8.0	8.0	7.9	7.9	7.9
	max	8.2	8.1	8.1	8.1	8	8.2
	mean	8.1	8.1	8.0	8.0	7.9	8.1
November	min	7.8	7.8	7.8	7.8	7.8	7.8
	max	8.0	8.0	8.0	8.0	7.9	8.0
	mean	8.0	8.0	7.9	7.9	7.9	8.0
December	min	7.9	7.9	8.0	7.9	7.9	7.9
	max	8.2	8.2	8.1	8.1	8.0	8.2
	mean	8.1	8.1	8.1	8.0	8.0	8.1
Annual	min	7.7	7.7	7.6	7.6	7.7	7.6
	max	8.5	8.2	8.2	8.2	8.1	8.5
	mean	8.1	8.1	8.0	8.0	7.9	8.1

Appendix A.1 *continued*

Transmissivity (%)		**Depth (m)** **1–9**	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
January	min	52	47	77	81	87	47
	max	88	88	90	90	90	90
	mean	79	83	85	87	89	82
February	min	35	34	75	66	80	34
	max	87	88	90	90	90	90
	mean	79	85	85	86	88	83
March	min	39	34	75	81	74	34
	max	87	88	89	89	90	90
	mean	78	83	85	87	86	82
April	min	49	59	85	84	85	49
	max	88	89	89	90	90	90
	mean	78	86	87	88	89	83
May	min	62	64	67	78	87	62
	max	89	89	88	89	89	89
	mean	81	86	85	87	88	84
June	min	61	58	66	77	88	58
	max	89	89	90	90	90	90
	mean	80	84	83	87	89	83
July	min	43	38	78	85	87	38
	max	90	89	89	89	90	90
	mean	81	84	87	89	89	84
August	min	5	71	81	85	87	5
	max	89	89	89	89	89	89
	mean	80	85	87	88	89	84
September	min	15	71	76	75	86	15
	max	88	88	88	88	88	88
	mean	81	85	85	86	88	83
October	min	60	55	77	83	87	55
	max	89	89	89	89	89	89
	mean	84	85	86	87	88	85
November	min	52	60	79	85	86	52
	max	88	88	88	88	88	88
	mean	79	83	85	87	87	83
December	min	52	44	80	77	83	44
	max	88	88	88	88	88	88
	mean	81	84	86	86	87	84
Annual	min	5	34	66	66	74	5
	max	90	89	90	90	90	90
	mean	80	84	86	87	88	83

Appendix A.1 *continued*

		Depth (m)					
Chlorophyll *a* (μg/L)		**1–9**	**10–19**	**20–28**	**29–38**	**39–55**	**1–55**
January	min	1.0	1.9	1.8	0.6	0.3	0.3
	max	9.1	9.4	9.3	7.8	7.7	9.4
	mean	4.2	5.2	4.4	2.7	2.5	4.3
February	min	2.2	2.8	2.6	2.7	3.6	2.2
	max	7.5	7.9	7.7	7.1	7.1	7.9
	mean	4.6	4.6	4.6	4.5	4.7	4.6
March	min	0.5	0.5	0.5	0.7	0.4	0.4
	max	6.9	13.4	7.5	2.4	1.0	13.4
	mean	2.0	2.6	1.6	1.1	0.7	2.0
April	min	0.6	1.0	1.0	0.8	0.4	0.4
	max	23.2	14.4	3.6	2.0	2.0	23.2
	mean	4.7	2.3	1.8	1.4	0.9	3.0
May	min	0.4	0.4	1.1	1.0	0.8	0.4
	max	5.5	4.2	18.3	6.6	1.5	18.3
	mean	1.4	1.4	3.3	2.2	1.0	1.8
June	min	0.5	0.7	0.9	0.7	0.5	0.5
	max	5.1	18.8	23.2	8.4	1.1	23.2
	mean	1.6	2.9	4.7	1.7	0.7	2.5
July	min	0.4	0.5	0.9	0.8	0.6	0.4
	max	6.7	8.4	11.8	2.6	1.9	11.8
	mean	1.8	2.0	1.9	1.2	1.1	1.8
August	min	0.4	0.7	1.2	1.1	0.6	0.4
	max	69.0	15.0	5.5	3.5	1.5	69.0
	mean	4.0	2.6	2.0	1.6	1.1	2.9
September	min	0.4	0.5	1.0	0.8	0.7	0.4
	max	39.8	15	10.7	9.5	1.8	39.8
	mean	3.4	2.4	2.9	1.8	1.1	2.7
October	min	0.5	0.6	1.1	1.0	1.0	0.5
	max	6.5	5.5	3.4	3.3	1.7	6.5
	mean	1.2	1.8	2.0	1.9	1.3	1.6
November	min	0.5	0.8	1.2	1.2	0.9	0.5
	max	4.9	3.9	3.1	2.0	1.6	4.9
	mean	1.7	2.1	1.9	1.6	1.2	1.8
December	min	0.6	0.8	1.3	1.0	0.9	0.6
	max	5.0	4.5	4.3	2.7	1.8	5.0
	mean	2.1	2.3	2.0	1.5	1.1	2.1
Annual	min	0.4	0.4	0.5	0.6	0.3	0.3
	max	69.0	18.8	23.2	9.5	7.7	69.0
	mean	2.7	2.7	2.8	1.9	1.4	2.6



Appendix A.2

Dissolved oxygen recorded in the SBOO region during winter (February), spring (May), summer (August), and fall (November) of 2013. Data were collected over three consecutive days during each of these surveys.

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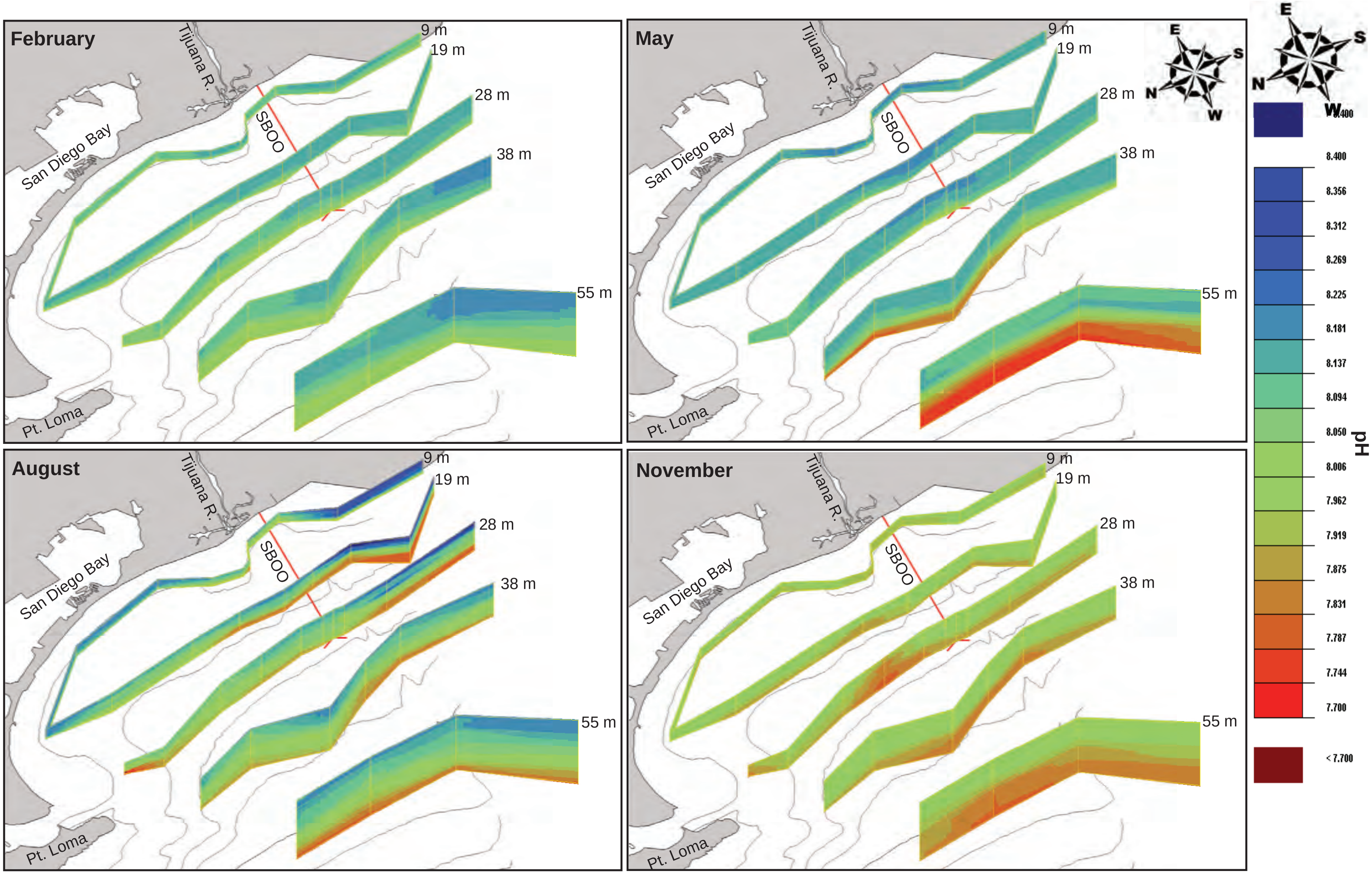

Appendix A.3

pH recorded in the SBOO region during winter (February), spring (May), summer (August), and fall (November) of 2013. Data were collected over three consecutive days during each of these surveys.

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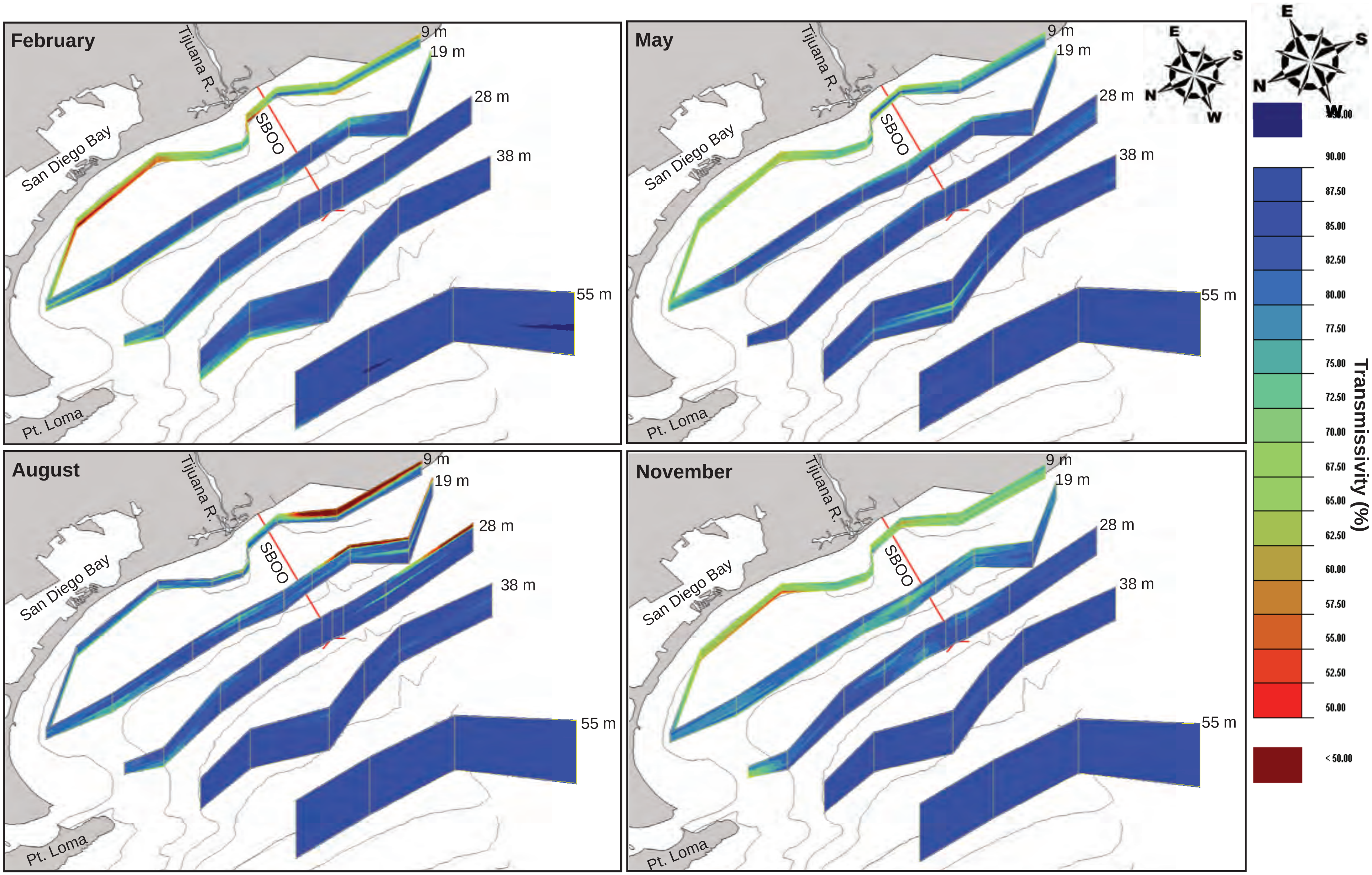

Appendix A.4

Transmissivity recorded in the SBOO region during winter (February), spring (May), summer (August), and fall (November) of 2013. Data were collected over three consecutive days during each of these surveys.

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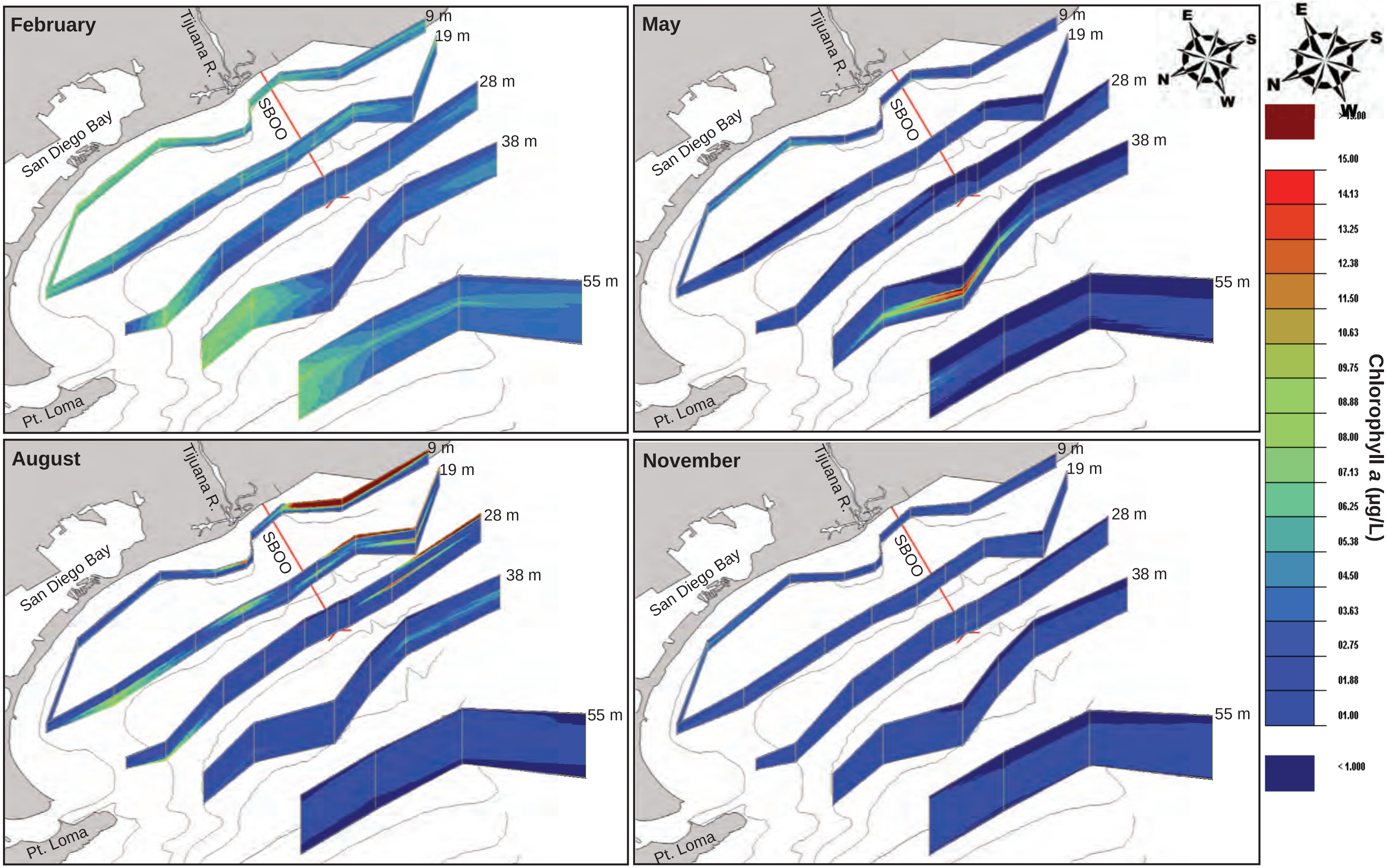

Appendix A.5

Concentrations of chlorophyll *a* recorded in the SBOO region during winter (February), spring (May), summer (August), and fall (November) of 2013. Data were collected over three consecutive days during each of these surveys.

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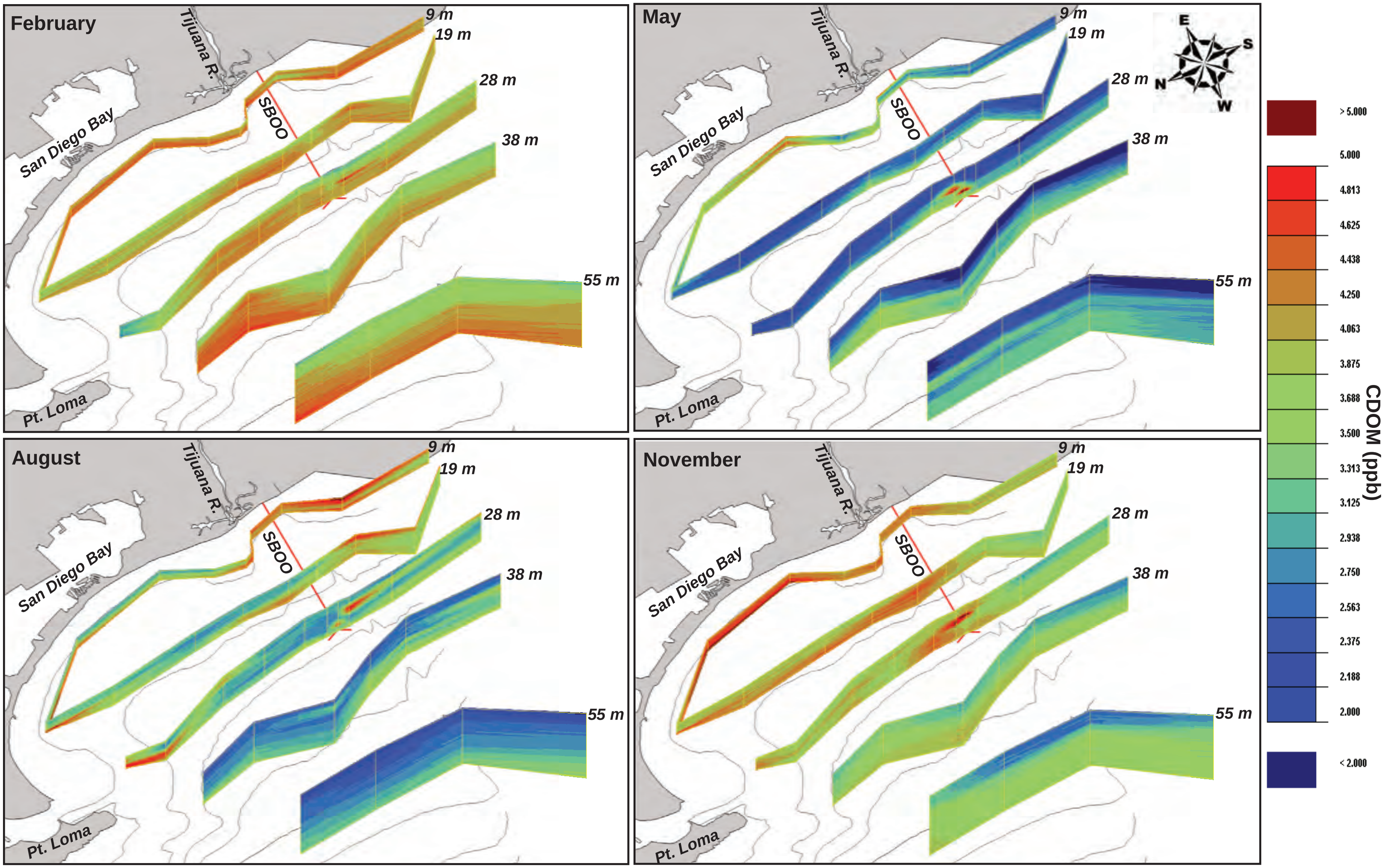
Appendix B

Supporting Data

2013 SBOO Stations

Water Quality Compliance & Plume Dispersion



Appendix B.1

CDOM values recorded in the SBOO region during winter (February), spring (May), summer (August), and fall (November) of 2013. Data were collected over three consecutive days during each of these surveys.

Appendix B.2

Summary of rainfall and bacteria levels at SBOO shore stations during 2013. Total coliform, fecal coliform, and *Enterococcus* densities are expressed as mean CFU/100 mL per month. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed north to south from top to bottom; n = total number of samples.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Rain (in):		1.21	0.63	1.22	0.01	0.26	0.00	0.05	0.00	0.00	0.25	1.48	0.46
S9	*Total*	3	6	2	24	65	20	24	65	60	55	25	9
	Fecal	3	2	2	2	6	2	2	12	7	7	10	3
	Entero	3	2	2	2	2	2	8	14	4	2	20	4
S8	*Total*	6	11	11	13	3256	20	20	16	60	16	16	6
	Fecal	2	2	2	2	142	2	2	2	11	2	2	9
	Entero	2	2	2	2	6	2	2	2	7	5	6	2
S12	*Total*	57	12	4	21	1856	7	20	70	61	34	28	337
	Fecal	4	2	2	5	72	2	12	4	3	9	8	20
	Entero	4	2	2	11	8	2	5	4	4	4	44	9
S6	*Total*	93	14	4002	100	2310	16	17	16	25	16	425	49
	Fecal	8	2	402	11	104	2	3	2	10	3	24	12
	Entero	5	2	29	11	5	2	5	2	4	4	10	4
S11	*Total*	94	252	4056	14	4010	20	88	16	65	14	3012	52
	Fecal	13	11	1353	4	156	2	2	2	8	5	154	12
	Entero	4	3	52	4	10	2	3	2	6	4	26	5
S5	*Total*	4216	4175	3345	56	4015	16	28	16	65	40	4010	4104
	Fecal	2541	3008	3056	5	3002	2	4	4	5	9	3004	2457
	Entero	2491	3002	3010	8	902	2	5	2	4	5	341	2421
S10	*Total*	6120	3626	358	9	20	2	16	20	161	73	56	1117
	Fecal	1140	300	32	2	4	2	2	2	149	21	18	74
	Entero	147	93	3	2	2	2	4	2	6	10	7	5
S4	*Total*	6864	2610	359	33	8	40	50	16	70	14	26	956
	Fecal	330	198	22	4	2	5	20	2	3	4	10	94
	Entero	59	34	4	2	3	10	18	4	4	6	21	20
S3	*Total*	7044	2225	3460	44	376	6	19	16	16	97	42	186
	Fecal	428	41	164	4	54	2	2	4	2	7	18	7
	Entero	110	18	24	5	12	2	2	8	6	9	29	16
S2	*Total*	1520	1605	4004	57	223	6	16	17	6	649	44	150
	Fecal	221	42	3002	4	10	2	2	8	2	111	16	43
	Entero	66	10	3002	2	4	2	2	3	3	40	32	19
S0	*Total*	4272	965	1021	3600	830	86	570	1771	4122	4916	1902	6356
	Fecal	548	116	32	2614	76	14	38	496	288	454	381	978
	Entero	1002	129	100	730	38	2	26	56	194	141	93	490
	n	55	44	44	55	44	44	55	44	44	55	44	55
Monthly Means	*Total*	2776	1409	1841	361	1543	22	79	185	428	539	871	1211
	Fecal	476	339	734	242	330	3	8	49	44	57	332	337
	Entero	354	300	566	71	90	3	7	9	22	21	57	272

Appendix B.3

Summary of elevated bacteria densities in samples collected at SBOO shore stations during 2013. Bold values exceed benchmarks for total coliform (>10,000 CFU/100 mL), fecal coliform (>400 CFU/100 mL), *Enterococcus* (>104 CFU/100 mL), and/or the FTR criterion (total coliform >1000 CFU/100 mL and F:T>0.10).

Station	Date	Total	Fecal	Entero	F:T
S3	2 Jan 13	**>16,000**	**620**	**280**	0.04
S4	2 Jan 13	**>16,000**	**1200**	**200**	0.08
S0	8 Jan 13	**>16,000**	**2400**	**4800**	**0.15**
S2	8 Jan 13	3600	220	**140**	0.06
S3	8 Jan 13	2800	82	**200**	0.03
S4	8 Jan 13	**>16,000**	400	84	0.02
S5	8 Jan 13	**>16,000**	**>12,000**	**>12,000**	**0.75**
S10	8 Jan 13	**>16,000**	**4000**	**180**	**0.25**
S5	15 Jan 13	**4200**	**660**	**420**	**0.16**
S10	15 Jan 13	**7800**	**1400**	**460**	**0.18**
S0	29 Jan 13	4800	260	**150**	0.05
S2	29 Jan 13	—	**740**	**120**	—
S3	29 Jan 13	**>16,000**	**1400**	22	0.09
S4	5 Feb 13	2200	280	56	**0.13**
S5	5 Feb 13	**>16,000**	**>12,000**	**>12,000**	**0.75**
S10	5 Feb 13	**11,000**	**1100**	**340**	0.10
S0	12 Feb 13	2000	160	**380**	0.08
S4	12 Feb 13	3400	380	50	**0.11**
S0	12 Mar 13	3200	100	**380**	0.03
S2	12 Mar 13	**>16,000**	**>12,000**	**>12,000**	**0.75**
S3	12 Mar 13	**13,000**	**620**	32	0.05
S5	19 Mar 13	—	**>12,000**	**>12,000**	—
S6	19 Mar 13	**>16,000**	**1600**	**110**	0.10
S11	19 Mar 13	**>16,000**	**5400**	**200**	**0.34**
S0	16 Apr 13	**>16,000**	**13,000**	**3600**	**0.81**
S5	7 May 13	**>16,000**	**>12,000**	**3600**	**0.75**
S8	7 May 13	**13,000**	**560**	16	0.04
S11	7 May 13	**>16,000**	**620**	36	0.04
S0	28 May 13	1400	160	58	**0.11**
S0	16 Jul 13	2800	180	**120**	0.06
S0	13 Aug 13	6000	**1800**	**120**	**0.30**
S10	10 Sep 13	420	**520**	18	1.24
S0	17 Sep 13	**>16,000**	**1100**	**720**	0.07
S0	15 Oct 13	**>16,000**	**1100**	**320**	0.07
S0	22 Oct 13	5000	**420**	100	0.08
S0	29 Oct 13	3400	**700**	**260**	**0.21**
S2	29 Oct 13	3200	**540**	**180**	**0.17**

Appendix B.3 *continued*

Station	Date	Total	Fecal	Entero	F:T
S2	5 Nov 13	140	60	**120**	0.43
S5	5 Nov 13	20	12	**160**	0.60
S12	5 Nov 13	40	24	**160**	0.60
S0	12 Nov 13	2600	200	**160**	0.08
S0	19 Nov 13	2400	**1200**	**130**	**0.50**
S5	26 Nov 13	**>16,000**	**>12,000**	**1200**	**0.75**
S11	26 Nov 13	**12,000**	**600**	60	0.05
S5	10 Dec 13	**>16,000**	**>12,000**	**>12,000**	**0.75**
S0	17 Dec 13	7400	**740**	**160**	0.10
S0	23 Dec 13	7000	**840**	**360**	**0.12**
S0	30 Dec 13	**>16,000**	**2800**	**1800**	**0.18**

Appendix B.4

Summary of bacteria levels at SBOO kelp bed and other offshore stations during 2013. Total coliform, fecal coliform, and *Enterococcus* densities are expressed as mean CFU/100 mL for all stations along each depth contour by month; n = total number of samples per month.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Rain (in):	1.21	0.63	1.22	0.01	0.26	0.00	0.05	0.00	0.00	0.25	1.48	0.46
Kelp Bed Stations												
9-m Depth Contour (n = 30)												
Total	51	126	92	18	19	4	12	10	4	17	477	25
Fecal	6	10	6	2	2	2	2	2	2	5	78	4
Entero	6	5	3	2	2	2	2	2	2	2	36	2
19-m Depth Contour (n = 15)												
Total	12	4	19	18	30	4	4	15	16	5	121	3
Fecal	2	3	2	2	3	2	2	2	2	3	28	2
Entero	2	2	2	2	2	2	2	2	2	2	10	3
Non-Kelp Bed Stations												
9-m Depth Contour (n = 27)												
Total	295	625	1233	3	1617	6	6	56	10	15	158	1636
Fecal	32	38	32	2	85	2	2	10	2	4	25	350
Entero	11	8	6	2	18	2	2	9	2	5	3	226
19-m Depth Contour (n = 9)												
Total	2	3	2	759	4	2	2	6	2	5	2	6
Fecal	2	2	2	17	2	2	2	3	2	2	2	4
Entero	2	2	2	2	2	2	2	3	2	2	2	2
28-m Depth Contour (n = 24)												
Total	7	15	3	18	18	68	3	4	5	2	3	29
Fecal	2	4	2	4	5	18	2	3	2	2	2	10
Entero	2	2	2	2	2	5	2	2	2	2	2	2
38-m Depth Contour (n = 9)												
Total	2	2	3	4	2	4	2	2	2	2	2	2
Fecal	2	2	2	2	2	2	2	2	2	2	2	2
Entero	2	2	2	2	2	2	2	2	2	2	2	2
55-m Depth Contour (n = 6)												
Total	2	3	2	2	38	2	5	2	2	2	2	2
Fecal	2	2	2	2	7	2	2	2	2	2	2	2
Entero	2	2	2	2	2	2	2	2	2	2	2	2

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Appendix B.5

Summary of elevated bacteria densities in samples collected at SBOO kelp bed stations during 2013. Bold values exceed benchmarks for total coliform (>10,000 CFU/100 mL), fecal coliform (>400 CFU/100 mL), *Enterococcus* (>104 CFU/100 mL), and/or the FTR criterion (total coliform >1000 CFU/100 mL and F:T >0.10).

Station	Date	Depth (m)	Total	Fecal	Entero	F:T
I25	2 Nov 13	2	1500	**480**	2	**0.32**
I26	24 Nov 13	6	3000	**520**	**400**	**0.17**
I26	24 Nov 13	9	6200	**580**	**400**	0.09

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Appendix B.6

Summary of total suspended solid (TSS) and oil and grease (O&G) concentrations in samples collected from the SBOO kelp bed and other offshore stations during 2013. Data include the number samples per month (n) and detection rate, as well as the minimum, maximum, and mean of detected concentrations for each month. The method detection limit = 0.2 mg/L for both TSS and O&G.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013 Kelp Bed Stations												
Total Suspended Solids (n = 9)												
Detection Rate (%)	100	100	100	100	89	100	100	100	100	100	100	100
Min	2.33	1.79	2.90	2.90	nd	1.60	2.00	1.40	1.60	2.80	4.10	4.10
Max	4.86	6.09	9.00	9.60	2.60	7.10	7.80	4.90	7.50	7.20	12.00	10.70
Mean	3.35	3.44	4.87	6.21	2.09	3.32	3.96	2.62	3.60	5.18	5.68	8.19
Oil and Grease (n = 3)												
Detection Rate (%)	0	0	0	0	0	0	0	0	0	0	0	0
Min	—	—	—	—	—	—	—	—	—	—	—	—
Max	—	—	—	—	—	—	—	—	—	—	—	—
Mean	—	—	—	—	—	—	—	—	—	—	—	—
2013 Non-Kelp Bed Stations												
Total Suspended Solids (n = 75)												
Detection Rate (%)	95	77	99	95	85	89	88	79	92	100	100	99
Min	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.00	2.00	nd
Max	8.43	17.30	17.20	16.10	13.00	12.60	18.20	46.70	23.40	13.80	11.10	11.50
Mean	3.26	3.88	4.58	4.74	3.61	3.93	3.93	4.86	4.53	5.30	4.00	4.60
Oil and Grease (n = 25)												
Detection Rate (%)	0	0	0	0	0	0	0	20	12	0	0	0
Min	—	—	—	—	—	—	—	nd	nd	—	—	—
Max	—	—	—	—	—	—	—	3.80	2.30	—	—	—
Mean	—	—	—	—	—	—	—	2.52	1.97	—	—	—

nd = not detected

Appendix B.7

Summary of elevated bacteria densities in samples collected at SBOO non-kelp bed offshore stations during 2013. Bold values exceed benchmarks for total coliform (>10,000 CFU/100 mL), fecal coliform (>400 CFU/100 mL), *Enterococcus* (>104 CFU/100 mL), and/or the FTR criterion (total coliform>1000 CFU/100 mL and F:T>0.10).

Station	Date	Depth (m)	Total	Fecal	Entero	F:T
I19	9 Jan 13	6	2400	**440**	96	**0.18**
I19	6 Feb 13	2	**14,000**	**560**	84	0.04
I19	6 Feb 13	6	2200	360	26	**0.16**
I40	12 Mar 13	2	**>16,000**	240	8	0.02
I32	7 May 13	2	**>16,000**	**800**	92	0.05
I32	7 May 13	6	**13,000**	**700**	**120**	0.05
I32	7 May 13	9	**14,000**	**680**	**220**	0.05
I5	6 Nov 13	6	3400	**460**	34	**0.14**
I5	6 Dec 13	2	**11,000**	**1800**	**3000**	**0.16**
I5	6 Dec 13	6	**>16,000**	**3600**	**1600**	**0.22**
I5	6 Dec 13	11	**>16,000**	**3600**	**1300**	**0.22**

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Appendix B.8

Summary of SBOO reference stations used during 2013 to calculate out-of-range thresholds for wastewater plume detection.

Month	Stations
January	I1, I2, I3, I7, I8, I9, I10, I13, I20, I21, I28, I29, I30, I31, I35
February	I1, I2, I3, I7, I8, I9, I13, I14, I15, I16, I17, I18, I20, I21, I22, I28, I31, I34
March	I1, I7, I13, I14, I15, I16, I17, I18, I20, I21, I22, I23, I27, I28, I29, I39
April	I1, I2, I3, I7, I8, I9, I10, I13, I20, I21, I28
May	I1, I2, I3, I7, I8, I9, I10, I13, I18, I20, I21, I27, I28, I30, I31, I33, I34, I35, I39
June	I1, I2, I3, I7, I8, I13, I14, I15, I20, I21, I31, I34
July	I1, I2, I3, I7, I8, I10, I13, I14, I15, I16, I17, I20, I21, I27
August	I1, I7, I8, I13, I14, I15, I17, I20, I21, I22, I27, I28, I29, I31, I33
September	I1, I2, I3, I7, I13, I14, I20, I21, I22, I27, I28, I29, I30, I33
October	I1, I2, I3, I7, I8, I9, I10, I13, I14, I16, I17, I20, I21, I22, I28
November	I1, I2, I3, I7, I8, I9, I10, I13, I17, I20, I21, I27, I28, I29, I33, I34
December	I2, I3, I7, I8, I9, I10, I13, I18, I20, I21, I23, I28

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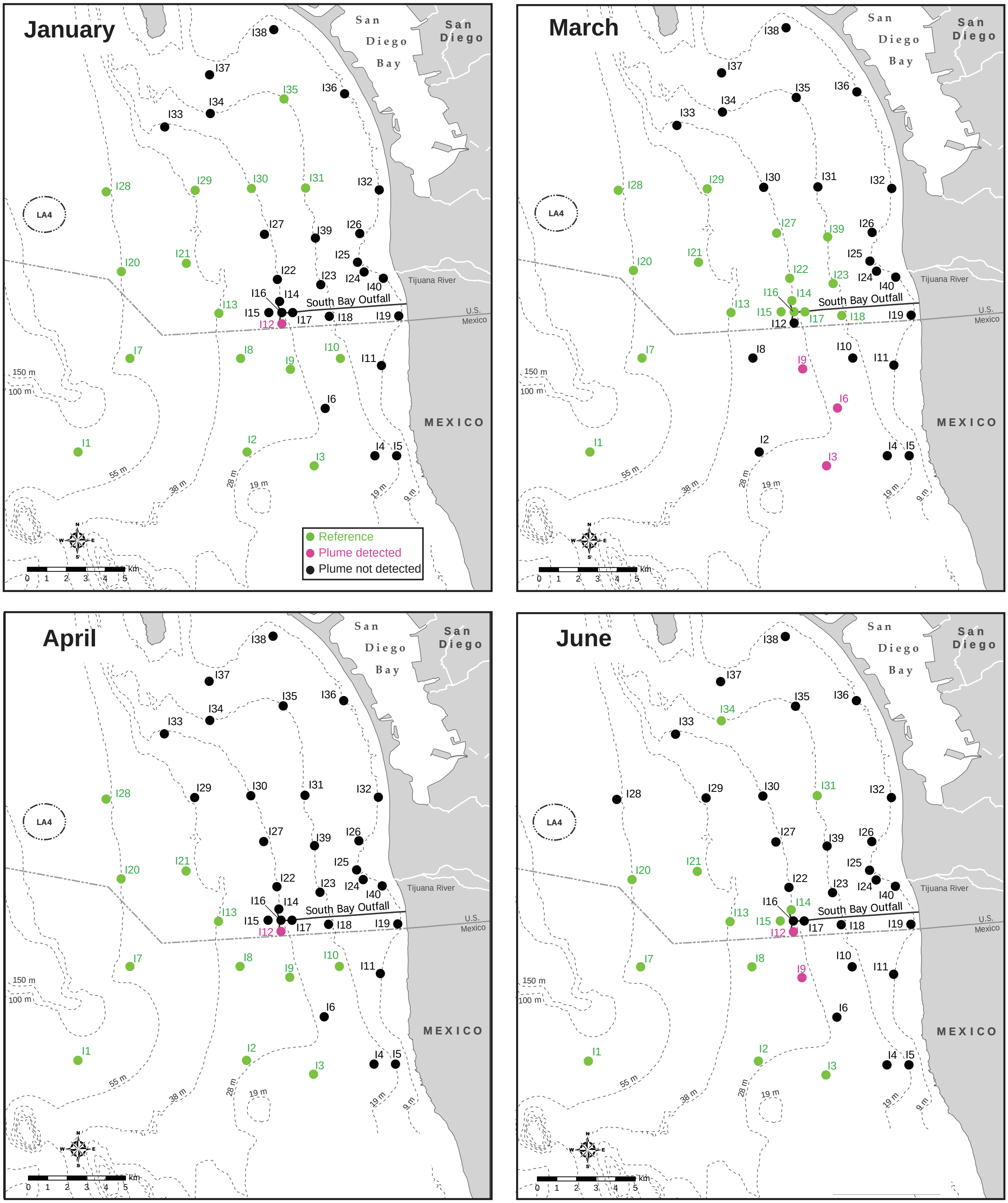
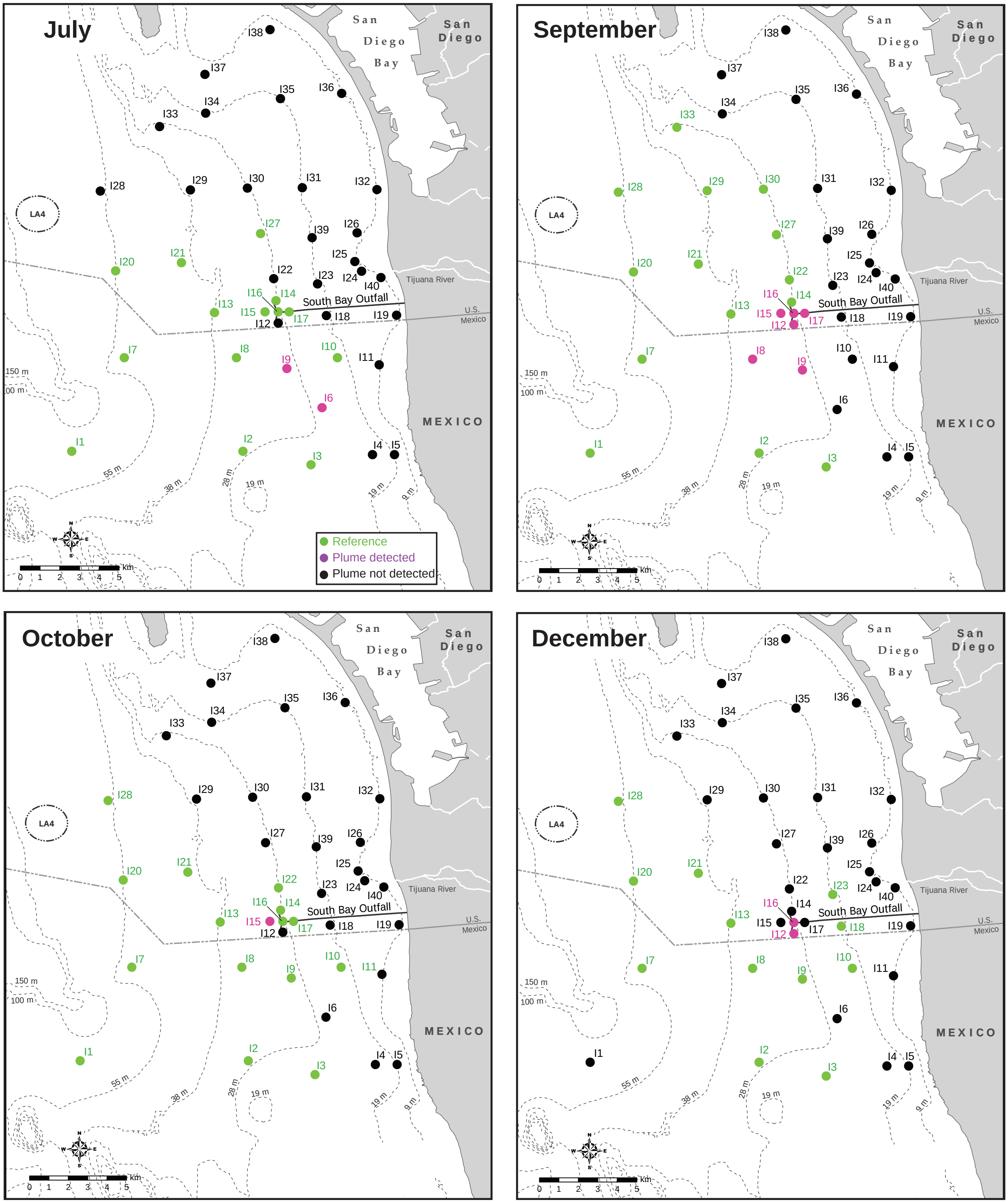
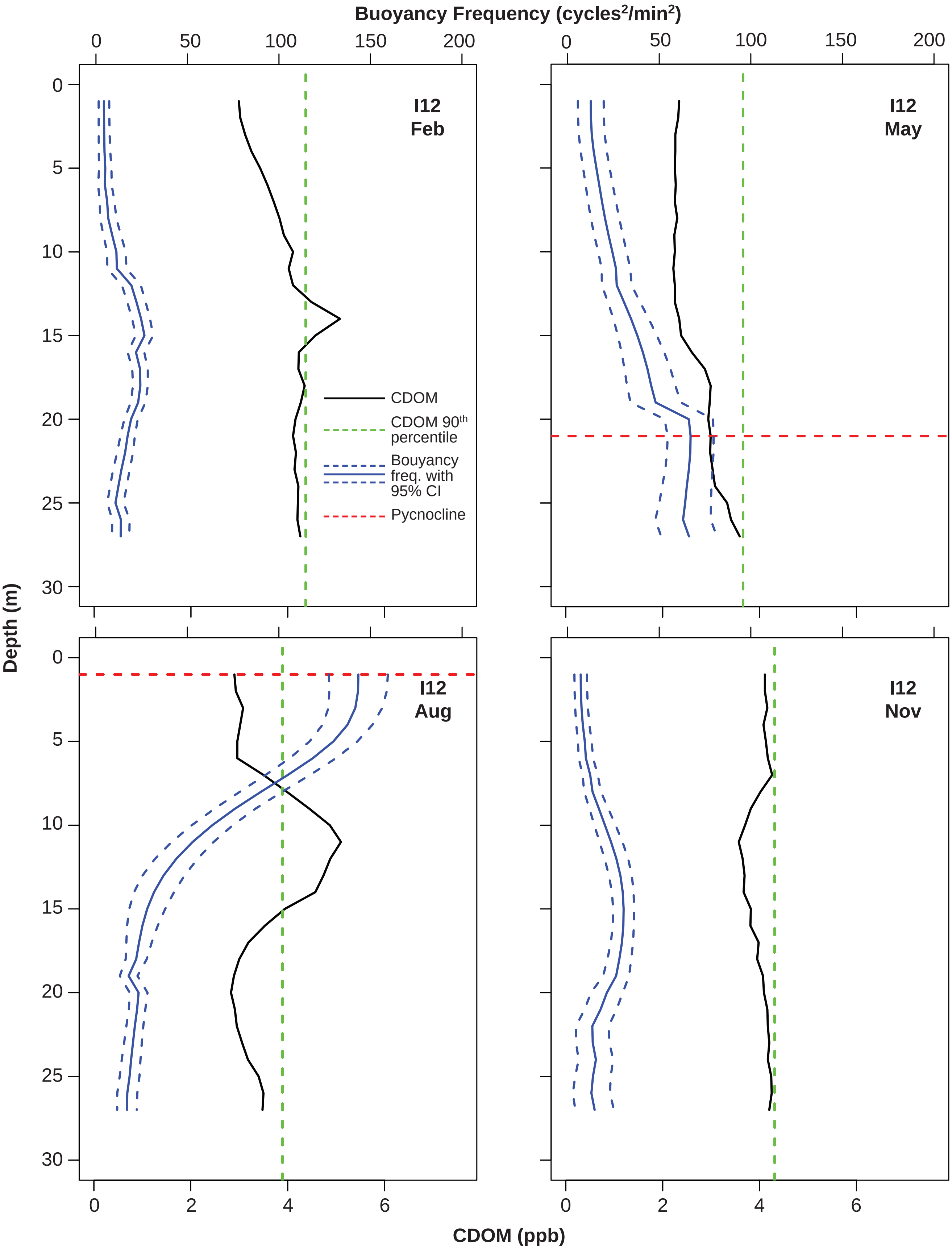


Appendix B.9

Distribution of stations where wastewater plume was detected (pink) and those used as reference stations for water quality compliance calculations (green) during selected SBOO monthly surveys in 2013.



Appendix B.9 *continued*



Appendix B.10

Representative vertical profiles of CDOM and buoyancy frequency from outfall station I12 during 2013.

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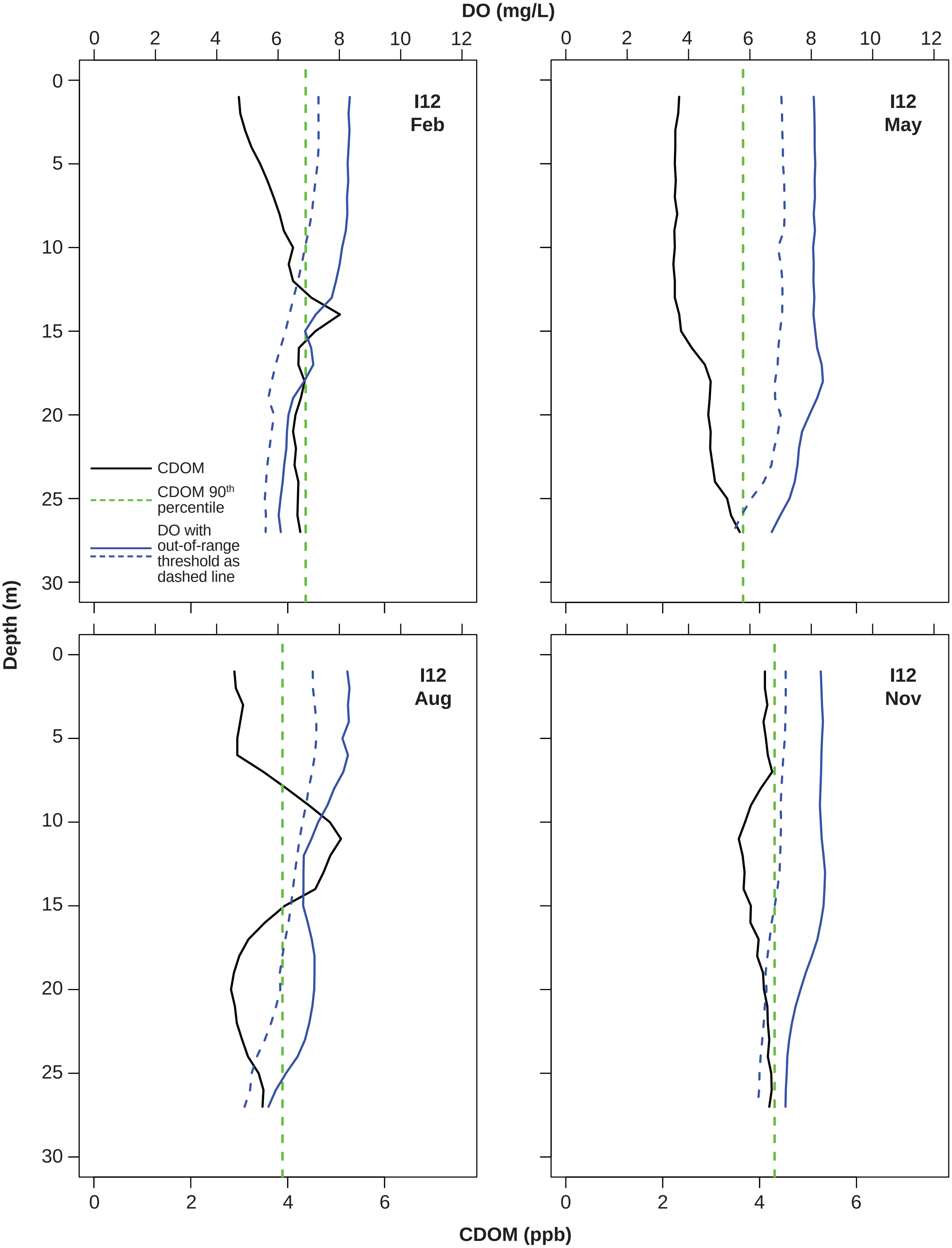
Appendix B.11

Summary of oceanographic data within detected plume at SBOO offshore stations and corresponding reference stations during 2013. Bold values indicate out-of-range values. DO = dissolved oxygen; XMS = transmissivity; SD = standard deviation; CI = confidence interval.

			Plume			Reference		
Station	Date	Plume Width (m)	Mean DO	Mean pH	Mean XMS	DO (Mean - SD)	pH (Mean - SD)	XMS (Mean - 95% CI)
I12	9 Jan 13	4	6.6	8.03	**85.0**	7.0	8.10	85.0
I12	6 Feb 13	3	7.3	8.11	**85.3**	7.1	8.11	85.9
I3	7 Mar 13	1	9.0	8.21	**81.9**	7.3	8.07	81.9
I6	7 Mar 13	2	8.4	8.18	**82.5**	5.7	7.95	84.2
I9	7 Mar 13	2	8.1	8.16	**84.0**	5.7	7.95	84.2
I12	12 Mar 13	3	5.1	7.90	87.1	5.3	7.92	84.6
I12	4 Apr 13	1	4.5	7.81	87.4	4.2	7.83	86.3
I15	9 May 13	3	7.3	8.09	86.2	7.4	8.06	83.9
I16	9 May 13	2	7.0	8.05	85.4	7.5	8.08	83.8
I29	7 May 13	1	7.6	8.08	84.5	7.4	8.07	83.6
I9	6 Jun 13	2	**5.6**	7.89	**81.8**	6.3	7.93	85.4
I12	5 Jun 13	5	7.4	8.02	**83.2**	6.4	7.94	85.0
I6	11 Jul 13	1	7.9	8.13	**85.1**	7.2	8.08	85.3
I9	11 Jul 13	3	7.7	8.11	86.6	7.2	8.09	85.4
I9	20 Aug 13	1	8.6	8.15	**84.5**	7.8	8.09	86.0
I12	21 Aug 13	8	7.1	8.04	**86.0**	7.4	8.06	86.5
I16	21 Aug 13	4	6.7	8.00	**86.8**	6.5	7.99	87.4
I8	4 Sep 13	1	9.3	8.17	86.3	7.5	8.02	83.4
I9	4 Sep 13	11	8.6	8.11	86.4	9.0	8.14	85.8
I12	5 Sep 13	8	8.7	8.12	86.9	8.4	8.08	84.6
I15	5 Sep 13	6	8.2	8.08	86.9	8.2	8.07	84.3
I16	5 Sep 13	3	8.8	8.13	86.3	9.0	8.13	85.5
I17	5 Sep 13	1	9.1	8.15	85.9	9.1	8.14	85.7

Appendix B.11 *continued*

			Plume			Reference		
Station	**Date**	**Plume Width (m)**	**Mean DO**	**Mean pH**	**Mean XMS**	**DO (Mean - SD)**	**pH (Mean - SD)**	**XMS (Mean - 95% CI)**
I15	1 Oct 13	1	8.8	8.10	88.3	7.8	8.03	85.7
I14	7 Nov 13	6	8.0	7.97	**83.3**	7.7	7.94	84.9
I15	7 Nov 13	8	7.8	7.96	**82.7**	7.7	7.94	84.8
I16	7 Nov 13	5	8.0	7.98	**82.6**	7.7	7.95	84.9
I22	7 Nov 13	12	6.9	7.89	**78.9**	7.2	7.89	85.7
I23	7 Nov 13	4	7.3	7.92	**78.2**	7.3	7.90	85.5
I12	5 Dec 13	11	7.8	8.10	86.6	7.9	8.09	85.1
I16	5 Dec 13	5	7.7	8.08	85.5	7.9	8.09	85.1



Appendix B.12

Representative vertical profiles of CDOM and dissolved oxygen (DO) from outfall station I12 during 2013.

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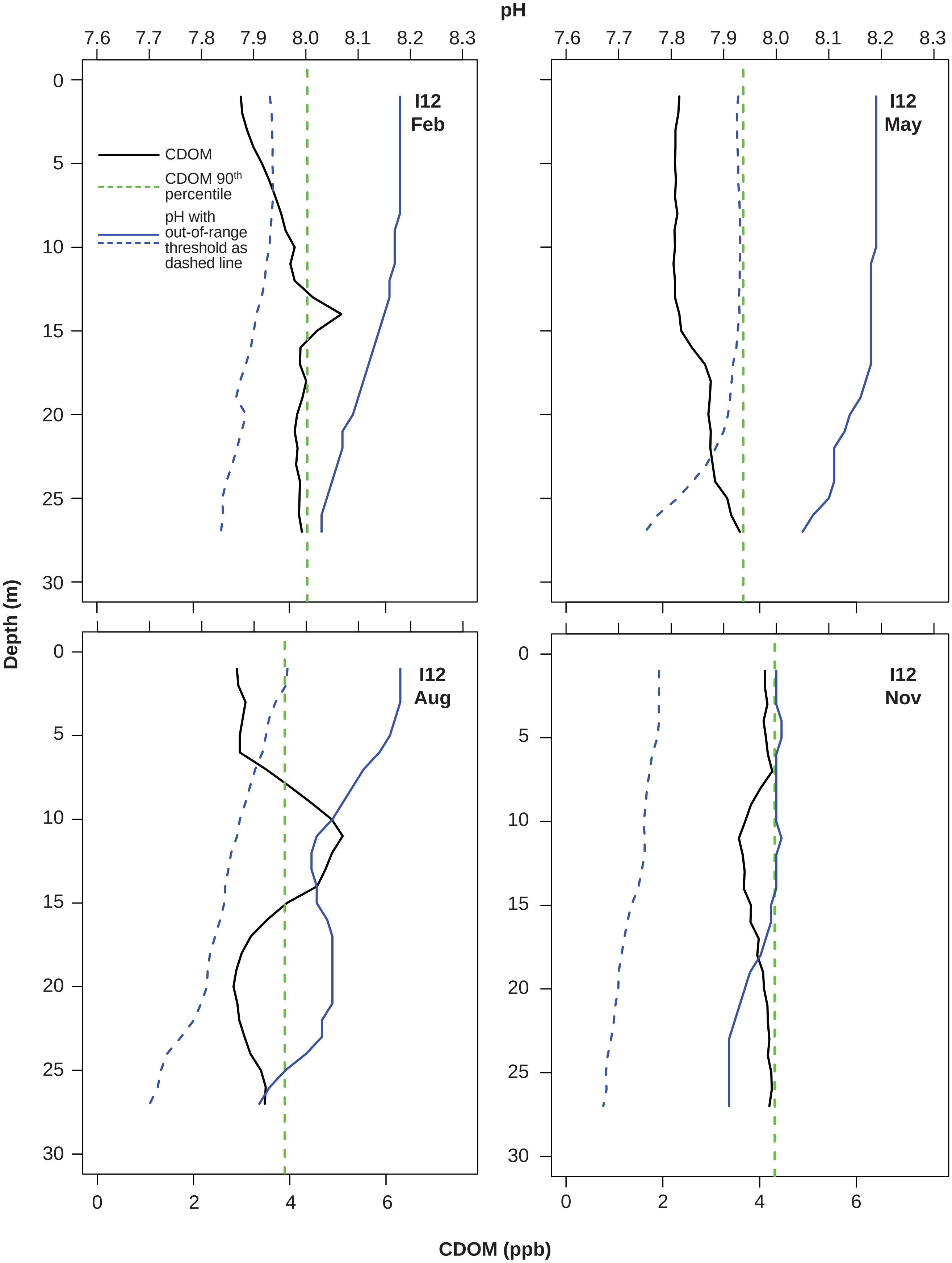

Appendix B.13

Representative vertical profiles of CDOM and pH from outfall station I12 during 2013.

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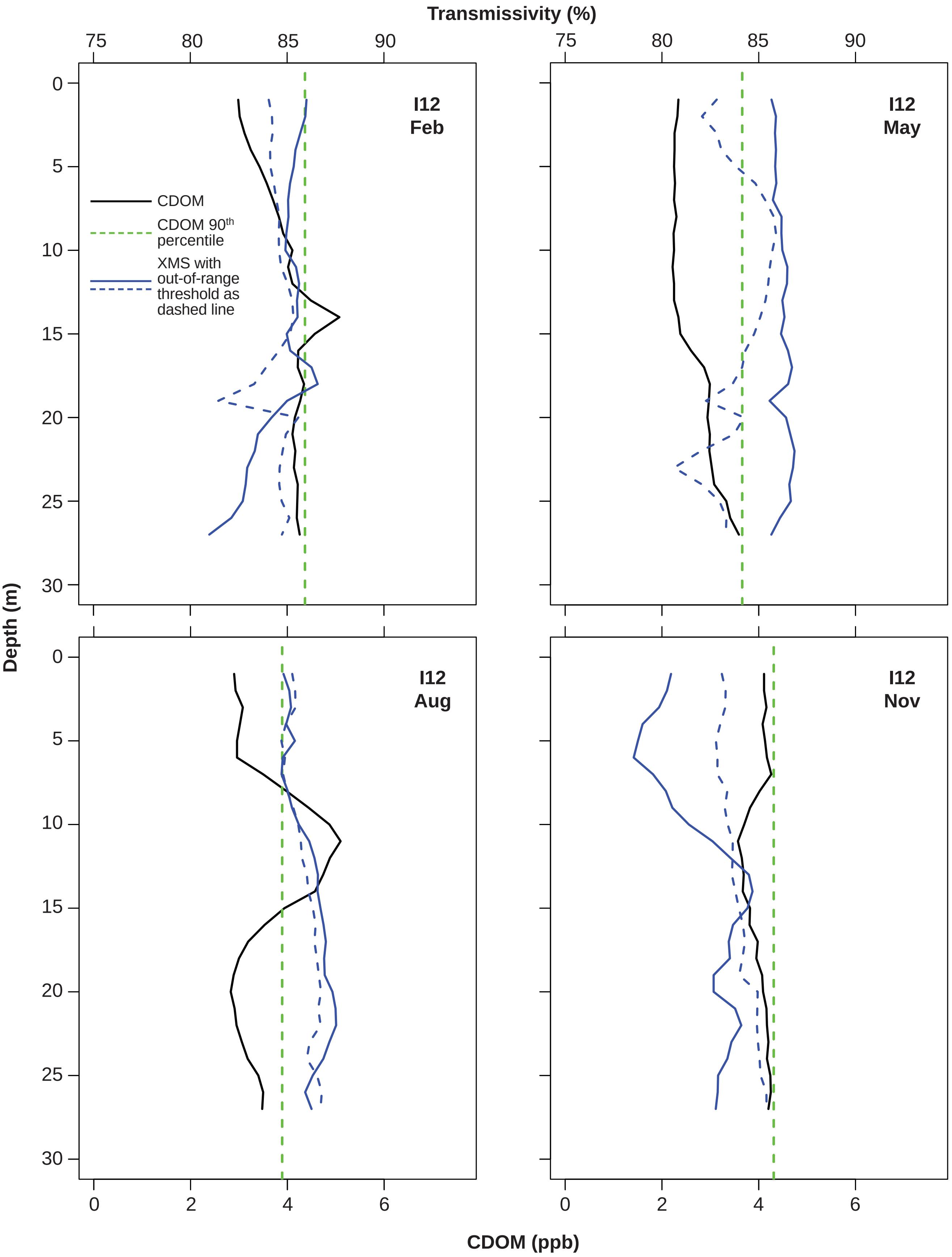

Appendix B.14

Representative vertical profiles of CDOM and transmissivity from outfall station I12 during 2013. XMS = transmissivity.

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Appendix C

Supporting Data

2013 SBOO Stations

Sediment Conditions

Appendix C.1

Constituents and method detection limits (MDL) used for the analysis of sediments collected from the SBOO region during 2013.

Parameter	MDL	Parameter	MDL
Organic Indicators			
Total Nitrogen (TN, % wt.)	0.005	Total Sulfides (ppm)	0.14
Total Organic Carbon (TOC, % wt.)	0.01	Total Volatile Solids (TVS, % wt.)	0.11
Metals (ppm)			
Aluminum (Al)	2	Lead (Pb)	0.8
Antimony (Sb)	0.3	Manganese (Mn)	0.08
Arsenic (As)	0.33	Mercury (Hg)	0.004
Barium (Ba)	0.02	Nickel (Ni)	0.1
Beryllium (Be)	0.01	Selenium (Se)	0.24
Cadmium (Cd)	0.06	Silver (Ag)	0.04
Chromium (Cr)	0.1	Thallium (Ti)	0.5
Copper (Cu)	0.2	Tin (Sn)	0.3
Iron (Fe)	9	Zinc (Zn)	0.25
Chlorinated Pesticides (ppt)[a]			
Hexachlorocyclohexane (HCH)			
HCH, Alpha isomer	150, 100	HCH, Delta isomer	700, 220
HCH, Beta isomer	310, 50	HCH, Gamma isomer	260, 190
Total Chlordane			
Alpha (cis) Chlordane	240, 160	Heptachlor epoxide	120, 300
Cis Nonachlor	240, 380	Methoxychlor	1100, 90
Gamma (trans) Chlordane	350, 190	Oxychlordane	240, 1200
Heptachlor	1200, 120	Trans Nonachlor	250, 240
Total Dichlorodiphenyltrichloroethane (DDT)			
o,p-DDD	830, 100	p,p-DDE	260, 90
o,p-DDE	720, 60	p,p-DDMU[b]	—
o,p-DDT	800, 110	p,p-DDT	800, 70
p,p-DDD	470, 160		
Miscellaneous Pesticides			
Aldrin	430, 70	Endrin	830, 510
Alpha Endosulfan	240, 720	Endrin aldehyde	830, 2400
Beta Endosulfan	350, 780	Hexachlorobenzene (HCB)	470, 70
Dieldrin	310, 340	Mirex	500, 60
Endosulfan Sulfate	260, 1100		

[a] MDL values reported separately for winter and summer 2013

[b] No MDL available for this parameter

Appendix C.1 *continued*

Parameter	MDL	Parameter	MDL
Polychlorinated Biphenyl Congeners (PCBs) (ppt)[a]			
PCB 18	540, 90	PCB 126	720, 70
PCB 28	660, 60	PCB 128	570, 80
PCB 37	340, 90	PCB 138	590, 80
PCB 44	890, 100	PCB 149	500, 110
PCB 49	850, 70	PCB 151	640, 80
PCB 52	1000, 90	PCB 153/168	600, 150
PCB 66	920, 100	PCB 156	620, 90
PCB 70	1100, 60	PCB 157	700, 100
PCB 74	900, 100	PCB 158	510, 70
PCB 77	790, 110	PCB 167	620, 30
PCB 81	590, 130	PCB 169	610, 90
PCB 87	600, 200	PCB 170	570, 80
PCB 99	660, 120	PCB 177	650, 70
PCB 101	430, 100	PCB 180	530, 80
PCB 105	720, 50	PCB 183	530, 60
PCB 110	640, 110	PCB 187	470, 110
PCB 114	700, 130	PCB 189	620, 60
PCB 118	830, 90	PCB 194	420, 80
PCB 119	560, 80	PCB 201	530, 70
PCB 123	660, 130	PCB 206	510, 50
Polycyclic Aromatic Hydrocarbons (PAHs) (ppb)			
1-methylnaphthalene	20	Benzo[G,H,I]perylene	20
1-methylphenanthrene	20	Benzo[K]fluoranthene	20
2,3,5-trimethylnaphthalene	20	Biphenyl	30
2,6-dimethylnaphthalene	20	Chrysene	40
2-methylnaphthalene	20	Dibenzo(A,H)anthracene	20
3,4-benzo(B)fluoranthene	20	Fluoranthene	20
Acenaphthene	20	Fluorene	20
Acenaphthylene	30	Indeno(1,2,3-CD)pyrene	20
Anthracene	20	Naphthalene	30
Benzo[A]anthracene	20	Perylene	30
Benzo[A]pyrene	20	Phenanthrene	30
Benzo[e]pyrene	20	Pyrene	20

[a] MDL values reported separately for winter and summer 2013

Appendix C.2

Particle size classification schemes (based on Folk 1980) used in the analysis of sediments collected from the SBOO region in 2013. Included is a subset of the Wentworth scale presented as "phi" categories with corresponding Horiba channels, sieve sizes, and size fractions.

Wentworth Scale

	Horiba[a]				
Phi Size	**Min µm**	**Max µm**	**Sieve Size[b]**	**Sub-Fraction**	**Fraction[c]**
-1	—	—	SIEVE_2000	Granules	Coarse Particles
0	1100	2000	SIEVE_1000	Very coarse sand	Coarse Particles
1	590	1000	SIEVE_500	Coarse sand	Med-Coarse Sands
2	300	500	SIEVE_250	Medium sand	Med-Coarse Sands
3	149	250	SIEVE_125	Fine sand	Fine Sands
4	64	125	SIEVE_63	Very fine sand	Fine Sands
5	32	62.5	SIEVE_0	Coarse silt	Fine Particles
6	16	31	—	Medium silt	Fine Particles
7	8	15.6	—	Fine silt	Fine Particles
8	4	7.8	—	Very fine silt	Fine Particles
9	≤	3.9	—	Clay	Fine Particles

[a] values correspond to Horiba channels; particles >2000 µm measured by sieve

[b] SIEVE_0 = sum of all silt and clay, which cannot be distinguished for samples processed by nested sieves

[c] Fine particles also referred to as percent fines

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Appendix C.3

Summary of the constituents that make up total DDT, total HCH, total chlordane, total PCB, and total PAH in sediments from the SBOO region during 2013.

Station	Class	Constituent	Winter	Summer	Units
I1	DDT	p,p-DDE	nd	110	ppt
I2	PCB	PCB 18	nd	79	ppt
I2	PCB	PCB 28	nd	150	ppt
I2	PCB	PCB 37	nd	150	ppt
I2	PCB	PCB 66	nd	210	ppt
I2	PCB	PCB 70	nd	210	ppt
I2	PCB	PCB 74	nd	110	ppt
I3	DDT	p,p-DDE	nd	430	ppt
I9	DDT	p,p-DDE	nd	245	ppt
I12	DDT	p,p-DDE	190	130	ppt
I14	DDT	p,p-DDE	nd	350	ppt
I14	PCB	PCB 66	nd	66	ppt
I14	PCB	PCB 110	nd	110	ppt
I14	PCB	PCB 138	nd	98	ppt
I14	PCB	PCB 153/168	nd	110	ppt
I16	PAH	2,6-dimethylnaphthalene	nd	9.37	ppb
I20	HCH	HCH, Alpha isomer	790	nd	ppt
I20	HCH	HCH, Beta isomer	490	nd	ppt
I20	CHLORDANE	Heptachlor	410	nd	ppt
I20	DDT	p,p-DDE	340	nd	ppt
I22	CHLORDANE	Heptachlor	nd	120	ppt
I22	DDT	p,p-DDD	nd	210	ppt
I22	DDT	p,p-DDE	240	280	ppt
I22	DDT	p,p-DDT	nd	130	ppt
I22	PCB	PCB 28	91	nd	ppt
I22	PCB	PCB 37	92	nd	ppt
I22	PCB	PCB 44	70	nd	ppt
I22	PCB	PCB 49	98	nd	ppt
I22	PCB	PCB 52	110	nd	ppt
I22	PCB	PCB 66	92	nd	ppt
I22	PCB	PCB 70	89	nd	ppt
I22	PCB	PCB 74	85	nd	ppt

nd = not detected

Appendix C.3 *continued*

Station	Class	Constituent	Winter	Summer	Units
I23	DDT	p,p-DDE	nd	440	ppt
I27	DDT	p,p-DDE	125	86	ppt
I28	DDT	p,p-DDE	1500	450	ppt
I28	DDT	p,p-DDT	570	180	ppt
I28	PAH	2,6-dimethylnaphthalene	nd	13.1	ppb
I28	PCB	PCB 66	nd	89	ppt
I28	PCB	PCB 70	nd	99	ppt
I28	PCB	PCB 101	nd	180	ppt
I28	PCB	PCB 110	nd	200	ppt
I28	PCB	PCB 138	130	180	ppt
I28	PCB	PCB 149	nd	170	ppt
I28	PCB	PCB 153/168	140	240	ppt
I28	PCB	PCB 180	nd	260	ppt
I29	DDT	p,p-DDE	110	770	ppt
I29	PAH	2,6-dimethylnaphthalene	nd	12.3	ppb
I29	PAH	Benzo[A]pyrene	nd	10.5	ppb
I29	PAH	Pyrene	nd	11.4	ppb
I30	DDT	p,p-DDE	130	120	ppt
I33	DDT	p,p-DDE	nd	70	ppt
I33	PAH	3,4-benzo(B)fluoranthene	nd	25.1	ppb
I33	PAH	Benzo[A]anthracene	nd	31.5	ppb
I33	PAH	Benzo[A]pyrene	nd	18.5	ppb
I33	PAH	Chrysene	nd	17.6	ppb
I33	PAH	Fluoranthene	nd	39.4	ppb
I33	PAH	Phenanthrene	nd	29.4	ppb
I33	PAH	Pyrene	nd	36.7	ppb
I34	DDT	p,p-DDE	nd	75	ppt
I35	DDT	p,p-DDE	280	120	ppt
I35	PAH	2,6-dimethylnaphthalene	nd	18.5	ppt

nd = not detected

Appendix C.4

Summary of particle size parameters with sub-fractions (%) for each SBOO station sampled during winter 2013. Visual observations are from sieved “grunge” (i.e., particles retained on 1-mm mesh screen and preserved with infauna for benthic community analysis). VCSand = Very Coarse Sand; CSand = Coarse Sand; MSand = Medium Sand; FSand = Fine Sand; VFSand = Very Fine Sand; CSilt = Coarse Silt; MSilt = Medium Silt; Silt = Fine Silt; VFSilt = Very Fine Silt.

		Coarse Particles		Coarse Sand		Fine Sand		Fine Particles					Visual Observations
		Granules	VCSand	CSand	MSand	FSand	VFSand	CSilt	MSilt	FSilt	VFSilt	Clay	
19-m Stations	I35	0.0	0.0	0.1	2.8	16.2	38.1	23.7	9.6	5.1	2.7	1.9	organic debris[b]
	I34[s]	25.7	15.4	16.1	25.4	14.2	0.5	2.7	—	—	—	—	gravel/shell hash
	I31	0.0	0.0	0.0	2.0	25.1	60.5	7.9	1.7	1.5	1.0	0.2	organic debris[b]
	I23	0.0	0.0	0.1	3.5	26.0	54.4	9.8	2.5	2.1	1.3	0.4	shell hash/organic debris[b]
	I18	0.0	0.0	0.0	2.2	24.9	60.2	8.8	1.5	1.3	0.9	0.1	
	I10	0.0	0.0	0.0	2.5	28.5	57.1	7.8	1.7	1.4	0.9	0.1	
	I4	0.0	0.0	0.1	3.7	25.4	56.6	10.3	1.7	1.3	0.8	0.1	shell hash/organic debris
28-m Stations	I33	0.0	0.0	0.1	4.7	35.6	41.1	7.1	4.2	3.9	2.3	1.0	organic debris[b]
	I30	0.0	0.0	0.0	1.0	16.0	60.5	15.6	2.7	2.1	1.5	0.6	organic debris[b]
	I27	0.0	0.0	0.0	1.8	17.8	57.3	15.2	3.1	2.4	1.6	0.8	
	I22	0.0	0.0	0.1	4.4	26.9	47.6	12.1	3.5	2.9	1.8	0.7	organic debris[b]
	I14[a]	0.0	0.0	0.0	2.1	20.4	56.5	13.7	2.9	2.4	1.5	0.6	organic debris[b]
	I16[a]	0.0	0.1	8.1	24.7	40.3	19.2	3.6	1.5	1.5	0.9	0.1	organic debris[b]
	I15[a]	0.0	0.0	3.8	33.3	37.3	16.9	5.4	1.4	1.1	0.7	0.0	organic debris[b]
	I12[a]	0.0	0.0	0.0	3.9	32.8	47.0	9.7	2.5	2.1	1.4	0.4	organic debris[b]
	I9	0.0	0.0	0.1	2.0	16.8	57.7	17.5	2.6	1.7	1.2	0.5	organic debris[b]
	I6	0.0	4.3	28.2	44.3	16.7	4.1	1.5	0.6	0.3	0.0	0.0	shell hash/organic debris[b]
	I2	0.0	3.1	17.2	44.9	31.0	2.8	0.2	0.3	0.5	0.0	0.0	
	I3	0.0	8.4	58.8	28.2	4.5	0.1	0.0	0.0	0.0	0.0	0.0	shell hash
38-m Stations	I29	0.0	0.0	0.1	12.2	33.3	19.1	12.2	8.4	7.6	4.7	2.4	red relict sand/shell hash
	I21	0.0	3.8	39.3	46.6	9.1	1.1	0.0	0.0	0.0	0.0	0.0	shell hash/organic debris[b]
	I13	0.0	3.4	26.9	45.8	17.2	3.7	0.9	0.7	0.8	0.5	0.0	shell hash
	I8	0.0	3.4	21.5	47.5	23.2	3.0	0.3	0.3	0.6	0.1	0.0	
55-m Stations	I28[s]	9.5	11.1	26.2	17.9	5.5	26.8	3.0	—	—	—	—	black sand
	I20	0.0	9.5	60.3	23.8	6.0	0.4	0.0	0.0	0.0	0.0	0.0	
	I7	0.0	8.4	51.2	27.1	6.4	1.6	0.9	1.3	1.7	1.2	0.1	red relict sand/shell hash
	I1	0.0	0.0	0.1	7.4	46.1	34.6	4.6	2.3	2.6	1.7	0.6	

[a] nearfield stations; [b] contained worm tubes; [s] measured by sieve (not Horiba; silt and clay fractions are indistinguishable)

Appendix C.4 *continued*

Summary of particle size parameters with sub-fractions (%) for each SBOO station sampled during summer 2013. Visual observations are from sieved “grunge” (i.e., particles retained on 1-mm mesh screen and preserved with infauna for benthic community analysis). VCSand = Very Coarse Sand; CSand = Coarse Sand; MSand = Medium Sand; FSand = Fine Sand; VFSand = Very Fine Sand; CSilt = Coarse Silt; MSilt = Medium Silt; FSilt = Fine Silt; VFSilt = Very Fine Silt.

		Coarse Particles		**Coarse Sand**		**Fine Sand**		**Fine Particles**					**Visual Observations**
		Granules	**VCSand**	**CSand**	**MSand**	**FSand**	**VFSand**	**CSilt**	**MSilt**	**FSilt**	**VFSilt**	**Clay**	
19-m Stations	I35	0.0	0.0	0.0	2.3	15.1	40.8	23.2	8.2	5.8	2.9	1.6	shell hash/organic debris[b]
	I34	0.0	0.0	3.3	33.8	48.7	7.3	1.5	1.5	2.3	1.3	0.1	shell hash
	I31	0.0	0.0	0.0	1.9	21.6	62.0	8.7	1.7	2.2	1.4	0.4	
	I23	0.0	0.0	0.1	2.4	20.2	57.8	12.4	2.6	2.5	1.4	0.5	shell hash/organic debris[b]/algae
	I18	0.0	0.0	0.0	2.1	21.0	60.6	10.9	1.9	2.0	1.2	0.2	organic debris[b]
	I10	0.0	0.0	0.1	3.1	25.0	57.0	9.3	2.0	2.1	1.2	0.2	organic debris[b]
	I4	0.0	0.0	0.1	4.8	24.6	54.1	10.4	2.1	2.2	1.3	0.4	shell hash/organic debris[b]
28-m Stations	I33	0.0	0.0	0.1	4.0	33.0	43.9	6.4	3.1	5.0	3.2	1.2	organic debris[b]/phyllospadix
	I30	0.0	0.0	0.1	1.9	14.1	54.3	16.6	3.9	4.7	3.0	1.4	organic debris[b]
	I27	0.0	0.0	0.0	1.8	15.3	59.2	15.4	2.8	2.9	1.8	0.7	organic debris[b]
	I22	0.0	0.0	0.1	3.6	21.4	50.3	14.0	3.5	3.8	2.3	1.0	organic debris[b]
	I14[a]	0.0	0.0	0.1	2.7	17.1	55.1	15.2	3.2	3.5	2.1	1.0	organic debris[b]
	I16[a]	0.0	0.0	0.4	7.3	33.2	43.5	8.5	2.3	2.7	1.6	0.4	shell hash/organic debris[b]
	I15[a]	0.0	0.0	7.8	52.7	22.7	7.1	3.6	1.9	2.5	1.4	0.3	organic debris[b]
	I12[a]	0.0	0.0	0.6	8.2	28.1	43.5	10.6	2.8	3.3	2.0	0.8	shell hash/organic debris[b]
	I9	0.0	0.0	0.1	2.4	14.5	54.0	18.3	3.6	3.7	2.2	1.2	organic debris[b]
	I6	0.0	0.1	10.8	64.2	19.3	2.3	1.0	0.9	1.1	0.4	0.0	red relict sand
	I2	0.0	0.0	4.5	44.3	41.8	4.3	0.9	1.2	1.8	1.0	0.0	
	I3	0.0	8.2	52.0	30.9	7.3	0.4	0.0	0.2	0.7	0.2	0.0	red relict sand/organic debris[b]
38-m Stations	I29	0.0	0.0	0.1	2.3	14.7	44.6	21.8	6.0	5.4	3.2	1.8	organic debris[b]
	I21	0.0	6.1	44.4	34.6	7.4	1.6	1.0	1.3	2.1	1.3	0.1	red relict sand/shell hash
	I13	0.0	0.0	3.6	26.6	39.2	16.8	3.1	2.5	4.3	2.9	1.0	shell hash/organic debris[b]
	I8	0.0	4.0	25.5	39.2	23.4	3.9	0.9	0.8	1.4	0.9	0.0	
55-m Stations	I28	1.7	0.0	0.0	1.1	10.1	32.2	18.2	9.2	13.3	9.2	4.9	black sand/pea gravel
	I20	0.0	0.0	0.1	21.8	37.9	6.0	3.6	6.8	13.1	7.8	2.8	red relict sand
	I7	0.0	0.0	0.1	17.8	32.1	8.8	4.4	8.4	16.4	9.1	2.9	red relict sand
	I1	0.0	0.0	0.1	6.1	39.5	38.3	5.7	2.7	4.1	2.6	1.0	

[a] nearfield stations; [b] contained worm tubes

Appendix C.5

Summary of organic indicators in sediments from SBOO stations sampled during winter and summer 2013.

	Winter				Summer			
	Sulfides (ppm)	**TN (% wt)**	**TOC (% wt)**	**TVS (% wt)**	**Sulfides (ppm)**	**TN (% wt)**	**TOC (% wt)**	**TVS (% wt)**
19-m Stations								
I35	3.6	0.033	0.26	1.37	8.6	0.033	0.23	1.30
I34	1.2	nd	1.71	0.66	1.4	0.014	0.04	0.50
I31	3.1	0.012	0.09	0.64	1.0	0.020	0.10	0.70
I23	1.3	0.016	0.12	0.78	1.1	0.023	0.11	0.90
I18	1.1	0.014	0.10	0.71	7.1	0.022	0.10	0.90
I10	1.1	0.015	0.11	0.79	2.6	0.024	0.11	0.90
I4	0.9	0.016	0.09	0.69	1.9	0.023	0.10	0.70
28-m Stations								
I33	9.4	0.039	0.33	1.68	9.7	0.033	0.22	1.30
I30	1.8	0.021	0.16	1.18	2.1	0.025	0.14	1.00
I27	2.2	0.022	0.17	1.05	2.7	0.023	0.12	1.00
I22	1.7	0.020	0.15	0.98	1.3	0.029	0.15	1.00
I14[a]	1.9	0.019	0.15	1.00	2.2	0.033	0.19	1.10
I16[a]	4.5	0.018	0.13	0.66	1.8	0.027	0.13	0.90
I15[a]	0.6	0.010	0.07	0.50	0.3	0.016	0.05	0.50
I12[a]	4.5	0.019	0.14	0.92	1.3	0.031	0.15	0.95
I9	1.3	0.021	0.15	1.16	1.5	0.031	0.19	1.20
I6	1.9	0.007	0.04	0.44	0.3	0.012	0.03	1.00
I2	2.5	0.008	0.05	0.46	0.8	0.015	0.04	0.40
I3	0.7	nd	0.02	0.32	0.3	0.012	0.02	0.30
38-m Stations								
I29	0.9	0.012	0.08	0.41	0.8	0.041	0.32	1.80
I21	0.3	0.008	0.04	0.49	0.3	0.014	0.04	0.90
I13	1.0	0.009	0.06	0.58	0.6	0.024	0.11	0.80
I8	2.3	0.009	0.06	0.40	0.6	0.014	0.05	0.50
55-m Stations								
I28	3.5	0.043	0.38	1.66	2.0	0.049	0.42	1.80
I20	nd	0.005	0.02	0.36	0.3	0.016	0.05	0.40
I7	2.8	0.010	0.06	0.54	0.1	0.014	0.06	0.60
I1	1.8	0.023	0.18	0.97	0.6	0.026	0.15	1.00
Detection Rate (%)	96	93	100	100	100	100	100	100

[a] nearfield stations; nd = not detected

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Appendix C.6

Results of Spearman rank correlation analyses of particle size fractions, organic indicators, and metals from all SBOO benthic stations sampled from 2004 through 2013. Data include the number of detected values (n) and correlation coefficient (r_s) for all parameters with detection rates >50% over the past 10 years (see Materials and Methods and Table 4.2). Correlation coefficients $r_s \geq 0.70$ are highlighted in gray below; select correlations with coefficients $r_s \geq 0.80$ are illustrated in Figure 4.8. See Appendix C.1 for translation of periodic table symbols.

	n	Fine Particles	Fine Sands	Med-Coarse Sands	Coarse Part.	Sulf.	TN	TOC	TVS	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Sn
Fine Sands	535	0.58																			
Med-Coarse Sands	535	-0.83	-0.85																		
Coarse Particles	535	-0.64	-0.85	0.82																	
Sulfides	412	0.57	0.45	-0.56	-0.46																
TN	486	0.77	0.48	-0.65	-0.47	0.56															
TOC	534	0.69	0.40	-0.59	-0.35	0.45	0.76														
TVS	535	0.79	0.47	-0.66	-0.45	0.55	0.79	0.80													
Al	535	0.81	0.59	-0.74	-0.59	0.52	0.67	0.59	0.73												
As	532	-0.07	-0.57	0.42	0.44	-0.14	-0.07	-0.06	-0.02	-0.14											
Ba	535	0.84	0.64	-0.80	-0.63	0.59	0.67	0.63	0.74	0.91	-0.17										
Be	310	0.31	0.13	-0.15	-0.11	0.36	0.33	0.15	0.30	0.46	0.13	0.32									
Cd	291	0.27	0.12	-0.18	-0.11	0.22	0.23	0.29	0.32	0.30	0.02	0.27	0.31								
Cr	535	0.57	0.23	-0.39	-0.32	0.32	0.45	0.35	0.52	0.74	0.24	0.64	0.41	0.35							
Cu	514	0.73	0.44	-0.61	-0.42	0.57	0.66	0.61	0.69	0.73	-0.06	0.78	0.33	0.28	0.52						
Fe	535	0.58	0.18	-0.35	-0.25	0.30	0.46	0.40	0.56	0.76	0.32	0.63	0.46	0.33	0.90	0.52					
Pb	505	0.34	0.01	-0.14	-0.07	0.41	0.42	0.28	0.42	0.38	0.31	0.30	0.51	0.27	0.53	0.40	0.55				
Mn	535	0.65	0.48	-0.59	-0.46	0.42	0.55	0.50	0.64	0.90	-0.10	0.78	0.51	0.32	0.68	0.60	0.77	0.39			
Ni	519	0.84	0.53	-0.71	-0.54	0.54	0.71	0.64	0.77	0.89	-0.11	0.85	0.43	0.45	0.69	0.77	0.68	0.43	0.77		
Sn	448	0.18	0.06	-0.08	-0.02	-0.01	0.04	0.20	0.22	0.35	0.07	0.26	0.28	0.53	0.32	0.21	0.36	0.05	0.43	0.35	
Zn	535	0.79	0.49	-0.67	-0.51	0.53	0.68	0.61	0.75	0.93	-0.01	0.89	0.42	0.37	0.77	0.78	0.80	0.45	0.85	0.88	0.36

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Appendix C.7

Concentrations of trace metals (ppm) in sediments from SBOO stations sampled during winter 2013. See Appendix C.1 for MDLs and translation of periodic table symbols. Values that exceed thresholds are highlighted in yellow (see Table 4.1).

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
19-m Stations																		
I35	13,600	0.54	2.7	47.4	0.200	0.14	16.2	6.4	12,600	6.37	174.0	0.020	6.05	0.42	nd	nd	1.37	31.8
I34	2920	nd	2.6	9.7	0.066	nd	3.5	1.2	3480	2.18	45.6	nd	1.76	0.29	nd	nd	1.19	6.4
I31	7490	0.77	1.4	24.0	0.130	0.08	10.1	2.0	6970	2.89	153.0	nd	2.88	0.51	nd	nd	1.33	14.2
I23	7280	0.70	1.6	37.1	0.130	0.09	10.6	2.6	7230	2.90	118.0	nd	3.40	0.45	nd	nd	1.40	15.5
I18	7660	0.70	1.5	29.9	0.150	0.09	12.0	2.7	8430	2.80	133.0	nd	3.40	0.42	0.28	nd	1.20	16.5
I10	8510	0.46	1.6	30.0	0.120	nd	11.9	2.8	8110	2.95	124.0	nd	3.82	0.36	nd	nd	1.09	16.7
I4	7710	0.80	1.4	32.4	0.130	0.13	12.4	3.2	7510	3.20	119.0	nd	4.90	0.37	nd	nd	1.60	15.9
28-m Stations																		
I33	8430	0.48	1.7	31.8	0.150	0.10	10.2	3.9	7700	5.01	120.0	0.016	3.95	0.31	nd	nd	1.42	19.3
I30	9120	0.60	1.9	29.9	0.140	0.09	11.8	3.5	7430	4.00	91.9	0.005	4.30	0.29	nd	nd	1.40	18.2
I27	9180	0.60	1.7	34.0	0.150	0.09	12.0	3.8	7980	3.90	104.0	0.005	4.50	0.32	nd	nd	1.40	19.1
I22	7560	0.70	1.6	28.0	0.130	0.09	11.0	2.8	7230	3.30	116.0	0.004	3.70	0.46	nd	nd	1.50	15.7
I14[a]	10,300	2.00	1.7	39.8	0.200	0.84	17.7	4.8	9750	6.40	167.0	0.004	6.10	0.41	nd	nd	3.50	24.6
I16[a]	5830	2.10	1.5	23.9	0.150	0.95	11.7	2.7	6960	4.20	122.0	nd	3.70	0.44	nd	nd	3.60	15.1
I15[a]	4770	2.10	2.3	13.8	0.140	0.99	15.5	2.1	7120	4.90	106.0	nd	3.80	nd	nd	nd	3.80	15.0
I12[a]	9300	1.70	1.8	44.2	0.180	0.71	16.5	4.2	9910	5.70	160.0	nd	5.40	0.34	nd	nd	2.90	24.7
I9	11,900	1.60	1.9	47.7	0.200	0.58	18.3	5.6	10,800	6.00	157.0	0.004	7.00	0.56	nd	nd	2.70	27.4
I6	2130	0.80	3.8	5.4	0.070	0.16	9.3	0.7	4510	2.20	42.6	nd	1.50	0.42	nd	nd	1.30	5.6
I2	4900	0.65	0.9	14.6	0.105	0.13	8.9	2.0	5350	2.55	86.2	nd	3.90	0.31	nd	nd	1.40	11.0
I3	1730	0.40	1.6	2.8	0.040	nd	5.8	0.4	1560	1.05	17.4	nd	1.40	0.49	nd	nd	1.35	3.0
38-m Stations																		
I29	2470	nd	4.5	6.0	0.090	nd	6.0	1.1	6610	2.10	30.9	nd	1.60	0.26	nd	nd	1.30	7.6
I21	1970	0.40	9.5	3.5	0.100	0.08	11.9	0.9	8450	3.00	25.9	nd	1.40	0.30	nd	nd	1.30	7.6
I13	3090	0.55	3.2	6.3	0.080	nd	11.5	1.1	6410	2.53	80.0	nd	1.86	0.38	nd	nd	0.96	8.1
I8	2550	1.00	2.5	5.2	0.090	0.40	11.8	0.8	4870	3.00	47.5	nd	2.30	0.38	nd	nd	2.10	8.4
55-m Stations																		
I28	8810	0.70	2.4	28.2	0.170	0.12	11.8	7.4	9220	5.40	109.0	0.019	6.60	0.59	nd	nd	1.70	20.6
I20	2010	0.40	3.5	3.3	0.090	nd	5.0	0.6	5220	1.80	22.4	nd	1.30	0.55	nd	nd	1.40	6.3
I7	2130	0.80	5.2	4.3	0.090	0.30	11.1	0.9	7080	3.20	46.8	nd	1.90	nd	nd	nd	1.90	7.5
I1	1580	0.35	1.1	3.7	0.050	nd	5.8	0.3	1880	1.14	13.4	0.006	1.62	nd	nd	nd	1.25	2.5
Detection Rate (%)	100	93	100	100	100	74	100	100	100	100	100	33	100	89	4	0	100	100

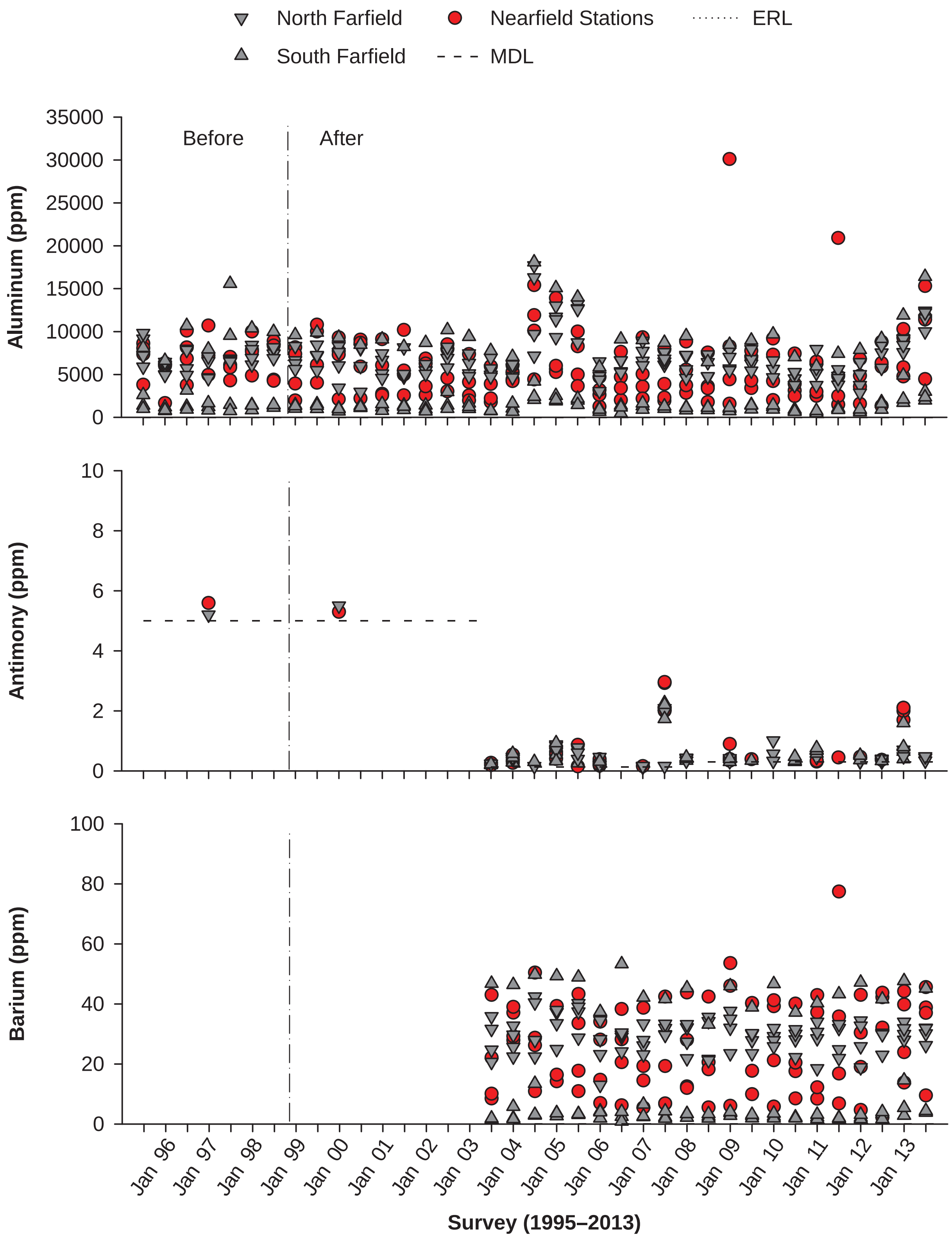
[a] nearfield stations; nd=not detected

Appendix C.7 *continued*

Concentrations of trace metals (ppm) in sediments from SBOO stations sampled during summer 2013. See Appendix C.1 for MDLs and translation of periodic table symbols. Values that exceed thresholds are highlighted in yellow (see Table 4.1).

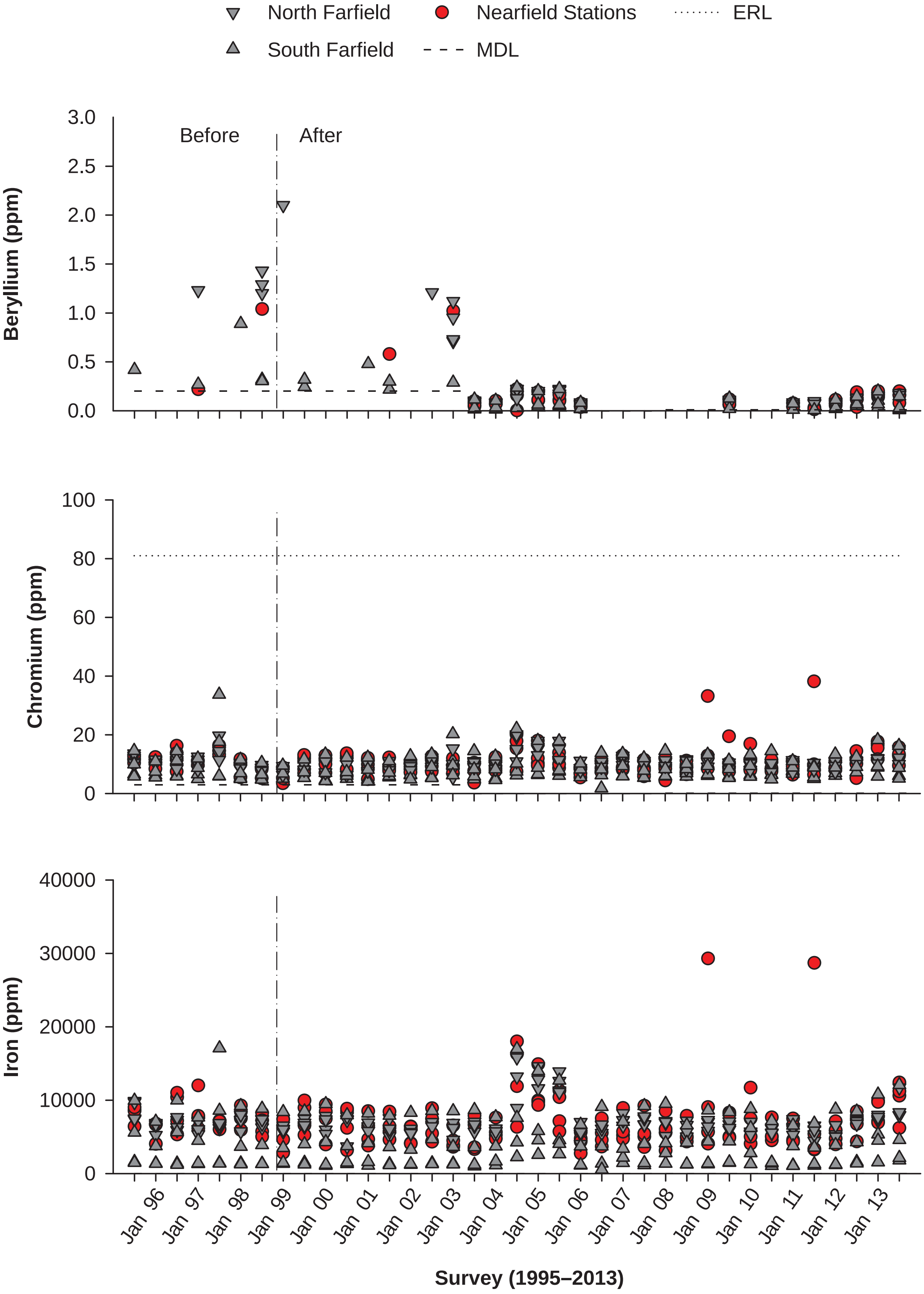
	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
19-m Stations																		
I35	16,300	0.57	2.4	47.4	0.220	0.16	15.7	7.8	12,700	6.74	241.0	0.023	9.45	nd	4.30	nd	0.55	36.2
I34	5370	nd	2.0	13.6	0.100	nd	4.9	1.7	4860	2.91	103.0	0.006	4.47	nd	1.10	nd	0.71	11.3
I31	7670	0.98	1.1	20.1	0.140	0.08	9.6	2.1	8710	3.02	298.0	nd	5.23	0.38	9.64	nd	nd	18.9
I23	9870	1.02	1.3	39.6	0.160	0.07	12.6	3.2	10,900	3.49	322.0	0.004	6.34	0.40	11.20	nd	nd	23.7
I18	11,800	0.50	1.2	44.8	0.170	nd	17.5	3.1	15,200	4.50	362.0	nd	4.90	0.39	nd	nd	nd	26.3
I10	13,300	0.30	1.3	36.0	0.150	0.07	16.9	3.4	14,400	5.40	326.0	nd	5.50	0.31	nd	nd	nd	27.0
I4	5040	nd	1.4	15.9	0.010	nd	7.4	1.4	5330	nd	119.0	nd	2.10	nd	nd	3.10	nd	8.8
28-m Stations																		
I33	10,000	0.48	1.7	26.2	0.160	0.10	10.0	5.0	8340	5.56	186.0	0.020	6.67	nd	2.93	nd	0.59	22.7
I30	12,200	0.34	1.6	31.8	0.180	0.09	12.2	4.3	7940	4.29	141.0	0.007	7.37	0.38	2.04	nd	0.86	22.3
I27	11,500	0.43	1.4	30.1	0.170	0.08	11.7	3.8	7940	3.83	157.0	0.135	7.30	0.37	2.66	nd	0.55	21.6
I22	12,400	nd	1.5	32.0	0.160	nd	15.1	3.7	11,700	4.70	267.0	0.004	5.40	0.34	nd	nd	nd	22.6
I14[a]	15,300	nd	1.9	45.6	0.200	0.08	15.8	4.7	12,400	6.10	220.0	0.005	6.30	0.44	nd	nd	0.52	25.6
I16[a]	11,400	nd	1.5	37.0	0.160	nd	13.4	4.0	11,200	4.60	245.0	nd	4.80	0.41	0.35	nd	nd	22.7
I15[a]	4450	nd	3.3	9.5	0.080	nd	9.5	1.1	6190	2.40	77.0	nd	2.20	0.39	nd	nd	0.82	10.6
I12[a]	11,700	nd	1.7	38.8	0.160	nd	12.8	3.6	10,600	4.60	180.0	0.005	4.80	0.42	nd	nd	nd	22.8
I9	16,400	nd	1.8	45.2	0.150	nd	16.3	5.1	12,100	6.00	171.0	nd	7.40	nd	nd	nd	0.79	27.6
I6	2370	nd	5.3	4.4	0.030	nd	8.8	0.6	4620	1.30	36.8	nd	1.40	nd	0.38	nd	0.94	4.1
I2	3020	nd	1.0	4.0	0.010	nd	6.1	0.5	1830	1.10	26.3	nd	1.50	0.37	nd	nd	1.05	3.4
I3	2010	nd	2.2	3.8	0.020	nd	5.2	0.5	2150	0.90	16.7	nd	1.50	0.37	0.07	nd	0.86	2.6
38-m Stations																		
I29	13,700	0.66	2.1	37.8	0.200	0.10	14.9	6.3	11,000	5.94	229.0	0.016	9.05	0.44	5.62	nd	0.35	27.8
I21	3350	nd	11.2	6.3	0.090	0.07	12.9	1.2	9370	3.90	35.0	nd	1.80	0.36	nd	nd	1.09	7.3
I13	5480	0.30	3.4	9.3	0.100	nd	12.2	1.5	9520	4.00	201.0	0.004	2.70	0.46	nd	nd	nd	12.5
I8	4600	nd	2.8	8.0	0.060	nd	10.7	0.9	5760	2.40	63.2	nd	2.50	nd	0.40	nd	1.25	8.9
55-m Stations																		
I28	11,100	0.53	2.3	27.8	0.200	0.12	11.7	6.6	9370	5.67	178.0	na	9.45	0.39	3.49	nd	0.40	24.3
I20	3420	nd	4.2	6.0	0.070	nd	6.4	0.8	5800	2.10	28.9	nd	1.90	0.39	nd	nd	1.29	6.5
I7	3630	nd	6.9	6.2	0.050	nd	10.7	1.1	8190	3.10	54.1	nd	2.20	nd	0.19	nd	0.91	7.4
I1	7930	0.30	1.0	15.4	0.110	0.06	10.3	2.1	8990	4.40	227.0	0.006	4.80	0.39	nd	nd	nd	15.9
Detection Rate (%)	100	44	100	100	100	44	100	100	100	96	100	46	100	70	52	4	63	100

[a] nearfield stations; nd=not detected; na=not analyzed

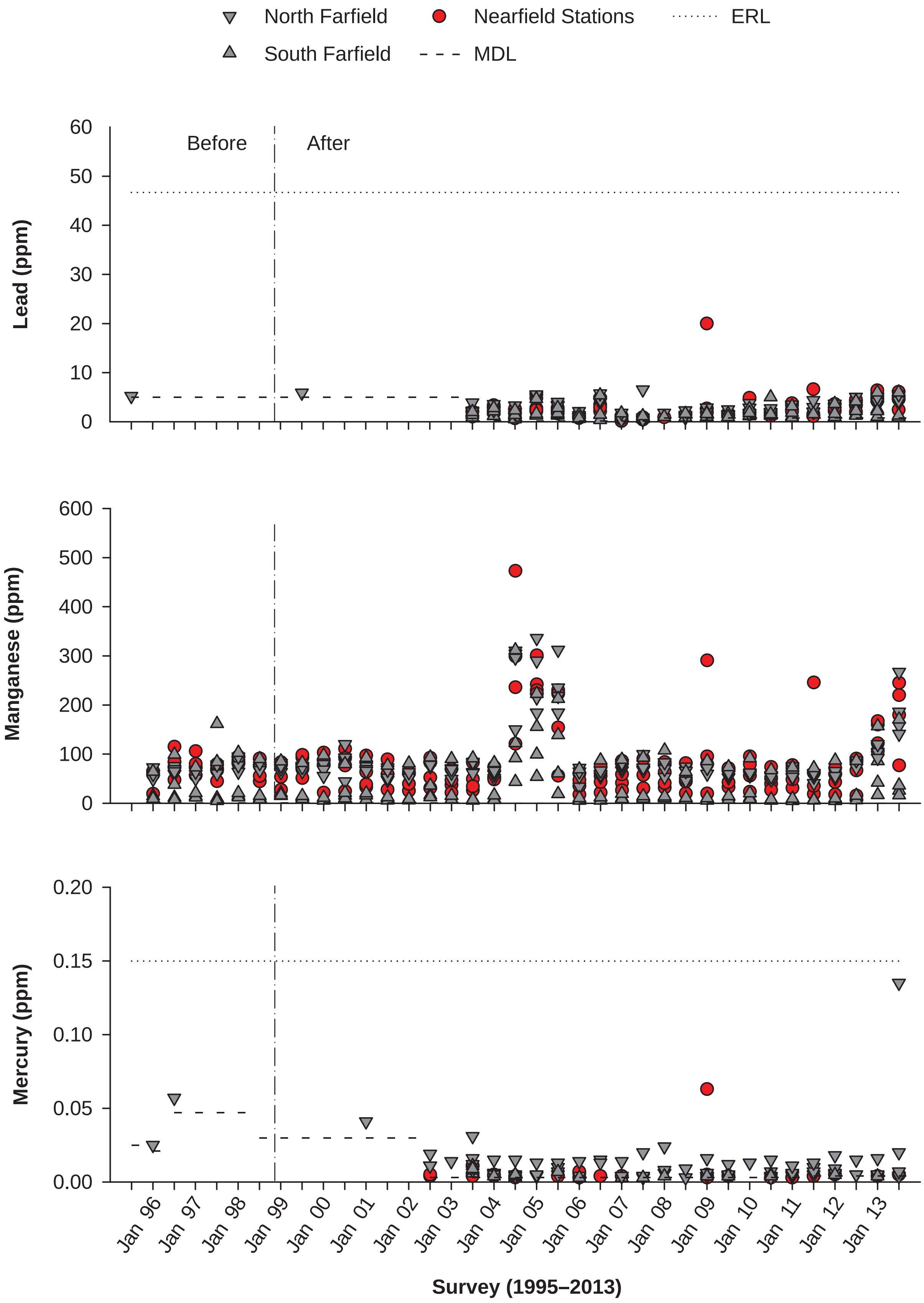


Appendix C.8

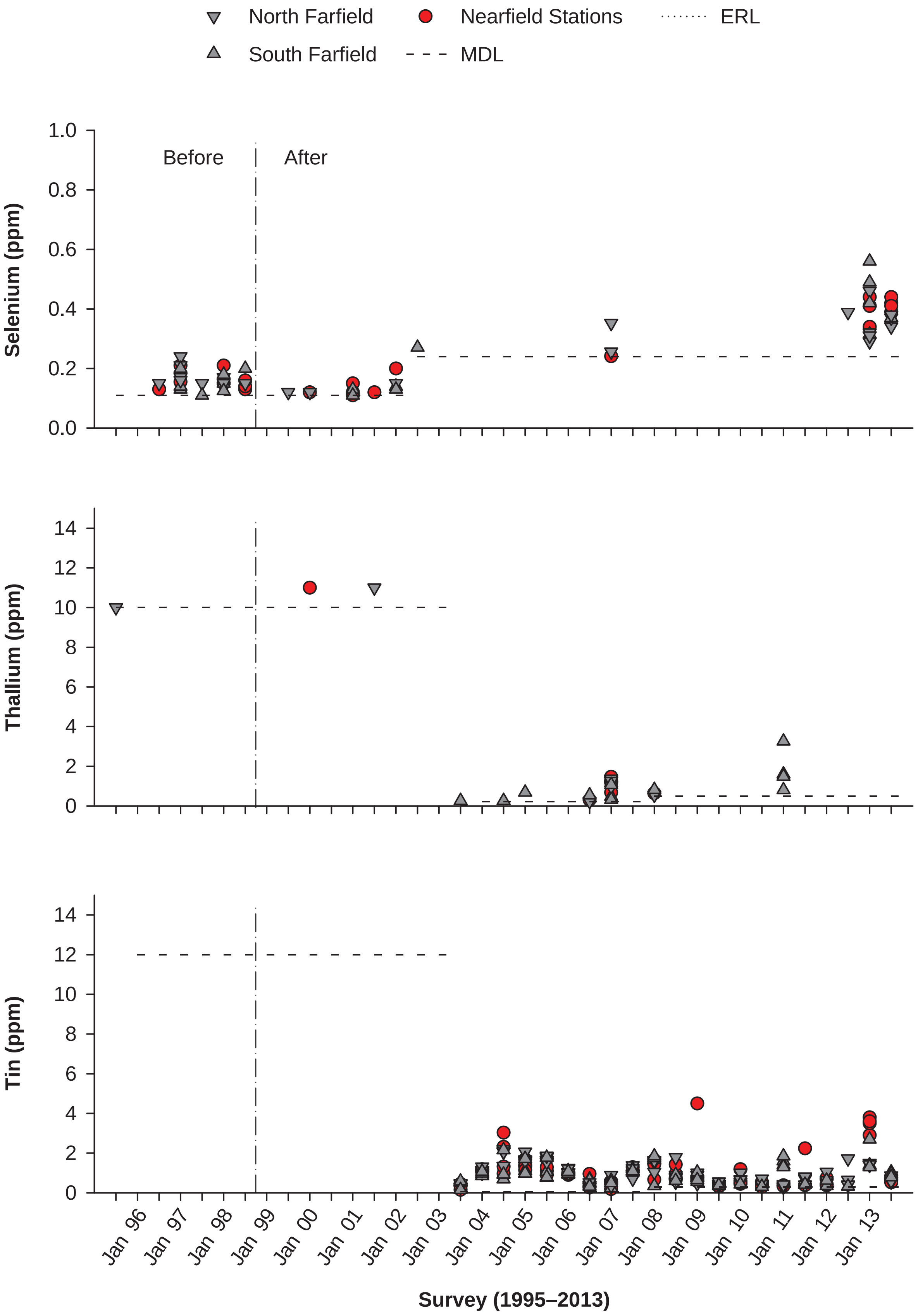
Concentrations of select metals in sediments from SBOO north farfield, nearfield, and south farfield outfall depth stations sampled from 1995 through 2013. Data represent detected values from each station, n≤12 samples per survey. Dashed lines indicate onset of discharge from the SBOO. See Table 4.1 for values of ERLs.



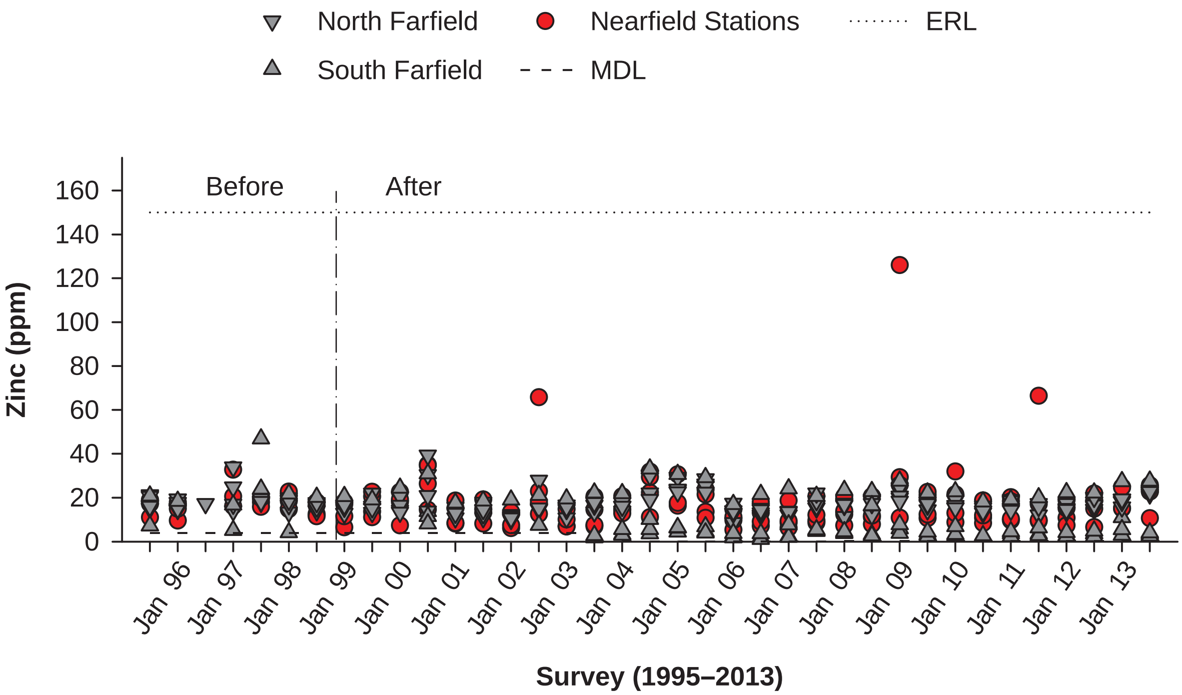
Appendix C.8 *continued*



Appendix C.8 *continued*



Appendix C.8 *continued*



Appendix C.8 *continued*

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Appendix C.9

Concentrations of total DDT, hexachlorobenzene (HCB), total hexachlorocyclohexane (tHCH), total chlordane (tChlor), total PCB, and total PAH detected in sediments from SBOO stations sampled during winter and summer 2013. Values that exceed thresholds are highlighted (see Table 4.1).

	Winter						Summer					
	tDDT (ppt)	HCB (ppt)	tHCH (ppt)	tChlor (ppt)	tPCB (ppt)	tPAH (ppb)	tDDT (ppt)	HCB (ppt)	tHCH (ppt)	tChlor (ppt)	tPCB (ppt)	tPAH (ppb)
19-m Stations												
I35	280	nd	nd	nd	nd	nd	120	nd	nd	nd	nd	18.5
I34	nd	nd	nd	nd	nd	nd	75	64	nd	nd	nd	nd
I31	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
I23	nd	nd	nd	nd	nd	nd	440	nd	nd	nd	nd	nd
I18	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
I10	nd	nd	nd	nd	nd	nd	nd	150	nd	nd	nd	nd
I4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
28-m Stations												
I33	nd	nd	nd	nd	nd	nd	70	50	nd	nd	nd	198.2
I30	130	nd	nd	nd	nd	nd	120	75	nd	nd	nd	nd
I27	125	nd	nd	nd	nd	nd	86	nd	nd	nd	nd	nd
I22	240	nd	nd	nd	727	nd	620	nd	nd	120	nd	nd
I14 [a]	nd	nd	nd	nd	nd	nd	350	nd	nd	nd	384	nd
I16 [a]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	9.4
I15 [a]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
I12 [a]	190	nd	nd	nd	nd	nd	130	nd	nd	nd	nd	nd
I9	nd	nd	nd	nd	nd	nd	245	nd	nd	nd	nd	nd
I6	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
I2	nd	nd	nd	nd	nd	nd	nd	92	nd	nd	909	nd
I3	nd	nd	nd	nd	nd	nd	430	nd	nd	nd	nd	nd
38-m Stations												
I29	110	nd	nd	nd	nd	nd	770	nd	nd	nd	nd	34.2
I21	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
I13	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
I8	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
55-m Stations												
I28	2070	87	nd	nd	270	nd	630	nd	nd	nd	1418	13.1
I20	340	nd	1280	410	nd	nd	nd	nd	nd	nd	nd	nd
I7	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
I1	nd	nd	nd	nd	nd	nd	110	nd	nd	nd	nd	nd
Detect. Rate (%)	30	4	4	4	7	0	52	19	0	4	11	19

[a] nearfield station; nd = not detected

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Appendix D

Supporting Data

2013 SBOO Stations

Macrobenthic Communities

Appendix D.1

Macrofaunal community parameters by grab for SBOO benthic stations sampled during 2013. SR=species richness; Abun=abundance; H'=Shannon diversity index; J'=evenness; Dom=Swartz dominance; BRI=benthic response index. Stations are listed north to south from top to bottom for each depth contour.

Depth Contour	Station	Survey	Grab	SR	Abun	H'	J'	Dom	BRI
19-m	I35	winter	1	68	194	3.9	0.92	31	26
			2	81	228	4.0	0.91	34	28
		summer	1	67	277	3.2	0.76	21	26
	I34	winter	1	51	307	3.0	0.77	11	24
			2	35	348	1.8	0.51	3	16
		summer	1	67	2027	1.6	0.38	2	18
	I31	winter	1	42	129	2.8	0.76	13	14
			2	53	196	3.0	0.75	18	15
		summer	1	65	402	2.1	0.51	6	19
	I23	winter	1	67	149	3.9	0.92	30	27
			2	69	221	3.7	0.88	25	23
		summer	1	77	226	3.7	0.86	30	15
	I18	winter	1	53	164	3.3	0.84	19	16
			2	50	138	3.4	0.87	21	20
		summer	1	64	811	1.3	0.32	1	18
	I10	winter	1	45	126	2.9	0.77	14	21
			2	57	172	3.1	0.76	20	19
		summer	1	87	2009	1.1	0.24	1	16
	I4	winter	1	57	177	3.5	0.87	21	21
			2	19	76	2.5	0.83	7	-4
		summer	1	72	1071	2.0	0.47	5	21
28-m	I33	winter	1	103	484	3.9	0.83	30	30
			2	81	277	3.7	0.85	24	29
		summer	1	157	1797	2.8	0.56	14	29
	I30	winter	1	74	225	3.7	0.87	28	23
			2	102	381	4.0	0.86	33	24
		summer	1	140	2012	2.6	0.52	9	24
	I27	winter	1	70	209	3.5	0.83	26	25
			2	58	162	3.3	0.82	23	22
		summer	1	116	1668	2.0	0.41	5	25
	I22	winter	1	92	394	3.5	0.78	24	25
			2	84	336	3.6	0.82	26	25
		summer	1	110	1065	2.6	0.55	12	25
	I14[a]	winter	1	73	267	3.5	0.81	22	24
			2	73	270	3.3	0.78	24	25
		summer	1	112	1520	1.8	0.38	3	27

[a] nearfield station

Appendix D.1 *continued*

Depth Contour	Station	Survey	Grab	SR	Abun	H'	J'	Dom	BRI
28-m	I16[a]	winter	1	98	844	2.7	0.59	10	26
			2	76	637	2.9	0.67	10	25
		summer	1	92	1103	2.2	0.48	6	23
	I15[a]	winter	1	76	507	2.8	0.64	11	27
			2	100	479	3.5	0.77	23	26
		summer	1	82	2626	1.1	0.25	1	20
	I12[a]	winter	1	122	707	3.6	0.74	24	25
			2	110	744	3.4	0.71	22	26
		summer	1	133	1883	2.2	0.44	7	24
	I9	winter	1	81	331	3.6	0.82	27	27
			2	84	332	3.7	0.84	27	23
		summer	1	122	2295	1.8	0.38	3	26
	I6	winter	1	61	508	2.5	0.60	7	16
			2	55	522	2.3	0.57	5	14
		summer	1	71	2397	0.8	0.20	1	15
	I2	winter	1	43	332	2.2	0.60	7	16
			2	57	307	2.8	0.68	12	20
		summer	1	57	757	1.6	0.39	2	17
	I3	winter	1	27	104	2.0	0.61	6	13
			2	34	105	3.0	0.86	12	12
		summer	1	38	281	2.1	0.57	6	13
38-m	I29	winter	1	43	290	2.8	0.74	8	19
			2	55	205	3.4	0.84	16	14
		summer	1	152	936	3.9	0.78	34	21
	I21	winter	1	79	329	3.3	0.76	25	14
			2	57	268	3.0	0.75	14	15
		summer	1	70	395	2.7	0.65	13	18
	I13	winter	1	74	374	3.3	0.77	16	23
			2	52	230	3.2	0.81	14	23
		summer	1	112	748	3.3	0.69	20	23
	I8	winter	1	54	332	2.7	0.68	12	22
			2	51	345	2.4	0.62	7	20
		summer	1	65	703	2.0	0.48	5	27
55-m	I28	winter	1	130	493	4.2	0.87	43	17
			2	148	701	4.0	0.81	34	18
		summer	1	123	605	4.0	0.82	33	20
	I20	winter	1	49	201	3.2	0.82	14	15
			2	60	245	3.3	0.79	16	11
		summer	1	61	356	2.4	0.59	8	14

[a] nearfield station

Appendix D.1 *continued*

Depth Contour	Station	Survey	Grab	SR	Abun	H'	J'	Dom	BRI
55-m	I7	winter	1	83	351	3.7	0.85	26	11
			2	68	209	3.6	0.85	26	13
		summer	1	72	553	2.0	0.47	4	12
	I1	winter	1	70	350	3.3	0.79	19	14
			2	73	213	3.9	0.90	27	17
		summer	1	68	245	3.6	0.85	20	21

[a] nearfield station

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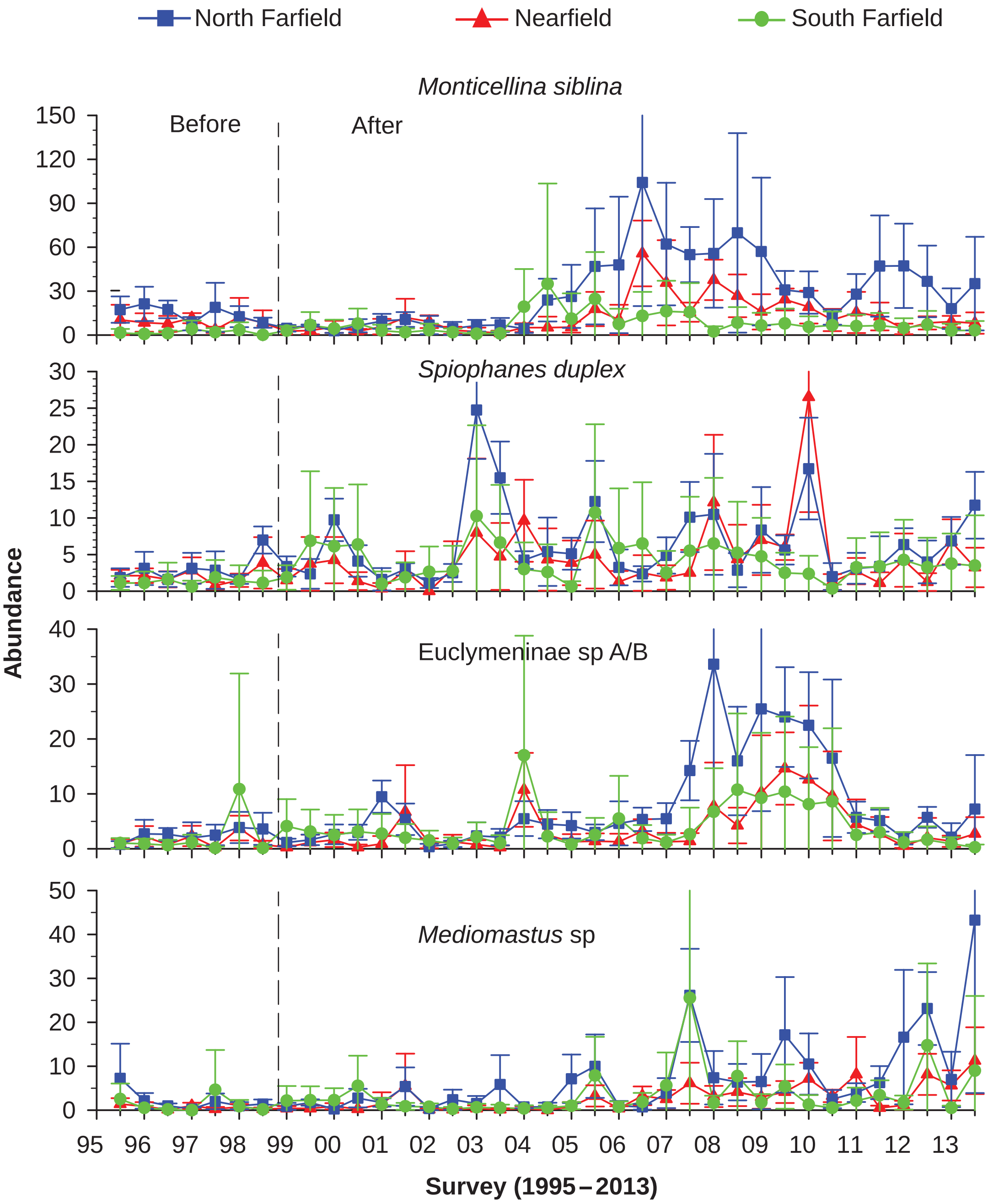

Appendix D.2

Four of the five historically most abundant species recorded from 1995 through 2013 at SBOO north farfield, nearfield, and south farfield stations (*Spiophanes norrisi* shown in Figure 5.3). Data for each station group are expressed as means ±95% confidence intervals per grab (n=8 except for summer 2013 when n=4). Dashed lines indicate onset of wastewater discharge.

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Appendix D.3

Mean abundance of the 15 most abundant species found in each cluster group A–H (defined in Figure 5.5). Bold values indicate taxa that account for 25% of intra-group similarity according to SIMPER analysis.

	Cluster Groups							
Taxa	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Micropodarke dubia	**53.5**	0.0	0.0	0.0	0.0	0.1	0.5	0.2
NEMATODA	38.0	0.0	0.5	1.3	0.2	2.1	0.8	1.8
Spio maculata	17.0	0.0	0.0	0.0	0.0	0.0	**11.8**	2.3
Spiophanes norrisi	15.5	**60.0**	9.0	**36.1**	**652.2**	**502.4**	**66.2**	**640.2**
Pareurythoe californica	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prionospio (*Prionospio*) *jubata*	13.5	**21.0**	**12.5**	2.4	0.6	**36.1**	7.0	3.9
Pisione sp	12.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Branchiostoma californiense	9.0	0.0	0.0	0.0	0.0	0.2	0.0	6.2
Protodorvillea gracilis	7.0	0.0	0.0	0.0	0.0	0.1	0.5	2.3
Eumida longicornuta	6.0	0.0	0.0	0.0	0.0	1.5	0.0	0.9
Ampelisca cristata cristata	3.5	0.0	0.0	3.4	7.6	1.3	1.8	3.3
Sigalion spinosus	3.0	0.0	3.0	0.9	2.4	1.2	1.7	0.2
Scoloplos armiger Cmplx	2.5	0.0	5.5	1.4	1.0	2.1	2.2	7.2
Hesionura coineaui difficilis	2.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2
Spiochaetopterus costarum Cmplx	1.5	19.5	**11.5**	2.0	16.0	**42.3**	**20.8**	34.7
Phyllodoce hartmanae	1.5	1.0	0.0	0.7	6.4	11.5	3.3	11.9
Lumbrineris ligulata	1.0	11.5	0.0	0.0	0.0	0.5	1.7	1.4
Foxiphalus obtusidens	1.0	0.0	1.0	0.0	0.8	4.7	3.8	0.8
Glycinde armigera	1.0	0.0	0.5	3.7	5.2	4.3	0.0	0.6
Axiothella sp	1.0	0.0	0.0	0.3	0.6	3.4	0.7	16.7
Actiniaria	1.0	0.0	0.0	0.0	0.0	0.6	0.3	0.3
Amphiuridae	0.5	2.0	0.5	1.0	0.2	1.8	0.0	5.2
Carinoma mutabilis	0.5	1.5	0.0	1.7	4.4	2.3	0.0	12.5
Mediomastus sp	0.5	0.5	0.5	2.3	**22.0**	16.8	0.2	0.7
Lumbrinerides platypygos	0.5	0.0	0.0	0.1	0.0	1.1	4.0	9.1
Mooreonuphis sp SD1	0.5	0.0	0.0	0.0	0.0	0.2	6.8	3.5
Sthenelanella uniformis	0.0	**37.5**	**13.0**	0.7	0.2	5.8	1.8	0.1
Photis californica	0.0	**32.0**	48.5	0.0	0.0	0.4	0.7	0.0
Euphilomedes carcharodonta	0.0	**21.0**	**14.0**	0.3	0.2	3.3	2.7	2.4
Chaetozone hartmanae	0.0	**17.0**	0.0	0.0	0.0	0.0	0.0	0.0
Amphiodia urtica	0.0	**11.5**	2.0	0.0	0.0	0.2	0.3	3.0
Ampelisca indentata	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0
Euclymeninae sp B	0.0	8.5	1.0	0.9	0.0	3.3	0.8	0.4
Amphissa undata	0.0	8.0	8.0	0.0	0.0	0.2	0.3	0.0
Byblis millsi	0.0	7.5	0.0	0.0	0.0	0.4	3.0	0.0
Chloeia pinnata	0.0	7.0	15.0	0.0	0.0	0.0	87.8	0.2
Leptochelia dubia Cmplx	0.0	7.0	7.5	0.6	0.6	2.4	1.5	1.5
Monticellina siblina	0.0	7.0	1.5	1.7	1.4	16.6	0.0	0.3
Spiophanes duplex	0.0	6.5	5.5	**6.1**	11.0	**9.6**	1.8	0.6
Aricidea (*Acmira*) *simplex*	0.0	4.0	8.5	0.0	0.0	0.0	0.3	0.1
Mesolamprops bispinosus	0.0	3.0	**12.0**	0.0	0.0	0.1	0.0	0.4
Goniada maculata	0.0	3.0	0.0	0.9	0.4	0.4	1.8	0.0
Ampelisca brevisimulata	0.0	2.5	0.0	2.7	0.4	**12.3**	0.2	0.0

Appendix D.3 *continued*

	Cluster Groups							
Taxa	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Nereis sp A	0.0	2.0	0.0	5.1	1.4	5.9	0.2	0.7
Paraprionospio alata	0.0	2.0	0.0	5.0	4.0	6.0	0.2	0.2
Amphiodia digitata	0.0	1.5	2.0	0.3	0.6	0.2	0.0	0.1
Ampharete labrops	0.0	1.5	0.0	1.7	8.2	11.0	1.0	1.6
Mooreonuphis nebulosa	0.0	1.5	0.0	0.0	0.0	10.8	0.0	0.0
Ampelisca careyi	0.0	1.0	9.5	0.0	0.0	1.1	0.0	0.0
Notomastus latericeus	0.0	0.5	0.0	2.6	1.4	9.7	0.0	6.3
Eurydice caudata	0.0	0.5	0.0	0.0	0.0	0.1	5.8	4.7
Dialychone veleronis	0.0	0.0	7.0	0.4	0.2	4.3	0.0	0.9
Chaetozone sp	0.0	0.0	4.0	0.0	0.8	0.8	0.0	0.6
Rhepoxynius menziesi	0.0	0.0	3.0	2.4	3.2	2.4	0.0	0.0
Rhepoxynius stenodes	0.0	0.0	1.0	3.0	2.0	3.5	0.3	0.1
Magelona sacculata	0.0	0.0	0.0	**5.9**	21.4	9.3	0.0	51.6
Tellina modesta	0.0	0.0	0.0	**4.1**	1.6	4.5	0.0	0.1
Scoletoma tetraura Cmplx	0.0	0.0	0.0	3.6	1.2	0.1	0.0	0.0
Apoprionospio pygmaea	0.0	0.0	0.0	3.1	12.6	6.0	0.0	0.8
Magelona hartmanae	0.0	0.0	0.0	3.1	5.0	5.5	0.0	0.3
Exogone lourei	0.0	0.0	0.0	2.0	3.4	1.6	1.5	5.8
Praxillella pacifica	0.0	0.0	0.0	0.7	0.0	1.8	7.7	0.0
Acteocina culcitella	0.0	0.0	0.0	0.6	1.4	0.3	0.0	0.0
Rhepoxynius heterocuspidatus	0.0	0.0	0.0	0.4	0.0	0.1	0.7	4.6
Photis sp OC1	0.0	0.0	0.0	0.3	8.2	2.3	0.0	0.6
Glycera oxycephala	0.0	0.0	0.0	0.0	0.2	2.9	2.5	6.7
Ampelisciphotis podophthalma	0.0	0.0	0.0	0.0	0.0	9.7	0.0	0.0
Mooreonuphis sp	0.0	0.0	0.0	0.0	0.0	0.5	**9.3**	3.1
Cyclaspis nubila	0.0	0.0	0.0	0.0	0.0	0.1	2.7	0.0
Acidostoma hancocki	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

Appendix E

Supporting Data

2013 SBOO Stations

Demersal Fishes and Megabenthic Invertebrates

Appendix E.1

Taxonomic listing of demersal fish species captured during 2013 at SBOO trawl stations. Data are number of fish (n), biomass (BM, wet weight, kg), minimum (Min), maximum (Max), and mean length (standard length, cm). Taxonomic arrangement and scientific names are of Eschmeyer and Herald (1998) and Lawrence et al. (2013).

					Length (cm)		
Taxon/Species		**Common Name**	**n**	**BM**	**Min**	**Max**	**Mean**
TORPEDINIFORMES							
Torpedinidae							
	Torpedo californica	Pacific electric ray[a]	1	4.5	65	65	65
RAJIFORMES							
Rajidae							
	Raja inornata	California skate[a]	3	0.5	28	32	31
CLUPEIFORMES							
Engraulidae							
	Engraulis mordax	northern anchovy	3	0.1	7	10	8
AULOPIFORMES							
Synodontidae							
	Synodus lucioceps	California lizardfish	2428	29.8	7	24	11
OPHIDIIFORMES							
Ophidiidae							
	Ophidion scrippsae	basketweave cusk-eel	2	0.2	10	13	12
BATRACHOIDIFORMES							
Batrachoididae							
	Porichthys myriaster	specklefin midshipman	5	0.4	15	27	19
	Porichthys notatus	plainfin midshipman	17	1.0	6	26	11
GASTEROSTEIFORMES							
Syngnathidae							
	Syngnathus californiensis	kelp pipefish	56	1.1	10	25	18
	Syngnathus leptorhynchus	bay pipefish	12	0.1	13	20	16
SCORPAENIFORMES							
Scorpaenidae							
	Scorpaena guttata	California scorpionfish	3	1.1	14	16	15
	Sebastes dallii	calico rockfish	9	0.5	3	6	4
	Sebastes goodei	chilipepper	1	0.1	6	6	6
	Sebastes miniatus	vermilion rockfish	20	0.7	3	7	4
	Sebastes saxicola	stripetail rockfish	9	0.3	3	6	4
Hexagrammidae							
	Ophiodon elongatus	lingcod	1	0.1	15	15	15
	Zaniolepis latipinnis	longspine combfish	126	2.7	8	16	13
Cottidae							
	Chitonotus pugetensis	roughback sculpin	48	2.2	5	13	10
	Icelinus quadriseriatus	yellowchin sculpin	84	0.9	6	8	7
	Icelinus tenuis	spotfin sculpin	1	0.1	6	6	6
Agonidae							
	Agonopsis sterletus	southern spearnose poacher	4	0.2	6	8	8
	Odontopyxis trispinosa	pygmy poacher	9	0.6	5	9	8
PERCIFORMES							
Serranidae							
	Paralabrax clathratus	kelp bass	3	0.1	10	10	10
Malacanthidae							
	Caulolatilus princeps	ocean whitefish	1	0.1	5	5	5

[a] Length measured as total length, not standard length (see text)

Appendix E.1 *continued*

Taxon/Species			Common Name	n	BM	Length (cm) Min	Max	Mean
	Sciaenidae							
		Genyonemus lineatus	white croaker	270	6.9	8	20	11
		Seriphus politus	queenfish	4	0.2	10	12	11
	Embiotocidae							
		Cymatogaster aggregata	shiner perch	8	0.1	9	10	9
	Stichaeidae							
		Plectobranchus evides	bluebarred prickleback	1	0.1	8	8	8
	Clinidae							
		Heterostichus rostratus	giant kelpfish	2	0.2	14	14	14
	Labrisomidae							
		Neoclinus blanchardi	sarcastic fringehead	2	0.2	6	19	12
	Gobiidae							
			unidentified goby	1	0.1	3	3	3
	Scombridae							
		Scomber japonicus	Pacific chub mackerel	1	0.1	22	22	22
	Stromateidae							
		Peprilus simillimus	Pacific pompano	33	1.0	9	10	10
PLEURONECTIFORMES								
	Paralichthyidae							
		Citharichthys sordidus	Pacific sanddab	204	5.1	4	19	7
		Citharichthys stigmaeus	speckled sanddab	5080	38.4	3	13	7
		Citharichthys xanthostigma	longfin sanddab	62	4.2	4	21	14
		Paralichthys californicus	California halibut	10	17.6	24	84	39
		Xystreurys liolepis	fantail sole	20	3.3	8	26	18
	Pleuronectidae							
		Parophrys vetulus	English sole	80	8.7	9	29	18
		Pleuronichthys decurrens	curlfin sole	43	1.4	4	17	8
		Pleuronichthys ritteri	spotted turbot	3	0.3	14	17	15
		Pleuronichthys verticalis	hornyhead turbot	165	8.8	4	21	11
	Cynoglossidae							
		Symphurus atricaudus	California tonguefish	123	1.9	6	16	9

Appendix E.2

Total abundance by species and station for demersal fish at SBOO trawl stations during 2013.

	Winter 2013							
Name	**SD15**	**SD16**	**SD17**	**SD18**	**SD19**	**SD20**	**SD21**	**Species Abundance by Survey**
Speckled sanddab	118	129	91	69	134	146	38	725
California lizardfish	18	34	67	17	44	25	32	237
Hornyhead turbot	2	8	6	3	7	12	4	42
Kelp pipefish	3	7	3	2	6	11	2	34
California tonguefish		3	6	7	6	4	1	27
Longspine combfish			5	7	2	4	2	20
Longfin sanddab				2	4	4	3	13
Bay pipefish						12		12
English sole					4	3	4	11
Shiner perch							8	8
Fantail sole		2	2			1	1	6
Plainfin midshipman	1	3	1	1				6
Roughback sculpin	2					2	1	5
California halibut			1	1			1	3
Kelp bass				3				3
California skate		1					1	2
Giant kelpfish				1			1	2
Pacific pompano							2	2
Pacific chub mackerel			1					1
Curlfin sole	1							1
Pacific electric ray				1				1
Pygmy poacher	1							1
Sarcastic fringehead	1							1
Spotted turbot			1					1
White croaker					1			1
Survey Total	147	187	184	114	208	224	101	1165

Appendix E.2 *continued*

Name	Spring 2013							Species Abundance by Survey
	SD15	SD16	SD17	SD18	SD19	SD20	SD21	
Speckled sanddab	409	151	140	280	318	173	147	1618
White croaker						2	267	269
Hornyhead turbot	7	10	5	11	5	8	17	63
California lizardfish	1	23	18	13	1	6		62
English sole	2	4	4	10	1	6	6	33
Pacific pompano					28		3	31
Roughback sculpin	11	12	2	3	1			29
California tonguefish		1	2	4	5	2	13	27
Longspine combfish		5		1	5	11	3	25
Kelp pipefish	1	2			7	12		22
Pacific sanddab			18	2				20
Longfin sanddab		5	7	4				16
Vermilion rockfish	3			1	1	6	4	15
Yellowchin sculpin			9	1				10
Curlfin sole	1			1		5	1	8
Fantail sole		1	3	2			2	8
Plainfin midshipman				2	2		3	7
Stripetail rockfish					4	3		7
California halibut	1			2	1	1	1	6
Calico rockfish			1	4				5
Queenfish						3	1	4
Northern anchovy							3	3
Basketweave cusk-eel							1	1
Bluebarred prickleback		1						1
Chilipepper						1		1
Unidentified goby				1				1
Ocean whitefish						1		1
Pygmy poacher	1							1
Sarcastic fringehead							1	1
Spotted turbot			1					1
Survey Total	437	215	210	342	379	240	473	2296

Appendix E.2 *continued*

Name	Summer 2013							Species Abundance by Survey
	SD15	SD16	SD17	SD18	SD19	SD20	SD21	
Speckled sanddab	143	384	380	587	410	445	388	2737
California lizardfish	118	68	76	218	726	235	688	2129
Pacific sanddab	153		31					184
Longspine combfish	1	6	2		11	23	38	81
Yellowchin sculpin			5	1	30	24	14	74
California tonguefish		1	3		5	1	59	69
Hornyhead turbot	9	3	10	7	12	7	12	60
English sole	1	2	5	7	7	6	8	36
Curlfin sole	15		3	9	2	1	4	34
Longfin sanddab		4	5	7	6	4	7	33
Roughback sculpin	1	2			3	7	1	14
Pygmy poacher		1		2		2	2	7
Fantail sole	1	2		2		1		6
Specklefin midshipman		1					4	5
Vermilion rockfish			1			4		5
Calico rockfish			1	1	2			4
Plainfin midshipman					2	2		4
Southern spearnose poacher		1					3	4
California scorpionfish						2	1	3
Stripetail rockfish			2					2
Basketweave cusk-eel						1		1
California halibut						1		1
California skate		1						1
Lingcod						1		1
Spotfin sculpin				1				1
Spotted turbot			1					1
Survey Total	442	476	525	842	1216	767	1229	5497
Annual Total	**1026**	**878**	**919**	**1298**	**1803**	**1231**	**1803**	**8958**

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Appendix E.3

Biomass (kg) by species and station for demersal fish at SBOO trawl stations during 2013.

Name	Winter 2013							Species Biomass by Survey
	SD15	SD16	SD17	SD18	SD19	SD20	SD21	
Speckled sanddab	1.0	1.3	0.9	0.9	1.2	0.9	0.1	6.3
Pacific electric ray				4.5				4.5
California lizardfish	0.3	0.3	0.7	0.1	0.5	0.2	0.7	2.8
Hornyhead turbot	0.1	0.1	0.1	0.4	0.1	0.5	0.1	1.4
English sole					0.2	0.8	0.1	1.1
Fantail sole		0.5	0.1			0.2	0.1	0.9
Kelp pipefish	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7
California tonguefish		0.1	0.1	0.1	0.1	0.1	0.1	0.6
California halibut			0.3	0.1			0.1	0.5
Longfin sanddab				0.1	0.2	0.1	0.1	0.5
Longspine combfish			0.1	0.1	0.1	0.1	0.1	0.5
Plainfin midshipman	0.1	0.1	0.1	0.1				0.4
California skate		0.2					0.1	0.3
Roughback sculpin	0.1					0.1	0.1	0.3
Giant kelpfish				0.1			0.1	0.2
Bay pipefish						0.1		0.1
Pacific chub mackerel			0.1					0.1
Curlfin sole	0.1							0.1
Kelp bass				0.1				0.1
Pacific pompano							0.1	0.1
Pygmy poacher	0.1							0.1
Sarcastic fringehead	0.1							0.1
Shiner perch							0.1	0.1
Spotted turbot			0.1					0.1
White croaker					0.1			0.1
Survey Total	2.0	2.7	2.7	6.7	2.6	3.2	2.1	22.0

Appendix E.3 *continued*

Name	Spring 2013							Species Biomass by Survey
	SD15	SD16	SD17	SD18	SD19	SD20	SD21	
California halibut	0.6			14.0	0.4	0.4	0.5	15.9
Speckled sanddab	1.5	1.5	1.7	2.3	1.5	1.3	1.1	10.9
White croaker						0.1	6.7	6.8
Hornyhead turbot	0.5	0.3	0.5	1.0	0.5	0.1	1.7	4.6
English sole	0.1	0.3	0.3	0.6	0.1	0.5	0.9	2.8
Longfin sanddab		0.5	0.8	0.4				1.7
California lizardfish	0.1	0.5	0.4	0.3	0.1	0.1		1.5
Fantail sole		0.1	0.2	0.8			0.3	1.4
Roughback sculpin	0.1	0.1	1.0	0.1	0.1			1.4
Pacific pompano					0.8		0.1	0.9
California tonguefish		0.1	0.1	0.1	0.1	0.1	0.1	0.6
Longspine combfish		0.1		0.1	0.1	0.2	0.1	0.6
Curlfin sole	0.1			0.2		0.1	0.1	0.5
Vermilion rockfish	0.1			0.1	0.1	0.1	0.1	0.5
Kelp pipefish	0.1	0.1			0.1	0.1		0.4
Plainfin midshipman				0.1	0.1		0.2	0.4
Calico rockfish			0.1	0.1				0.2
Pacific sanddab			0.1	0.1				0.2
Queenfish						0.1	0.1	0.2
Stripetail rockfish					0.1	0.1		0.2
Yellowchin sculpin			0.1	0.1				0.2
Basketweave cusk-eel							0.1	0.1
Bluebarred prickleback		0.1						0.1
Chilipepper						0.1		0.1
Unidentified goby				0.1				0.1
Northern anchovy							0.1	0.1
Ocean whitefish						0.1		0.1
Pygmy poacher	0.1							0.1
Sarcastic fringehead							0.1	0.1
Spotted turbot			0.1					0.1
Survey Total	3.3	3.7	5.4	20.5	4.1	3.5	12.3	52.8

Appendix E.3 *continued*

	Summer 2013							
Name	**SD15**	**SD16**	**SD17**	**SD18**	**SD19**	**SD20**	**SD21**	**Species Biomass by Survey**
California lizardfish	1.4	0.9	0.7	2.1	8.3	3.1	9.0	25.5
Speckled sanddab	1.2	2.3	2.0	4.7	4.2	3.3	3.5	21.2
Pacific sanddab	4.7		0.2					4.9
English sole	0.2	0.2	1.2	1.0	0.5	0.7	1.0	4.8
Hornyhead turbot	0.2	0.1	1.0	0.6	0.5	0.1	0.3	2.8
Longfin sanddab		0.3	0.1	0.8	0.5	0.1	0.2	2.0
Longspine combfish	0.1	0.1	0.1		0.2	0.3	0.8	1.6
California halibut						1.2		1.2
California scorpionfish						1.0	0.1	1.1
Fantail sole	0.1	0.2		0.2		0.5		1.0
Curlfin sole	0.2		0.1	0.1	0.1	0.1	0.2	0.8
Yellowchin sculpin			0.1	0.1	0.2	0.1	0.2	0.7
California tonguefish		0.1	0.1		0.1	0.1	0.3	0.7
Roughback sculpin	0.1	0.1			0.1	0.1	0.1	0.5
Pygmy poacher		0.1		0.1		0.1	0.1	0.4
Specklefin midshipman		0.1					0.3	0.4
Calico rockfish			0.1	0.1	0.1			0.3
California skate		0.2						0.2
Plainfin midshipman					0.1	0.1		0.2
Southern spearnose poacher		0.1					0.1	0.2
Vermilion rockfish			0.1			0.1		0.2
Basketweave cusk-eel						0.1		0.1
Lingcod						0.1		0.1
Spotfin sculpin				0.1				0.1
Spotted turbot			0.1					0.1
Stripetail rockfish			0.1					0.1
Survey Total	8.2	4.8	6.0	9.9	14.9	11.2	16.2	71.2
Annual Total	**13.5**	**11.2**	**14.1**	**37.1**	**21.6**	**17.9**	**30.6**	**146.0**

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Appendix E.4

Pairwise r- and significance values for all year comparisons (Factor B) from the SBOO two-way crossed ANOSIM for demersal fish assemblages sampled from 1995 through 2013. Data are limited to summer surveys. Shading indicates significant difference (see Table 6.3).

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1996	r-value	0.488																	
	sig value	3.3																	
1997	r-value	0.326	0.116																
	sig value	10	26.7																
1998	r-value	0.326	0.628	0.465															
	sig value	8.9	2.2	2.2															
1999	r-value	0.837	0.744	0.07	0.721														
	sig value	1.1	1.1	38.9	1.1														
2000	r-value	0.512	0.419	-0.163	0.605	0.116													
	sig value	2.2	5.6	83.3	1.1	34.4													
2001	r-value	0.535	0.372	-0.116	0.372	0.488	0.395												
	sig value	5.6	5.6	63.3	6.7	2.2	8.9												
2002	r-value	0.674	0.651	0.023	0.791	0.047	0.047	0.465											
	sig value	1.1	1.1	47.8	1.1	44.4	47.8	4.4											
2003	r-value	1	1	0.674	0.767	0.698	0.628	0.93	0.605										
	sig value	1.1	1.1	1.1	1.1	6.7	2.2	1.1	2.2										
2004	r-value	1	1	0.698	0.814	0.395	0.488	0.837	0.233	0.279									
	sig value	1.1	1.1	1.1	1.1	6.7	4.4	1.1	17.8	6.7									
2005	r-value	0.674	0.721	0.512	0.767	0.628	0.558	0.791	0.488	0.558	0.233								
	sig value	3.3	3.3	1.1	2.2	3.3	2.2	1.1	4.4	5.6	13.3								
2006	r-value	0.651	0.698	0.535	0.674	0.674	0.628	0.791	0.605	0.744	0.395	0.14							
	sig value	3.3	3.3	3.3	2.2	3.3	1.1	1.1	1.1	1.1	1.1	33.3							
2007	r-value	0.744	0.744	0.581	0.814	0.488	0.605	0.814	0.605	0.744	0.093	0.163	0.372						
	sig value	2.2	2.2	1.1	1.1	6.7	1.1	1.1	2.2	3.3	36.7	24.4	6.7						
2008	r-value	0.698	0.86	0.791	0.721	0.744	0.791	0.814	0.721	0.907	0.465	-0.023	0.558	0.233					
	sig value	3.3	2.2	1.1	1.1	2.2	1.1	1.1	1.1	2.2	1.1	60	2.2	10					
2009	r-value	0.953	1	0.884	0.837	0.907	0.884	0.907	0.884	0.953	0.814	0.349	0.535	0.628	0.372				
	sig value	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	13.3	8.9	5.6	10				
2010	r-value	0.977	1	0.953	0.884	1	0.884	0.93	0.884	0.907	0.721	0.395	0.651	0.721	0.419	0.14			
	sig value	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	10	2.2	1.1	2.2	28.9			
2011	r-value	0.721	0.628	0.326	0.581	0.442	0.395	0.581	0.279	0.535	0.326	0.023	0.349	0.209	0.302	0.349	0.488		
	sig value	1.1	1.1	3.3	1.1	1.1	1.1	1.1	11.1	1.1	4.4	44.4	10	16.7	6.7	2.2	2.2		
2012	r-value	0.744	0.767	0.744	0.698	0.814	0.721	0.884	0.698	0.767	0.628	0.488	0.581	0.628	0.535	0.512	0.395	0.233	
	sig value	3.3	3.3	1.1	2.2	2.2	2.2	1.1	3.3	3.3	2.2	7.8	5.6	4.4	7.8	5.6	4.4	16.7	
2013	r-value	1	1	1	1	1	1	1	1	0.907	0.953	0.907	0.86	0.907	0.907	0.814	0.581	0.535	0.512
	sig value	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2.2	1.1	1.1	3.3	4.4	6.7	4.4

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Appendix E.5

Taxonomic listing of megabenthic invertebrate taxa captured during 2013 at SBOO trawl stations. Data are number of individuals (n). Taxonomic arrangement from SCAMIT (2013).

Taxon/ Species				**n**
CNIDARIA				
	Anthozoa			
		Virgulariidae	*Acanthoptilum* sp	2
			Stylatula elongata	6
MOLLUSCA				
	Polyplacophora			
		Ischnochitonidae	*Lepidozona scrobiculata*	2
	Gastropoda			
		Calliostomatidae	*Calliostoma annulatum*	3
			Calliostoma tricolor	2
		Turbinidae	*Megastraea turbanica*	1
			Megastraea undosa	2
		Naticidae	*Euspira draconis*	1
			Euspira lewisii	2
		Bursidae	*Crossata ventricosa*	5
		Buccinidae	*Kelletia kelletii*	41
		Nassariidae	*Caesia perpinguis*	25
		Muricidae	*Pteropurpura festiva*	3
		Pseudomelatomidae	*Crassispira semiinflata*	8
			Megasurcula carpenteriana	6
		Philinidae	*Philine auriformis*	11
		Aglajidae	*Aglaja ocelligera*	2
		Pleurobranchidae	*Pleurobranchaea californica*	1
		Onchidorididae	*Acanthodoris brunnea*	29
			Acanthodoris rhodoceras	5
		Arminidae	*Armina californica*	7
		Tritoniidae	*Tritonia tetraquetra*	1
		Dendronotidae	*Dendronotus iris*	14
			Dendronotus venustus	3
		Flabellinidae	*Flabellina iodinea*	3
	Bivalvia			
		Pectinidae	*Leptopecten latiauratus*	1
	Cephalopoda			
		Octopodidae	*Octopus bimaculatus*	1
			Octopus rubescens	25
ANNELIDA				
	Polychaeta			
		Aphroditidae	*Aphrodita refulgida*	2
	Hirudinea		Hirudinea (unidentified)	2
ARTHROPODA				
	Malacostraca			
		Hemisquillidae	*Hemisquilla californiensis*	9
		Cymothoidae	*Elthusa vulgaris*	64
		Sicyoniidae	*Sicyonia ingentis*	22
			Sicyonia penicillata	20

Appendix E.5 *continued*

Taxon/ Species					n
			Hippolytidae	*Heptacarpus palpator*	2
				Heptacarpus stimpsoni	2
			Pandalidae	*Pandalus danae*	1
			Crangonidae	*Crangon alba*	21
				Crangon nigromaculata	286
			Diogenidae	*Paguristes ulreyi*	2
			Paguridae	*Pagurus armatus*	6
				Pagurus spilocarpus	11
			Calappidae	*Platymera gaudichaudii*	6
			Leucosiidae	*Randallia ornata*	2
		Majoidea		Majoidea (unidentified)	1
			Epialtidae	*Pugettia producta*	1
				Loxorhynchus crispatus	4
				Loxorhynchus grandis	6
			Inachidae	*Ericerodes hemphillii*	3
				Podochela lobifrons	2
			Inachoididae	*Pyromaia tuberculata*	38
			Parthenopidae	*Latulambrus occidentalis*	86
			Cancridae	*Metacarcinus gracilis*	75
				Romaleon antennarium	1
ECHINODERMATA					
	Asteroidea				
			Luidiidae	*Luidia armata*	7
				Luidia foliolata	3
			Astropectinidae	*Astropecten californicus*	1304
			Asteriidae	*Pisaster brevispinus*	25
	Ophiuroidea				
			Ophiuridae	*Ophiura luetkenii*	9
			Amphiuridae	*Amphiodia psara*	1
			Ophiotricidae	*Ophiothrix spiculata*	13
	Echinoidea				
			Toxopneustidae	*Lytechinus pictus*	14
			Dendrasteridae	*Dendraster terminalis*	41

Appendix E.6

Total abundance by species and station for megabenthic invertebrates at the SBOO trawl stations during 2013.

	Winter 2013							Species Abundance by Survey
Name	**SD15**	**SD16**	**SD17**	**SD18**	**SD19**	**SD20**	**SD21**	
Astropecten californicus	108	26	11	13	18	15	8	199
Latulambrus occidentalis			24			1		25
Metacarcinus gracilis	1	12		2	1	3	5	24
Crangon nigromaculata				2	6	7	1	16
Pagurus spilocarpus	2	1	2	2		3	1	11
Kelletia kelletii		1	3	2		4		10
Pisaster brevispinus	1	1	6	1		1		10
Pyromaia tuberculata	2	2	3	3				10
Crangon alba	4	2	1					7
Philine auriformis					4	3		7
Elthusa vulgaris		2			3			5
Hemisquilla californiensis		1		1	2	1		5
Ophiothrix spiculata			3	2				5
Sicyonia ingentis				1	1	3		5
Dendronotus iris							4	4
Loxorhynchus crispatus			1	3				4
Lytechinus pictus			1	2			1	4
Octopus rubescens	1		1	2				4
Armina californica						3		3
Dendraster terminalis	3							3
Acanthoptilum sp			1	1				2
Crossata ventricosta		1	1					2
Heptacarpus palpator				2				2
Heptacarpus stimpsoni						1	1	2
Acanthodoris rhodoceras				1				1
Aglaja ocelligera					1			1
Amphiodia psara				1				1
Calliostoma tricolor			1					1
Crassispira semiinflata				1				1
Flabellina iodinea				1				1
Hirudinea (unidentified)			1					1
Luidia foliolata		1						1
Majoidea (unidentified)						1		1
Megastraea turbanica		1						1
Megasurcula carpenteriana			1					1
Octopus bimaculatus				1				1
Randallia ornata		1						1
Sicyonia penicillata						1		1
Survey Total	122	52	61	44	36	47	21	383

Appendix E.6 *continued*

	Spring 2013							
Name	**SD15**	**SD16**	**SD17**	**SD18**	**SD19**	**SD20**	**SD21**	**Species Abundance by Survey**
Astropecten californicus	286	32	21	33		28	9	409
Crangon nigromaculata				1	46	23	197	267
Acanthodoris brunnea			7	6		2	8	23
Metacarcinus gracilis	1		1	1	4	3	11	21
Caesia perpinguis				18			2	20
Latulambrus occidentalis	1		15	3			1	20
Elthusa vulgaris		3	5	3	5	3		19
Sicyonia ingentis		1	2		4	2	4	13
Pyromaia tuberculata	1	1	4	2			2	10
Crangon alba	7			2				9
Sicyonia penicillata		1	1	1	4	2		9
Dendronotus iris					3	3	1	7
Dendraster terminalis	5		1					6
Pisaster brevispinus	2		3	1				6
Philine auriformis					1	3		4
Platymera gaudichaudii	2	1		1				4
Armina californica	2	1						3
Hemisquilla californiensis			1		1	1		3
Luidia armata		2		1				3
Megasurcula carpenteriana				2	1			3
Octopus rubescens					1		2	3
Ophiura luetkenii			1	2				3
Euspira lewisii				2				2
Ophiothrix spiculata			1	1				2
Podochela lobifrons		1	1					2
Stylatula elongata			1	1				2
Crassispira semiinflata				1				1
Flabellina iodinea			1					1
Hirudinea (unidentified)			1					1
Kelletia kelletii				1				1
Loxorhynchus grandis		1						1
Luidia foliolata							1	1
Paguristes ulreyi	1							1
Pandalus danae							1	1
Pteropurpura festiva			1					1
Pugettia producta						1		1
Tritonia tetraquetra		1						1
Survey Total	308	45	68	83	70	71	239	884

Appendix E.6 *continued*

	Summer 2013							
Name	**SD15**	**SD16**	**SD17**	**SD18**	**SD19**	**SD20**	**SD21**	**Species Abundance by Survey**
Astropecten californicus	443	102	66	25	26	11	23	696
Latulambrus occidentalis			19	19	2	1		41
Elthusa vulgaris	8	6		4	13	1	8	40
Dendraster terminalis	30		2					32
Kelletia kelletii		2	9	14	1	3	1	30
Metacarcinus gracilis		2	1		2	4	21	30
Octopus rubescens					2	9	7	18
Pyromaia tuberculata		4	4	4			6	18
Lytechinus pictus			8	2				10
Sicyonia penicillata				1	2	1	6	10
Pisaster brevispinus	1		5	1		2		9
Acanthodoris brunnea				2	1		3	6
Crassispira semiinflata		1	1	2	1	1		6
Ophiothrix spiculata	1			3		2		6
Ophiura luetkenii				1			5	6
Pagurus armatus	2		2	1		1		6
Caesia perpinguis			3	2				5
Crangon alba	4		1					5
Loxorhynchus grandis			1	3		1		5
Acanthodoris rhodoceras	1			3				4
Luidia armata		2		2				4
Sicyonia ingentis			2	1			1	4
Stylatula elongata	3		1					4
Calliostoma annulatum					3			3
Crangon nigromaculata			1		1		1	3
Crossata ventricosa			2	1				3
Dendronotus iris		1				2		3
Dendronotus venustus	3							3
Ericerodes hemphillii					3			3
Aphrodita refulgida		1			1			2
Lepidozona scrobiculata					2			2
Megastraea undosa	1		1					2
Megasurcula carpenteriana		1		1				2
Platymera gaudichaudii				1			1	2
Pteropurpura festiva				2				2
Aglaja ocelligera				1				1
Armina californica			1					1
Calliostoma tricolor				1				1

Appendix E.6 *continued*

Name	**Summer 2013** ***continued***							**Species Abundance by Survey**
	SD15	**SD16**	**SD17**	**SD18**	**SD19**	**SD20**	**SD21**	
Euspira draconis			1					1
Flabellina iodinea		1						1
Hemisquilla californiensis							1	1
Leptopecten latiauratus					1			1
Luidia foliolata							1	1
Paguristes ulreyi				1				1
Pleurobranchaea californica				1				1
Randallia ornata		1						1
Romaleon antennarium					1			1
Survey Total	497	124	131	99	62	39	85	1037
Annual Total	**927**	**221**	**260**	**226**	**168**	**157**	**345**	**2304**

Appendix E.7

Pairwise r- and significance values for all year comparisons (Factor B) from the SBOO two-way crossed ANOSIM for megabenthic invertebrate assemblages sampled from 1995 through 2013. Data are limited to summer surveys. Shading indicates significant difference (see Table 6.7).

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1996	r-value	-0.279																	
	sig value	94.4																	
1997	r-value	-0.047	0.047																
	sig value	60	41.1																
1998	r-value	-0.047	0.302	0.186															
	sig value	53.3	14.4	22.2															
1999	r-value	0.349	-0.116	0.326	0.442														
	sig value	8.9	73.3	10	8.9														
2000	r-value	0.419	0.419	0.488	0.419	0.465													
	sig value	7.8	8.9	6.7	5.6	5.6													
2001	r-value	0.349	0.186	0.163	0.651	0.605	0.535												
	sig value	5.6	12.2	24.4	3.3	3.3	5.6												
2002	r-value	-0.07	-0.186	0.093	0.419	0.163	0.279	-0.07											
	sig value	63.3	80	36.7	7.8	25.6	15.6	66.7											
2003	r-value	0.023	-0.163	0.07	0.442	-0.023	0.349	0.093	-0.302										
	sig value	44.4	93.3	34.4	6.7	55.6	10	32.2	91.1										
2004	r-value	-0.047	0.14	0.326	0.326	0.442	0.512	0.419	-0.279	-0.047									
	sig value	60	26.7	8.9	12.2	4.4	4.4	5.6	86.7	57.8									
2005	r-value	0.256	0.023	0.233	0.256	0.372	0.605	0.651	0.209	0.163	0.279								
	sig value	15.6	50	12.2	12.2	10	2.2	3.3	22.2	20	11.1								
2006	r-value	0.093	-0.07	0.116	0.186	0.14	0.535	0.302	0.023	0.186	0.256	0.07							
	sig value	31.1	66.7	26.7	18.9	27.8	4.4	10	48.9	20	12.2	41.1							
2007	r-value	-0.07	0.093	0.279	0.233	0.326	0.372	0.349	0.023	-0.093	0.093	0.279	0.116						
	sig value	57.8	37.8	13.3	20	8.9	10	8.9	46.7	65.6	37.8	8.9	35.6						
2008	r-value	-0.163	0.07	0.198	-0.081	0.163	0.291	0.233	0.081	0.233	0.186	0.047	-0.023	0.047					
	sig value	75.6	33.3	16.7	68.9	24.4	14.4	7.8	38.9	11.1	21.1	46.7	58.9	42.2					
2009	r-value	0.395	0.349	0.442	0.581	0.419	0.535	0.605	0.326	0.209	0.442	0.395	0.488	0	-0.07				
	sig value	3.3	10	3.3	2.2	3.3	3.3	3.3	4.4	8.9	2.2	5.6	2.2	55.6	70				
2010	r-value	0.605	0.581	0.512	0.767	0.558	0.721	0.814	0.488	0.651	0.395	0.605	0.558	0.512	0.209	-0.209			
	sig value	3.3	3.3	4.4	2.2	5.6	2.2	2.2	5.6	3.3	6.7	4.4	2.2	4.4	16.7	84.4			
2011	r-value	0.279	0.163	0.326	0.488	0.628	0.791	0.512	0.279	0.605	0.279	0.558	0.535	0.14	0.186	0.14	0.349		
	sig value	16.7	25.6	6.7	7.8	2.2	2.2	2.2	14.4	2.2	17.8	2.2	2.2	32.2	26.7	25.6	11.1		
2012	r-value	0.349	0.326	0.465	0.442	0.488	0.349	0.767	0.186	0.419	0.372	0.442	0.442	0.07	-0.047	0.209	0.349	0.047	
	sig value	10	6.7	2.2	3.3	3.3	6.7	2.2	27.8	4.4	8.9	3.3	3.3	38.9	55.6	13.3	5.6	43.3	
2013	r-value	0.535	0.628	0.674	0.86	0.837	0.814	0.907	0.605	0.953	0.698	0.907	0.977	0.442	0.419	0.372	0.465	0.349	0.372
	sig value	4.4	2.2	2.2	2.2	1.1	1.1	1.1	1.1	1.1	2.2	1.1	1.1	1.1	4.4	2.2	3.3	12.2	2.2

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Appendix F

Supporting Data

2013 SBOO Stations

Bioaccumulation of Contaminants in Fish Tissues

Appendix F.1

Lengths and weights of fishes used for each composite (Comp) tissue sample from SBOO trawl and rig fishing stations during April and October 2013. Data are summarized as number of individuals (n), minimum, maximum, and mean values.

				Length (cm, size class)			Weight (g)		
Station	**Comp**	**Species**	**n**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
April 2013									
RF3	1	Mixed rockfish	3	19	21	20	195	245	221
RF3	2	California scorpionfish	2	17	22	20	177	355	266
RF3	3	Gopher rockfish	3	15	19	17	90	164	126
RF4	1	Mixed rockfish	3	20	22	21	174	252	210
RF4	2	Mixed rockfish	3	23	26	25	230	510	352
RF4	3	Tree rockfish	3	23	29	26	469	716	568
SD15	1	English sole	3	16	26	21	62	308	178
SD15	2	English sole	5	14	26	18	39	273	103
SD15	3	Hornyhead turbot	3	14	19	17	76	183	122
SD16	1	Longfin sanddab	7	13	20	15	50	172	83
SD16	2	English sole	11	14	23	17	41	172	78
SD16	3	Hornyhead turbot	3	13	17	15	33	70	55
SD17	1	English sole	5	20	25	22	103	231	150
SD17	2	Longfin sanddab	6	14	21	17	50	204	110
SD17	3	English sole	11	14	20	16	37	107	61
SD18	1	English sole	6	19	25	21	100	215	151
SD18	2	Hornyhead turbot	6	17	20	19	103	210	173
SD18	3	Longfin sanddab	6	15	20	16	64	182	101
SD19	1	Hornyhead turbot	5	18	20	19	173	225	199
SD19	2	English sole	6	17	22	20	56	163	103
SD19	3	Longfin sanddab	3	13	21	17	49	220	135
SD20	1	English sole	9	15	21	17	54	125	79
SD20	2	English sole	3	18	31	23	77	494	227
SD20	3	English sole	10	14	24	17	41	226	82
SD21	1	English sole	4	23	24	23	189	216	204
SD21	2	Hornyhead turbot	5	20	22	21	186	292	239
SD21	3	Hornyhead turbot	6	15	21	18	89	274	174

Appendix F.1 *continued*

Station	Comp	Species	n	Length (cm, size class) Min	Max	Mean	Weight (g) Min	Max	Mean
October 2013									
RF3	1	Vermilion rockfish	3	21	26	23	259	499	388
RF3	2	Mixed rockfish	3	23	27	25	294	510	380
RF3	3	Mixed rockfish	3	21	33	25	265	1267	613
RF4	1	California scorpionfish	3	25	28	26	403	672	529
RF4	2	California scorpionfish	3	24	31	28	360	900	663
RF4	3	California scorpionfish	3	25	27	26	460	504	481
SD15	1	Hornyhead turbot	5	14	21	18	72	242	145
SD15	2	Hornyhead turbot	5	12	20	18	41	204	155
SD15	3	Hornyhead turbot	5	12	20	18	41	204	155
SD16	1	Longfin sanddab	3	15	22	18	63	267	146
SD16	2	Hornyhead turbot	4	17	23	19	132	334	198
SD16	3	Longfin sanddab	7	13	18	15	47	122	70
SD17	1	Hornyhead turbot	4	15	21	17	81	250	147
SD17	2	Hornyhead turbot	4	14	19	17	84	173	141
SD17	3	Hornyhead turbot	8	14	16	15	73	117	88
SD18	1	Hornyhead turbot	4	18	20	19	136	200	176
SD18	2	Hornyhead turbot	6	16	20	18	113	172	147
SD18	3	Longfin sanddab	3	15	19	17	73	146	113
SD19	1	Hornyhead turbot	5	14	21	17	67	254	142
SD19	2	Longfin sanddab	5	14	17	16	55	108	83
SD19	3	Longfin sanddab	3	15	20	18	76	175	122
SD20	1	Longfin sanddab	3	19	21	20	149	181	163
SD20	2	Longfin sanddab	5	14	18	16	56	132	82
SD20	3	Longfin sanddab	4	16	17	16	79	118	93
SD21	1	Longfin sanddab	3	15	20	18	56	175	124
SD21	2	Longfin sanddab	3	14	19	17	61	128	105
SD21	3	Longfin sanddab	3	17	18	18	98	137	112

Appendix F.2

Constituents and method detection limits (MDL) used for the analysis of liver and muscle tissues of fishes collected from the SBOO region during 2013.

	MDL			MDL	
Parameter	**Liver**	**Muscle**	**Parameter**	**Liver**	**Muscle**
Metals (ppm)					
Aluminum (Al)	3.0	3.0	Lead (Pb)	0.2	0.2
Antimony (Sb)	0.2	0.2	Manganese (Mn)	0.1	0.1
Arsenic (As)	0.24	0.24	Mercury (Hg)	0.002	0.002
Barium (Ba)	0.03	0.03	Nickel (Ni)	0.2	0.2
Beryllium (Be)	0.006	0.006	Selenium (Se)	0.06	0.06
Cadmium (Cd)	0.06	0.06	Silver (Ag)	0.05	0.05
Chromium (Cr)	0.1	0.1	Thallium (Tl)	0.4	0.4
Copper (Cu)	0.3	0.3	Tin (Sn)	0.2	0.2
Iron (Fe)	2.0	2.0	Zinc (Zn)	0.15	0.15
Chlorinated Pesticides (ppb)					
Hexachlorocyclohexane (HCH)					
HCH, Alpha isomer	17.4	1.74	HCH, Delta isomer	6.32	0.63
HCH, Beta isomer	10.3	1.03	HCH, Gamma isomer	50.40	5.04
Total Chlordane					
Alpha (cis) chlordane	2.02	0.20	Heptachlor epoxide	3.79	0.38
Cis nonachlor	1.91	0.19	Oxychlordane	2.92	0.29
Gamma (trans) chlordane	3.07	0.31	Trans nonachlor	1.44	0.14
Heptachlor	2.10	0.21			
Total Dichlorodiphenyltrichloroethane (DDT)					
o,p-DDD	1.98	0.20	p,p-DDD	2.86	0.29
o,p-DDE	2.52	0.25	p,p-DDE	4.94	0.49
o,p-DDT	2.05	0.20	p,p-DDT	2.76	0.28
p,-p-DDMU	1.82	0.18			
Miscellaneous Pesticides					
Aldrin	25.3	2.53	Endrin	30.3	3.03
Alpha endosulfan	24.7	2.47	Hexachlorobenzene (HCB)	2.29	0.23
Dieldrin	12.6	1.26	Mirex	1.77	0.18

Appendix F.2 *continued*

	MDL			MDL	
Parameter	**Liver**	**Muscle**	**Parameter**	**Liver**	**Muscle**
Polychlorinated Biphenyls Congeners (PCBs) (ppb)					
PCB 18	1.49	0.15	PCB 126	1.93	0.19
PCB 28	1.47	0.15	PCB 128	2.28	0.23
PCB 37	2.03	0.20	PCB 138	1.93	0.19
PCB 44	1.88	0.19	PCB 149	1.92	0.19
PCB 49	1.67	0.17	PCB 151	1.52	0.15
PCB 52	1.66	0.17	PCB 153/168	3.76	0.38
PCB 66	1.86	0.19	PCB 156	2.33	0.23
PCB 70	2.05	0.20	PCB 157	2.77	0.28
PCB 74	2.11	0.21	PCB 158	2.55	0.26
PCB 77	3.32	0.33	PCB 167	2.05	0.21
PCB 81	1.91	0.19	PCB 169	1.41	0.14
PCB 87	1.95	0.19	PCB 170	2.16	0.22
PCB 99	1.54	0.15	PCB 177	1.96	0.20
PCB 101	1.70	0.17	PCB 180	2.89	0.29
PCB 105	2.28	0.23	PCB 183	2.06	0.21
PCB 110	2.13	0.21	PCB 187	2.25	0.23
PCB 114	2.77	0.28	PCB 189	1.78	0.18
PCB 118	2.56	0.26	PCB 194	3.41	0.34
PCB 119	2.72	0.27	PCB 201	2.76	0.28
PCB 123	3.04	0.30	PCB 206	1.84	0.18
Polycyclic Aromatic Hydrocarbons (PAHs) (ppb)					
1-methylnaphthalene	27.9	26.4	Benzo[K]fluoranthene	32.0	37.3
1-methylphenanthrene	17.4	23.3	Benzo[e]pyrene	41.8	40.6
2,3,5-trimethylnaphthalene	21.7	21.6	Biphenyl	38.0	19.9
2,6-dimethylnaphthalene	21.7	19.5	Chrysene	18.1	23.0
2-methylnaphthalene	35.8	13.2	Dibenzo(A,H)anthracene	37.6	40.3
3,4-benzo(B)fluoranthene	30.2	26.8	Fluoranthene	19.9	12.9
Acenaphthene	28.9	11.3	Fluorene	27.3	11.4
Acenaphthylene	24.7	9.1	Indeno(1,2,3-CD)pyrene	25.6	46.5
Anthracene	25.3	8.4	Naphthalene	34.2	17.4
Benzo[A]anthracene	47.3	15.9	Perylene	18.5	50.9
Benzo[A]pyrene	42.9	18.3	Phenanthrene	11.6	12.9
Benzo[G,H,I]perylene	27.2	59.5	Pyrene	9.1	16.6

Appendix F.3

Summary of constituents that make up total DDT, total chlordane, total PCB, and total PAH in composite (Comp) tissue samples from the SBOO region during April and October 2013.

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	RF3	1	Mixed rockfish	Muscle	PCB	PCB 138	0.2	ppb
2013-2	RF3	1	Mixed rockfish	Muscle	PCB	PCB 153/168	0.3	ppb
2013-2	RF3	1	Mixed rockfish	Muscle	DDT	p,p-DDE	1.9	ppb
2013-2	RF3	2	California scorpionfish	Muscle	PCB	PCB 118	0.3	ppb
2013-2	RF3	2	California scorpionfish	Muscle	PCB	PCB 138	0.2	ppb
2013-2	RF3	2	California scorpionfish	Muscle	PCB	PCB 153/168	0.5	ppb
2013-2	RF3	2	California scorpionfish	Muscle	PCB	PCB 180	0.2	ppb
2013-2	RF3	2	California scorpionfish	Muscle	PCB	PCB 206	0.2	ppb
2013-2	RF3	2	California scorpionfish	Muscle	DDT	p,p-DDD	0.2	ppb
2013-2	RF3	2	California scorpionfish	Muscle	DDT	p,p-DDE	3.6	ppb
2013-2	RF3	3	Gopher rockfish	Muscle	PCB	PCB 49	0.1	ppb
2013-2	RF3	3	Gopher rockfish	Muscle	PCB	PCB 52	0.2	ppb
2013-2	RF3	3	Gopher rockfish	Muscle	PCB	PCB 66	0.1	ppb
2013-2	RF3	3	Gopher rockfish	Muscle	PCB	PCB 153/168	0.2	ppb
2013-2	RF3	3	Gopher rockfish	Muscle	DDT	p,p-DDE	1.0	ppb
2013-2	RF4	1	Mixed rockfish	Muscle	PCB	PCB 206	0.2	ppb
2013-2	RF4	1	Mixed rockfish	Muscle	DDT	p,p-DDE	1.0	ppb
2013-2	RF4	2	Mixed rockfish	Muscle	PCB	PCB 138	0.2	ppb
2013-2	RF4	2	Mixed rockfish	Muscle	PCB	PCB 153/168	0.5	ppb
2013-2	RF4	2	Mixed rockfish	Muscle	PCB	PCB 180	0.2	ppb
2013-2	RF4	2	Mixed rockfish	Muscle	DDT	p,p-DDE	4.0	ppb
2013-2	RF4	3	Treefish	Muscle	PCB	PCB 66	0.1	ppb
2013-2	RF4	3	Treefish	Muscle	PCB	PCB 101	0.3	ppb
2013-2	RF4	3	Treefish	Muscle	PCB	PCB 118	0.4	ppb
2013-2	RF4	3	Treefish	Muscle	PCB	PCB 138	0.3	ppb
2013-2	RF4	3	Treefish	Muscle	PCB	PCB 149	0.1	ppb
2013-2	RF4	3	Treefish	Muscle	PCB	PCB 153/168	0.8	ppb
2013-2	RF4	3	Treefish	Muscle	PCB	PCB 180	0.3	ppb
2013-2	RF4	3	Treefish	Muscle	DDT	p,p-DDD	0.2	ppb
2013-2	RF4	3	Treefish	Muscle	DDT	p,p-DDE	7.1	ppb
2013-2	SD15	1	English sole	Liver	PCB	PCB 118	5.9	ppb
2013-2	SD15	1	English sole	Liver	PCB	PCB 138	6.5	ppb
2013-2	SD15	1	English sole	Liver	PCB	PCB 149	3.7	ppb
2013-2	SD15	1	English sole	Liver	PCB	PCB 153/168	12.0	ppb
2013-2	SD15	1	English sole	Liver	PCB	PCB 187	8.2	ppb
2013-2	SD15	1	English sole	Liver	DDT	p,p-DDE	79.0	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 49	1.1	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 66	2.2	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 70	1.2	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 74	1.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	SD15	2	English sole	Liver	PCB	PCB 101	6.1	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 110	4.8	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 118	6.9	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 138	8.4	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 149	7.2	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 151	2.0	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 153/168	16.0	ppb
2013-2	SD15	2	English sole	Liver	PCB	PCB 187	9.7	ppb
2013-2	SD15	2	English sole	Liver	DDT	o,p-DDE	25.0	ppb
2013-2	SD15	2	English sole	Liver	DDT	p,-p-DDMU	65.0	ppb
2013-2	SD15	2	English sole	Liver	DDT	p,p-DDE	370.0	ppb
2013-2	SD15	3	Hornyhead turbot	Liver	PCB	PCB 138	2.1	ppb
2013-2	SD15	3	Hornyhead turbot	Liver	PCB	PCB 153/168	5.1	ppb
2013-2	SD15	3	Hornyhead turbot	Liver	DDT	p,p-DDE	26.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 66	1.5	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 74	0.8	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 101	13.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 118	13.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 128	4.8	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 138	24.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 149	5.9	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 151	4.1	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 153/168	52.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 170	6.5	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 180	18.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 183	5.5	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 187	20.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 201	7.0	ppb
2013-2	SD16	1	Longfin sanddab	Liver	PCB	PCB 206	3.8	ppb
2013-2	SD16	1	Longfin sanddab	Liver	DDT	o,p-DDE	6.1	ppb
2013-2	SD16	1	Longfin sanddab	Liver	DDT	p,-p-DDMU	8.2	ppb
2013-2	SD16	1	Longfin sanddab	Liver	DDT	p,p-DDE	300.0	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 49	1.2	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 66	1.3	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 101	6.1	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 110	3.4	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 118	7.6	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 138	11.0	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 149	8.7	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 151	3.3	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 153/168	27.0	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 180	9.5	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 183	4.0	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 187	16.0	ppb
2013-2	SD16	2	English sole	Liver	PCB	PCB 206	2.7	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	SD16	2	English sole	Liver	DDT	o,p-DDE	3.4	ppb
2013-2	SD16	2	English sole	Liver	DDT	p,-p-DDMU	3.1	ppb
2013-2	SD16	2	English sole	Liver	DDT	p,p-DDE	130.0	ppb
2013-2	SD16	3	Hornyhead turbot	Liver	PCB	PCB 153/168	3.9	ppb
2013-2	SD16	3	Hornyhead turbot	Liver	DDT	p,p-DDE	35.0	ppb
2013-2	SD17	1	English sole	Liver	PCB	PCB 66	0.9	ppb
2013-2	SD17	1	English sole	Liver	PCB	PCB 70	1.1	ppb
2013-2	SD17	1	English sole	Liver	PCB	PCB 138	4.1	ppb
2013-2	SD17	1	English sole	Liver	PCB	PCB 149	2.8	ppb
2013-2	SD17	1	English sole	Liver	PCB	PCB 153/168	8.1	ppb
2013-2	SD17	1	English sole	Liver	PCB	PCB 180	2.6	ppb
2013-2	SD17	1	English sole	Liver	PCB	PCB 187	2.2	ppb
2013-2	SD17	1	English sole	Liver	DDT	p,p-DDE	47.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 49	1.2	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 52	1.9	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 66	1.6	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 74	1.1	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 101	13.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 110	3.7	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 118	15.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 128	4.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 138	27.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 149	5.3	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 151	5.3	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 153/168	62.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 158	2.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 170	6.9	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 180	21.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 183	6.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 187	22.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 201	6.1	ppb
2013-2	SD17	2	Longfin sanddab	Liver	PCB	PCB 206	4.3	ppb
2013-2	SD17	2	Longfin sanddab	Liver	DDT	o,p-DDE	4.8	ppb
2013-2	SD17	2	Longfin sanddab	Liver	DDT	p,-p-DDMU	13.0	ppb
2013-2	SD17	2	Longfin sanddab	Liver	DDT	p,p-DDD	6.7	ppb
2013-2	SD17	2	Longfin sanddab	Liver	DDT	p,p-DDE	390.0	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 49	2.6	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 52	2.0	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 66	3.4	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 70	2.1	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 74	1.4	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 101	8.3	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 110	4.9	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 118	11.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	SD17	3	English sole	Liver	PCB	PCB 138	15.0	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 149	10.0	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 151	2.4	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 153/168	28.0	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 170	3.7	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 180	10.0	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 183	3.6	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 187	13.0	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 201	5.9	ppb
2013-2	SD17	3	English sole	Liver	PCB	PCB 206	3.0	ppb
2013-2	SD17	3	English sole	Liver	DDT	o,p-DDE	16.0	ppb
2013-2	SD17	3	English sole	Liver	DDT	p,-p-DDMU	32.0	ppb
2013-2	SD17	3	English sole	Liver	DDT	p,p-DDD	3.9	ppb
2013-2	SD17	3	English sole	Liver	DDT	p,p-DDE	270.0	ppb
2013-2	SD18	1	English sole	Liver	PCB	PCB 66	0.8	ppb
2013-2	SD18	1	English sole	Liver	PCB	PCB 101	2.9	ppb
2013-2	SD18	1	English sole	Liver	PCB	PCB 138	4.8	ppb
2013-2	SD18	1	English sole	Liver	PCB	PCB 149	4.8	ppb
2013-2	SD18	1	English sole	Liver	PCB	PCB 153/168	9.6	ppb
2013-2	SD18	1	English sole	Liver	DDT	o,p-DDE	1.5	ppb
2013-2	SD18	1	English sole	Liver	DDT	p,p-DDE	53.5	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PAH	2,6-dimethylnaphthalene	60.4	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 49	1.0	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 66	0.8	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 101	3.8	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 118	4.2	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 138	6.6	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 149	3.4	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 151	1.2	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 153/168	16.0	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 180	6.6	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 183	2.1	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 187	6.4	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	PCB	PCB 206	1.9	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	DDT	o,p-DDE	1.8	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	DDT	p,-p-DDMU	6.6	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	DDT	p,p-DDD	3.5	ppb
2013-2	SD18	2	Hornyhead turbot	Liver	DDT	p,p-DDE	150.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 101	18.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 105	5.2	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 110	5.6	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 118	21.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 128	6.5	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 138	38.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 149	9.5	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 28	1.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 49	2.3	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 52	3.8	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 66	2.9	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 70	1.5	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 74	1.9	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 151	5.4	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 153/168	65.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 158	2.4	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 167	2.2	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 170	8.4	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 177	4.9	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 180	30.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 183	7.8	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 187	31.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 194	8.1	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 201	7.8	ppb
2013-2	SD18	3	Longfin sanddab	Liver	PCB	PCB 206	4.4	ppb
2013-2	SD18	3	Longfin sanddab	Liver	DDT	o,p-DDE	7.6	ppb
2013-2	SD18	3	Longfin sanddab	Liver	DDT	p,-p-DDMU	16.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	DDT	p,p-DDD	8.6	ppb
2013-2	SD18	3	Longfin sanddab	Liver	DDT	p,p-DDE	410.0	ppb
2013-2	SD18	3	Longfin sanddab	Liver	DDT	p,p-DDT	6.3	ppb
2013-2	SD18	3	Longfin sanddab	Liver	Chlordane	Trans Nonachlor	4.5	ppb
2013-2	SD19	1	Hornyhead turbot	Liver	PCB	PCB 138	2.8	ppb
2013-2	SD19	1	Hornyhead turbot	Liver	PCB	PCB 149	1.3	ppb
2013-2	SD19	1	Hornyhead turbot	Liver	PCB	PCB 153/168	5.7	ppb
2013-2	SD19	1	Hornyhead turbot	Liver	PCB	PCB 180	2.3	ppb
2013-2	SD19	1	Hornyhead turbot	Liver	DDT	p,-p-DDMU	2.6	ppb
2013-2	SD19	1	Hornyhead turbot	Liver	DDT	p,p-DDE	52.0	ppb
2013-2	SD19	2	English sole	Liver	PCB	PCB 66	0.8	ppb
2013-2	SD19	2	English sole	Liver	PCB	PCB 101	2.0	ppb
2013-2	SD19	2	English sole	Liver	PCB	PCB 138	3.7	ppb
2013-2	SD19	2	English sole	Liver	PCB	PCB 149	1.8	ppb
2013-2	SD19	2	English sole	Liver	PCB	PCB 153/168	7.9	ppb
2013-2	SD19	2	English sole	Liver	PCB	PCB 180	3.1	ppb
2013-2	SD19	2	English sole	Liver	PCB	PCB 187	4.0	ppb
2013-2	SD19	2	English sole	Liver	DDT	p,p-DDE	68.0	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 66	1.0	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 101	6.3	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 105	1.9	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 110	1.9	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 118	8.5	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 128	2.6	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 138	13.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 149	3.6	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 151	1.9	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 153/168	27.0	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 170	2.9	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 180	10.0	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 183	2.3	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 187	8.6	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 201	3.1	ppb
2013-2	SD19	3	Longfin sanddab	Liver	PCB	PCB 206	2.2	ppb
2013-2	SD19	3	Longfin sanddab	Liver	DDT	o,p-DDE	3.2	ppb
2013-2	SD19	3	Longfin sanddab	Liver	DDT	p,-p-DDMU	6.5	ppb
2013-2	SD19	3	Longfin sanddab	Liver	DDT	p,p-DDD	2.2	ppb
2013-2	SD19	3	Longfin sanddab	Liver	DDT	p,p-DDE	180.0	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 49	2.2	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 52	1.6	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 66	2.2	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 70	1.9	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 74	0.9	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 87	2.7	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 101	8.5	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 105	3.3	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 110	6.5	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 118	14.0	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 138	12.0	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 149	7.3	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 151	3.4	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 153/168	24.0	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 170	2.7	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 180	8.4	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 183	2.9	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 187	11.0	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 201	3.2	ppb
2013-2	SD20	1	English sole	Liver	PCB	PCB 206	3.2	ppb
2013-2	SD20	1	English sole	Liver	DDT	o,p-DDE	2.6	ppb
2013-2	SD20	1	English sole	Liver	DDT	p,-p-DDMU	3.8	ppb
2013-2	SD20	1	English sole	Liver	DDT	p,p-DDD	3.2	ppb
2013-2	SD20	1	English sole	Liver	DDT	p,p-DDE	130.0	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 49	1.1	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 66	1.4	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 70	1.1	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 74	0.7	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 101	5.1	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 110	3.3	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 118	7.7	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 138	9.1	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 149	5.6	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	SD20	2	English sole	Liver	PCB	PCB 151	1.7	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 153/168	19.0	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 180	6.0	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 183	1.9	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 187	7.1	ppb
2013-2	SD20	2	English sole	Liver	PCB	PCB 206	2.2	ppb
2013-2	SD20	2	English sole	Liver	DDT	o,p-DDE	2.5	ppb
2013-2	SD20	2	English sole	Liver	DDT	p,p-DDE	95.0	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 49	1.1	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 66	1.2	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 70	0.9	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 101	5.8	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 110	3.1	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 118	7.3	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 138	11.0	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 149	7.1	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 151	1.8	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 153/168	21.0	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 180	7.3	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 183	2.7	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 187	9.6	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 201	3.4	ppb
2013-2	SD20	3	English sole	Liver	PCB	PCB 206	2.3	ppb
2013-2	SD20	3	English sole	Liver	DDT	o,p-DDE	3.0	ppb
2013-2	SD20	3	English sole	Liver	DDT	p,p-DDE	110.0	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 66	0.9	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 101	3.4	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 110	1.6	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 138	5.8	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 149	4.6	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 153/168	13.0	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 180	5.4	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 187	5.6	ppb
2013-2	SD21	1	English sole	Liver	PCB	PCB 206	2.2	ppb
2013-2	SD21	1	English sole	Liver	DDT	o,p-DDE	1.6	ppb
2013-2	SD21	1	English sole	Liver	DDT	p,p-DDE	67.0	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 49	0.9	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 66	1.1	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 101	4.1	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 118	5.9	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 138	9.3	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 149	2.6	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 153/168	14.0	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 180	4.5	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 183	1.2	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 187	4.8	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	PCB	PCB 206	2.1	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	DDT	p,p-DDD	2.2	ppb
2013-2	SD21	2	Hornyhead turbot	Liver	DDT	p,p-DDE	59.0	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 49	0.8	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 66	0.8	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 101	3.3	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 118	3.3	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 138	5.5	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 149	2.5	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 153/168	11.1	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 180	2.6	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	PCB	PCB 187	4.3	ppb
2013-2	SD21	3	Hornyhead turbot	Liver	DDT	p,p-DDE	41.5	ppb
2013-4	RF3	1	Vermilion rockfish	Muscle	PCB	PCB 153/168	0.1	ppb
2013-4	RF3	1	Vermilion rockfish	Muscle	DDT	p,p-DDE	1.3	ppb
2013-4	RF3	2	Mixed rockfish	Muscle	PCB	PCB 153/168	0.1	ppb
2013-4	RF3	2	Mixed rockfish	Muscle	DDT	p,p-DDE	1.0	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 49	0.2	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 66	0.1	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 70	0.1	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 74	0.1	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 99	0.4	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 101	0.6	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 110	0.3	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 118	0.6	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 128	0.1	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 138	0.4	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 149	0.4	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 153/168	1.1	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 170	0.1	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 180	0.2	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 183	0.1	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	PCB	PCB 187	0.3	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	DDT	p,-p-DDMU	0.4	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	DDT	p,p-DDD	0.5	ppb
2013-4	RF3	3	Mixed rockfish	Muscle	DDT	p,p-DDE	11.0	ppb
2013-4	RF4	1	California scorpionfish	Muscle	PCB	PCB 153/168	0.2	ppb
2013-4	RF4	1	California scorpionfish	Muscle	PCB	PCB 187	0.1	ppb
2013-4	RF4	1	California scorpionfish	Muscle	DDT	p,p-DDE	1.0	ppb
2013-4	RF4	2	California scorpionfish	Muscle	PCB	PCB 118	0.3	ppb
2013-4	RF4	2	California scorpionfish	Muscle	PCB	PCB 138	0.2	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	RF4	2	California scorpionfish	Muscle	PCB	PCB 149	0.1	ppb
2013-4	RF4	2	California scorpionfish	Muscle	PCB	PCB 153/168	0.5	ppb
2013-4	RF4	2	California scorpionfish	Muscle	PCB	PCB 180	0.1	ppb
2013-4	RF4	2	California scorpionfish	Muscle	PCB	PCB 187	0.1	ppb
2013-4	RF4	2	California scorpionfish	Muscle	DDT	p,p-DDE	5.6	ppb
2013-4	RF4	3	California scorpionfish	Muscle	PCB	PCB 138	0.1	ppb
2013-4	RF4	3	California scorpionfish	Muscle	PCB	PCB 153/168	0.2	ppb
2013-4	RF4	3	California scorpionfish	Muscle	PCB	PCB 187	0.1	ppb
2013-4	RF4	3	California scorpionfish	Muscle	DDT	p,p-DDE	3.4	ppb
2013-4	SD15	1	Hornyhead turbot	Liver	PCB	PCB 138	1.9	ppb
2013-4	SD15	1	Hornyhead turbot	Liver	PCB	PCB 149	1.0	ppb
2013-4	SD15	1	Hornyhead turbot	Liver	PCB	PCB 153/168	4.5	ppb
2013-4	SD15	1	Hornyhead turbot	Liver	PCB	PCB 180	2.0	ppb
2013-4	SD15	1	Hornyhead turbot	Liver	PCB	PCB 187	1.4	ppb
2013-4	SD15	1	Hornyhead turbot	Liver	DDT	p,p-DDE	28.0	ppb
2013-4	SD15	2	Hornyhead turbot	Liver	PCB	PCB 138	1.3	ppb
2013-4	SD15	2	Hornyhead turbot	Liver	PCB	PCB 153/168	3.1	ppb
2013-4	SD15	2	Hornyhead turbot	Liver	PCB	PCB 180	1.0	ppb
2013-4	SD15	2	Hornyhead turbot	Liver	PCB	PCB 187	1.3	ppb
2013-4	SD15	2	Hornyhead turbot	Liver	DDT	p,-p-DDMU	1.2	ppb
2013-4	SD15	2	Hornyhead turbot	Liver	DDT	p,p-DDE	24.0	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	PCB	PCB 138	1.2	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	PCB	PCB 149	1.0	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	PCB	PCB 153/168	2.9	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	PCB	PCB 180	1.2	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	PCB	PCB 187	2.0	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	DDT	o,p-DDE	0.8	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	DDT	p,-p-DDMU	1.3	ppb
2013-4	SD15	3	Hornyhead turbot	Liver	DDT	p,p-DDE	25.0	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 66	0.8	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 99	3.6	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 101	2.7	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 118	5.7	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 138	8.1	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 149	2.5	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 151	1.8	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 153/168	17.0	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 170	2.3	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 180	7.4	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 183	1.9	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 187	8.7	ppb
2013-4	SD16	1	Longfin sanddab	Liver	PCB	PCB 201	2.8	ppb
2013-4	SD16	1	Longfin sanddab	Liver	DDT	o,p-DDE	2.2	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD16	1	Longfin sanddab	Liver	DDT	p,-p-DDMU	4.3	ppb
2013-4	SD16	1	Longfin sanddab	Liver	DDT	p,p-DDE	110.0	ppb
2013-4	SD16	2	Hornyhead turbot	Liver	PCB	PCB 153/168	2.0	ppb
2013-4	SD16	2	Hornyhead turbot	Liver	PCB	PCB 187	0.9	ppb
2013-4	SD16	2	Hornyhead turbot	Liver	DDT	p,p-DDE	14.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 49	1.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 66	1.8	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 70	0.9	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 74	1.3	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 99	12.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 101	5.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 105	3.7	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 110	2.5	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 118	18.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 128	4.2	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 138	27.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 149	5.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 151	4.3	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 153/168	52.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 158	1.5	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 167	1.4	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 170	8.1	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 180	22.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 183	5.7	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 187	26.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 194	5.7	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 201	8.3	ppb
2013-4	SD16	3	Longfin sanddab	Liver	PCB	PCB 206	3.8	ppb
2013-4	SD16	3	Longfin sanddab	Liver	DDT	o,p-DDE	6.2	ppb
2013-4	SD16	3	Longfin sanddab	Liver	DDT	p,-p-DDMU	13.0	ppb
2013-4	SD16	3	Longfin sanddab	Liver	DDT	p,p-DDD	5.2	ppb
2013-4	SD16	3	Longfin sanddab	Liver	DDT	p,p-DDE	400.0	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 118	2.4	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 138	3.0	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 149	1.5	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 151	0.8	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 153/168	6.1	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 177	0.9	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 180	3.1	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 183	1.0	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 187	3.4	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	PCB	PCB 206	1.5	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	DDT	o,p-DDE	1.1	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	DDT	p,-p-DDMU	4.1	ppb
2013-4	SD17	1	Hornyhead turbot	Liver	DDT	p,p-DDE	65.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD17	2	Hornyhead turbot	Liver	PCB	PCB 118	2.1	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	PCB	PCB 138	1.7	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	PCB	PCB 149	0.9	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	PCB	PCB 153/168	3.9	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	PCB	PCB 180	1.6	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	PCB	PCB 187	1.9	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	DDT	o,p-DDE	0.9	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	DDT	p,-p-DDMU	2.5	ppb
2013-4	SD17	2	Hornyhead turbot	Liver	DDT	p,p-DDE	45.0	ppb
2013-4	SD17	3	Hornyhead turbot	Liver	PCB	PCB 138	1.6	ppb
2013-4	SD17	3	Hornyhead turbot	Liver	PCB	PCB 149	0.9	ppb
2013-4	SD17	3	Hornyhead turbot	Liver	PCB	PCB 153/168	3.7	ppb
2013-4	SD17	3	Hornyhead turbot	Liver	PCB	PCB 180	1.3	ppb
2013-4	SD17	3	Hornyhead turbot	Liver	PCB	PCB 187	1.8	ppb
2013-4	SD17	3	Hornyhead turbot	Liver	DDT	p,p-DDE	34.5	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 49	0.8	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 118	3.1	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 138	3.4	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 149	1.7	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 153/168	7.9	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 170	1.3	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 180	3.7	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 183	1.4	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	PCB	PCB 187	4.1	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	DDT	o,p-DDE	1.5	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	DDT	p,-p-DDMU	6.0	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	DDT	p,p-DDD	2.3	ppb
2013-4	SD18	1	Hornyhead turbot	Liver	DDT	p,p-DDE	89.0	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PAH	1-methylphenanthrene	83.2	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PAH	Fluoranthene	53.4	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PAH	Pyrene	49.2	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 118	2.2	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 138	3.1	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 149	1.1	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 153/168	5.9	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 170	0.9	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 180	2.6	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 187	2.6	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	PCB	PCB 194	1.0	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	DDT	p,-p-DDMU	2.7	ppb
2013-4	SD18	2	Hornyhead turbot	Liver	DDT	p,p-DDE	61.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 49	0.9	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 66	1.6	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 70	0.9	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 74	1.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 99	7.1	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 101	4.8	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 105	2.1	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 110	2.1	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 118	8.4	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 128	2.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 138	13.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 149	4.6	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 151	2.1	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 153/168	25.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 158	0.8	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 170	3.1	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 180	9.4	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 183	2.6	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 187	11.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 194	2.9	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 201	3.9	ppb
2013-4	SD18	3	Longfin sanddab	Liver	PCB	PCB 206	1.9	ppb
2013-4	SD18	3	Longfin sanddab	Liver	DDT	o,p-DDE	4.3	ppb
2013-4	SD18	3	Longfin sanddab	Liver	DDT	p,-p-DDMU	12.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	DDT	p,p-DDD	6.4	ppb
2013-4	SD18	3	Longfin sanddab	Liver	DDT	p,p-DDE	250.0	ppb
2013-4	SD18	3	Longfin sanddab	Liver	DDT	p,p-DDT	2.1	ppb
2013-4	SD19	1	Hornyhead turbot	Liver	PCB	PCB 138	2.0	ppb
2013-4	SD19	1	Hornyhead turbot	Liver	PCB	PCB 153/168	4.0	ppb
2013-4	SD19	1	Hornyhead turbot	Liver	PCB	PCB 180	1.9	ppb
2013-4	SD19	1	Hornyhead turbot	Liver	PCB	PCB 187	1.8	ppb
2013-4	SD19	1	Hornyhead turbot	Liver	DDT	p,p-DDE	41.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 28	0.8	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 49	1.1	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 66	1.7	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 70	0.9	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 74	1.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 99	8.9	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 105	2.5	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 110	2.3	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 118	11.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 128	2.6	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 138	15.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 149	4.4	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 151	2.5	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 153/168	29.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 158	1.1	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 167	0.8	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 170	4.2	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 177	2.9	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 180	11.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 183	3.1	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 187	13.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 201	4.9	ppb
2013-4	SD19	2	Longfin sanddab	Liver	PCB	PCB 206	2.4	ppb
2013-4	SD19	2	Longfin sanddab	Liver	DDT	o,p-DDE	5.2	ppb
2013-4	SD19	2	Longfin sanddab	Liver	DDT	p,-p-DDMU	12.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	DDT	p,p-DDD	7.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	DDT	p,p-DDE	270.0	ppb
2013-4	SD19	2	Longfin sanddab	Liver	DDT	p,p-DDT	2.4	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PAH	1-methylphenanthrene	60.7	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PAH	Fluoranthene	50.4	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 49	1.4	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 66	1.8	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 70	1.0	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 74	0.7	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 99	6.6	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 105	1.7	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 110	2.7	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 118	7.2	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 128	2.2	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 138	10.0	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 149	5.4	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 151	1.5	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 153/168	21.0	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 158	0.7	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 167	0.7	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 170	3.1	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 177	2.3	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 180	6.8	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 183	2.2	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 187	10.0	ppb
2013-4	SD19	3	Longfin sanddab	Liver	PCB	PCB 201	4.0	ppb
2013-4	SD19	3	Longfin sanddab	Liver	DDT	o,p-DDE	4.6	ppb
2013-4	SD19	3	Longfin sanddab	Liver	DDT	p,-p-DDMU	11.0	ppb
2013-4	SD19	3	Longfin sanddab	Liver	DDT	p,p-DDD	7.1	ppb
2013-4	SD19	3	Longfin sanddab	Liver	DDT	p,p-DDE	190.0	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 49	0.7	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 66	1.2	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 70	0.7	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 74	0.6	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 99	4.3	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 101	3.2	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 105	1.3	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 110	1.9	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 118	5.9	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 128	1.5	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 138	8.7	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 149	3.3	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 151	1.8	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 153/168	18.0	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 170	2.5	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 177	2.1	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 180	6.5	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 183	1.8	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 187	8.4	ppb
2013-4	SD20	1	Longfin sanddab	Liver	PCB	PCB 201	2.9	ppb
2013-4	SD20	1	Longfin sanddab	Liver	DDT	o,p-DDE	4.1	ppb
2013-4	SD20	1	Longfin sanddab	Liver	DDT	p,-p-DDMU	8.7	ppb
2013-4	SD20	1	Longfin sanddab	Liver	DDT	p,p-DDD	5.4	ppb
2013-4	SD20	1	Longfin sanddab	Liver	DDT	p,p-DDE	180.0	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PAH	Phenanthrene	51.5	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 28	0.8	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 49	1.3	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 66	2.0	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 70	1.1	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 74	1.1	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 99	7.4	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 101	5.0	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 105	2.1	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 110	2.2	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 118	9.0	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 128	2.5	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 138	13.5	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 149	5.5	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 151	3.3	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 153/168	28.0	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 158	0.9	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 167	0.7	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 170	3.6	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 177	2.7	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 180	10.4	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 183	2.6	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 187	12.5	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 194	2.8	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 201	3.7	ppb
2013-4	SD20	2	Longfin sanddab	Liver	PCB	PCB 206	2.3	ppb
2013-4	SD20	2	Longfin sanddab	Liver	DDT	o,p-DDD	2.2	ppb
2013-4	SD20	2	Longfin sanddab	Liver	DDT	o,p-DDE	5.9	ppb
2013-4	SD20	2	Longfin sanddab	Liver	DDT	p,-p-DDMU	17.5	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD20	2	Longfin sanddab	Liver	DDT	p,p-DDD	9.8	ppb
2013-4	SD20	2	Longfin sanddab	Liver	DDT	p,p-DDE	305.0	ppb
2013-4	SD20	2	Longfin sanddab	Liver	DDT	p,p-DDT	7.1	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 28	0.7	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 49	1.1	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 66	1.5	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 70	0.8	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 74	0.7	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 99	5.6	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 101	3.8	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 118	6.9	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 128	2.0	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 138	10.0	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 149	5.6	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 151	1.7	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 153/168	20.0	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 170	2.3	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 177	2.1	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 180	5.9	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 183	1.7	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 187	9.3	ppb
2013-4	SD20	3	Longfin sanddab	Liver	PCB	PCB 201	2.9	ppb
2013-4	SD20	3	Longfin sanddab	Liver	DDT	o,p-DDE	4.9	ppb
2013-4	SD20	3	Longfin sanddab	Liver	DDT	p,-p-DDMU	12.0	ppb
2013-4	SD20	3	Longfin sanddab	Liver	DDT	p,p-DDD	5.3	ppb
2013-4	SD20	3	Longfin sanddab	Liver	DDT	p,p-DDE	190.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 28	1.2	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 49	2.7	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 52	4.3	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 66	4.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 70	1.3	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 74	2.1	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 99	29.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 101	13.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 105	6.5	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 110	6.8	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 118	33.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 123	4.1	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 128	7.7	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 138	43.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 149	9.9	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 151	5.1	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 153/168	79.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 156	3.7	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 158	3.2	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 167	2.2	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 170	10.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 177	6.4	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 180	23.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 183	7.2	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 187	31.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 194	7.2	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 201	10.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	PCB	PCB 206	4.9	ppb
2013-4	SD21	1	Longfin sanddab	Liver	DDT	o,p-DDE	6.2	ppb
2013-4	SD21	1	Longfin sanddab	Liver	DDT	p,-p-DDMU	13.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	DDT	p,p-DDD	7.8	ppb
2013-4	SD21	1	Longfin sanddab	Liver	DDT	p,p-DDE	300.0	ppb
2013-4	SD21	1	Longfin sanddab	Liver	DDT	p,p-DDT	3.1	ppb
2013-4	SD21	1	Longfin sanddab	Liver	Chlordane	Trans Nonachlor	2.6	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 28	1.2	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 49	2.5	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 52	2.9	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 66	3.1	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 70	1.1	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 74	1.4	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 99	15.0	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 101	8.6	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 105	3.5	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 110	3.8	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 118	19.0	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 123	2.1	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 128	4.8	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 138	27.0	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 149	8.9	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 151	4.2	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 153/168	53.0	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 156	2.2	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 158	1.7	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 167	1.5	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 170	6.7	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 177	4.5	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 180	16.0	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 183	4.7	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 187	23.0	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 194	5.8	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 201	6.9	ppb
2013-4	SD21	2	Longfin sanddab	Liver	PCB	PCB 206	4.3	ppb
2013-4	SD21	2	Longfin sanddab	Liver	DDT	o,p-DDE	5.2	ppb
2013-4	SD21	2	Longfin sanddab	Liver	DDT	p,-p-DDMU	12.0	ppb
2013-4	SD21	2	Longfin sanddab	Liver	DDT	p,p-DDD	5.9	ppb
2013-4	SD21	2	Longfin sanddab	Liver	DDT	p,p-DDE	230.0	ppb

Appendix F.3 *continued*

Yr-Qtr	Station	Comp	Species	Tissue	Class	Constituent	Value	Units
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 28	1.4	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 49	2.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 52	2.3	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 66	7.1	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 70	1.7	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 74	3.4	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 99	46.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 101	8.3	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 105	8.6	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 110	7.6	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 118	52.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 128	12.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 138	87.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 149	8.7	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 151	3.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 153/168	210.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 156	4.4	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 158	4.4	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 167	4.1	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 170	12.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 177	3.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 180	40.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 183	17.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 187	41.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 194	8.6	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 201	9.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	PCB	PCB 206	3.9	ppb
2013-4	SD21	3	Longfin sanddab	Liver	DDT	o,p-DDE	4.2	ppb
2013-4	SD21	3	Longfin sanddab	Liver	DDT	p,-p-DDMU	9.6	ppb
2013-4	SD21	3	Longfin sanddab	Liver	DDT	p,p-DDD	5.7	ppb
2013-4	SD21	3	Longfin sanddab	Liver	DDT	p,p-DDE	210.0	ppb
2013-4	SD21	3	Longfin sanddab	Liver	DDT	p,p-DDT	2.5	ppb

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